BioMed Research International

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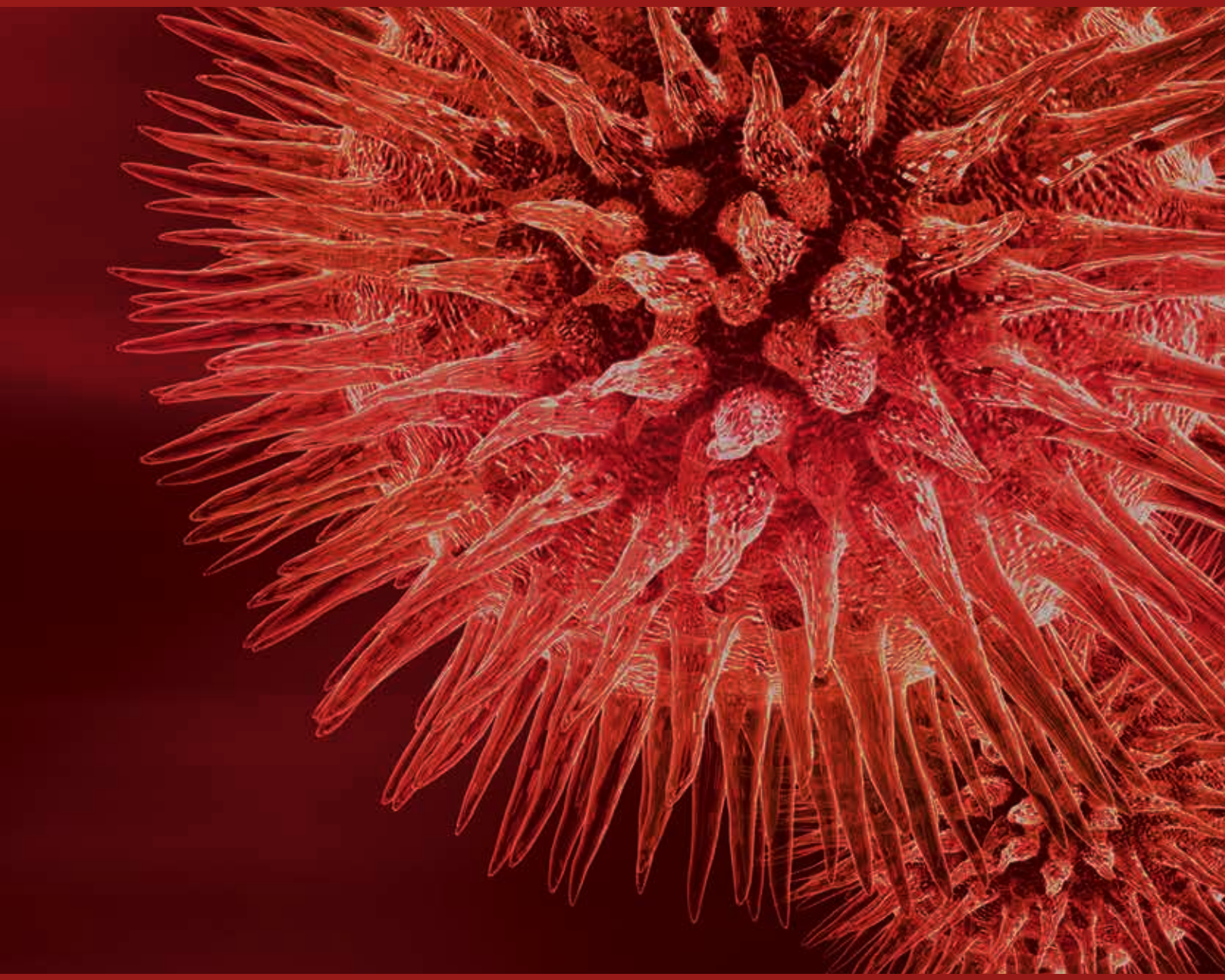
Guest Editors: Klaus Boening, Mieszko Wieckiewicz, Anna Paradowska-Stolarz, Piotr Wiland, and Yuh-Yuan Shiau



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Editorial

Temporomandibular Disorders and Oral Parafunctions: Mechanism, Diagnostics, and Therapy

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Temporomandibular disorders (TMD) and oral parafunctions are very common problems in the modern society. TMD are a group of symptoms related to impaired function of the temporomandibular joints (TMJs) and associated muscles. The symptoms can include pain or tenderness of TMJs area, clicking or grating sounds in the TMJs, limited jaw movements, muscle pain, headache, tinnitus, impaired hearing, and earache. It had been proved that they are related to multiple causes, such as psychological, occlusal, and general health factors [1–3]. There is also evidence that TMD may be related to cervical spine disorders and its mobility [4, 5].

The paradigm shift and the growing awareness that diagnosis and treatment of TMD usually require a multidisciplinary approach were the goal intention to initiate a special issue on this topic. Interdisciplinary therapeutic strategies should focus not only on TMJs structures, but also on the surrounding tissues including especially neuromuscular system and last but not least the entire patient and his or her social environment [6]. Regarding the difficulties in diagnosis and multipronged treatment which is due to the symptom diversity and the complexity of associated problems, it was the editors' intention to condense the knowledge on temporomandibular disorders from different perspectives for the readers of this special issue.

In this special issue original and review articles related to TMD and oral parafunction topics are associated with multiple branches of medicine. The papers underline the multidisciplinary character of TMD to the readers. The aim of the issue was also to show novelties and advances in the treatment of TMD. A number of papers describe the pathogenesis of the disorders, as well as its epidemiology, stat-of-the-art diagnostics, and treatment methods.

The goal of the special issue was to familiarize the reader with multidimensional causes related to the specific disease process of TMD.

Acknowledgments

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Klaus Boening
Mieszko Wieckiewicz
Anna Paradowska-Stolarz
Piotr Wiland
Yuh-Yuan Shiau

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Research Article

Assessment of the TMJ Dysfunction Using the Computerized Facebow Analysis of Selected Parameters

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The Purpose of the Paper. Qualitative and quantitative analysis of selected parameters of mandible movements, electronically registered in patients with temporomandibular joint dysfunction and healthy ones. *Material*. Function test of the mandible movements was conducted in 175 patients. Gender distribution was 143 women and 32 men, aged 9 to 84. *Methods*. The studied population, after accurate clinical examination, was divided into age groups with the range of five years. All the patients had Zebris JMA computerized facebow examination done, according to the generally accepted principles and procedures. *Results*. Mean values of mouth opening calculated to 45.6 mm in healthy group and 37.6 mm in TMJ dysfunction group. Mean length of condylar path amounted to $39 \pm 7\%$ of the maximum value of mouth opening in the group of healthy people, $44 \pm 11\%$ in the case of muscle-based disorders, and $35 \pm 11\%$ with joint-based. The mean value of the condylar path inclination oscillated in the range of 25° to 45°. *Conclusions*. The ratio of length of the condylar path to the size of mouth opening may be a significant value characterising the type and degree of intensification of the TMJ dysfunctions.

1. Introduction

Joint-muscle and dental system dysfunctions, often also known as the locomotor system function disorders (LSFD), are a serious diagnostic and therapeutic difficulty in dental practice [1–5]. In the recent years the number of people with pain in the area of head and neck increased [6]. According to the latest tests conducted in highly-developed countries, it is assumed that even approximately 75–90% of the population suffer from temporomandibular disorders, according to Carlsson [7], Macfarlane et al. [8], and Rugh and Solberg [9]. The basic symptoms of the TMJ dysfunctions are pain during mandible movements, limitation of its mobility and related hindered or painful mastication, clicking in temporomandibular joints during movement, masticatory organ muscles hypertension, headaches, and cervical pain. Frequently, dysfunctions are accompanied by various types of parafunctions, for example, bruxism [10–13]. The factors generating the temporomandibular disorders include mental stress [14], bad habits, acute and chronic injuries, incorrect muscles functioning, traumatic occlusion, iatrogenic factors, mental disorders, and hormonal disorders, as well as generalised joints diseases, which was confirmed by Greek [15], LeResche at al. [16] and Egermark-Eriksson et al. [17] and Curcic [18]. Temporomandibular joints are most often used joints in the human body. They also participate in many physiological activities, such as speech, receiving food, singing, yawning, and even expressing emotions. It has been observed that within a day dental arches are in contact for ca. 30 min—mainly during swallowing saliva. Incorrect teeth contact caused by, for example, tooth loss, bruxism, and nontreated dental caries are the source of

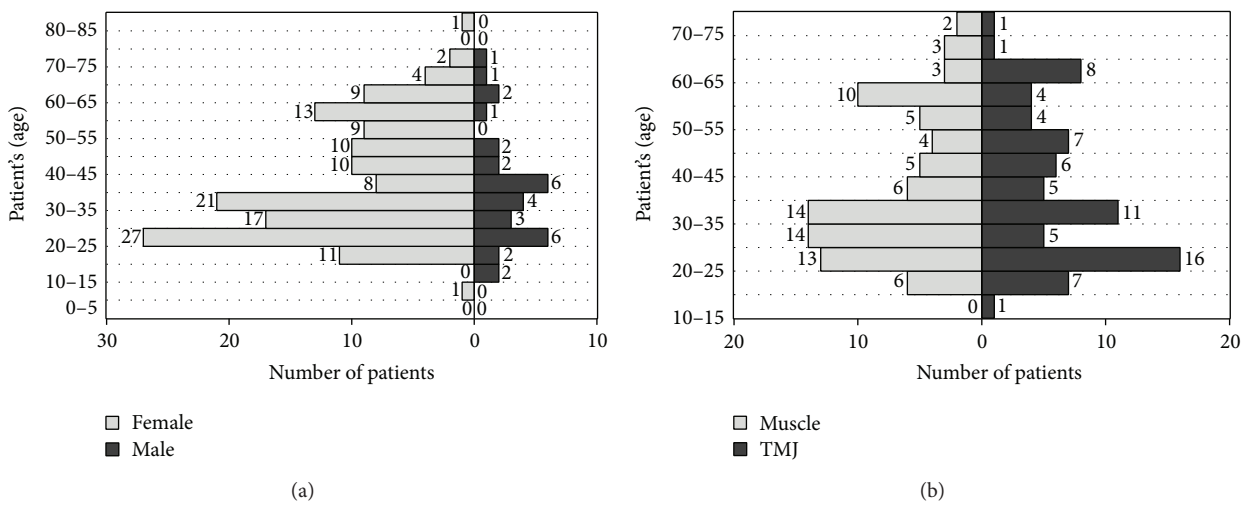

Figure 1: Characteristics of the studied population owing to age: (a) the number of people in groups of examined patients with the distinction of gender, (b) cause dysfunction of the mastication organ.

stresses in temporomandibular joints, which sometimes can lead to activation of a cascade of unfavourable events, which as a consequence leads to a serious disorders. The purpose of the paper was qualitative and quantitative analysis of selected parameters during mandible movements, registered in patients with TMJ dysfunctions and healthy ones. Clinical tests were conducted by computerized Zebris JMA facebow.

2. Material

Function test of the human mastication organ was conducted in 175 patients: 143 women and 32 men aged 9 to 84, who, in the period of the last 7 years, volunteered to the Department of Prosthetic Dentistry of the Pomeranian Medical University in Szczecin because of disorders in the mastication organ functions. A reference material was a group of 13 potentially healthy people, that is, ones who reported no ailments, and the results of conducted clinical tests have not demonstrated symptoms of a human mastication system dysfunctions. Graphic records, reflecting the stomatognathic system functioning in healthy people, were recognised as a model. From anamnesis in every patient the following was recorded: age, height, body weight, and opinions expressed with regard to symptoms and ailments. The studied population was divided into age groups with the range of five years. The average age of the tested group of women was 38.6 and standard deviation was equal to 15.95. With regard to the group of men, the average age was 36.25 and standard deviation was equal to 15.68. The oldest man was 73 years old, while the youngest was 12. Then, additional three groups were separated. The first one was represented by 76 patients: 60 women and 16 men in whom the clinical test diagnosed improper operation of the temporomandibular joints. The second group qualified 86 patients, including 75 women and 11 men, with diagnosed improper mastication organ muscles functioning. The last third group of 13 tested were healthy people, that is, not reporting any ailments. The average age of the people was close for each of the separated groups and was accordingly: for the sick with joint basis of disorders ca. 37.9, with muscle troubles 39.5 and 31.3 in the case of healthy people. Differences in numbers of particular age groups and the participation of women and men in the surveyed population are presented in Figure 1(a).

On the basis of the conducted analyses, it was determined that the mastication organ functioning disorders occur over 4 times more often in women than men. The diagram shows that from the point of view of source of the disorder: joint or muscle dysfunctions is a feature not statistically important, because the conditions coming directly from joints occur equally often as the muscle cause of disorders and are independent from age of the studied persons (Figure 1(b)).

3. Methodology of Research

The clinical test was conducted according to the generally binding principles and any standard procedures for this type of cases. The symptoms of function disorders were assessed as well as the level of condition progress: presence of spontaneous pain disorders in the surroundings of the stomatognathic system of the facial part of the cranium, their location, and duration. The clinical diagnostics was mainly aimed at determination of the nature and grounds of disorders: joint TMD (Temporomandibular Disc Displacements) or muscle (Muscle Disorders). Assignment to groups was based on the generally accepted diagnostic protocol RDC/TMD. The first group—the joint—are persons who meet the criteria of groups IIa and IIb of the said classification. The second established a person with symptoms of belonging to both groups—Ia and Ib muscle diseases by the RDC/TMD.

The clinical test in most cases is insufficient and must be supplemented with additional tests with the use of specialist apparatus. Such action is necessary, because the classic diagnostics, conducted usually with the data from anamnesis and physical examination, visual, auscultation and

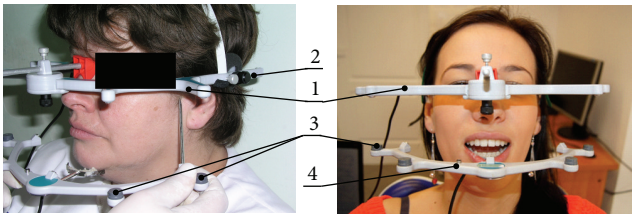

Figure 2: Electronic Zebris JMA facebow, graphic imaging of procedure of introducing measuring points, and assembled device ready for use.

palpation, is often insufficient. Therefore, in order to precisely formulate the diagnosis, in the least burdensome manner for the patient as well as the doctor, patients underwent electronic assessment of efficiency of the mastication organ with the Zebris JMA device (Figure 2).

Zebris JMA is a complex recording system, computer-controlled, whose spectrum of applications in functional diagnostics has been significantly extended. The apparatus has two stiff measurement arches, whose installation in a proper position is definitely simplified. The face ring, upper arch (1), is put on the nose and fastened at the back of the head over the ears using a plastic belt (2). Measurement sensors (3) are located in the mobile arch (4) which must be precisely fixed to the labial surface, front teeth of the mandible. Additionally, connection of the sensor with the teeth cannot disturb when recording functional movements of proper intercuspidation. Low weight of the lower arch amounting only to 20 g does not tire or overload the patient. The sensors located in the lower, mobile arch record change in intensity of ultrasonic waves, generated with the frequency of 900 Hz, through immobile transmitters located in the upper arch. The results are precise, recorded with the accuracy of ±0.1 mm, three-dimensional trajectories, on which the heads of condyloid process and incisors move. The course of the examination is relatively short and simple. After the installation of measurement arch, the patient performs a dozen or so mandibular movements. At this point, the sensory system records trajectories: abduction and adduction, double-sided laterotrusive movements and protrusive movements; the computer saves the real-time measurement data. An important function of the discussed apparatus is the possibility to introduce additional orientation points, characterising the individually variable characteristics of geometric structure of the facial part of the patient's cranium, the effect of which is a multiparameter analysis of occlusion and joints operation. According to the authors of such registration, it can be done using any electronic device of similar effect, which has the ability to individualize research—introducing arbitrary points. At this point, the following should be listed: for example, optoelectronic computer systems (Condylocomp, Cadiax), devices using for recording mandibular function movements ultrasonic sensors (Zebris JMA, Arcus digma), and magnetic (K-7). These are complex recording systems, computer-controlled, where the spectrum of applications in functional diagnostics has been significantly extended. Discussed system was used only because of its availability.

4. Test Results: Results of Statistical Analysis

During statistical analyses performance, the following statistical tests were used: Kolmogorov, Kolmogorov-Smirnov, and Test for Homogeneity of Variances, which was preceded by the Bartlett test. All necessary calculations were made assuming the levels of significance: $\alpha = 0.01$ and $\alpha = 0.05$. Statistical analyses started from verification of the tested population, in terms of application of homogenous objective and subjective data assessment criteria, collected in clinical conditions. Special attention was paid to checking whether the populations of women and men form normal distributions and are homogeneous in terms of age. The conducted Kolmogorov statistical tests proved, at the assumed level of significance $\alpha = 0.01$, that the tested groups of women and men are normal distributions. We can believe so, since the calculated statistics values λ amount to, respectively, 1.548 and 0.701 and are smaller than the critical value $\lambda_{0.01} = 1.627$. The Kolmogorov-Smirnov equality test clearly demonstrated $\lambda = 0.64$ that both groups are homogeneous in terms of age of the tested persons, and thus they can be analysed together.

Still on the basis of graphic records of the recorded measurement data, detailed assessment covered the following parameters: the scope of mouth opening gaps Y, namely, the degree of mandible abduction, that is, maximum dimension measured between the incisal edges of central incisors; the length of articular route—the scope of movement of condyloid process heads in abduction movements S_i and a measurable parameter being inclination angle of the articular route SCI.

The graphically pictured data show that there are no statistically significant differences between the maximum values of mandible abduction in the group of women and men (Figure 3(a)). Average values of the analysed parameter were accordingly, for healthy people 45.6 mm, for people with joints functioning dysfunction 37.6 mm and muscles 44 mm (Figure 3(b)).

The diagram (Figure 4(a)), presents the statistical values of the articular route in particular examined groups. Similarly as in the analysis of maximum dental arches opening Y, so in the case of the articular route S_S, reference of the analysed parameters to healthy patients indicates that, in people complaining about ailments, whose source is incorrect joints and muscles operation, a substantial reduction in the length of the articular route is observed (Figure 4(b)). The highest values of the length of the articular route were recorded in the group of women with muscle etiology of the disorder. This issue is better illustrated by a collective graph of dependencies between the average length of the articular route S_S and the size of opening gap Y (Figure 5(a)).

The diagram (Figure 5(b)) statistics describing the relation of average length of the articular route S_S to maximum dental arches opening gap Y were compared.

The operation of both joints is well illustrated in the graph of relation between the length of the right S_P and the left S_L articular route in healthy individuals (Figure 6(a)). The distribution of data included in Figure 6(b) indicates that the relation between the average lengths of articular routes, the right and left condyloid process in healthy patients and

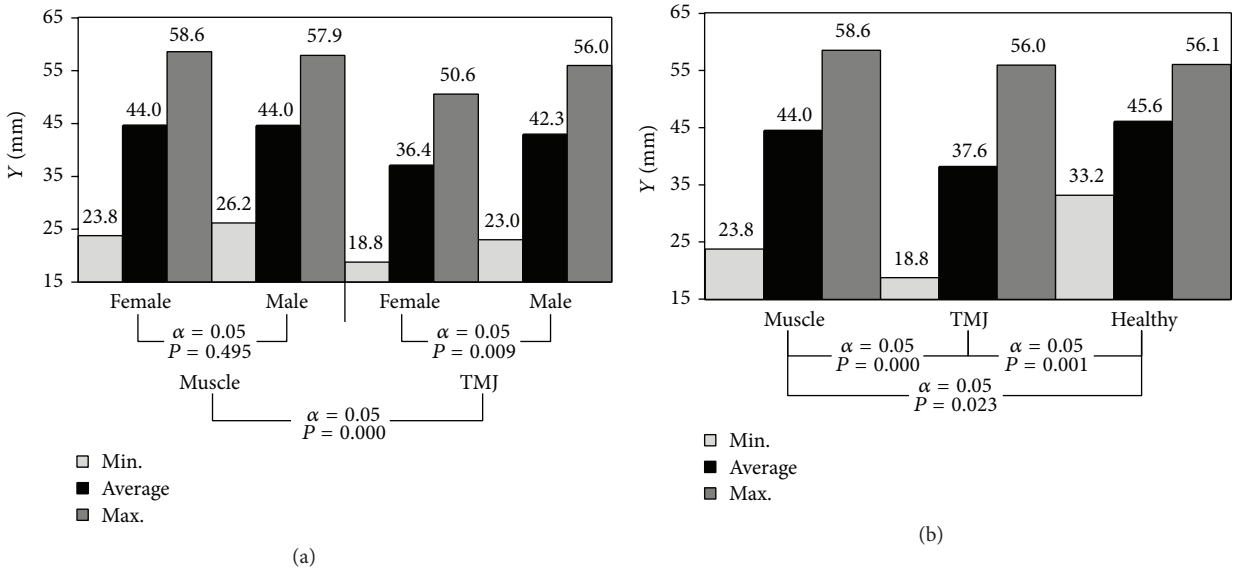

Figure 3: The diagrams illustrating the maximum opening gap depending on (a) gender and (b) source of dysfunction.

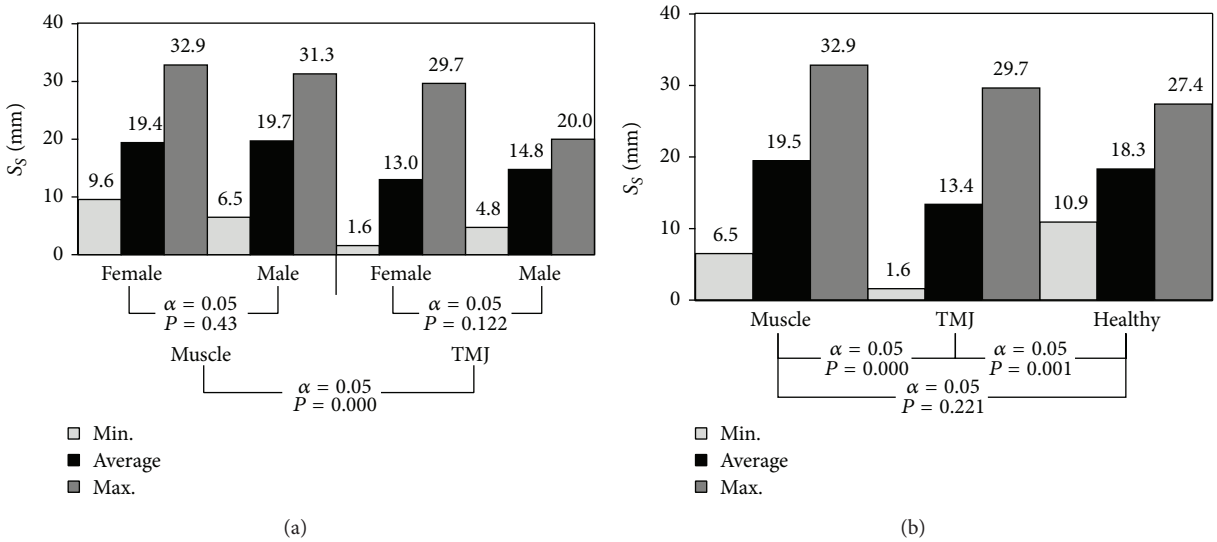

Figure 4: The diagrams illustrating the route of condyloid process heads depending on (a) gender and (b) source of dysfunction.

with disorders, oscillates within the approximating straight line.

The data included in the chart (Figure 7(a)) show great compliance of the concerned parameter in the majority of examined people as compared to the healthy people. However, the largest deviations are observed in the group of men and women with joint disorders. Among measurable kinematic sizes, one of the most essential is the so-called inclination angle of the articular route *SCI*, which was referred to the average articular route (Figure 7(b)). Its value, on average, is a few dozen degrees and is in fact the route that the condyloid process head covers during abduction and adduction of the mandible.

The conducted statistical analyses indicated that the lowest average value of articular angle in the examined population occurs in the group of the sick having dysfunction of articular etiology (Figure 8(a)). The obtained results prove unambiguously that the average value of the inclination angle of the articular route SCI_S, oscillates between 25 and 45° (Figure 8(b)).

5. Discussion

An important role in LSFD diagnostics apart from anamnesis and physical examination is played by the image examination: Panoramic X-rays, as check-up examination, computer tomography techniques (CT), and magnetic resonance (MR) and axiographic evaluation. Direct imaging methods have already been discussed many times for example, by Tanimoto et al. [19], Görgü et al. [20], Wong et al. [21], Sukovic [22],

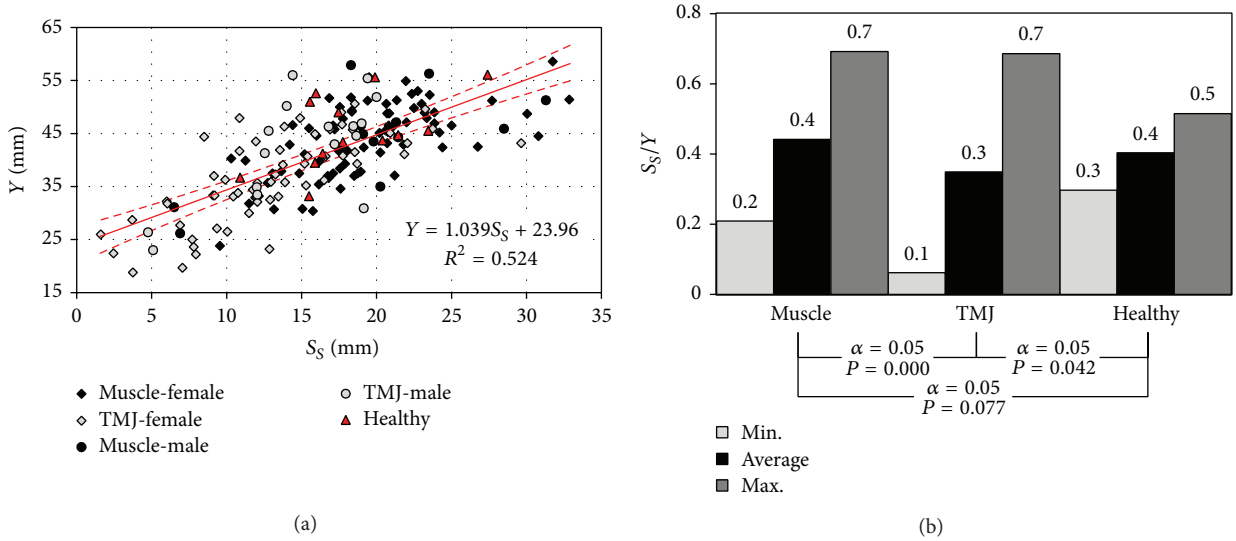

Figure 5: (a) The relation occurring between maximum dental arches opening Y and the average articular route S_S and (b) diagram showing statistics calculated on the basis of the relation and average articular route to the maximum dental arches opening.

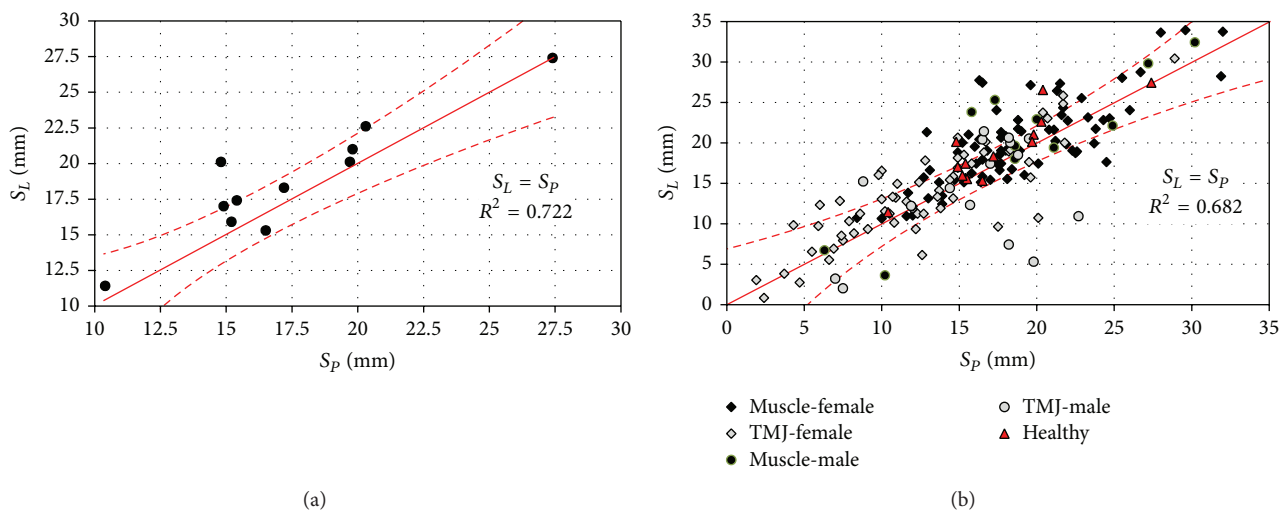

Figure 6: The causal relation existing between the average length of the right and the left articular route and in the abduction movement: (a) in healthy patients and (b) all the examined patients.

and many others. In recent years many researchers emphasise the importance of electronic axiography in differential diagnostics of mastication organ dysfunctions, due to accuracy and precision of the measurement data obtained, Celar and Tamaki [23] and Pröschel et al. [24]. The use in daily clinical practice of modern, often complex diagnostic techniques is becoming necessary, especially with regard to patients with intensified symptoms of stomatognathic system functions disorders, often accompanied by morphological changes [8, 9, 24, 25].

Research results obtained by various researchers indicate the main difference in the scope of dental arches opening in the group of women and men. Men on average by ca. 5 mm open their mouths broader as compared to women, as indicated in the paper [26]. On the other hand, the results of latest research conducted with the group of 12 men and 15 women, aged 19 to 30 determine this difference at the level of approximately 10 mm [27]. It is believed that a typical scope of maximum dental arches opening in the group of men is within the range from 50 to 60 mm and women from 45 to 55 mm [28]. The size of an opening gap is one of the parameters indicating the degree of intensification of mastication organ dysfunction, which is determined, for example, on the basis of the Helkimo index [29]. Literature reports indicate that the range of mouth opening changes with age of the body. Additionally, in the initial period of life it grows [30] until achieving maturity. At the time of achieving maturity the possibility of broad mouth opening is becoming gradually limited [31].

On the basis of the conducted statistical analyses of population with muscle etiology, it has been stated that the average values of maximum dental arches opening were

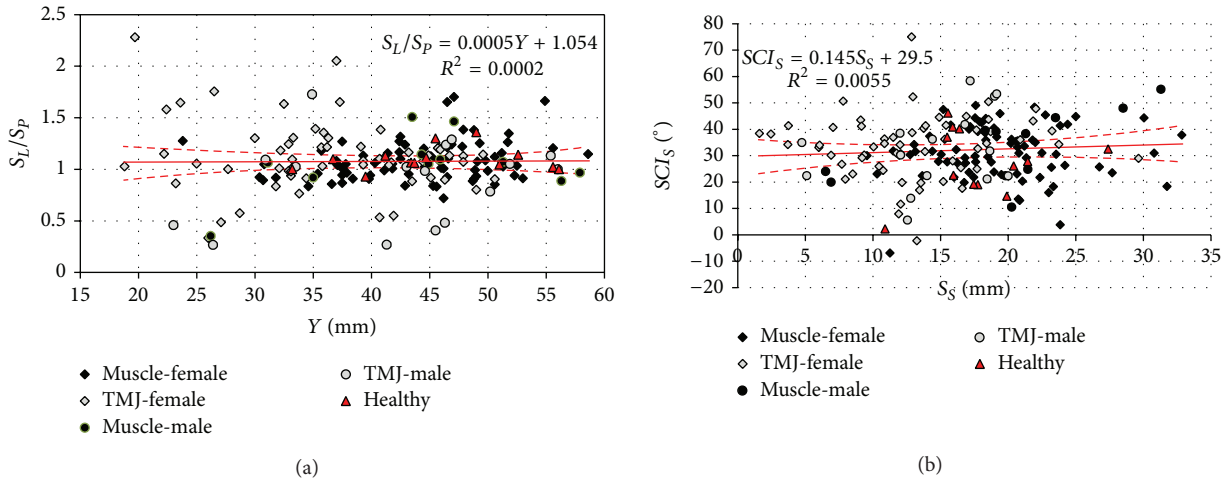

Figure 7: Relation characterising the relation between (a) the relation of the length of articular routes in joints and the maximum opening gap and (b) average articular angle SCI_S and the average articular route S_S.

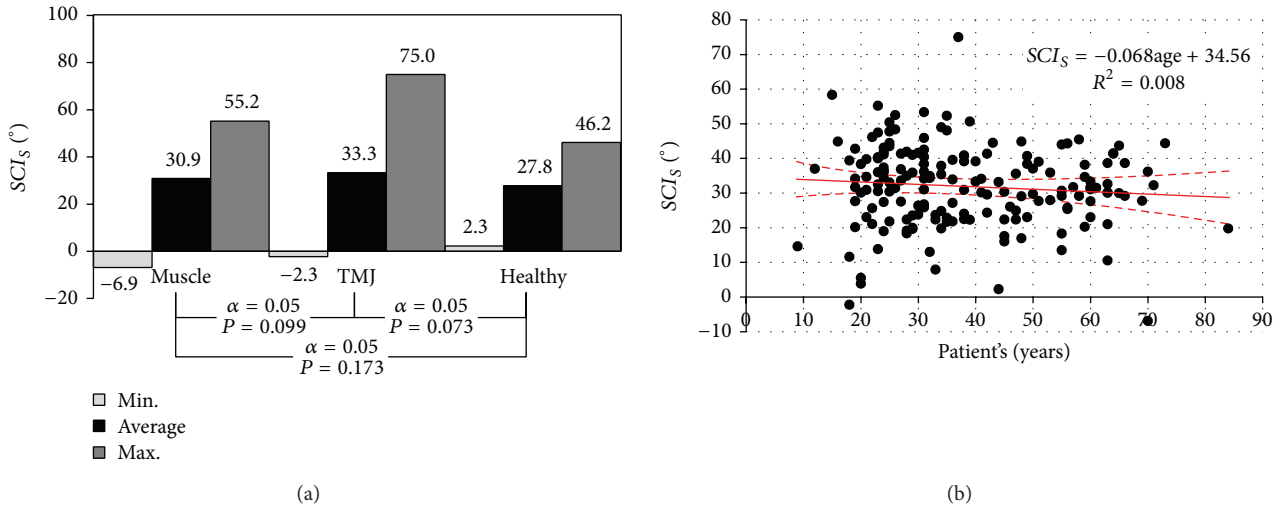

Figure 8: The relation characterising the relation of the average articular angle: (a) diagram showing the statistics in particular groups of studied population and (b) the age of the patient.

almost identical $P = 0.495$ (Figure 3(a)). On the other hand, in the group of patients with an articular-related ailment, a statistically significant difference was observed $P = 0.009$. As compared to healthy patients, it turns out that both in people suffering due to articular-related dysfunction as well as muscle, we are dealing with substantial reduction in the scope mandible abduction, and this reduction is particularly noticeable in patients with incorrectly functioning temporomandibular joints (Figure 3(b)). This limitation is the highest in patients with articular conditions and results directly from a considerable reduction in the length of articular route S_S. Knowledge of the aforementioned parameters may be important when selecting the mode of therapeutic conduct, because in the case of confirmed muscle etiology of the dysfunction, a satisfactory therapeutic effect may be achieved using correctly performed massages [32].

The physiological scope of the condyloid process head movement in an arrow plane, recorded during mandible abduction, should be within 10 to 16 mm, which is said [33–35]. Similar results were obtained in the paper [36] where research was conducted on the group of 21 women aged 20 to 24. Additionally, this research was completed with the use of an electronic facebow Gnathohexograph JM-100. The obtained results indicate that the average value of dental arches opening 41.1 ± 3.5 mm corresponds to the average articular route of the condyloid process equal to ca, 12.8 ± 2.8 mm. At this point, it is worth mentioning the fact that the scopes of variability of recorded parameters were accordingly within 35.6 to 50.9 mm with regard to maximum dental arches opening and 8.1 to 19.2 mm in the case of articular route of condyloid processes. Studies on the length of articular route were also the object of publications

[37]. In this study, a population of 25 people was studied. The research was conducted also with the application of an optoelectronic facebow Gnathohexograph JM-100 and the obtained results indicated that the average length of articular route is 14.16 mm. In cephalographic studies carried out by Muto and Kanazawa [38], the length of articular routes was recorded at the level of 20.5 mm for men and 18.1 mm for women. These values significantly exceeded the boundaries set out in the papers [33–35]. At this point, it is worth mentioning the fact that rigorous marking out boundaries between correct mastication organ movement and disturbed does not work in the clinical practice. To confirm the above it is worth mentioning the indications included in the paper [39], where attention was paid to the fact that exceeding the scopes deemed to be the standard is not always a sign of dysfunction. It is considered that this kind of disorders is symptoms of excessive ligaments slackening. Additionally, the disorders may be inborn or acquired. Acquired disorders undoubtedly prove ligaments pathology, while inborn should be regarded as a normal condition. Partial confirmation of this thesis can be obtained by analyzing the high variability of these parameters in a group of healthy people.

Statistical analyses carried out in this paper on the group of 13 healthy people indicate that the length of articular route covered by condyloid process heads assumes on average 39 ± 7% (mean ± SD) of maximum distance measured between the edges of central incisors. This ratio is much closer to the information provided in the paper by Ioi et al. [40] than the one suggested in the publications [33–35]. In the case of persons with mastication organ incorrect functioning, relation of articular route to the maximum opening gap of dental arches reached accordingly the level of 44 ± 11% in the case of disorders caused by improper muscles operation and 35 ± 11% in people with dysfunction caused by temporomandibular joints operation. At this point it is required to specify clearly and expressly that the gender of the patients did not have significant effect on the computed relations, since statistics values amounted to, accordingly, $P = 0.467$ in the case of muscle disorder and $P = 0.479$ in the case of articular dysfunction. In the light of the research conducted the relation of articular route length to the maximum dental arches opening proves to be an important indicator enabling to approximately determine the source of dysfunction.

On the basis of data distribution it may be concluded that there is close correlation between the length of the average articular route and the size of an opening gap. Additionally, most often listed length of condyloid process route ranges from 10 to 25 mm. This range corresponds to the opening gap measured between the edges of incisors contained within 30 to 50 mm. Values which are significantly different from average relate to individual people and are an insignificant percentage of the patients. Diagram (Figure 5(b)) compares statistical data characterising the relation of average length of articular route to the maximum size of an opening gap. The presented data show that the length of articular route is, on average, ca. 0.4 of the opening gap value expressed in millimetres. Variations of this coefficient in the group of healthy people were insignificant and contained in the range of 0.3 to 0.4. Numeric data which are significantly different from the mentioned were recorded in both groups of patients. Additionally, the largest discrepancies were observed in people with articular ailment, where extreme values ranged 0.06 to 0.69. Low values undoubtedly prove significant impairment of mobility in joint.

The presence of acoustic noises in temporomandibular joints is one of the symptoms of their incorrect operation [41, 42]. The external symptoms of these irregularities are various kinds of trajectory deviations recorded during mandible movements. In the case of ideally symmetric operation, the length of articular route of the left condyloid process S_L should be equal to the length of the right condyloid process route S_P. With such an assumption as the starting point, a coefficient of adjusting measurement data for patients not reporting any disorders in the functioning of mastication organ were calculated ($R^2 = 0.722$). It should be borne in mind that comparable scopes of the length of articular routes S_L and S_P are not a sufficient condition to state proper operation of the mastication organ. The results of the conducted research indicate that correct mastication organ functioning exists when the length of both articular routes are comparable and in addition their values are within 13 to 23 mm. All the other cases can be treated as a sign of disorder. Additionally, the length of articular routes, whose value is within 0 to 13 mm, in the surveyed population where the result of incorrect operation of the joints. On the contrary, ones whose values were greater than 25 mm may prove disorder caused by improper muscular functioning (Figure 6(b)). It is confirmed by results of clinical tests also presented in Figure 5(a). The length of average articular route to be covered by condyloid process heads significantly determines the size of opening gap Y (Figure 7(a)). In the case of comparing measurement data, it is also possible to initially diagnose the reasons causing improper operation of the mastication organ. The studied parameter has an important diagnostic feature, since the analysis of location of item on a plane S_L/S_P-Y, enables with a very high degree of probability to indicate the side responsible for the dysfunction.

The inclination angle of the articular route assessment *SCI* was also the subject matter of work [43], where a group of 4 men and 6 women was studied. From the studied population two groups were selected: *A—the group of the functional occlusal clutch* and *B—the group of the tray clutch.* The obtained results indicate that the average values of inclination angle of the articular route *SCI* are within the range of around 34.7 to 41.8 (group B) and from 35.6 to 42.8 (group A) and are similar to ones obtained by the authors of this study. The subject matter of the research, whose results were published in work [44] was comparison of the inclination angle of the articular route, measured by means of two various facebows. One of them was Gerber Dynamic Facebow, the second an electronic facebow Arcus Digma II. The research was conducted on a group of 35 women, aged 18 to 35. The average values of inclination angle of the articular route recorded with the ARCUSdigma II device for the right joint amounted to 33.1 ± 10.58 (mean ± SD) and left 32.4 ± 13.93. These angles are on average 13 larger as compared to the data recorded using the Gerber Dynamic Facebow (the right joint: 20.1 ± 9.94, the left joint: 19.4 ± 9.4). The obtained average

values of inclination angle of the articular route SCI_S are consistent (Figure 8(a)) with the measurements conducted with the use of the electronic ARCUSdigma II facebow. In particular, studied groups they assume accordingly the values 27.8 ± 12.27 for the healthy group, 33.3 ± 12.47 in the group with troubles of articular origin, and 30.91 ± 10.87 for the group of patients with muscles functions disorders. It is worth bearing in mind the fact that the inclination angle of the articular route does not other words, along with ageing of the body its value is flattened, which indirectly may indicate geometrical shape of articular tubercle.

6. Conclusions

The ratio of the length of the articular route to opening gap of dental arches may be a significant indicator, characterising the degree of dysfunction intensification enabling initial diagnosis of the source of the human mastication organ incorrect functioning. An undoubtedly significant parameter informing the dentist about the location, that is, on which side there is the source of disorder is the ratio defined as the relation of the right length to the left of the articular route. In the case of proper mastication organ functioning, the ratio should be close to homogeneity. It seems that such research should be still continued in order to define clear criteria on the basis of which it will be possible to efficiently and effectively formulate the diagnosis. It seems that you should continue to pursue this kind of research, in order to define clear criteria on the basis of which it will be possible to formulate efficient and effective diagnosis. It should first of all determine the patterns characteristic of healthy people, which could become the reference criteria. Such actions were not subject of this research. The authors are aware that a group of 13 healthy subjects is too small to carry such an assumption.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Jaw Dysfunction Is Associated with Neck Disability and Muscle Tenderness in Subjects with and without Chronic Temporomandibular Disorders

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Purpose. Tender points in the neck are common in patients with temporomandibular disorders (TMD). However, the correlation among neck disability, jaw dysfunction, and muscle tenderness in subjects with TMD still needs further investigation. This study investigated the correlation among neck disability, jaw dysfunction, and muscle tenderness in subjects with and without chronic TMD. *Participants*. Forty females between 19 and 49 years old were included in this study. There were 20 healthy controls and 20 subjects who had chronic TMD and neck disability. *Methods*. Subjects completed the neck disability index and the limitations of daily functions in TMD questionnaires. Tenderness of the masticatory and cervical muscles was measured using an algometer. *Results*. The correlation between jaw disability and neck disability was significantly high ($r = 0.915$, $P < 0.05$). The correlation between level of muscle tenderness in the masticatory and cervical muscles with jaw dysfunction and neck disability showed fair to moderate correlations ($r = 0.32$–0.65). *Conclusion*. High levels of muscle tenderness in upper trapezius and temporalis muscles correlated with high levels of jaw and neck dysfunction. Moreover, high levels of neck disability correlated with high levels of jaw disability. These findings emphasize the importance of considering the neck and its structures when evaluating and treating patients with TMD.

1. Introduction

Temporomandibular disorders (TMD) are a musculoskeletal disorder affecting the masticatory muscles, the temporomandibular joint (TMJ), and associated structures. Evidence suggests that TMD are commonly associated with other conditions of the head and neck region, including cervical spine disorders and headache. Presence of neck pain was shown to be associated with TMD 70% of the time [1, 2]. Neuroanatomical and functional connections between masticatory and cervical regions are discussed as explanations for concomitant jaw and neck symptoms [3, 4]. The presence of pain in the masticatory system, especially related to myogenic TMD, could be caused by dysfunctions in the cervical column, or vice versa, showing the intrinsic relationship between the different structures [1, 5].

Although the association of cervical spine disorders and TMD has been studied by different authors, it is far from being exhaustively explained [6, 7]. Most of the studies agree that symptoms from the cervical spine can be referred to the stomatognathic region through the trigeminocervical nucleus. Several studies have examined the presence of signs and symptoms in the cervical region of patients suffering with TMD and that the presence of tender points in the cervical area of these patients is very common [8–13]. de Laat et al. [11] found that, on palpation, 23–67% of the patients with TMD had neck muscle tenderness in the sternocleidomastoid and upper trapezius as well as other cervical and shoulder

muscles, which was only rarely present in the control group. Recently, Greenspan et al. [14] measured pressure pain threshold (PPT) in the center of the temporalis, masseter, and trapezius muscles in subjects with and without TMD. They showed that patients with TMD were more sensitive to a wide range of mechanical and thermal pain tests than control subjects, including not only the orofacial area, but also the trapezius muscle.

Muscle tenderness in the cervical spine and jaw was shown to be associated with increased levels of jaw and neck disability. For example, one study by our team revealed a strong relationship between neck disability and jaw disability ($r = 0.82$). A subject with a high level of TMD disability (grade IV) had an increase of about 19 points in the NDI when compared with a person without TMD disability [15]. Disability associated with jaw and neck pain interferes greatly with daily activities and can affect the patient's lifestyle which declines the individual's ability to work and interact in a social environment [6, 8].

Muscle tenderness is the most common sign [8, 16–18] and muscle pain is the most common symptom [19] found in patients with TMD, and their evaluation is still one of the most important methods of establishing a clinical diagnosis of TMD [17, 20], being of particular interest to clinicians treating orofacial pain. Treatment strategies such as exercises, manual therapy, stretching, and education can be targeted to painful and sensitive muscles in order to reduce pain in the orofacial region [8, 20–22].

Although several studies have evaluated neck tenderness in subjects with TMD, none of these studies have evaluated the relationship between the level of tenderness and jaw dysfunction. Moreover, most studies that investigated muscle tenderness in subjects with TMD used palpation techniques, which are difficult to quantify and standardize [10, 11].

There is a great interest on the knowledge for further relationship between stomatognathic system and cervical spine. If further relationship is established, new clinical strategies that target both regions should be considered and, therefore, the need of a multidisciplinary approach should be reinforced in the management of patients with alterations of the stomatognathic system, including TMD patients. In order to further investigate this relationship, the objective of this study was to determine the correlation among neck disability, jaw dysfunction, and muscle tenderness in subjects with chronic TMD. We hypothesized that the higher the level of neck disability, the higher the level of jaw dysfunction and the higher the level of muscle tenderness.

2. Methods

2.1. Subjects. A convenience sample of 20 female subjects diagnosed with chronic TMD (at least 3-month duration) and 20 healthy female subjects participated in this cross-sectional study. Subjects were recruited from the TMD/Orofacial Pain Clinic at the University of Alberta and by using advertising around the university and on the local television news. Sample size calculation was based on bivariate correlation. Based on a moderated and conservative correlation ($r = 0.4$, effect size) and using $\alpha = 0.05$, $\beta = 0.20$, and power = 80%, approximately 37 subjects were needed for this study [23].

Subjects with TMD were classified with either myogenous TMD (mainly muscle complaints) or mixed TMD (myogenous and arthrogenous) and presented concurrent neck disability. The subjects were excluded if they presented arthrogenic TMD only, a medical history of neurological, bone, or systemic diseases, cancer, acute pain or dental problems other than TMD, or a history of trauma or surgery to the upper quarter within the last year or if they had taken any pain medication or muscle relaxants less than 4 hours before the diagnostic session.

The healthy group included subjects with no pain or clinical pathology involving the masticatory system or cervical spine for at least one year prior to the start of the study. Exclusion criteria included previous surgery, neurological problems, any acute or chronic musculoskeletal injury, or any systemic diseases that could interfere with the procedure and taking any medication such as pain relieving drugs, muscle relaxants, or anti-inflammatory drugs.

After obtaining consent, all subjects were examined clinically using the research diagnostic criteria for temporomandibular disorders (RDC/TMD) [24] by a physical therapist specialized in TMD. Neck disability was evaluated using the Neck Disability Index (NDI) [25]. The TMD group should score more than 4 points on the NDI in order to be classified as presenting neck disability. To measure their level of jaw disability, all subjects completed the Limitations of Daily Functions in the TMD Questionnaire (LDF-TMDQ) [26]. The healthy group had to score less than 4 points on the Neck Disability Index in order to be considered as having no neck dysfunction.

This study was approved by the Ethics Review Board from the University of Alberta, where the study was conducted.

2.2. Questionnaires. The "Limitations of Daily Functions in TMD Questionnaire" (LDF-TMDQ) was used to measure the jaw function of all the subjects in this study. The LDF-TMDQ is multidimensional and includes specific evaluations for TMD patients [26]. The LDF-TMDQ consists of 10 items and 3 factors and these factors are extracted by exploratory factor analysis. The first factor is named "limitation in executing a certain task" and is composed of five items including several problems in daily physical and psychosocial activities; the second factor is called "limitation of mouth opening" which is composed of three items, and the third factor, "limitation of sleeping," is composed of two items. The internal consistency of the questionnaire was calculated using Cronbach's alpha which was 0.78 for the 10 items, 0.72 for "limitation in executing a certain task," 0.73 for "limitation of mouth opening," and 0.77 for "limitation of sleeping," indicating good consistency. The LDF-TMDQ was tested for concurrent validity with the dental version of the McGill Pain Questionnaire and the authors found correlations ranging between 0.49 and 0.54 [26].

The NDI is a questionnaire designed to give information about how neck pain affects the ability of the subject to manage her everyday life [25, 27–30]. The NDI includes 10 items—7 items are associated with activities of daily living,

2 are linked to pain, and 1 is related to concentration [25, 29]. Each item is scored from 0 (no pain or disability) to 5 (severe pain and disability), and the total score is expressed as a percentage (total possible score = 100%), with higher scores corresponding to greater disability [25, 29]. Depending on the score, the patient was classified as having neck disability or not (0–4 = no disability; 5–14 = mild disability; 15–24 = moderate disability; 25–34 = severe disability; >35 = complete disability) [27]. The NDI has proven to be valid and reliable in measuring neck disability, allowing its use as a guide for clinical-decision making [28–30].

2.3. Pressure Pain Threshold (PPT) Measurements. The manual pressure algometer (force dial) was used to measure the muscle tenderness in both groups by one investigator, blinded to the subjects' group allocation. Muscle tenderness was measured bilaterally in the following muscles: masseter (i.e., deep masseter, anterior, and inferior portions of the superficial masseter), temporalis (i.e., anterior temporalis, medial temporalis, and posterior temporalis), sternocleidomastoid, and upper trapezius (i.e., occipital region and half way between C7 and acromion) in a supine position for all muscles but trapezius muscle which was evaluated in seating [17, 31, 32]. These muscles were selected for investigation because previous studies reported that patients with TMD tended to develop tenderness in these muscles [31, 32]. Furthermore, these muscles were easy to evaluate because of their anatomic position, which avoided confusion with other anatomic structures such as joints, ligaments, and other muscles.

The pressure pain threshold (PPT) was defined in this study as the point at which a sensation of pressure changed to pain. At this moment, the subject said "yes," the algometer was immediately removed, and the PPT was noted [33]. Before the test was performed, the procedure was demonstrated on the investigator's hand and a practice trial was performed on the subject's right hand [33]. During the test, the algometer was held perpendicular to the masticatory (i.e., masseter and temporalis) and neck muscles (i.e., sternocleidomastoid and upper trapezius). Figure 1 shows the sites in which the muscles were measured. The measurements were repeated 3 times at each site, with 30-second intervals with pressure rate of 1 Kg/sec for the neck muscles and 0.5 Kg/sec for the masticatory muscles [34, 35]. Since the first PPT of a session is usually higher than consecutive measurements, the first PPT measurement was discarded and the mean of the other two PPT measurements was considered to be the final pressure threshold of the sites tested [34].

Pressure rates were decided based on previously studies that showed the most reliable rates to use on cervical and facial muscles [18, 36–38].

2.4. Statistical Analysis. Muscle tenderness data for all analyzed muscles, jaw, and neck disability levels were analyzed descriptively. A paired t-test was performed to verify whether there were any differences between right and left sides in each pair of muscles. Spearman's rho was used to determine

Figure 1: PPT points evaluated (✦ temporalis muscle, ■ masseter muscle, ▲ sternocleidomastoid muscle, and **X** upper trapezius muscle).

whether there was a correlation among neck disability, jaw dysfunction, and muscle tenderness. The criteria used to interpret the correlation coefficient were as follows: 0.00–0.25: little correlation, 0.26–0.49: low correlation, 0.50–0.69: moderate correlation, 0.70–0.89: high correlation, and 0.90–1.00: very high correlation. The correlation was considered important when the correlation coefficient value was higher than 0.70. The reference values to make this decision were based on values reported by Munro [39].

Level of significance for all statistical analyses was set at $\alpha = 0.05$. The SPSS (SPSS Inc., Chicago), Statistical Program version 18.0 (Statistical Package for the Social Sciences), was used to perform the statistical analysis.

3. Results

3.1. Subjects Demographics. Mean age for TMD group was 31.05 (SD = 6.9) and for the healthy group was 32.3 (SD = 7.2). Thirteen subjects were classified as having mixed TMD and 7 were classified as having myogenic TMD. The range of neck disability ranged from 0 to 31 (no to severe disability) and the range of jaw dysfunction ranged from 10 to 50 (no to severe disability) among all subjects included in this study.

3.2. Correlation between Level of Muscle Tenderness and Jaw Dysfunction and Neck Disability. The correlations (Spearman's rho) between level of muscle tenderness and jaw dysfunction (LDF-TMDQ) as well as between level of muscle tenderness and neck disability (NDI) ranged from low to moderate correlations. Spearman's rho ranged from 0.387 to 0.647 for muscle tenderness and jaw dysfunction and Spearman's rho ranged from 0.319 to 0.554 for muscle tenderness and neck disability (Table 1).

3.3. Correlation between Neck Disability and Jaw Dysfunction. It was found that the correlation (Spearman's rho) between jaw disability and neck disability was significantly high ($r = 0.915$, $P < 0.001$). The coefficient of variation was 0.82

Table 1: Correlation between muscle tenderness (PPTs) and neck disability and jaw dysfunction.

Side	Muscle	Spearman's rho	
		Jaw dysfunction	Neck disability
Right	Temporalis	**−0.585**	**−0.517**
	Masseter	**−0.512**	−0.443
	Sternocleidomastoid	−0.387	−0.319
	Upper trapezius	−0.408	−0.352
Left	Temporalis	**−0.646**	**−0.554**
	Masseter	**−0.595**	−0.48
	Sternocleidomastoid	−0.426	−0.374
	Upper trapezius	**−0.647**	**−0.518**

indicating that approximately 82% of the variance of jaw disability is explained by the neck disability in this population. Thus, subjects who had no or low levels of jaw disability (evaluated through the JDI) also presented with no or low levels of neck disability (evaluated through the NDI).

4. Discussion

This study investigated the correlation among neck disability, jaw dysfunction, and muscle tenderness in subjects with and without chronic TMD.

The main results of this study were that jaw dysfunction and neck disability were strongly correlated, showing that changes in jaw dysfunction might be explained by changes in neck disability and vice versa. Also, the results showed that the higher the level of muscle tenderness in upper trapezius and temporalis muscles is, the higher the level of jaw and neck dysfunction the subject will have. These results add to the body of knowledge in this area providing new information regarding these associations. Furthermore, they corroborated the importance of looking at cervical spine and stomatognathic system as a functional entity when evaluating and treating subjects with TMD, neck pain, and muscle tenderness. Another study that is corroborated to this association was the study by Herpich and colleagues [40], where head and neck posture was found to be different between patients with bruxism and controls. They also found a relationship between posture alterations and the TMD severity.

The discussion will focus on each of the results separately, as well as highlighting the strengths and limitations of this study.

4.1. Correlation between Level of Muscle Tenderness of Masticatory and Cervical Muscles and Jaw Dysfunction and Neck Disability. Several studies examined the presence of signs and symptoms in the cervical area of patients suffering with TMD and they have been showing that the presence of tender points in the cervical area of TMD's patients is quite common, which is in line with the findings of this study [8–13]. Both upper trapezius and temporalis muscles had a moderate correlation with jaw dysfunction and neck disability. This finding indicates that increased levels of tenderness in these two muscles were related to higher levels of dysfunction in patients having TMD with concurrent neck disability. Therefore, assessing temporalis and upper trapezius muscles in patients with TMD and concurrent neck disability may allow physical therapists to have a better understanding of the level of dysfunction of these patients and to consider the need of managing these patients as a whole. However, although these results show a trend, moderate correlations just indicate association between levels of dysfunction in patients having TMD and concurrent neck disability with levels of muscle tenderness in both upper trapezius and temporalis muscles [23].

Muscle tenderness is only one factor among multiple factors that could contribute to maintaining or perpetuating a level of dysfunction in people with TMD either in the jaw or in the neck. Usually, jaw dysfunction and neck disability are both related to gender, psychological factors, and social factors. For example, studies have shown that the presence of muscle tenderness is more commonly found in women than in men suffering with signs and symptoms of TMD [8, 41–44]. Females' hormones seem to play a possible etiologic role, since there is a higher prevalence of signs and symptoms of TMD in women than in men as well as a lower prevalence for women in the postmenopausal years [41]. Increased rates of occurrence of TMD have been shown during specific phases of the menstrual cycle and possible adverse effects of oral contraceptives have been cited in the literature [41, 45]. Sherman et al. [45] showed significant differences in terms of pressure pain threshold during different phases of a woman's menstrual cycle. Women who have TMD and have not been using oral contraceptives showed lower pressure pain thresholds during menses and midluteal phases, while women with TMD and using oral contraceptives had stable pressure pain threshold throughout menses, ovulatory, and midluteal phases, with increased intensity at the late luteal phase [45]. Fluctuations in estrogen levels during the menstrual cycle may be related to the level of pressure pain in women [45]. The authors speculated that TMD patients, when exposed to experimental pain stimuli, might benefit from the use of oral contraceptives, since these patients did not experience the same intensity of estrogen depletion levels throughout late luteal and menses phases of the menstrual cycle nor the wide swings in estrogen levels during the ovulation [45].

"Pain is a complex phenomenon influenced by both biologic and psycologic *[sic]* factors" [46] (pp. 236). Younger et al. [47] found several limbic abnormalities in subjects suffering with TMD, showing that these patients had alterations not only in the sensory system, but also within the limbic system. The authors found alterations in the basal ganglia nuclei, which contain neurons responsive to nociceptive input and serve the function of preparing behavioral responses to noxious stimuli. They also found alterations in the anterior insula of patients with TMD. These alterations have been reported to be responsible for the integration of emotional and bodily states [47]. According to the authors, alterations in the anterior insula region appear to be very important in the emotional awareness of internal states and the emotional aspects of the pain experience and anticipation of sensation. It is important to note that pain is also perceived differently by different people, since factors such as fear, anxiety, attention,

and expectations of pain can amplify the levels of pain experience [46]. On the other hand, self-confidence, positive emotional state, relaxation, and beliefs that pain is manageable may decrease the sensation of pain [46]. Studies have shown that psychosocial factors are significantly associated with both jaw pain and neck pain [48–50]. Vedolin et al. [50], for example, showed that the PPTs of jaw muscles of patients with TMD were lower throughout a natural stressful event (i.e., academic examination), showing a relationship between stress and anxiety levels with level of muscle tenderness. Another study by Mongini et al. [32] also showed a high relationship between jaw and neck muscle tenderness with the prevalence of anxiety and depression among patients suffering from TMD. Increased levels of stress, anxiety, and depression could enhance sympathetic activity and the release of epinephrine at sympathetic terminals, leading to an increase in acetylcholine activity at the motor endplate. This could start a cascade of events, causing a decreased pressure pain threshold in the muscles [50]. The results of these studies suggest that a more integrated treatment approach including psychosocial assessment is important when treating patients with TMD. Factors that might be related to the development of jaw dysfunction or neck disability were not evaluated in this study, so further conclusions regarding social, emotional, and psychological factors are beyond the scope of this specific study.

4.2. Correlation between Neck Disability and Jaw Dysfunction. The correlation (Spearman's rho = 0.915) between jaw disability and neck disability was significantly high in this study. This means that the variance of jaw dysfunction is highly dependent on the neck disability (approximately 82%). Thus, subjects who had high levels of jaw disability (evaluated through the JDI) also presented with high levels of neck disability (evaluated through the NDI) and vice versa. Recently, the study by Armijo-Olivo and colleagues [15] was the first to show the relationship between jaw disability and neck disability. As in the present study, a high correlation between jaw disability and neck disability was found. Until now, the association between neck and jaw was always reported in terms of signs and symptoms, but the authors showed the importance of assessing the impact that the level of disability can have on patients suffering with TMD.

Disability is a complex concept, since it involves more than accounting for the individual signs and symptoms alone. It also includes the perception of the patient about his or her condition as an important factor [15]. The International Classification of Functioning, Disability and Health from the World Health Organization is helping health professionals to understand the importance of viewing chronic pain patients from different perspectives such as body, individual, societal, and environmental [51]. The impact that the disability has on patient's body functions, body structures, activities, and participation shows a more realistic vision of how the disease is impacting an individual's quality of life [15, 51]. TMD patients are a good example of how signs and symptoms can be perceived differently by different individuals. Sometimes severe TMD signs and symptoms may only have a small impact on the quality of life of a patient, while mild signs and symptoms may greatly interfere in other patients' lives. Therefore, assessing the level of disability of patients suffering with TMD is important to have a better view of how this condition is affecting these patients and which treatment approach is best for each situation [15].

The fact that jaw disability and neck disability are strongly related also shows that one has an effect on the other, which provides further information about the importance of assessing and treating both regions when evaluating chronic TMD patients. Assessment of the neck structures such as joints and muscles as well as the disability of patients with TMD could direct clinicians to include the cervical spine in their treatment approach. In addition, if patients with TMD have neck disability in addition to jaw disability, or vice versa, physical therapists and dentists should work together to manage these patients.

As strong correlation between jaw disability and neck disability does not indicate a cause and effect relationship, longitudinal studies where subjects with TMD are followed up to determine the appearance of neck disability are still necessary to determine any cause and effect connection.

4.3. Clinical Relevance. This study showed that the higher the level of muscle tenderness, mainly in upper trapezius and temporalis muscles, the higher the level of jaw and neck disability. Therefore, when clinicians assess higher levels of muscle tenderness either in the jaw and/or in the neck regions, they should infer that this could be possibly related to higher levels of jaw and neck disability. This information will guide health professionals to consider new clinical strategies that focus on both masticatory and cervical regions to improve patients' outcomes. Jaw dysfunction and neck disability were strongly correlated, showing that changes in jaw dysfunction might be explained by changes in neck disability and vice versa. This provides further information about the importance of assessing and treating both the jaw and neck regions as a complex system in TMD patients.

4.4. Limitations. The convenience sample used increased the potential subject self-selection bias. It was difficult to recognize what characteristics were present in those who offer themselves as subjects, as compared with those who did not, and it was unclear how these attributes might have affected the ability to generalize the outcomes [32]. Although probability samples would have been ideal for this type of study, having accessibility to the general population of TMD patients was limited in this study. Furthermore, even with random selection, not all of the TMD patients who could have been invited to participate in the study would give their consent.

5. Conclusions

High levels of muscle tenderness were correlated with high levels of jaw and neck disabilities. Furthermore, jaw dysfunction and neck disability were strongly correlated, showing that changes in jaw dysfunction may be explained by changes in neck disability and vice versa in patients with TMD. This study has highlighted the importance of assessing TMD

patients not only at the level of the jaw, but also including the neck region. Muscle tenderness, however, is only one aspect of the TMD. TMD is a complex problem and involves many factors such as gender, levels of anxiety and stress, and the level of socialization of the patient. Future studies investigating the association between neck and jaw should also include factors other than muscle tenderness which are still needed.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

The Diagnostic Value of Pressure Algometry for Temporomandibular Disorders

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The aim of this study is to determine the diagnostic value of pressure algometry in temporomandibular disorders. Two hundred volunteers aged 19.3 to 27.8 (mean 21.50, SD 0.97) participated in this study. An analogue pressure algometer was used for the evaluation of muscle tenderness of the following masticatory muscles: superficial and deep parts of the masseter muscle; anterior and posterior parts of the temporal muscle; and the tissues adjacent to the lateral and dorsal part of the temporomandibular joint capsule. Each patient described the algometry result for the individual components of the masticatory motor system, by selecting each time the intensity of pain on a 100 mm Visual Analogue Scale (VAS) ruler. The area under the receiver operating characteristic (ROC) curve, indicating the discriminatory efficiency for asymptomatic subjects and patients with temporomandibular dysfunction according to the dysfunction Di index, was the largest for the mean pain value (AUC = 0.8572; SEM = 0.0531). The 7.4 VAS cut-off point marked 95.3% specificity for this variable in identifying healthy subjects and 58.4% sensitivity in identifying patients with symptoms of dysfunctions (accuracy 68.1%). Assuming comparable sensitivity (74.9%) and specificity (74.2%) for a diagnostic test, there was test accuracy of 74.5% at the 4.2 VAS cut-off point.

1. Introduction

The high universal prevalence of temporomandibular dysfunction among the population means that it is important to look for methods of early diagnosis. In order to limit the negative consequences of adaptive compensation and to prevent prospective decompensation, it is essential to detect pain-free functional disorders in the masticatory system early and to apply therapeutic procedures, which are often simple in nature. Modern instrumental diagnostic methods make it possible to record the dynamics of the symptomatology of functional disorders objectively and quantitatively, as well as enabling the monitoring of therapeutic procedures [1–3].

The diagnosis of temporomandibular dysfunction includes a detailed and focused anamnesis and scrupulous clinical investigation. However, the main symptoms of masticatory motor system dysfunctions such as tenderness, restriction of mandibular movement, or temporomandibular joint noises are evaluated during a routine examination which includes methods characterised by low objectivity [4]. The perception threshold of the examiner is an important constraint in diagnostic efficiency when dealing with discrete signs of dysfunction. Thus, the diagnosis becomes critically dependent on accuracy, that is, the consistency of a practical assessment of a symptom with its true value. However, for many parameters of functional significance, the margin between physiology and pathology is often difficult to observe during a clinical examination. Differentiation between physiology and pathology relies to a greater extent

Table 1: The exclusion criteria adopted in anamnesis.

Exclusion criteria	Number of the excluded subjects
Depressive disorders	0
Pain in other parts of the body	4
Inflammations	3
Taking painkillers and antidepressants	1
Periodontal diseases	1
Completed treatment of masticatory motor system dysfunctions	2
Completed orthodontic treatment	15
Total	26

Table 2: Anamnestic index of temporomandibular dysfunction (Ai).

Ai	Symptoms
I	No subjective symptoms of temporomandibular dysfunction—no symptoms reported by patient.
II	Mild symptoms of temporomandibular dysfunction—temporomandibular joint noise, feeling of "jaw fatigue" (fatigue of masticatory muscles), and feeling of "jaw rigidity" (increased tone of masticatory muscles).
III	Severe symptoms of temporomandibular dysfunction—restricted mouth opening, painful lower jaw movements, temporomandibular joint pain, masticatory muscle pain, temporomandibular joint luxation, and lockjaw.

on definition rather than on biometric reality, thus becoming an act of making decisions rather than investigation.

Muscle tenderness on palpation is one of the most important clinical symptoms of masticatory motor system dysfunctions, occurring in about 90% of patients. Manual muscle palpation is the most popular and the most common clinical method for evaluating muscle pain, as well as being at the same time the "gold standard." However, the main disadvantages of this method include a quantitative assessment of its results and lack of repeatability [5, 6].

The alternative is pressure algometry. This is a diagnostic test which makes it possible to assess muscle pain quantitatively and ensures the repeatability of the diagnostic factor applied.

The aim of this study is to determine the diagnostic value of pressure algometry in temporomandibular disorders.

2. Materials and Methods

The research was approved by the Ethics Committee of the Pomeranian Medical University in Szczecin, Poland (number BN-001/45/07), as being consistent with the principles of GCP (Good Clinical Practice). All the patients were informed about the aim and research design and they gave their consent to all of the procedures. After the examination the patients received the information about their condition and function of the masticatory motor system.

Two hundred volunteers (100 females and 100 males), aged 19.3 to 27.8 (mean 21.50, SD 0.97), referred to the Orthodontic Department of the Pomeranian Medical University in Szczecin, participated in this random sampling study. As a result of the application of the adopted exclusion criteria listed in Table 1, 174 of these (93 females and 81 males) qualified for further examinations.

The anamnestic interviews included the patients' general medical history as well as detailed information about their masticatory motor system. They were conducted according to a three-point anamnestic index of temporomandibular dysfunction—Ai (Table 2) [7].

The assessment of the function of the masticatory motor system included clinical examination and pressure algometry. Clinical examination involving visual and auscultatory assessment as well as palpation made it possible to qualitatively and quantitatively evaluate the function of the masticatory system. The clinical index of temporomandibular dysfunction (Di) was used for the analysis of the data obtained from the clinical study (Table 3). The interpretation of the results of the clinical index of temporomandibular dysfunction (Di), based on the total number of points obtained during the tests, was performed according to the following model (Table 4) [7].

An analogue pressure algometer of our own construction was used for the evaluation of muscle tenderness of selected components in the masticatory motor system, such as the superficial and deep parts of the masseter muscle; the anterior and posterior parts of the temporal muscle; and tissues immediately adjacent to the lateral and dorsal parts of the temporomandibular joint capsule. The examination of the abovementioned muscles was performed extraorally, while the dorsal part of the temporomandibular joint was examined by external acoustic pore. Algometer consisted of casing, slide, and steel spring. The housing was constructed of plastic in the shape of a reinforced sleeve finished handle. A precision scale on the cover allow for assessing the force. The slider in the shape of piston had a circular footplate with an overlay of soft rubber. Footplate area size was 1 cm^2. Force generating element was steel screw spring with specific parameters scaled and described on the scale of the housing. The accuracy of the algometer was 0.5 N. The algometric measurements

Table 3: Clinical index of temporomandibular dysfunction (Di).

Di	Symptoms
	Mandibular movements
0	Normal range
1	Small reduction in amplitude
5	Large reduction in amplitude
	Temporomandibular joint function
0	Smooth, noiseless abduction and adduction of mandible, trajectory asymmetry <2 mm
1	Noise in one joint or both joints during abduction and adduction of mandible, trajectory asymmetry >2 mm
5	Abduction of mandible impossible and/or luxation
	Masticatory muscle pain
0	No tenderness
1	Tenderness of 1–3 sites
5	Tenderness of 4 and more sites
	Temporomandibular joint pain
0	No tenderness
1	Unilateral or bilateral tenderness
5	Unilateral or bilateral tenderness of the dorsal surface of joint
	Pain during movement of mandible
0	No pain
1	Pain during one out of all possible movement directions
5	Pain during more than one out of all possible movement directions

Table 4: Interpretation of the clinical index of temporomandibular dysfunction (Di).

Range	Severity of dysfunction	Description
0	Di 0	No dysfunction
1–4	Di I	Mild dysfunction
5–9	Di II	Moderate dysfunction
10–25	Di III	Severe dysfunction

were performed by the same examiner, alternately on the right and left sides with a constant sequence of examined structures. There was a five-second interval between the examination of the right and left sides. The examination was performed with the patients' dental arches in a slightly open position and the muscles relaxed. During the examination, the footplate of the algometer was always held perpendicular to the skin, in the centre of the belly of the examined muscle, applying a constant force of 18 N (pressure 180 kPa) for duration of 2 s. In the examination of the tissues surrounding the temporomandibular joint, a force of 8 N (pressure 80 kPa) was applied for 2 s. During the test a constant rate of pressure increase was maintained—80 kPa s^{-1}. The patients described the algometry results for the individual components of the masticatory motor system, by selecting each time the intensity of pain on a 100 mm Visual Analogue Scale (VAS) ruler.

The Kruskal-Wallis test, the median, and the Mann-Whitney U test were used to verify the hypotheses relating to the existence or absence of differences between the mean values of the independent variables (Di group). The correlation between the variables was assessed using Spearman's rank correlation coefficient. The assessment of the accuracy of the classifier (a single variable or the whole model) together with a description of its sensitivity and specificity was based on an analysis of the receiver operating characteristic (ROC) curve. This method made it possible to determine the optimal cut-off points for the specific misclassification costs as well as the *a priori* probabilities for the occurrence of the studied phenomenon. A level of $P = 0.05$ was considered to be statistically significant.

3. Results

The findings for the pressure algometry of muscles and temporomandibular joints on the right and left sides for both genders in groups with different severities of temporomandibular dysfunction according to the Di index are presented in Table 5.

The analysis of the mean total values of pain defined according to the Visual Analogue Scale (VAS) during the test showed an increase in pain in direct proportion to the severity of temporomandibular dysfunction ($P < 0.0000$; Figure 1). Gender was not a factor affecting the results ($P < 0.85643$). The lowest level of pain was recorded in the group with no dysfunction (Di 0 = 2.13 VAS; $P < 0.0000$). Significantly higher algometry measurements were found in the groups with mild dysfunction (Di 1 = 6.79 VAS; $P < 0.0000$), moderate dysfunction (Di 2 = 18.26 VAS; $P < 0.0000$), and severe dysfunction (Di 3 = 34.85 VAS; $P < 0.0000$).

A regression analysis of the results of algometry and the clinical examination of masticatory motor system dysfunction according to the Di algorithm showed precise correlations between both tests (Table 6). The analysis showed that

Table 5: Muscle and temporomandibular joint algometry [VAS] findings depending on the temporomandibular dysfunction index Di.

Side/gender	Di group											
	0			I			II			III		
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Superficial part of masseter muscle												
Left												
Females	22	5.57	5.71	39	14.47	10.10	25	23.94	18.08	7	41.29	22.13
Males	23	4.76	4.07	29	10.31	9.06	23	41.50	21.81	6	40.33	5.43
Total	**45**	**5.16**	**4.90**	**68**	**12.70**	**9.82**	**48**	**32.35**	**21.64**	**13**	**40.85**	**16.04**
Right												
Females	22	6.52	6.72	39	19.32	14.78	25	34.88	28.69	7	61.00	13.56
Males	23	5.15	3.41	29	11.53	8.57	23	48.43	24.80	6	60.67	5.57
Total	**45**	**5.82**	**5.28**	**68**	**16.00**	**13.02**	**48**	**41.38**	**27.48**	**13**	**60.85**	**10.25**
Deep part of masseter muscle												
Left												
Females	22	2.73	3.98	39	7.90	8.81	25	24.28	16.75	7	35.14	22.52
Males	23	3.54	4.09	29	9.14	10.54	23	39.35	19.89	6	23.00	7.97
Total	**45**	**3.14**	**4.01**	**68**	**8.43**	**9.53**	**48**	**31.50**	**19.66**	**13**	**29.54**	**17.88**
Right												
Females	22	3.39	3.53	39	7.41	8.49	25	19.98	12.03	7	29.57	15.40
Males	23	1.59	1.10	29	9.17	10.26	23	31.17	15.67	6	47.33	4.08
Total	**45**	**2.47**	**2.72**	**68**	**8.16**	**9.25**	**48**	**25.34**	**14.86**	**13**	**37.77**	**14.51**
Anterior part of temporal muscle												
Left												
Females	22	0.84	0.54	39	4.13	4.97	25	7.70	7.24	7	5.29	1.60
Males	23	0.76	0.77	29	2.60	2.58	23	13.48	10.83	6	9.00	10.10
Total	**45**	**0.80**	**0.66**	**68**	**3.48**	**4.17**	**48**	**10.47**	**9.50**	**13**	**7.00**	**6.89**
Right												
Females	22	1.07	0.94	39	4.87	5.39	25	9.78	10.04	7	19.43	10.06
Males	23	1.07	1.31	29	3.90	4.31	23	17.26	11.97	6	39.00	7.35
Total	**45**	**1.07**	**1.13**	**68**	**4.46**	**4.95**	**48**	**13.36**	**11.52**	**13**	**28.46**	**13.28**
Posterior part of temporal muscle												
Left												
Females	22	1.48	1.26	39	5.37	5.93	25	6.50	5.24	7	10.29	8.22
Males	23	0.61	0.81	29	3.17	3.94	23	7.02	5.09	6	22.00	1.55
Total	**45**	**1.03**	**1.13**	**68**	**4.43**	**5.25**	**48**	**6.75**	**5.12**	**13**	**15.69**	**8.47**
Right												
Females	22	1.43	1.17	39	4.80	5.18	25	9.82	7.52	7	18.86	18.87
Males	23	0.98	0.71	29	3.67	4.41	23	9.39	6.37	6	14.00	9.36
Total	**45**	**1.20**	**0.98**	**68**	**4.32**	**4.86**	**48**	**9.61**	**6.93**	**13**	**16.62**	**14.86**
Lateral surface of temporomandibular joint												
Left												
Females	22	0.89	1.34	39	4.65	8.39	25	6.24	7.58	7	10.00	8.60
Males	23	1.43	1.37	29	2.71	2.65	23	11.87	8.34	6	32.17	2.71
Total	**45**	**1.17**	**1.37**	**68**	**3.82**	**6.62**	**48**	**8.94**	**8.37**	**13**	**20.23**	**13.13**
Right												
Females	22	1.61	1.75	39	5.49	6.49	25	10.00	10.31	7	29.29	14.75
Males	23	0.93	1.15	29	3.93	3.39	23	17.11	13.04	6	48.00	13.55
Total	**45**	**1.27**	**1.50**	**68**	**4.83**	**5.41**	**48**	**13.41**	**12.12**	**13**	**37.92**	**16.72**

Table 5: Continued.

Side/gender	Di group 0			I			II			III		
	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
Dorsal surface of temporomandibular joint												
Left												
Females	22	1.82	2.37	39	6.98	8.70	25	12.80	11.04	7	57.57	26.65
Males	23	0.54	0.42	29	3.53	2.82	23	13.87	10.65	6	62.33	17.91
Total	**45**	**1.17**	**1.79**	**68**	**5.51**	**7.01**	**48**	**13.31**	**10.76**	**13**	**59.77**	**22.25**
Right												
Females	22	1.45	0.87	39	5.99	6.17	25	11.54	8.23	7	56.71	23.68
Males	23	1.17	0.90	29	4.50	4.31	23	13.83	8.80	6	71.33	15.91
Total	**45**	**1.31**	**0.89**	**68**	**5.35**	**5.47**	**48**	**12.64**	**8.50**	**13**	**63.46**	**21.05**

Table 6: Correlations between algometry findings and temporomandibular dysfunction index Di.

Algometry	Total Di value		Muscle and joint pain in Di	
	r_s	P value	r_s	P value
Mean pain value[1]	0.7532	0.0000	0.9011	0.0000
Mean absolute difference in pain between right and left side[1]	0.5529	0.0000	0.7377	0.0000

[1] Mean value for 12 measurement points.

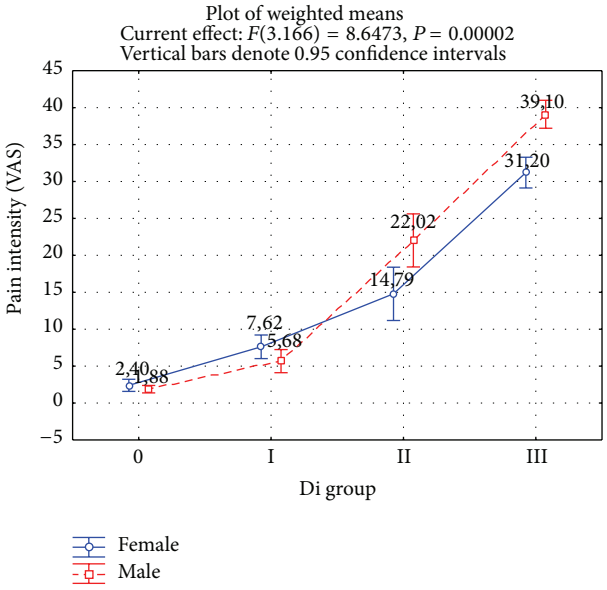

Figure 1: Mean pain value for 12 measurement points depending on the temporomandibular dysfunction index Di.

in algometric tests the mean pain value was a better predictor in terms of functional disorders ($r_s = 0.7532$; $P < 0.0000$) than the mean absolute difference in pain between the right and left sides ($r_s = 0.5529$; $P < 0.0000$).

For both analysed variables the degree of correlation increased with respect to muscle and joint pain according to the Di index ($r_s = 0.9011$ and $r_s = 0.7377$).

A mathematical analysis of the ROC curve made it possible to compare the sensitivity and specificity of diagnostics tests within the entire range and showed the highest diagnostic efficiency of pressure algometry for the mean pain value (Table 7). The area under the ROC curve, indicating the discriminatory efficiency for asymptomatic subjects and patients with temporomandibular dysfunction according to the Di index, was slightly larger for this variable than in other cases (area under ROC curve (AUC) = 0.8572; standard error of mean (SEM) = 0.0531; $P < 0.1532$). The 7.4 VAS cut-off point marked 95.3% specificity for this variable in identifying healthy subjects and 58.4% sensitivity in identifying subjects with symptoms of dysfunctions (accuracy 68.1%). Assuming a comparable sensitivity (74.9%) and specificity (74.2%) of a diagnostic test, there was test accuracy of 74.5% at the 4.2 VAS cut-off point.

The mean absolute difference in pain between the right and left sides showed a slightly lower diagnostic efficiency in the identification of people with symptoms of dysfunction according to the Di index (AUC = 0.8142; SEM = 0.0495). The 4.1 VAS cut-off point defined 95.5% specificity of this variable in identifying healthy patients and 42.3% sensitivity in identifying subjects with symptoms of dysfunctions (accuracy 68.1%). Assuming comparable sensitivity (68.1%) and specificity (68.4%) for a diagnostic test, there was test accuracy of 68.2% at the 1.7 VAS cut-off point.

4. Discussion

Pressure algometry, because of the specific nature of the examination, is dependent on many factors. A crucial element is maintaining constant test conditions. One of the principal local factors which is particularly important in this respect is the invariable position of the algometer in relation to the examined structures. Other important elements include the dynamics of the pressure exerted, the area to which pressure is applied, and the differences between algometers.

Table 7: Data for some cut-off points in algometry as discriminators for patients without symptoms of temporomandibular dysfunction or with Di group I, II, or III.

Variable	Parameter	Sensitivity = specificity	Specificity = 95%	AUC (SEM)
Mean pain value[1]	Cut-off point	4.2 VAS	7.4 VAS	0.8572 (0.0531)
	Sensitivity	74.9%	58.4%	
	Specificity	74.2%	95.3%	
	Accuracy	74.5%	68.1%	
Mean absolute difference in pain between right and left side[1]	Cut-off point	1.7 VAS	4.1 VAS	0.8142 (0.0495)
	Sensitivity	68.1%	42.3%	
	Specificity	68.4%	95.5%	
	Accuracy	68.2%	52.5%	

[1] Mean value for 12 measurement points.
AUC: area under ROC curve, SEM: standard error of mean.

A number of short- and long-term clinical experiments conducted by Farella et al. [8] on a group of healthy volunteers and patients with dysfunctions of the masticatory system showed less variation in the repeatability of the pain threshold during pressure algometry than individual variability in this respect. The influence of other factors on the pain threshold did not exceed 25% of the possible variance. Importantly, the prediction interval for the pain threshold relating to various factors is considerably smaller in comparison to the range of differences between healthy subjects and patients with functional disorders of the masticatory system (4–50% of the variance).

High accuracy and precision of pressure algometry was also confirmed in a study by Bernhardt et al. [9]. The study, conducted on a group of 15 healthy volunteers and 15 patients with masticatory motor system dysfunctions, showed high accuracy and repeatability of measurements made using two pressure algometers, with the intraclass correlation coefficient within a range between 0.73 and 0.99.

The results of our own algometric studies showed an increase in the level of pain correlated with the severity of the symtoms of the functional disorders expressed by the Di clinical index of the temporomandibular dysfunction. This was the basis for the evaluation of the diagnostic and discriminant efficiency of this study in relation to the results of a comprehensive clinical trial consistent with the algorithm of the Di index.

The occurrence of the symptom of increased pain on palpation in the structures of the masticatory system in patients with functional disorders has been the subject of numerous studies. Mohn et al. [10] examined the occurrence of pain under experimental conditions in response to transcutaneous electrical stimulation and pressure algometry. Patients with temporomandibular disorders experienced greater pain in response to electrical stimulation and an increase in pain during an isometric contraction, which was not observed in healthy subjects. According to the authors, the increase in pain during an isometric contraction may indicate centralisation of pain sensitivity in patients with temporomandibular dysfunction.

A study by Etöz and Ataoğlu [11] showed a lower pain threshold in a group of 50 people with functional disorders in comparison to a group of 45 healthy people. It also showed a significantly lower pain threshold in patients with a less than 40 mm range of vertical mandibular opening. According to the authors, the lower pain threshold can be a manifestation of subjective symptoms of functional disorders in this group of patients. An algometric study by McBeth and Gratt [12] revealed a significantly greater sensation of pain in the front and middle areas of the temporal muscle, both parts of the masseter muscles, and the lateral surfaces of the temporomandibular joints in a group of 20 patients with functional pain disorders than in a group of 21 people without any symptoms of dysfunction. The respondents assessed the level of pain using a six-point verbal descriptor scale with constant pressure on the muscles (1.8 kg/cm^2) and temporomandibular joints (0.8 kg/cm^2). The possibility of discriminating subjects with functional disorders of the masticatory motor system on the basis of algometry was confirmed by Bernhardt et al. [9]. Tests conducted by means of two pressure algometers made it possible to identify the patients with functional disorders and the healthy volunteers.

The possibility of using pressure algometry in the process of diagnosing masticatory system dysfunctions was also confirmed by Visscher et al. [13]. The authors conducted research on a group of 250 respondents, of which 148 manifested subjective pain symptoms, and demonstrated the usefulness of pressure algometry. Their clinical study was based on the principles of a blind sample and involved evaluating through palpation the masseter and temporal muscles as well as the temporomandibular joints. Regression analysis showed that the diagnostic effectiveness of algometry was similar to that of palpation ($r^2 = 0.22$ and $r^2 = 0.21$, resp.). The highest sensitivity to pain was observed in the masseter muscles and the temporomandibular joints, and the lowest in the temporal muscles.

Variations in the pain threshold for pressure algometry in patients with objective and subjective symptoms of functional disorders ($n = 50$) compared to those without symptoms ($n = 49$) were the subject of research conducted by Silva et al. [14]. An algometric test of the masseter muscles as well as the anterior, middle, and posterior fibres of the temporal muscle showed a significantly lower pain threshold for all the tested muscles in the group with symptoms of functional disorders

($P < 0.001$). In addition, there were significant differences in the level of pain experienced in individual muscles. The lowest threshold of pain was recorded for the masseter muscles, and then for the anterior, middle, and posterior temporal muscle fibres in that order. High (98%) specificity of the algometric test was obtained for the following cut-off points of the muscles: masseter muscles 1.5 kgf/cm^2; temporal muscles: anterior 2.47 kgf/cm^2, middle 2.75 kgf/cm^2, and posterior 2.77 kgf/cm^2. A ROC curve analysis showed the largest area under the curve (AUC), respectively, for the anterior part (0.92), the middle part (0.90), and the posterior part (0.90) of the temporal muscles and the masseter muscles (0.84). The findings presented by the authors of the study confirmed that the temporal muscles and the masseter muscles have different cut-off points for identifying patients with functional disorders of the masticatory system among a group of healthy patients. Moreover, the greatest diagnostic efficiency of algometric tests was noted for the anterior part of the temporal muscle due to its highest sensitivity amounting to 77%.

The diagnostic value of pressure algometry was the subject of a series of studies conducted by Farella et al. [15]. The studies were conducted by a single physician and were based on the blind sample principle. The algometer used had a pressure area of 1 cm^2, and the pressure was increased at the rate of 20 kPa/s. The results of this study in a group of 40 women with subjective symptoms of functional disorders of the masticatory system showed a significantly lower pain threshold for the masseter and temporal muscles than in a group of 40 healthy women ($P < 0.001$). The pain threshold for the masseter muscles and the anterior parts of the temporal muscles in women with functional disorders was about 40–50% lower than in the control group. In addition, muscle pain on palpation was significantly greater on the side with more intense subjective symptoms. The placement of the cut-off point one standard deviation below the mean value of the pain threshold in the control group determined the sensitivity and specificity of pressure algometry for the masseter muscles at, respectively, 67% and 85%, and for the temporal muscles at 77% and 87%. The authors also determined the probability of the occurrence of the condition in patients who had a positive result in the algometric test, that is, the positive predictive value of the test, which is closely correlated with the prevalence of a specific disease in the population. From adopted prevalence of masticatory system dysfunctions at a level of 17.4%, the positive predictive value for the temporal muscles was 55% and for the masseter muscles 48%. Thus, the use of pressure algometry for screening may generate 50% false-positive results in a population of women. Assuming, however, the prevalence of functional disorders at a level of 33%, the positive predictive value for temporal muscles would be 74%, and for the masseter muscles 68%. Nevertheless, there is still the possibility of approximately 30% false-positive results, which according to the authors significantly reduces the possibility of using algometry for screening.

In conclusion, it is important to emphasise the possibility of analysing algometric tests in terms of both the intensity and the symmetry of pain within homonymous structures. Mathematical analysis also confirmed significant correlations between the results of algometric tests and a clinical trial consistent with the algorithm of the Di index. Furthermore, the intensity of pain indicated on a Visual Analogue Scale and its asymmetry may be a predictor of functional changes in the masticatory organ. A crucial element is also the stability and repeatability of the applied pressure, which enhances the credibility of the results obtained.

5. Conclusions

Respecting the limitations of this study, the evaluation of pressure algometry demonstrated its diagnostic effectiveness with regard to symptoms of temporomandibular dysfunction.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Clinical Study

The Electrical Activity of the Temporal and Masseter Muscles in Patients with TMD and Unilateral Posterior Crossbite

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The aim of this study was to assess the influence of unilateral posterior crossbite on the electrical activity of the temporal and masseter muscles in patients with subjective symptoms of temporomandibular dysfunctions (TMD). The sample consisted of 50 patients (22 female and 28 male) aged 18.4 to 26.3 years (mean 20.84, SD 1.14) with subjective symptoms of TMD and unilateral posterior crossbite malocclusion and 100 patients without subjective symptoms of TMD and malocclusion (54 female and 46 male) aged between 18.4 and 28.7 years (mean 21.42, SD 1.06). The anamnestic interviews were conducted according to a three-point anamnestic index of temporomandibular dysfunction (Ai). Electromyographical (EMG) recordings were performed using a DAB-Bluetooth Instrument (Zebris Medical GmbH, Germany). Recordings were carried out in the mandibular rest position and during maximum voluntary contraction (MVC). Analysis of the results of the EMG recordings confirmed the influence of unilateral posterior crossbite on variations in spontaneous muscle activity in the mandibular rest position and maximum voluntary contraction. In addition, there was a significant increase in the Asymmetry Index (As) and Torque Coefficient (Tc), responsible for a laterodeviating effect on the mandible caused by unbalanced right and left masseter and temporal muscles.

1. Introduction

Bilateral symmetry, characteristic of vertebrates, is extremely important for describing the morphology of the masticatory organ. This feature is strongly marked in the craniofacial area and is an important determinant of its correct structure. Assessment of bilateral symmetry in the craniofacial area is a fundamental component of the examination and description of people with and without disorders. It must be stated, however, that slight facial asymmetry is acceptable, being a common and frequently observed morphological feature [1, 2]. Such a disruption of symmetry is not a significant exception but a commonly accepted structural deviation. Unfortunately, the extent of acceptable craniofacial asymmetry has not been clearly defined. The concept of the bilateral symmetry of the human body is also connected with functional symmetry. An assessment of this feature in the craniofacial area is primarily related to the function of the largest and strongest facial bone, namely, the mandible. The symmetrical function of this bone, which is the single and only movable bone of the skull, is determined by two morphologically coupled temporomandibular joints.

In this context, a harmonised relationship between the dental arches is essential for maintaining functional symmetry. Malocclusion, particularly of the transverse type where disrupted symmetry of dental arches can be clinically observed, is a potential cause of functional disorders [3–6]. A priori knowledge clearly indicates the impact of the relationship between dental arches on the function of the masticatory organ [7–10].

The aim of this study was to assess the influence of unilateral posterior crossbite on the electrical activity of the temporal and masseter muscles in patients with subjective symptoms of temporomandibular dysfunctions (TMD).

2. Materials and Methods

Fifty patients (22 women and 28 men) aged between 18.4 and 26.3 years (mean 20.84, SD 1.14) with subjective symptoms of

TMD (Ai II-III) and unilateral posterior crossbite malocclusion were selected from patients referred to the Pomeranian University in Szczecin, Poland. The control group consisted of 100 subjects (54 women and 46 men) aged between 19.5 and 28.7 years (mean 21.42, SD 1.06) with no malocclusion and subjective symptoms of TMD (Ai I). Patients who had already finished their orthodontic treatment and those who were undergoing treatment at the time of the study were excluded.

The anamnestic interviews included the patients' general medical history as well as detailed information about their masticatory motor system. They were conducted according to a three-point anamnestic index of temporomandibular dysfunction—Ai (Table 1) [11, 12].

The assessment of the function of the masticatory motor system included clinical examination and electromyographic procedures. Clinical examination consisted of visual and auscultatory assessment as well as palpation. This made it possible to accurately and precisely evaluate the function of the masticatory system. Data obtained from the clinical study was analysed using the clinical temporomandibular dysfunction index (Di).

All the patients gave their informed consent to all of the procedures performed.

EMG recordings were performed using a DAB-Bluetooth Instrument (Zebris Medical GmbH, Germany). Each patient was sitting on a comfortable chair without head support and was requested to assume a natural head position.

Surface EMG signals were detected by four silver/silver chloride (Ag/AgCl), disposable, self-adhesive, bipolar electrodes (Noraxon Dual Electrode, Noraxon, USA) with a fixed interelectrode distance of 20 mm. The electrodes were accurately positioned on the anterior temporal muscle and the superficial masseter on both the left and the right sides parallel to the muscular fibres. Anterior temporal muscle is vertically along the anterior margin of the muscle; masseter muscle is parallel to the muscular fibres with the upper pole of the electrode at the intersection between the tragus-labial commissura and exocanthion-gonion lines. A reference electrode was applied inferior and posterior to the right ear [13].

To reduce skin impedance, the skin was cleaned with 70% ethyl alcohol and dried prior to the placement of the electrode. The recordings were performed 5 minutes later.

EMG activity was then recorded during three different tests.

(1) Rest activity of the masticatory muscles was performed in the clinical rest position.

(2) Maximum voluntary clench (MVC) was performed in the intercuspal position and the subject was asked to clench as hard as possible for 5 seconds.

(3) Maximum voluntary clench (MVC) was performed with two 10 mm thick cotton rolls positioned on the mandibular second premolars and molars and the subject was asked to clench as hard as possible for 5 seconds.

To avoid any effects of fatigue, a rest period of at least 5 minutes was allowed between each of the recordings.

For each muscle, the EMG potentials were expressed as a percentage of the MVC value using cotton rolls (unit μV/μV%). This kind of standardization should obviate any variability due to skin and electrode impedance, electrode positioning, and relative muscular hypo- or hypertrophy [14–16].

In the current study, muscular coordination and symmetry of the masticatory muscles were expressed through the use of indices.

The asymmetry between the activity of the left and right jaw muscles was quantified by the Asymmetry Index (As, unit %). This ranges from 0% (total symmetry) to 100% (total asymmetry):

$$\mathrm{As} = \frac{\sum_{i=1}^{N} \left|R_i - L_i\right|}{\sum_{i=1}^{N} \left(R_i + L_i\right)} \cdot 100. \quad (1)$$

To assess the presence of a possible laterodeviating effect on the mandible during the test caused by unbalanced TR and ML and TL and MR couples, the Torque coefficient (Tc, unit %) was calculated as follows:

$$\mathrm{Tc} = \frac{\sum_{i=1}^{N} \left|(TR + ML)_i - (TL + MR)_i\right|}{\sum_{i=1}^{N} \left[(TR + ML) + (TL + MR)\right]_i} \cdot 100. \quad (2)$$

Tc ranges from 0%, no torque during the test, to 100%, a significant laterodeviating effect on the mandible [17–19].

The Kruskal-Wallis test and the Mann-Whitney U test were used to verify the hypotheses relating to the existence or absence of differences between the mean values of the independent variables. The level of significance was set at $P = 0.05$.

The research was approved by the Ethics Committee of the Pomeranian Medical University in Szczecin (number BN-001/45/07).

3. Results

The analysis of the results of EMG recordings confirmed the influence of unilateral posterior crossbite on the variability of muscle activity in the mandibular rest position (Table 2, Figure 1). The rest activity of the temporal muscles was higher in subjects with crossbite and subjective symptoms of TMD (7.11 μV/μV%, $P < 0.0249$) compared with healthy subjects (4.07 μV/μV%). There were no significant differences in the rest activity of the masseter muscles in either examined group ($P < 0.5902$).

The results showed a significant increase in the Asymmetry Index in relation to both the rest activity of the temporal (29.30%, $P < 0.0001$) and masseter muscles (38.07%, $P < 0.0006$) in patients with unilateral posterior crossbite (Figure 2).

Additionally, a significant increase was observed in the torque for the pair of muscles responsible for the lateral functional shift of the mandible in the rest position in patients with crossbite (14.56%, $P < 0.0002$, Figure 3).

The differences presented regarding asymmetry in spontaneous muscle activity between the two examined groups were confirmed only for women.

Table 1: Anamnestic index of temporomandibular dysfunction (Ai).

Ai	Symptoms
I	No subjective symptoms of temporomandibular dysfunction: no symptoms reported by patient.
II	Mild symptoms of temporomandibular dysfunction: temporomandibular joint noise, feeling of "jaw fatigue" (fatigue of masticatory muscles), and feeling of "jaw rigidity" (increased tone of masticatory muscles).
III	Severe symptoms of temporomandibular dysfunction: restricted mouth opening, painful lower jaw movements, temporomandibular joint pain, masticatory muscle pain, temporomandibular joint luxation, and lockjaw.

Table 2: Electrical activity of muscles at clinical mandibular rest position depending on transversal malocclusion.

Region	Variable	Gender	Group					
			No malocclusion			Crossbite		
			n	Mean	SD	n	Mean	SD
Temporal muscles	Electrical activity [μV/μV%]	Females	54	4.07	2.02	22	7.08	6.45
		Males	46	4.08	2.06	28	7.14	5.10
		Total	100	4.07	2.03	50	7.11	5.67
	Asymmetry index [%]	Females	54	21.20	9.48	22	36.35	12.71
		Males	46	17.12	9.00	28	23.77	15.60
		Total	100	19.33	9.44	50	29.30	15.59
Masseter muscles	Electrical activity [μV/μV%]	Females	54	2.12	0.89	22	1.78	0.98
		Males	46	2.13	1.09	28	2.10	0.57
		Total	100	2.12	0.98	50	1.96	0.79
	Asymmetry index [%]	Females	54	23.03	14.97	22	45.78	19.99
		Males	46	31.63	14.14	28	32.01	17.37
		Total	100	26.99	15.15	50	38.07	19.63
Temporal/masseter muscles	Torque coefficient [%]	Females	54	7.20	7.66	22	19.43	13.53
		Males	46	4.37	3.95	28	10.73	12.83
		Total	100	5.90	6.36	50	14.56	13.72

An analysis of the EMG recordings during MVC confirmed the influence of transversal malocclusion on the activity of the masticatory muscles (Table 3, Figure 1). In patients with unilateral posterior crossbite a significant decrease in the activity of the temporal (91.59 μV/μV%, $P < 0.0000$) as well as masseter muscles (97.08 μV/μV%, $P < 0.0000$) in relation to subjects without malocclusion (temporal and masseter muscles 116.27 μV/μV% and 131.99 μV/μV%, resp.) was observed.

The importance of transverse defects was also reflected in significantly higher rates of muscle asymmetry for the temporal (17.96%, $P < 0.0000$) and masseter muscles (17.10%, $P < 0.0000$, Figure 2) during maximum isometric contraction in patients with unilateral posterior crossbite. Analysis revealed a considerable imbalance in the torque for the pair of muscles responsible for the lateral functional shift of the mandible in patients with crossbite (4.33%, $P < 0.0380$, Figure 3).

4. Discussion

In our study, an analysis of the influence of the relationships between dental arches on the electrical activity of muscles was performed with respect to two functions: in the mandibular rest position and during maximum isometric contraction. The results confirmed the significant impact of transversal malocclusions on the electrical activity of the temporal and masseter muscles in patients with subjective symptoms of TMD. In the analysis of the results of this scientific experiment, in addition to measurements which were specific for each research method, quotient indicators such as the Asymmetry Index and the Torque coefficient were used. The use of these mathematical tools made it possible to significantly increase the possibilities of describing the biomedical reality. As a result, the unbalanced torque of the two pairs of muscles responsible for the functional lateral shift of the mandible in subjects with unilateral posterior crossbite was observed. This was consistent with the clinical observations. Increased asymmetry in spontaneous muscles activity was revealed only in women and may suggest a higher sensitivity of this examined group for asymmetry of dental arches.

A review of the literature presented by McNamara et al. [20] indicates that there are relatively weak links between function and the alignment of dental arches. Only five occlusal features such as skeletal anterior open bite, overjet greater than 6 to 7 mm, retruded cuspal position/intercuspal position slides greater than 4 mm, unilateral lingual crossbite,

Table 3: Electrical activity of muscles at maximal voluntary contraction (MVC) in intercuspal position depending on transversal malocclusion.

Region	Variable	Gender	Group					
			No malocclusion			Crossbite		
			n	Mean	SD	n	Mean	SD
Temporal muscles	Electrical activity [μV/μV%]	Females	54	117.86	28.11	22	82.88	19.33
		Males	46	114.40	27.06	28	98.43	34.86
		Total	100	116.27	27.54	50	91.59	29.84
	Asymmetry index [%]	Females	54	9.95	8.18	22	22.10	11.14
		Males	46	8.48	5.73	28	14.71	9.81
		Total	100	9.27	7.16	50	17.96	10.95
Masseter muscles	Electrical activity [μV/μV%]	Females	54	131.06	26.23	22	76.72	37.22
		Males	46	133.07	33.94	28	113.08	42.73
		Total	100	131.99	29.89	50	97.08	43.96
	Asymmetry index [%]	Females	54	9.07	5.23	22	21.72	12.81
		Males	46	10.71	6.18	28	13.48	5.01
		Total	100	9.83	5.72	50	17.10	10.06
Temporal/masseter muscles	Torque coefficient [%]	Females	54	2.77	1.88	22	6.62	4.44
		Males	46	3.16	2.35	28	2.54	1.49
		Total	100	2.95	2.11	50	4.33	3.72

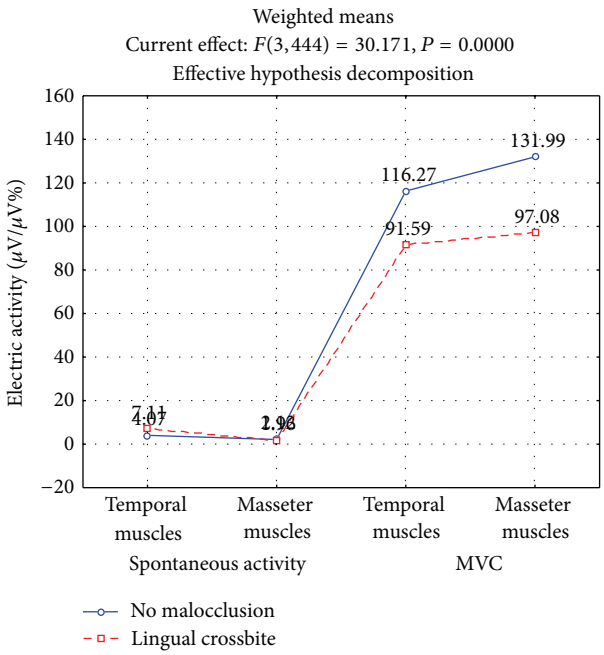

Figure 1: Electrical activity of muscles at clinical mandibular rest position and at maximal voluntary contraction (MVC) in intercuspal position depending on transversal malocclusion.

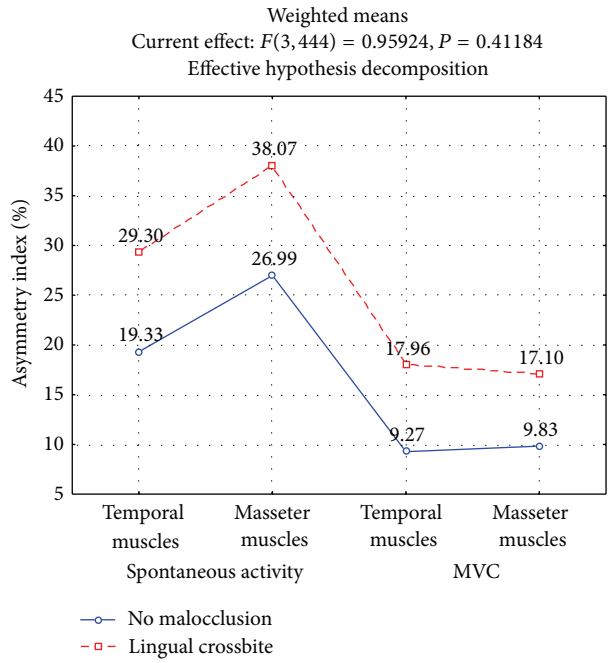

Figure 2: Asymmetry Index (As) of muscles at clinical mandibular rest position and at maximal voluntary contraction (MVC) in intercuspal position depending on transversal malocclusion.

and five or more missing posterior teeth have been associated with functional disorders of the masticatory motor system.

Mohlin et al. [21] in a methodical review of 58 studies on the correlations between symptoms of TMD and malocclusions found that there were small differences in terms of functional disorders between subjects with and without malocclusions and thus the authors critically assessed these studies. Moreover, they confirmed a lack of unanimity in the denotation of correlations between function and specific types of malocclusion.

The studies conducted by Egermark-Eriksson et al. [22] in a group of 238 subjects aged 7 to 15 years also showed weak association between functional disorders and malocclusions. The confirmation of this thesis was provided by a lack of

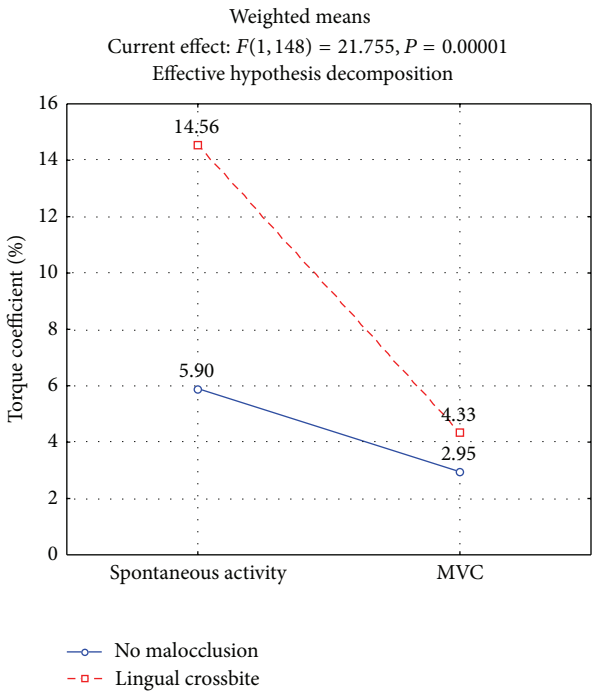

Figure 3: Torque coefficient (Tc) of muscles at clinical mandibular rest position and at maximal voluntary contraction (MVC) in intercuspal position depending on transversal malocclusion.

variability in the frequency of occurrence for the symptoms of functional disorders in the group who had received orthodontic treatment compared with the group of subjects without such treatment. Nevertheless, with regard to some malocclusions such as crossbite, both uni- and bilateral, anterior open bite, and post- and prenormal occlusion, a higher risk of developing functional disorders was recorded.

Later, a 20-year follow-up by Egermark et al. [23] and Magnusson et al. [24] showed weak correlations between malocclusions and both symptoms and signs of TMD in a group of 402 subjects. Only unilateral crossbite was correlated with symptoms of TMD ($r = 0.34$, $P < 0.01$). Subjects with malocclusion over a long period of time tended to report more subjective symptoms of dysfunctions and to show a higher dysfunction index, compared with subjects with no malocclusion.

An analysis of masticatory muscle activity in patients with altered occlusal relationships due to malocclusion was the subject of studies conducted by Ferrario et al. [25]. The examined group consisted of 10 subjects aged 16–18 years, with posterior unilateral crossbite, bilateral angle Class I, and an overjet and overbite between 2 and 5 mm. The control group consisted of 20 subjects with healthy dentition and with no malocclusion. Electromyographic recordings of masticatory muscles during chewing were performed. The findings of the study showed a decisive influence of crossbite on the electrical activity of the temporal and masseter muscles, manifesting itself in their disturbed coordination. Moreover, the functional changes were more apparent when the side with the altered transversal relationships was directly involved. Similar results were obtained by Rilo et al. [26, 27].

The relationship between transversal malocclusions and the electrical activity of the muscles was described by Alarcón et al. [28]. Electromyographic recordings of anterior and posterior temporal and masseter muscles as well as anterior digastric muscles in 30 subjects with unilateral posterior crossbite and in a control group of 30 normocclusive subjects were made at rest position, during swallowing and during mastication. The results of the study revealed that the posterior temporal muscle on the noncrossbite side was more active than that of the same side in subjects with crossbite at rest position and during swallowing. The activity of both anterior digastrics was higher in subjects with crossbite during swallowing. Moreover, during chewing the masseter muscle was less active in patients with crossbite than in the subjects in the control group. The similar findings were reported by Kecik et al. [29]. The influence of transversal malocclusions on function was confirmed in the prospective electromyographic studies conducted by Sohn et al. [30]. The authors obtained an improvement in masticatory efficiency after orthodontic treatment of anterior crossbite. The duration of muscle activity and the incidence of silent periods in the superficial part of the masseter muscle during chewing in fact decreased after treatment. There were no significant differences in the electrical activity of the anterior and posterior temporal muscles before and after treatment.

Saifuddin et al. [31] assessed the electrical activity of the temporal and masseter muscles in patients with lateral deviations of the mandible (from 5 to 14 mm), crossbite, crowding, and those with no subjective symptoms in the masticatory motor system. The control group consisted of subjects without significant craniofacial asymmetry (acceptable range from 0 to 3 mm), malocclusions, or subjective symptoms of functional disorders. The electromyographic recordings included not just selected activities but also the full daily activity including speech, eating, drinking, and sleeping. The analysis of muscle activity was divided into three periods: ordinary daily activities, mealtimes, and sleeping. The results showed that muscle activity in patients with disorders was significantly lower during all three periods for the masseter muscle and during ordinary daytime activities for the temporal muscle, in comparison to the control group. The Asymmetry Index (AI) in patients with a lateral shift of the mandible was significantly greater during usual daytime activities and sleep for the temporal muscle and significantly smaller during sleep for the masseter muscle, in comparison to the control group. The results clearly revealed that the asymmetry in the electrical activity during ordinary daytime activities and sleep in patients with lateral deviations of the mandible to a greater extent affects temporal muscles (anterior part) than masseter muscles. According to the authors, a reduction in temporal and masseter muscle electrical activity, with the accompanying asymmetry in the electrical activity of the temporal muscles, is closely related to occlusal instability due to malocclusions and lateral mandibular deviation.

A review of the literature presented does not indicate a clear association between malocclusions and TMD. However, the results of the aforementioned studies suggest a higher risk of the prevalence of TMD in patients with unilateral posterior crossbite.

5. Conclusions

The use of sEMG in the assessment of the function of the masticatory motor system provided tangible evidence of the determining influence of unilateral posterior crossbite on the electrical activity of the temporal and masseter muscles in patients with subjective symptoms of TMD.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Identification of Mastication Organ Muscle Forces in the Biocybernetic Perspective

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Purpose of the Paper. This paper is an attempt to mathematically describe the mastication organ muscle functioning, taking into consideration the impact of the central nervous system. *Material*. To conduct model tests, three types of craniums were prepared: short, normal, and long. The necessary numeric data, required to prepare the final calculation models of different craniofacial types, were used to identify muscle and occlusion forces generated by muscles in the area of incisors and molars. The mandible in model tests was treated as a nondeformable stiff form. *Methods*. The formal basis for the formulated research problem was reached using the laws and principles of mechanics and control theory. The proposed method treats muscles as "black boxes," whose properties automatically adapt to the nature of the occlusion load. The identified values of occlusion forces referred to measurements made in clinical conditions. *Results*. The conducted verification demonstrated a very good consistency of model and clinical tests' results. The proposed method is an alternative approach to the so far applied methods of muscle force identification. Identification of muscle forces without taking into account the impact of the nervous system does not fully reflect the conditions of mastication organ muscle functioning.

1. Introduction

While formulating the numeric model of the mastication organ, primarily passive forces and active forces affecting the mandible are defined. Passive forces assume reactions in temporomandibular joints and occlusion force, while active ones reflect muscle activity. One of the methods of muscle force identification is the solution of the issue of mastication organ biostatic balance. Additionally, the biostatic balance is defined as a situation when the mandible, loaded with any arrangement of forces, is not moved as well and does not change its orientation; that is, it remains in a stable position for any period of time. Research defined in such a way can be analysed by both static and dynamic methods. Regardless of the class of the formulated problem, proper causal relations are introduced by means of analytical or vector mechanic methods. From a theoretical point of view, two classes of identification methods of mastication organ muscle forces are distinguished. The first one is represented by methods where active muscle forces are replaced by single resultant. A detailed description of these methods is presented in the following works: Weijs, 1989, and Erhardson et al., 1993 [1, 2]. The second group includes methods whose formal basis is the direct identification of muscle forces, which are presented, for example, by Osborn and Baragar, 1985; Peck and Hannam, 2000; and Sellers and Crompton, 2004 [3–5]. In addition, we cannot forget about methods using the MES formalism, which is applicable in situations of stress and deformations of the mandible assessment. These methods are often applied during analyses of any kind of biomechanic

issues of the stomatognathic system, and they are described in works by Vollmer et al., 2000; Igić et al., 2001; Iwasaki et al. 2003; Koolstra and Van Eijden, 2004; Peck et al., 2004; and Hannam et al., 2008 [6–11].

Model tests of the mastication organ are very often conducted on flat models. Reduction of the spatial structure to a flat one each time assumes a symmetrical mandible load with active and passive forces. Despite a number of attempts, a clear method has not yet been formulated, enabling precise calculation of sizes of forces generated by particular mastication organ muscles. In addition, there is no technology enabling direct registration of muscle forces and loads affecting temporomandibular joints. For this reason, the numerically calculated values of muscle forces are hard to be verified. However, computer simulations bring the expected effects when the conditions of calculation model support are correctly defined. Usually, they are adopted as fixed articulated supports, located within temporomandibular joints. This way of model support is particularly convenient when static balance equations are used. In the case of application of formalism of method of finite elements, the modelling person has an available broad selection of various ways of articular reaction reflection. Reactions occurring in the joints can be modeled, at least in three ways: (1) as a support articulated elastic; (2) by means of active forces, distributed along surface of condyloid process heads, as described by Korioth et al., 1992 [12]; (3) or by contact connection occurring between transport disks the acetabulum and condyloid process heads.

The assessment of causal relations taking place between the occlusion force and muscle forces is a difficult issue from the point of view of biomechanics. These difficulties are caused by the fact that spatial structure of the placement of muscle fibres is able to generate various ranges of statically equivalent forces of combinations ensuring biostatic balance of the mandible. However, the advantage of this diversity, replacing the solutions is the possibility to counteract unwanted biomechanical reactions. Restrictions and difficulties related to identification of forces generated by muscles were the reason to undertake activities to formulate a biocybernetic mastication organ model. In the biocybernetic perspective, muscles are considered "black boxes" whose properties adapt automatically to the nature of the load on the dental arch of the mandible. The model approach proposed in this paper is an alternative to the so-far applied methods of muscles force identification. The formal basis for the solution, defined in such a way as a research problem, is the methods that can be used in mechanics and control theory.

2. Methods and Material: The Formulation of the Numerical Model

During numeric model formulation, used to identify the muscle forces of the mastication organ in the biocybernetic perspective, the following assumptions were adopted. A mathematical model was derived for the case of symmetrical dental arch load of the mandible with occlusion forces. The condyloid process heads assume a stable location in the articular space. The mandible was treated as a nondeformable rigid form. Adoption of the mandible as a rigid element is justified from the point of view of model tests, as its rigidity in comparison to muscle stiffness is much greater. In addition, during conducting numeric experiments, there is a possibility of angular movement of the mandible in relation to the axis running through the centres of condyloid process heads. The assumption is also justified, because in the initial phase of abduction mandibular movement may be described with great accuracy as "clear" rotation, the so-called pivoting movement. Additionally, limitations resulting from maximum force that particular muscles are able to generate during dental arches load have been taken into account. The force on the dental arch of the mandible changes from zero to the agreed value. Additionally, the direction of its operation is perpendicular to the horizontal axis of the coordinate system in respect of which numeric calculations were performed. Bearing in mind what the work of Ide and Nakazawa [13] stated and referring to the activity of particular muscles when generating occlusion forces in the set zones of dental arches of the mandible, additional model assumptions were made. According to the aforementioned authors, temporal muscles are inactive when occlusion forces are generated in the zone of incisors. In order to demonstrate the relevance of the information stated by the abovementioned researchers, measurements of masticator's function potentials and temporal muscles during closing dental arches in the surroundings of incisors on dynamometer covers were conducted. These preliminary tests clearly proved change in function potentials of temporal muscles. Additionally, their activity reaches the level of ca. 10% of masticators activity. In order to make a precise mapping of the biomechanical phenomena occurring at the time of incisors loading, cross-sectional area of the temporal muscle was taken at the level of 10% of the cross-sectional area masseter muscle. Such an assumption is justified from the physiological point of view, since growth in value of the recorded activity potential of the muscle is directly proportional to the force generated by the muscle. The schematic diagram, constituting a formal basis for bringing necessary analytical dependencies, which at the same time reflects the occurring relations between the skeletal system and the muscle system, is presented in Figure 1.

Bearing in mind the model assessment of the value of forces generated by adduction muscles of the mastication organ in various zones of the dental arch, the possibility of occlusion force displacement was considered F_O. The parameter defining the place of the occlusion force in the formulated model is dimension a_{ZO}. Points marked with symbols E_i (Figure 1) represent immobile muscles insertions to the cranial bones. The location of muscles insertion to the mandible is defined by polar coordinates, which are defined with the position vectors OA, OB, OC, and OD and angles φ_M, φ_P, φ_L, and φ_T. Lengths of particular muscles, included in computer simulations, are marked with symbols L_i. The differential equation of the mandible movement constituting a formal basis for muscles forces identification takes the form of

$$J\ddot{\varphi} + \frac{F_M R_M}{L_M}\left(h_M \cos\left(\varphi_M + \varphi\right) + a_M \sin\left(\varphi_M + \varphi\right)\right) + \frac{F_P R_P}{L_P}\left(h_P \cos\left(\varphi_P + \varphi\right) + a_P \sin\left(\varphi_P + \varphi\right)\right)$$

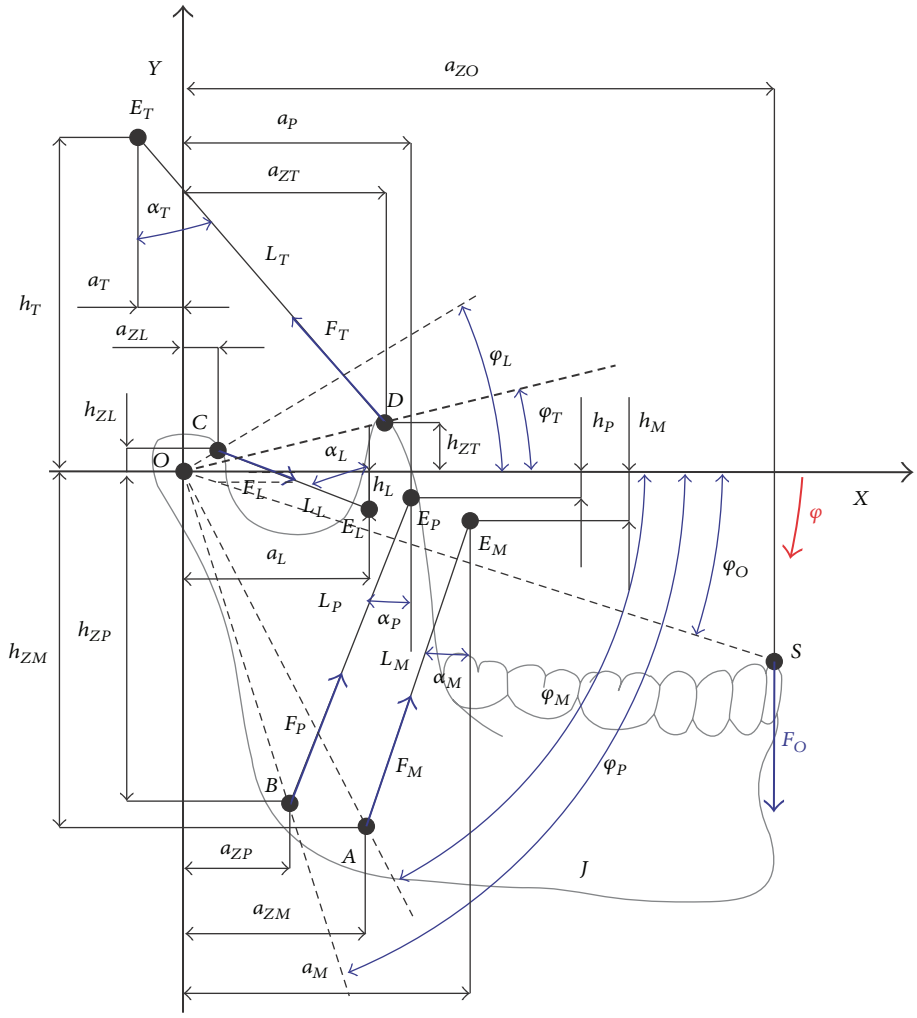

Figure 1: The schematic diagram reflecting the relations between the muscle system and the skeletal system of the mastication organ.

$$+\frac{F_T R_T}{L_T}\left(h_T\cos\left(\varphi_T-\varphi\right)-a_T\sin\left(\varphi_M-\varphi\right)\right)$$
$$-\frac{F_L R_L}{L_L}\left(h_L\cos\left(\varphi_{:}-\varphi\right)+a_L\sin\left(\varphi_L-\varphi\right)\right)=F_O a_{ZO}. \quad (1)$$

Equation (1) is nonlinear owing to the geometry of placement of the muscle fibers. Mass moment of mandible inertia J may be estimated based on research results published in the work by Zhang et al. [14]. From the biocybernetic perspective the unknown muscle forces are calculated on the basis of the adopted control law. The basis for identification in the proposed method is comparison of the set size (control) s_Z with the regulated size s_W. Additionally, comparison of these variables is possible as a result of applying negative feedback. General block diagram of muscle forces of the mastication organ identification in the biocybernetic perspective is presented in Figure 2.

The effect of the central nervous system (CNS) on muscles was reflected by applying regulators of continuous action, types PID and PI. The block diagram presented in Figure 2 has an additional loop of negative feedback applied. The initial computer simulation, based only on a single loop, would not provide satisfactory results. Lack of the assumed results was connected, first of all, with too great angle dislocation of the mandible, resulting from occlusion force. The application of an additional speed feedback loop substantially improved the quality of muscle forces identification. At this point it should be mentioned that the main task of the additional feedback is comparing the speed of shortening or extending muscle fibres. When formulating the final calculation model it should be determined which variables are adjustable sizes and which are control ones. In this paper regulated sizes s_W include changes in muscle length, while control sizes s_Z are forces generated by particular mastication organ muscles. Bearing in mind the adopted model assumptions, the control criterion was defined on the basis of diagram presented in Figure 2, whose general form is presented by the equation

$$\int_0^\infty \varepsilon(t)\,dt=0 \Longrightarrow \int_0^\infty \left(w_Z-\Delta l\right)dt=0. \quad (2)$$

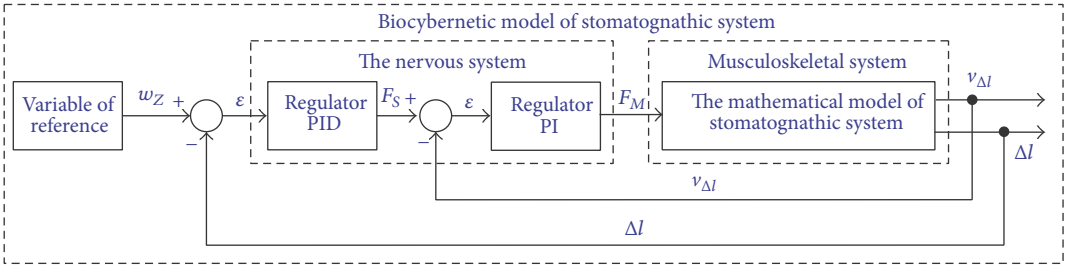

Figure 2: The generalised block diagram of muscle forces of the mastication organ identification.

The control criterion (2) demonstrates that, during loading the mandible with occlusion force, the length of the muscle cannot be changed, regardless of the value of the load exerted on the dental arch. If excessive occlusion load value results in mandible rotation, then there is no basis to state that the mandible remains in a biostatic balance. The analysed research task was formulated with the use of principles binding in issues concerning dynamics. In the formulated model, the mandible has the possibility of angular movement in relation to the axis running through the centres of condyloid process heads. Additionally, the movement must be compensated by regulators; otherwise, the analysed system becomes unstable. A detailed block diagram of adduction muscle forces of the mastication organ identification, in the biocybernetic perspective, is presented in Figure 3, and superscripts correspond to muscles: M is *masticator*, P is *medial pterygoid*, T is *temporalis*, and L is *lateral pterygoid*.

Control laws brought out on the basis of a detailed block diagram (Figure 3) data are then the following equations:

$$\begin{aligned}
&\varepsilon^L(s) = s_Z^L(s) - \Delta l^L(s),\\
&F_S^L(s) = K_1^L\varepsilon^L(s) + \frac{T_{1I}^L\varepsilon^L(s)}{s} + sT_D^L\varepsilon^L(s),\\
&\varepsilon_1^L(s) = F_S^L(s) - v_{\Delta l}^L(s),\\
&F_L(s) = K_2^L\cdot\varepsilon_1^L(s) + \frac{T_{2I}^L\varepsilon_1^L(s)}{s},\\
&\varepsilon^P(s) = s_Z^P(s) - \Delta l^P(s),\\
&F_S^P(s) = K_1^P\varepsilon^P(s) + \frac{T_{1I}^P\varepsilon^P(s)}{s} + sT_D^P\varepsilon^P(s),\\
&\varepsilon_1^P(s) = F_S^P(s) - v_{\Delta l}^P(s),\\
&F_P(s) = K_2^P\varepsilon_1^P(s) + \frac{T_{2I}^P\varepsilon_1^P(s)}{s},\\
&\varepsilon^T(s) = s_Z^T(s) - \Delta l^T(s),\\
&F_S^T(s) = K_1^T\varepsilon^T(s) + \frac{T_{1I}^T\varepsilon^T(s)}{s} + sT_D^T\varepsilon^T(s),\\
&\varepsilon_1^T(s) = F_S^T(s) - v_{\Delta l}^T(s),\\
&F_T(s) = K_2^T\varepsilon_1^T(s) + \frac{T_{2I}^T\varepsilon_1^T(s)}{s},\\
&\varepsilon^M(s) = s_Z^M(s) - \Delta l^M(s),\\
&F_S^M(s) = K_1^M\varepsilon^M(s) + \frac{T_{1I}^M\varepsilon^M(s)}{s} + sT_D^M\varepsilon^M(s),\\
&\varepsilon_1^M(s) = F_S^M(s) - v_{\Delta l}^M(s),\\
&F_M(s) = K_2^M\varepsilon_1^M(s) + \frac{T_{2I}^M\varepsilon_1^M(s)}{s}.
\end{aligned} \tag{3}$$

The included block diagrams and analytical dependencies from (1) to (3) are the formal basis for conducting necessary computer simulation, taking into account the effects of the central nervous system on forces generated by human masticatory system adduction muscles.

Identification of muscle forces was conducted for three mandible models which correspond to the following faces: short, normal, and long. The anterior lower face height to the anterior total face height ratio was used for assignment of the subjects as either SF, normal, or LF. The rationale behind the use of this ratio is its strong predictive power of vertical craniofacial morphology as has been established by the use of discriminant analyses. Following other studies of LF and SF morphology, 79 and 80 subjects with a ratio exceeding 59.0% were considered to have a LF, whereas subjects with a ratio smaller than 54.0% were labeled as SF, although selection of "golden" cut-off points is inevitably arbitrary. Each model was analysed, for mandible load cases with force F_O, in the area of incisors and molars. Additionally, the area of dental arch load has been obtained by changing the parameter value a_{ZO}. The diagram showing distribution of active forces, operating on the mandible and points describing its geometric structure, is presented in Figure 4.

Moments of time are marked in Figure 4 with symbols meaning t_1 the moment of loading the mandibular dental arch with force F_O. However, time t_2 defines the moment when the mandibular dental arch is relieved. Model assumptions as well as the adopted, idealized profile of occlusion force accumulation are an integral part of research in terms of muscle forces identification. Such an idealized nature of occlusion force increase was adopted for model tests, because

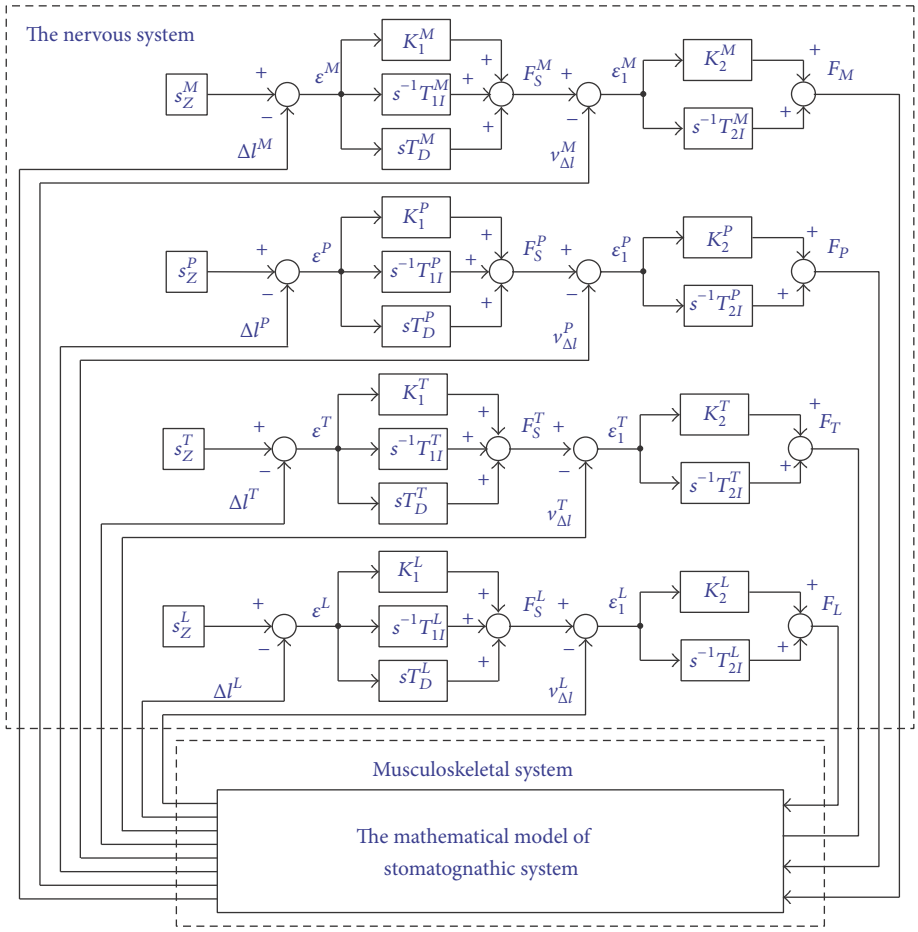

Figure 3: The generalised block diagram of muscle forces of the mastication organ identification.

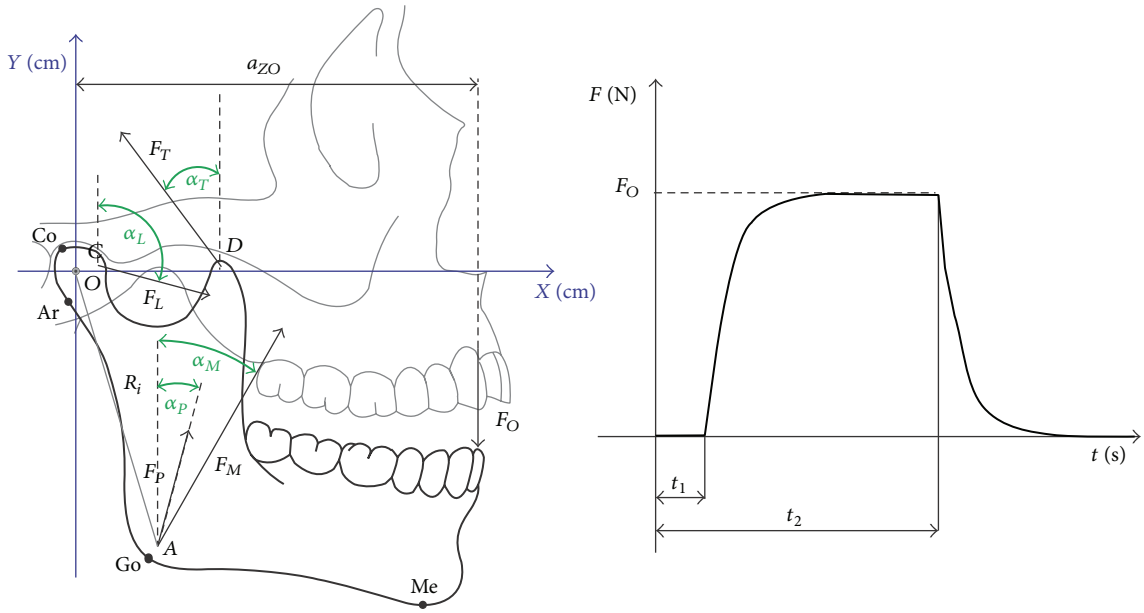

Figure 4: The diagram showing geometric structure of the mandible, along with marked places of mandible load with muscle forces and temporary characteristics of occlusion force accumulation.

Table 1: Numeric data adopted for the need to conduct numeric calculations.

	Muscle name	R_i [cm]	φ_i [°]	Area [cm^2]	F_{MAX} [N]	α_i [°]	Ar-Go [cm]	Go-Me [cm]	Co-Me [cm]	<Go [°]
Short face	Masticator	5.97	−77	6.22	217.7	−8	5.64	7.64	12.06	116
	Medial pterygoid	5.97	−77	4.23	148	−13				
	Lateral pterygoid	0.30	15	4.31	150.8	−97				
	Temporalis	3.53	4	6.02	210.7	27				
Normal face	Masticator	5.71	−75	4.77	166.9	−19	5.70	7.71	12.39	125
	Medial pterygoid	5.71	−75	3.23	113	−17				
	Lateral pterygoid	0.32	22	4.16	145.6	−97				
	Temporalis	3.64	2	5.07	177.4	27				
Long face	Masticator	5.37	−83	3.43	120	−17	4.61	7.43	12.15	134
	Medial pterygoid	5.37	−83	2.57	89.9	−18				
	Lateral pterygoid	0.52	−16	3.77	131.9	−99				
	Temporalis	3.85	−8	4.43	155	27				

it shows similarity to occlusion forces recorded with the use of an electronic dynamometer. However, in order to perform any model test, it is essential to have knowledge of specific numeric data. In this paper the required data in particular concerning the directions of muscle forces operation, muscles cross sections, and geometrical structure of the mandible were taken from the works by van Spronsen, 2010, and van Spronsen et al., 1996 [15, 16]. Table 1 compares parameters describing the adduction muscles and geometric construction of the studied craniofacial types. The numeric data are necessary to conduct a computer simulation concerning muscle forces identification in the biocybernetic perspective. In addition, an extremely significant biophysical size, defining the muscle, is the coefficient of unit efficiency of cross section, k. The research reports—Weijs and Hillen, 1985; Peck et al., 2000 [10, 17]—indicate that the value of this coefficient is within the scope from 30 to 40 N/cm^2. Additionally, such a discrepancy in values has a decisive impact on the final effect of identification. This happens because the product of cross section A and coefficient k determines the maximum value of force generated by a given muscle. For the purpose of model tests in this paper, the maximum efficiency of particular adduction muscles has been estimated assuming $k = 35$ N/cm^2.

Symbols presented in Table 1 are as follows: R_i are the place of muscle forces that is defined by position vectors OA, OB, OC, and OD (Figure 1). Parameters φ_i define the orientation of position vectors R_i in an arrow plane and are measured as presented in Figure 1; α_i defines the orientation of muscle forces identification in the arrow plane (Figure 4). While *Area* represents cross-sectional areas of muscles, F_{MAX} maximum forces, particular muscles, can generate. Change in forces generated by the mastication organ muscles is characterised by a nondimensional muscles activity coefficient w_A. In this study, these coefficients are defined as the relation of force generated by a given muscle to the sum of forces generated by all the muscles. Analytical dependencies, characterizing activity coefficients of particular muscles, which have been included in computer simulations, are expressed by the equations

$$\begin{aligned} w_A^{\text{Masseter}} &= \frac{F_M}{F_T + F_M + F_P + F_L}, \\ w_A^{\text{Temporalis}} &= \frac{F_T}{F_T + F_M + F_P + F_L}, \\ w_A^{\text{Medial pterygoid}} &= \frac{F_P}{F_T + F_M + F_P + F_L}, \\ w_A^{\text{Lateral pterygoid}} &= \frac{F_M}{F_T + F_M + F_P + F_L}, \end{aligned} \tag{4}$$

where F_M is masticator, F_T is temporalis, F_P is medial pterygoid, and F_L is lateral pterygoid.

3. Model Test Results

Model test results, which illustrate the change in muscles activity during loading the mandibular dental arch with occlusion forces, located in the zone of incisors and molars are presented in the charts (Figures 5, 6, and 7). At this point it should be expressly stated that the maximum values of forces shown in the charts are identical with the end of numeric calculations, namely, achieving the maximum efficiency by all the muscles included in computer simulations.

The next stage of model tests was estimation of maximum occlusion forces in the area of incisors and molars, which are caused by the activity of mastication organ muscles. Defined in such a manner research problem was solved in the way that calculation models, characterizing averaged mandibles of three types of anatomical craniofacial construction, were loaded with force F_O until achieving the border of system stability. The maximum value of forces F_O, which did not cause loss of calculation model stability, was considered the maximum occlusion force, generated by the mastication

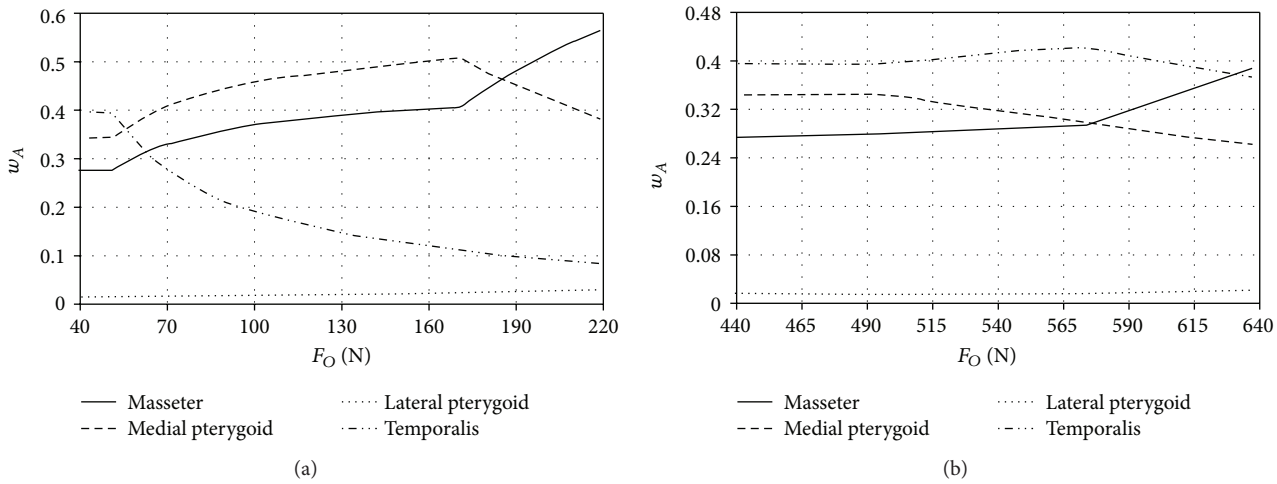

Figure 5: The activity of adduction muscles of the mastication organ of short craniofacial morphology during loading the mandibular dental arch in the area (a) of incisors and (b) of molars.

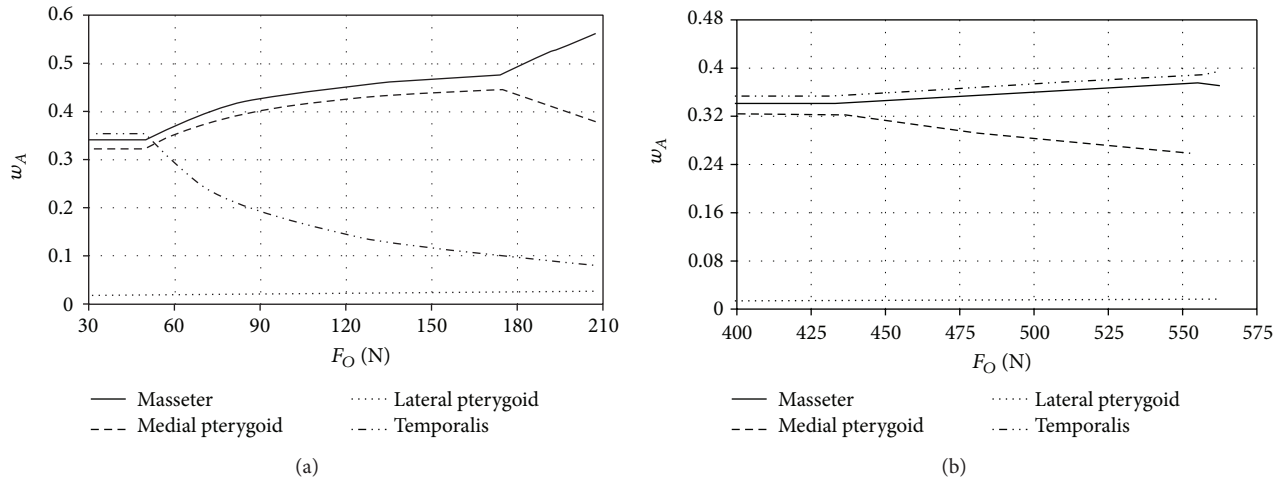

Figure 6: The activity of adduction muscles of the mastication organ of normal craniofacial morphology during loading the mandibular dental arch in the area (a) of incisors and (b) of molars.

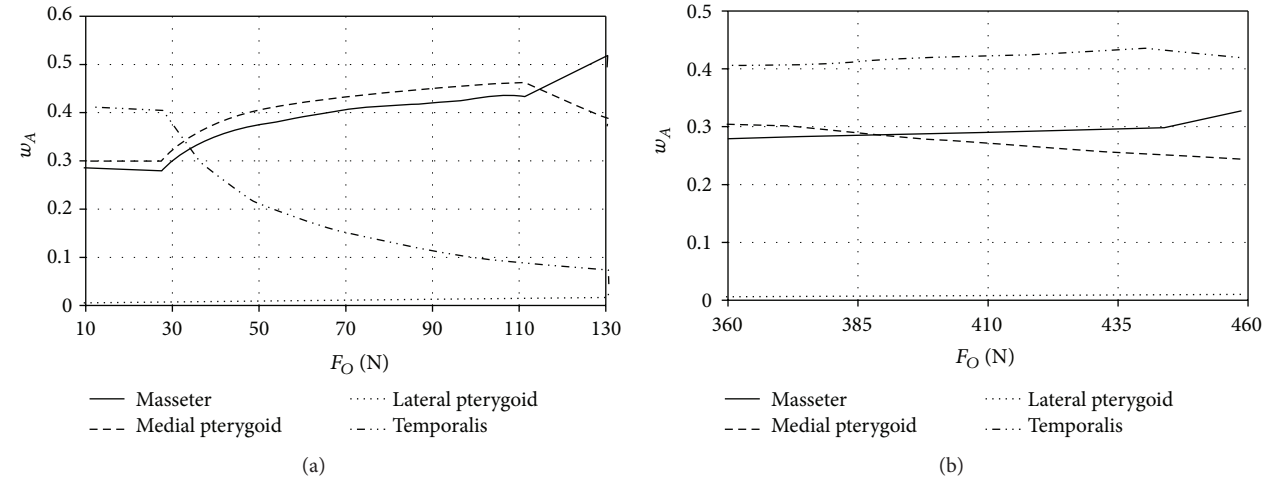

Figure 7: The activity of adduction muscles of the mastication organ of long craniofacial morphology during loading the mandibular dental arch in the area (a) of incisors and (b) of molars.

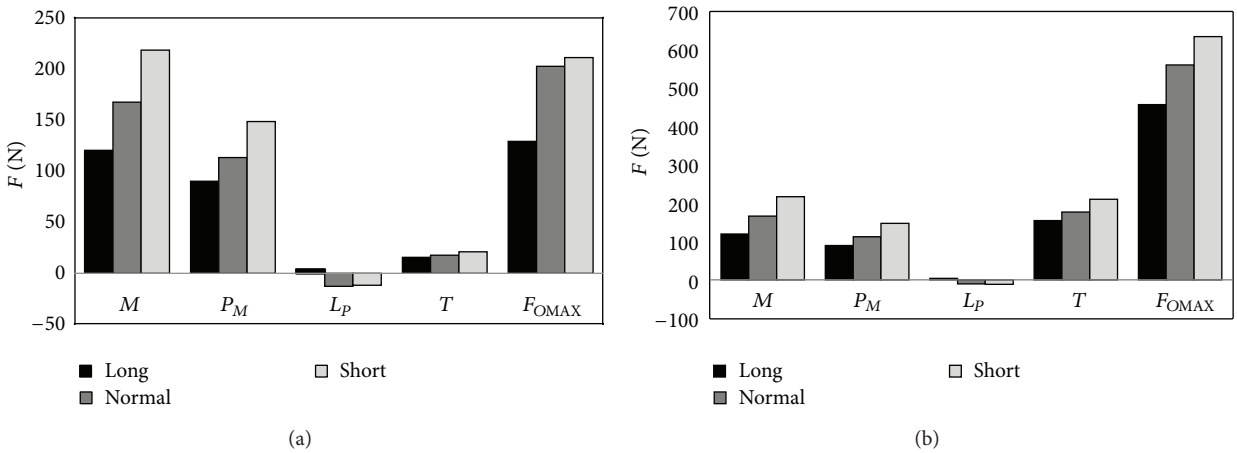

Figure 8: Force generated by the adduction muscles of the mastication organ during loading the mandibular dental arch with the maximum force in the area (a) of incisors and (b) of molars.

organ muscles in the set dental arch area. The results of computer simulation are graphically shown in Figure 8.

Symbols shown in Figure 8 represent the following muscles: M is masticator, P is medial pterygoid, L is lateral pterygoid, and T is temporalis. The conducted computer simulations assumed that the boundary value of angular mandible movement cannot exceed the value of 0.2°. However, regulation errors, determining the change in muscles length, were lower than 0.01 mm. Anatomical data concerning average values of the cross-sectional areas of muscles, their orientation, and geometrical structure of the mandible (Table 1) were the formal basis for conducting necessary computer simulation. The numerically calculated occlusion forces, loading the mandibular dental arch in the area of incisors, in the case of short face reached the value of 636.61 N, normal 562.4 N, and long 458.56 N. The calculated maximum values of occlusion forces, generated in the zone of incisors, amounted to 218.4 N for short face, 207.1 N for normal face, and 130.4 N for long face.

4. Discussion

The operation of the central nervous system is the basic element ensuring correct functioning of mastication organ muscles. Optimum muscular action is not possible without bioelectric stimulation, whose source is the nervous system. For this reason, when making attempts of numeric modelling of living organism's movement as well as during muscle forces identification, each time an account should be taken of causal relations occurring between the muscular-skeletal system and the nervous system. Test results obtained this way provide qualitatively new information on the functioning of living organism's muscles. An analysis of complex processes taking place within the stomatognathic system using classical methods is determined, above all, by difficulties, related to muscle forces identification. One of the ways of mathematical projection of the impact of the central nervous system on the muscles is the use during model tests optimisation methods: Osborn and Baragar, 1985 [3], and Trainor et al. [18]. From the point of view of biomechanics, one of the most important parameters, typical for muscles, is information concerning the maximum force generated by these muscles. Final data are required for that, concerning the cross-sectional size of the studied muscle A. The confirmation of this statement is in many publications on this issue: Hsu et al., 2001; Goto et al., 2002; Gionhaku and Lowe, 1989; Kitai et al., 2002; and van Spronsen et al., 1989, 1992 [19–23]. Based on data contained in works mentioned above, it is possible to determine the average values of cross sections of the stomatognathic system muscles and then define their maximum efficiency.

Model tests of biostatic balance of the human mastication organ included in this work focused on two issues. The first one was to determine characteristics describing the variability of activity coefficients w_A of particular mastication organ muscles depending on the occlusion force F_O. The second one focused on determining the maximum occlusion force possible to be generated by the stomatognathic system muscles in the area of incisors and molars. On the basis of the prepared characteristics describing the variability of activity coefficients of muscles w_A it can be stated that, regardless of craniofacial anatomical construction as well as the place of occlusion forces, the greatest activity in the initial phase of loading is shown by the temporal muscles (Figures 5 to 7). Subsequently there are medial pterygoid muscles and the lateral pterygoid muscles as the last ones. Only in the case of normal craniofacial anatomical construction do masticators generate greater forces as compared with medial pterygoids. In the case of the analysed normal face model this is connected with the average directions of α_i muscle forces actions (Table 1).

According to Ide and Nakazawa [13] occlusion load located in the area of incisors is caused mainly by simultaneous activity of masticators, medial pterygoids, and lateral pterygoids. Ide and Nakazawa state that, during generating loads in the area of incisors, fibres of the temporal muscles do not operate. Additionally, the function potentials measurements, conducted by the authors of the paper, that were recorded with surface electrodes placed above the front fibres of the temporal muscles show almost ten times lower

activity as compared with surface masticators fibres. The growing occlusion load operating in the area of incisors results in the fact that, in the first place, the maximum efficiency is achieved by the temporal muscles (Figures 5(a) to 7(a)). From that moment growth is observed in masticators activity and medial pterygoids activity. This situation lasts until medial pterygoids reach the limit value of their efficiency. After this time only the activity of masticators and lateral pterygoids increases. Additionally, such a condition is maintained until masticators reach their maximum efficiency and then rapid growth in activity of lateral pterygoids is observed. When occlusion forces are generated in the area of molars (Figures 5(b) to 7(b)) in the initial phase of loading the mandibular dental arch, the greatest activity is observed in the case of the temporal muscles. However, maximum efficiency is achieved by the medial pterygoids. The mechanism of mastication organ muscles functioning, at occlusion forces, located in the area of molars is analogous to the case of occlusion forces interacting in the area of incisors. The obtained model tests' results indicate that the maximum occlusion forces generated in the area of incisors are mainly the result of masticators activity and medial pterygoids activity. The importance of temporal muscles becomes evident when the forces loading the dental arch move towards the molars (Figure 8). In the case of craniofacial morphology of short anatomical construction, occlusion forces generated by masticators in the area of molars are the largest (Figure 5(b)).

Achieving maximum efficiency by one of the muscles directly causes changing the value of activity coefficients of the other muscles. In other words, if a given muscle reaches maximum efficiency, then its activity is limited at simultaneous growth in activity of other muscles. At this point, it is worth mentioning that the obtained results of the computer simulation indicate that, regardless of the load area of the dental arch and craniofacial type, the lateral pterygoids demonstrate low activity. The activity of these muscles is strictly related to the role they perform in the functioning of the stomatognathic system. The fact that lateral pterygoids are mainly responsible for pulling out the mandible and they support the suprahyoid muscles during abduction [24] is also worth mentioning. In addition, it should be remembered that ca. 30–40% of the area of lateral pterygoids muscle fibres insertion is located on transport disks. Therefore, one of their tasks is disks movement in accordance with the condyloid process movement. Thus, it is reasonable to claim that lateral pterygoids do not play any key role in issues related to the biostatic balance of the mastication organ. The statement seems to be contradictory in relation to the size of lateral pterygoid cross section of the casement, which would indicate its substantial efficiency. However, from the point of view of biomechanics, and particularly directions defining the courses of muscle fibres and location of insertions to the mandible, its meaning and role are generally insignificant in issues concerning biostatic balance of the mastication organ. Clearly, observations made by Ide and Nakazawa [13] indicate that symmetrical load of the mandibular dental arch in the area of molars is a result of intensive activity of most mastication organ muscles, except the lateral pterygoids, which demonstrate relatively low activity.

Regardless of the load area of the mandibular dental arch, it has been stated that the largest values of occlusion forces are observed in people with short face, while the lowest with long craniofacial anatomical construction. Bearing in mind the fact that so far there has been no technology enabling direct measurement of forces generated by muscles, other methods of verification of model tests' results should be applied. One indirect way which enables result evaluation of computer simulation is clinical tests in which occlusion forces are recorded. In these tests specialised dental dynamometers are implemented and it is possible to single out two basic constructions of measuring devices. The first group includes dynamometers where occlusion forces are determined on the basis of plastic deformation size of the measuring sample. This method of occlusion forces measurement was described in detail in the work by Chladek et al., 2001 [25]. The second group are dynamometers where the force is recorded by various types of sensors, among others, pressure, Braun et al., 1995; Kamegai et al., 2005 [26, 27], or piezoresistive, Flanagan et al., 2012 [28]. Adduction muscles of the human mastication organ, in the area of molars, are able to generate loads, which can exceed the value of even 1 kN according to Braun et al., 1995, and Ferrario et al., 2004 [26, 29]. However, values of this range are found in few people, wherein the values of this order can generate a few individuals. Average values of occlusion forces recorded in the area of molars are in the scope from 300 up to 600 N in the case of women and from 400 to 700 N in the case of men, which was shown in works by Bakke et al., 1990; Braun et al., 1995 [26, 30]. Along with relocation of measurement point towards incisors, decrease in the measured occlusion forces is observed for the value of ca. 100 N in the case of women and ca. 200 N in the case of men, which is confirmed by the following researches: Paphangkorakit and Osborn, 1997, 1998; Regalo et al., 2008 [31–33]. It should also be borne in mind that, along with general ageing of the body, occlusion forces generated by adduction muscles of the mastication organ are limited, Bakke et al., 1990 [30]. It is believed that this phenomenon is caused mainly by loss of muscle fibres, Faulkner et al., 2007 [34].

In order to verify the model tests' results obtained in this paper, the results of computer simulation referred to results published in the work by Abu Alhaija et al., 2010 [35]. Average values of occlusion forces were recorded in the area of molars in a group of 30 women and 30 men aged ca. 22. Among the focus group three subgroups with different craniofacial construction were selected. Occlusion forces were recorded by means of an electronic dental dynamometer GM10, obtaining average values in the area of molars for short face 679.6 N, normal face 593.08 N, and long face 453.57 N. Numerically calculated by the authors of this study, occlusion forces amounted to, accordingly, in the case of short faces 636.61 N, normal 562.4 N, and long 458.56 N. High compliance of the results obtained in the research model relative to the average forces recorded in the clinical trials was found. Clearly, relative errors of occlusion forces, obtained in the model tests and clinical tests, were for short face 6.33%, normal face 5.17%, and long face 1.10%.

In the event when the stomatognathic system muscles generated load in the area of incisors, the maximum occlusion

forces amounted to 218.4 N for short face, 207.1 N for normal face, and 130.4 N for long face. It is impossible for the results of these model tests to relate to specific clinical tests that were conducted on various craniofacial types as in the case of occlusion forces generated in the area of molars. However, the works by Paphangkorakit and Osborn, 1997, 1998; Regalo et al., 2008 [31–33], show that occlusion forces recorded in the area of incisors are within the scope from 120 N to 225 N in men and from 64 N to 185 N in women. The values are similar to the results obtained on the basis of the conduced computer simulation.

This kind of numeric considerations seems to be also important from the point of view of function disorders in diagnostics of the mastication organ movement system especially the temporomandibular joint dysfunctions [36–39]. It is known that patients suffering from bruxism [40] are able to generate occlusion forces often exceeding the value of 1 kN. Face type, short, normal, or long, may be a genetic feature but may equally well result from orthognathic or occlusion defects and such factors can significantly affect the length of the lower part of face, determining its comprehensive dimension. Vertical dimension of the face is important in issues of compressive forces exerted on articular structure, which was demonstrated by van Spronsen et al. [41]. In other words, elimination of occlusion defects, especially in vertical dimension, may contribute to change in face qualification from short, for example, to normal, which, in turn, affects the reduction mastication muscles forces, which can have destructive impact on particular elements of the stomatognathic system, mainly joints. The conducted research partially also seems to explain the importance of loss of occlusion height. Quality shortages of the dental hard tissues, pathological abrasion, untreated dental caries, or iatrogenic actions can affect normal face transformation to be short, which leads to increase in forces generated by muscles with all the negative effects.

5. Conclusions

To sum up, the method presented in this paper should be considered an alternative approach to identifying muscle forces and model evaluation of occlusion forces generated by adduction muscles of the mastication organ. The proposed method treats muscles as "black boxes" whose properties independently adapt to external conditions. On the basis of the conducted computer simulation it is possible to formulate the following general applications.

(1) Considering the limitations of the maximum force generated by particular muscles provides qualitatively and quantitatively new information about functioning of the masticatory muscels.

(2) Model assessment of occlusion forces generated by muscles and identification of the mastication organ adduction muscles forces may constitute an important tool in diagnostics of the mastication organ dysfunctions, especially related to vertical occlusion defects.

During identification of the mastication organ muscles forces it is not required to know the mathematical model of the muscle as well as to define the degree of its activity. The conducted model tests assume the criterion of constant value regulation. However, it should be expressly pointed out that it is possible to adopt control law reflecting the variable value regulation. Assuming such control laws, it is possible to identify forces generated by the mastication organ muscles in operation: mandible protrusion or abduction and in the action of chewing.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

The Influence of Emotional State on the Masticatory Muscles Function in the Group of Young Healthy Adults

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Stress may affect the function of all the components of the masticatory system and may ultimately lead to differentiated symptoms and finally to systemic and structural dysfunctions. *Objective*. To determine the effect of stress on the masticatory muscles function in young healthy adults. *Material and Methods*. A total of 201 young, Angle's first class, healthy volunteers, 103 female and 98 male, in the age between 18 and 21 years were recruited into the study. All the participants underwent clinical examination according to the Slavicek scheme, questionnaire survey according to Perceived Stress Scale, and assessment of masticatory muscles function in central occlusion. *Results*. Symptoms of masticatory system dysfunction were found in the group of 86 subjects (46,24%). All the muscles activity in central occlusion was comparable in female and male groups. Mean values of masseters activities in the group of low stress subjects (75,52 μV ± 15,97) were statistically different from the groups with medium (82,43 μV ± 15,04) and high (81,33 ± 12,05) perceived stress ($P < 0.05$). *Conclusion*. Chronic stress may reveal or exacerbate symptoms of masticatory dysfunction.

1. Introduction

A number of stress-related disorders (SRDs) may develop or exacerbate due to chronic stress. The disorders include obesity, type 2 diabetes, atherosclerosis, idiopathic hypertension, cardiac ischemia, peptic ulceration, irritable bowel syndrome, headaches, neck pain, migraine, spine aches, osteoporosis, and dermatological complications. The most common stress-related symptoms affecting mental health can vary from sleep disorders, depressed mood, sadness, restlessness, irritability, anxiety, and impaired concentration and memory to chronic fatigue syndrome, traumatic stress, social stress, anorexia nervosa, or bulimia. Stress is believed to underlie first episodes of depression, which in most people appear in adolescence or early adulthood. According to many researchers, stress also affects the function of the masticatory system [1–7]. Any surpassing of the adaptive potential of the body may lead to pathological reactions, especially in high-energy or low-resistance tissues. Dental arches are the somatic sites where excessive psychoemotional tension can be diffused and reduced [8–11]. This is manifested by clenching or grinding the teeth (bruxism). If the psychoemotional tension persists, strain and/or ischemia may appear in the overloaded muscles and trigger points are activated, causing myofascial pain and its sequels. All components of the masticatory system may be affected, which ultimately leads to differentiated symptoms, from the systemic (headaches, neck pain, shoulder girdle pain, and backache) to structural dysfunctions, such as hypertrophy and tenderness of masseter muscle attachments or increased tension in these muscles. Hard dental tissues show attrition, worn teeth, cervical lesions, periodontal atrophy, excessive dental mobility, pain of unknown etiology, anemisation of lingual and buccal mucosa, and temporomandibular joint (TMJ) disorder symptoms: cracking, clicking, reduced mobility, and pain on palpation [9].

According to the International Headache Society (IHS) criteria and guidelines of American Academy of Orofacial Pain (AAOP) [12], masticatory dysfunction can be diagnosed when at least three of the following symptoms are reported: pain and acoustic signs on mandibular movement, limited mandibular movement, difficulty in mouth opening, and occlusal or nonocclusal parafunctions. The etiology of masticatory dysfunction is diverse. Apart from genetic and environmental determinants, also a psychogenic factor may be

responsible, including civilization-related stress that reduces adaptive potentials of the human body [1, 3, 13, 14]. Anxiety, restlessness, and depression states may induce or exacerbate masticatory dysfunction. A number of clinical studies seem to confirm the relationship between the exacerbation of masticatory dysfunction and strong emotional experiences [4, 6, 15–19], especially in young individuals in the final stage of maturation and early adulthood (18–21 years). It is extremely important that the affected people should be immediately diagnosed and treated.

The study objective was to determine the effect of stress on the function of the masticatory muscles in young healthy adults.

2. Material

A total of 201 young people were randomly chosen, 103 female and 98 male aged 18–21 years (mean 19 years).

Inclusion in the study required participants to satisfy the following criteria:

(1) class I molar and canine relations;

(2) full natural dentition with well-aligned arches;

(3) vertical, transverse, and anteroposterior relationships well-related;

(4) normal growth and good health.

Subjects were excluded from the study when they demonstrated the following:

(1) previous orthodontic treatment;

(2) extensive fillings or edentulous spaces;

(3) history of trauma in the region of masticatory system;

(4) any treatment concerning pain in any region of masticatory system;

(5) prosthetic treatment before recruitment to the study.

The data were collected in the Department of Prosthodontics at the Medical University of Białystok, Poland, and the protocol conformed to the criteria of The Helsinki Declaration, ICH Guideline for Good Clinical Practice, and approved by the Ethical Committee of Jagiellonian University, Poland, with an approval number of KBET/89B/2009. The participants were recruited into the study after obtaining consent from educational authorities, school headmasters, parents, and participants themselves.

3. Methods

The study included the following:

(1) clinical examination according to the Slavicek scheme [20];

(2) questionnaire survey (Perceived Stress Scale PSS-10);

(3) assessment of the masticatory muscles function (electromyography of four pairs of masticatory muscles (EMG) in central occlusion).

3.1. Clinical Examination according to the Slavicek Scheme. All study participants underwent clinical examination according to the Slavicek scheme [20], which consists of general medical history, specialistic history, and clinical examination. In the first part, the focused history was taken on general health condition, that is, past or present infections, allergies, hormonal disorders, or psychological problems. The second part concerned dental complaints, especially problems during mastication, speaking, hypersensitivity of the teeth, pain or acoustic phenomena in TMJ during mouth opening, biting, and yawning, headaches, and bad postures. Other questions referred to the past history of serious injury, accident, or intubation. Then, the study participant was asked about past orthodontic therapy and treatment with occlusal splints. Final questions concerned mental state of the respondent, subjective opinion of the complaint severity, and the need for treatment.

Clinical examinations of the muscles, TMJ, and facial nerves were performed. Pain and excessive tension or hypertrophy were assessed by palpation. Intraoral and extraoral examinations included checking muscles of the head, neck, shoulders, temples, and masseters, pterygoid muscles, mylohyoid muscles, digastric muscles, suprahyoid and subhyoid muscles, sternocleidomastoid muscles, maxillary tumors, tongue, larynx, and base of the temporomandibular ligament.

The TMJ was examined by simultaneous palpation in statics and rotation and by checking the acoustic symptoms during lowering, lifting, and lateral movements of the mandible. Function of facial nerves was assessed. Olfactory nerve, optic nerve, oculomotor nerve, compound nerve, trigeminal nerve, abducens nerve, facial nerve, vestibulocochlear nerve, linguopharyngeal nerve, vagus nerve, accessory nerve, and sublingual nerve were examined.

One well-qualified researcher performed all of the clinical examinations to avoid potential disagreement. For reliability, another investigator, who was also familiar with the method used, repeated the clinical examination for 10% of the participants. Ninety percent agreement was found.

3.2. Questionnaire Survey. A questionnaire form was used, that is, a psychological scale designed by Cohen et al., the so-called Perceived Stress Scale (PSS-10). The scale contains 10 questions concerning various subjective feelings associated with problems and personal events that have occurred during the last month. There is a short introductory set of instructions at the top of the questionnaire. The respondents answered the questions using a five-grade scale (0–4), with 0 meaning never, 1 hardly ever, 2 sometimes, 3 quite often, and 4 very often. Calculation of the overall intensity of perceived stress followed a change in the score in positively formulated answers, that is, according to the rule, 0 = 4, 1 = 3, 3 = 1, and 4 = 0. The overall score obtained after summing up all the answers was then converted into standard units (stens). The higher the score, the greater the intensity of perceived stress and thus the lower the resistance to it (Table 1).

3.3. Assessment of the Masticatory Muscles Function. The EMG examination was performed using an EMG apparatus

Table 1: The intensity of perceived stress according to a psychological scale named Perceived Stress Scale (PSS-10).

Sten	PSS	Intensity of perceived stress
1–4 stens	0–13 points	Low
5-6 stens	14–19 points	Medium
7–10 stens	20–40 points	High

(BioResearch, Inc., Milwaukee, WI, USA). Electric potentials of four pairs of muscles were measured: anterior parts of temporal muscles, masseters, anterior bellies of digastric muscles, and sternocleidomastoid muscles. The muscular activity was registered using bipolar adhesion electrodes at the maximum intercuspal position (central occlusion). Bipolar electrodes covered with silver chloride (Ag/AgCl), with constant distance between the poles (19 mm between the centers of poles), were placed on the surface of the skin degreased with alcohol, over the most bulged muscle mass palpated in contraction, parallel to muscular fibers. The zero electrode was placed in the supraclavicular pit [21]. Before EMG registration, all the subjects were instructed in the procedure. They were instructed to hold their teeth firmly together for 1-2 seconds and then open and repeat the maximum clench 2 more times. Once 3 clenches were recorded, subsequently, they were instructed to perform lateral excursive movements, separately left lateral and right lateral. Each measurement was performed three times with a minute break between subsequent registrations. The mean of three measurements was calculated for analysis.

3.4. Statistical Analysis. The study parameters were divided according to qualitative and quantitative features. Bipartite tables with calculated percentage distributions were applied for the qualitative features. For the quantitative features, average and dispersion measures were used, that is, the arithmetic mean and standard deviation. An analysis of variance (ANOVA) was used to determine if the differences in the parameters analyzed between the groups were significant. The strength of relationships between pairs of measurable parameters was determined using Pearson's correlation coefficient or Spearman's correlation rank coefficient, and its significance was assessed using Student's t-test to evaluate the correlation coefficient. Differences in the correlation were considered significant at $P < 0.05$.

Statistical analysis was conducted using the STATISTICA 8.0.PL software.

4. Results

The medical history and its clinical verification revealed masticatory system dysfunction in 86 generally healthy subjects (46%), showing no masticatory complaints during recruitment into the study. The major complaints reported by the study subjects with diagnosed masticatory dysfunction included headaches, pain on wide mouth opening, and muscle pain. The study participants had no history of general complaints or previous medical interventions (Table 2).

Table 2: The most common complaints in the group of subjects with masticatory system dysfunction symptoms.

Symptom	Number	%
Headache	42	49.00
Muscle pain	25	28.91
Pain during wide mouth opening, biting, or yawing	28	32.57
Acoustic phenomena in TMJ	22	26.40
Pain in the TMJ region	17	20.10
Pain in the region of head, neck, or nape	14	16.33
Clenching or grinding	19	22.06
Teeth sensitivity	18	21.35

The PSS-10 is a method designed to examine stress and ways of stress management. According to the scale score value, the study group was divided into three subgroups as follows:

(i) group I, 1–4 stens (0–13 points), low score,

(ii) group II, 5-6 stens (14–19 points), medium score,

(iii) group III, 7–10 stens (20–40 points), high score.

The lowest scores in the PSS were noted in approximately 29% of the study subjects, medium scores in nearly 40%, and the highest scores in almost 31%. In group I (the lowest PSS score), the number of women was smaller as compared to that of men. However, in group II, the number of women and the number of men were comparable. The highest number of women was noted in group III, the number of men in this group being more than twice lower (Table 3).

The distribution of masticatory dysfunction symptoms in the respective groups is presented in Table 4. The percentages of study participants with early symptoms of dysfunction in the respective groups versus all patients in these groups were comparable. Among study subjects with diagnosed early symptoms of masticatory dysfunction high level of perceived stress was observed in 24 people, accounting for 28% of this group.

The EMG examination was performed to assess four pairs of masticatory muscles: anterior temporal muscles, masseters, anterior bellies of the digastric muscles, and sternocleidomastoid muscles. The levels of activity of all muscles in central occlusion were comparable in female and male groups. Higher activity was noted on the right side in the masseters in men, with the mean values of electric potentials being significantly higher than in their female counterparts. In male group, the sum of mean values of electric potentials in central occlusion of temporal muscles and masseters on the right and left side was higher and statistically significantly different than in female group (Table 5).

The assessment of the activity of muscles in the PSS-based groups revealed a significant difference between the mean value of electric potentials of masseters and the sum of electric potentials of temporal muscles and masseters in central occlusion in the respective groups. The mean

Table 3: The number of men and women in the subgroups separated on the base of PSS-10 values.

PSS-10	Total		Male group		Female group	
	Number	%	Number	%	Number	%
Group I (low stress)	55	30%	34	18%	21	11%
Group II (medium stress)	74	40%	36	19%	38	20%
Group III (high stress)	57	30%	18	10%	39	21%

Table 4: The distribution of masticatory dysfunction symptoms in the respective groups separated on the base of PSS-10.

	Group I (low stress)			Group II (medium stress)			Group III (high stress)		
	Number	Total %	% in the group	Number	Total %	% in the group	Number	Total %	% in the group
Lack of dysfunction symptoms	29	16	53	38	21	51	33	18	58
Presence of dysfunction symptoms	26	14	47	36	20	49	24	12	42

Table 5: The levels of activity of all muscles (μV) in central occlusion in female and male groups.

	Female group	Male group
	Mean ± SD	Mean ± SD
Temporales anteriores	72.25 ± 13.68	74.39 ± 15.99
Masseters	99.25 ± 13.86	120.45 ± 15.61
Sternocleidomastoideus	8.7 ± 7.4	8.6 ± 6.4
Digastricus	16.5 ± 15.0	16.8 ± 14.5
Symetry		
Temporal anterior right	72.91 ± 40.80	74.74 ± 37.06
Temporal anterior left	71.82 ± 40.24	77.26 ± 44.70
Masseter right	105.79* ± 55.46	127.33* ± 60.39
Masseter left	92.68* ± 44.81	117.71* ± 59.78
Synergy		
Anterior temporal muscle and masseter right	84.92* ± 18.32	106.78* ± 20.74
Anterior temporal muscle and masseter left	81.93* ± 17.92	89.88* ± 20.51

*Statistical difference between female and male groups ($P < 0.05$).

values of electric potentials of masseters in group I were considerably lower than in group II and group III. The sum of the mean values of electric potentials of temporal muscles and masseters on the right was the highest in group III and differed significantly as compared to group I and group II. No significant differences were found between the mean values of electric potentials for the other muscles in groups I, II, and III (Table 6).

5. Discussion

Numerous clinical studies prove that stress and psychological state of a patient have a substantial effect on the activity of the masticatory system. In the masticatory organ, chronic stressful situations trigger excessive muscular tension which is frequently reduced by motor reactions, parafunctions. The reactions may lead to masticatory system dysfunction [3, 22–29]. TMJ dysfunctions are considered the third most common disorder of the masticatory system, after caries and periodontal diseases [13, 30]. All age groups can be affected with various intensity, with the prevalence rate of 60–80%, even up to 93% of the human population [31–33]; however, only 3–7% require treatment [25].

Epidemiological studies prove that increased intensity of TMJ dysfunction can be observed between the age of 20 and 40 years, that is, in young and middle age adults, more commonly in women than men [22, 23, 25]. Genetic predisposition and hormonal factor may play an essential role, especially in puberty, reproductive period, and menopause characterized by hypersensitivity of women to psychosocial factors and everyday stress [3, 24, 26–28]. Our own study showed that in the high stress group the number of women was twice as high as men and that symptoms of masticatory dysfunction were observed in 46.24% of the whole study group. According to literature data, among the key factors in the etiopathogenesis of the stomatognathic disorders, excessive muscle tension and chronic stress account for 34% and mental diseases for 7.1% [10].

Based on the medical history and clinical verification in the current study, the percentage of subjects with symptoms of masticatory dysfunctions in the PSS groups as compared to the overall group was 13.87% in group I, 19.71% in group II, and 12.08% in group III. Among subjects with symptoms of disturbed function of the masticatory system, 27.9% had a high level of perceived stress. The higher number of people with masticatory dysfunction symptoms in group II (medium level of stress) may be due to the fact that it was the most numerous group. However, the slightly higher percentage of patients with symptoms of masticatory dysfunction in group I as compared to group III may prove that stress is only one of many etiological factors that disturb masticatory function.

In the current study, the effect of stress on the activity of muscles was assessed by measuring the activity of masseters and anterior temporal muscles in central occlusion in three PSS-dependent groups. The mean values of electric potentials of masseters in group I, that is, the lowest level of perceived stress, were lower than in group III, that is, with high level of felt stress, the differences being statistically significant ($P < 0.05$). In many patients, stress-induced tension is relieved through involuntary motor activities of the dental arches, resulting in parafunctions. The most common parafunction is

Table 6: The assessment of the muscles activities in the PSS-10-based groups (μV) in central occlusion.

	Group I: PSS-10, low Mean ± SD	Group II: PSS-10, medium Mean ± SD	Group III: PSS-10, high Mean ± SD
Temporal muscle right	67.49 ± 18.93	75.19 ± 25.34	77.51 ± 29.87
Temporal muscle left	71.49 ± 20.60	74.09 ± 23.90	77.32 ± 23.08
Masseter right	120.25 ± 26.47	122.53 ± 23.43	103.37 ± 22.83
Masseter left	107.24 ± 31.16	108.22 ± 33.69	96.97 ± 36.07
Temporales muscles	69.20 ± 17.82	74.43 ± 11.34	77.66 ± 15.64
Masseters	110.52^{*x} ± 15.97	115.23* ± 15.04	100.33^{x} ± 12.05
Temporal muscle and masseter right (synergy)	93.54^{x} ± 20.39	98.86^{i} ± 17.84	90.44^{xi} ± 20.08
Temporal muscle and masseter left (synergy)	89.36 ± 21.82	91.15 ± 19.19	87.14 ± 17.63

*Statistical difference between groups I and II.
^{x}Statistical difference between groups I and III.
^{i}Statistical difference between groups II and III.

bruxism. According to literature data, the majority of human populations (85–90%) at certain time of life clench or grind their teeth. Two types of bruxism have been distinguished: sleep bruxism (SB) and awake bruxism (AB). Lobbezoo et al. have shown that these two types differ in etiology, course, and effects [9]. SB occurs mainly during microawakening during sleep, unconsciously, and is manifested by tooth grinding. According to various studies, sleep episodes of bruxism occur in 5% to 8% of the world population [34, 35]. On the other hand, awake bruxism is a conscious patient-controlled phenomenon, manifested by soundless clenching of the teeth and lack of grinding, typical of SB. Its prevalence is estimated at approximately 20% of the general population. Awake bruxism is psychologically related and its intensity may depend on the emotional state of patients [36, 37]. AB can be an independent phenomenon or may accompany sleep bruxism. Until now, bruxism in dentistry has been defined as a parafunction, that is, unconscious abnormal fixed activity of the masticatory organ, differing in quality and quantity from the normal function. The latest results show that bruxism can be referred to as not a disorder but a physiological activity in response to stress [38], which was phylogenetically encoded in humans, where baring the teeth in primitive people meant warning [10].

The appearance or exacerbation of symptoms of masticatory dysfunction to a large extent depends on individual predisposition and the related specific features of character. Various personality tests are used to evaluate psychoemotional state of patients with stomatognathic system disorders. Mongini using the Minnesota Multiphasic Personality Inventory (MMPI) test [39] has found that approximately 40% of patients with masticatory system dysfunction show elevated levels of hysteria and hypochondria. These patients frequently complain of headaches and psychoemotional symptoms, such as anxiety, restlessness, and fear. Higher levels of psychological, behavioral, and somatic symptoms of stress in people with masticatory system dysfunctions as compared to healthy subjects have been confirmed by other authors [4, 18, 40–45]. The role of psychological factor, especially stress, neuroticism, and depression, in the etiology of functional disorders of the masticatory organ has been more frequently emphasized in patients with myofascial pain than in subjects with TMJ disorders [15–17, 19, 46]. Pain is a significant symptom of masticatory dysfunction, forcing patients to see a specialist. Thus, one of the latest classifications of functional disorders of the masticatory system, the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) presented by Dworkin and LeResche in 1992, takes into account both the clinical factor of masticatory dysfunction and the psychological one, that is, stress, nervousness, depression, and somatization of pain [21, 47]. The classification, based on the general biopsychosocial model, is the best available diagnostic criterion of functional disorders of the masticatory system. It is recommended for scientific research and routine clinical examinations [48, 49]. Although stress and mental diseases are not the only factors of masticatory organ dysfunctions, they have an increasingly important role, especially in more vulnerable subjects. Therefore, detailed psychological diagnostic examinations, as well as psychosocial and psychiatric assessment, are recommended in patients with masticatory organ dysfunctions, who complain of chronic pain accompanied by anxiety, stress, or depression.

6. Conclusions

(1) Among young healthy adults with a complete natural dentition, some individuals do not report symptoms of masticatory system dysfunction despite their presence. Those who complain of dysfunction symptoms do not associate them with the masticatory system.

(2) Adults with higher level of perceived stress tended to have increased activity of masseters in central occlusion.

(3) Chronic stress may reveal or exacerbate symptoms of masticatory dysfunction.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Muscle Fatigue in the Temporal and Masseter Muscles in Patients with Temporomandibular Dysfunction

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The aim of this study is to evaluate muscle fatigue in the temporal and masseter muscles in patients with temporomandibular dysfunction (TMD). Two hundred volunteers aged 19.3 to 27.8 years (mean 21.50, SD 0.97) participated in this study. Electromyographical (EMG) recordings were performed using a DAB-Bluetooth Instrument (Zebris Medical GmbH, Germany). Muscle fatigue was evaluated on the basis of a maximum effort test. The test was performed during a 10-second maximum isometric contraction (MVC) of the jaws. An analysis of changes in the mean power frequency of the two pairs of temporal and masseter muscles (MPF%) revealed significant differences in the groups of patients with varying degrees of temporomandibular disorders according to Di ($P < 0.0000$). The study showed an increase in the muscle fatigue of the temporal and masseter muscles correlated with the intensity of temporomandibular dysfunction symptoms in patients. The use of surface electromyography in assessing muscle fatigue is an excellent diagnostic tool for identifying patients with temporomandibular dysfunction.

1. Introduction

According to various reports, the prevalence of functional disorders in the population aged 3–74 years ranges from 7% to 84% [1–6]. According to Luther, such a large discrepancy is probably the result of using different methodologies in assessing these types of disorders [7].

A review of epidemiological studies conducted by McNeill [1] indicates that about 75% of the population has at least one objective symptom of functional disorders, whereas only 33% reports subjective symptoms. It is also estimated that a need for treatment is expressed by only 5-6% of a large population of people with temporomandibular dysfunction. Only a 7% rate in the occurrence of subjective symptoms of temporomandibular dysfunction was reported by List et al. [8] in a group of 826 children and adolescents aged 12 to 18 years.

Similar conclusions regarding the disparity between the prevalence of subjective symptoms and the recorded evidence of functional disorders were presented by Mohlin et al. [2] following a critical review of 58 studies. A significant difference in the prevalence of subjective and objective symptoms was also revealed by a meta-analysis of 51 studies in the area of temporomandibular dysfunction conducted by de Kanter et al. [9]. The incidence of subjective symptoms was found to range between 6% and 93% and the incidence of objective symptoms, confirmed by clinical examination, between 0% and 93%. A significant discrepancy between the prevalence of subjective symptoms and objective symptoms, which are clinically confirmed signs of temporomandibular dysfunction, was also observed by Suvinen et al. [10]. An analysis of this phenomenon conducted by the authors revealed a relatively weak, on the borderline of statistical significance, correlation between subjective symptoms and objective symptoms observed in routine dental examination. Luther [11] demonstrates beyond any doubt that the disparity connected with a higher incidence of objective symptoms in relation to subjective symptoms is a characteristic feature of temporomandibular dysfunction.

Table 1: The exclusion criteria adopted in anamnesis and the number of patients included in the study.

Total number of patients participated in the study		200
Exclusion criteria	Depressive disorders	0
	Pain in other parts of the body	4
	Inflammations	3
	Taking painkillers and antidepressants	1
	Periodontal diseases	1
	Completed treatment of masticatory motor system dysfunctions	2
	Completed orthodontic treatment	15
Total number of patients included in the study		174

In the light of the evidence presented, expanding the repertoire of modern noninvasive diagnostic methods should result in obtaining more objective research results [12–14].

The aim of this study is to evaluate muscle fatigue in the temporal and masseter muscles in patients with temporomandibular dysfunction.

2. Materials and Methods

The research was approved by the Ethics Committee of the Pomeranian Medical University in Szczecin, Poland (number BN-001/45/07) as being consistent with the principles of Good Clinical Practice (GCP). All the patients were informed about the aim and research design and they gave their consent in order to participate.

Two hundred volunteers (100 females and 100 males) aged 19.3 to 27.8 (mean 21.50, SD 0.97) referred to the Orthodontic Department of the Pomeranian Medical University in Szczecin participated in this study. Inclusion criteria were that the participants should be aged between 19 and 28 years and express consent to participate voluntarily in the study. As a result of the application of the adopted exclusion criteria listed in Table 1, 174 of these (93 females and 81 males) qualified for further examination.

Anamnestic interviews which included the patients' general medical history as well as detailed information about their masticatory motor system were conducted. The patients were divided according to a three-point anamnestic index of temporomandibular dysfunction (Ai).

The assessment of the function of the masticatory motor system included clinical as well as electromyographic examinations. The former involved visual and auscultatory assessment as well as palpation and made it possible to qualitatively and quantitatively evaluate the function of the masticatory system. The clinical index of temporomandibular dysfunction was used for the analysis of the data obtained from the clinical study (Table 2). The interpretation of the results of the clinical index of temporomandibular dysfunction (Di), based on the total number of points obtained during the tests, was performed according to the following model (Table 3) [15, 16].

EMG recordings were performed using a DAB-Bluetooth Instrument (Zebris Medical GmbH, Germany). During these recordings each patient was sitting on a comfortable chair without head support and was instructed to assume a natural head position during electromyographic examination.

Table 2: Clinical index of temporomandibular dysfunction (Di).

Di	Symptoms
	Mandibular movements
0	Normal range
1	Small reduction in amplitude
5	Large reduction in amplitude
	Temporomandibular joint function
0	Smooth, noiseless abduction and adduction of mandible, trajectory asymmetry <2 mm
1	Noise in one joint or both joints during abduction and adduction of mandible, trajectory asymmetry >2 mm
5	Abduction of mandible impossible and/or luxation
	Masticatory muscle pain
0	No tenderness
1	Tenderness of 1–3 sites
5	Tenderness of 4 and more sites
	Temporomandibular joint pain
0	No tenderness
1	Unilateral or bilateral tenderness
5	Unilateral or bilateral tenderness of the dorsal surface of joint
	Pain during movement of mandible
0	No pain
1	Pain during one out of all possible movement directions
5	Pain during more than one out of all possible movement directions

Table 3: Interpretation of the clinical index of temporomandibular dysfunction (Di).

Range	Severity of dysfunction	Description
0	Di 0	No dysfunction
1–4	Di I	Mild dysfunction
5–9	Di II	Moderate dysfunction
10–25	Di III	Severe dysfunction

Surface EMG signals were detected by four silver/silver chloride (Ag/AgCl), disposable, self-adhesive, bipolar electrodes (Naroxon Dual Electrode, Naroxon, USA) with a fixed interelectrode distance of 20 mm. The electrodes were positioned on the anterior temporal muscles and the superficial masseter on both the left and the right sides parallel to the muscular fibres, for the anterior temporal muscle: vertically along the anterior margin of the muscle; for the masseter muscle: parallel to the muscular fibres with the upper pole of the electrode at the intersection between the tragus-commissura labiorum and exocanthion-gonion lines. A reference electrode was placed inferior and posterior to the right ear [17].

Before the recordings, in order to reduce impedance, the skin was carefully cleaned with 70% ethyl alcohol and dried. The EMG procedures were performed 5 minutes later.

Table 4: Changes in mean power frequency (MPF%) of muscles during 10 s of maximal voluntary contraction in intercuspal position depending on the temporomandibular dysfunction index Di.

Side/gender		Di group 0			I			II			III		
		n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
Temporal muscles													
Left	Females	22	−2.18	6.99	39	−6.64	5.13	25	−14.71	5.81	7	−10.44	9.14
	Males	23	−2.80	3.54	29	−6.10	5.34	23	−11.49	6.17	6	−27.83	0.82
	Total	**45**	**−2.50**	**5.45**	**68**	**−6.41**	**5.19**	**48**	**−13.17**	**6.14**	**13**	**−18.47**	**11.11**
Right	Females	22	−3.55	7.82	39	−7.39	6.11	25	−15.03	4.04	7	−11.70	3.56
	Males	23	−3.10	4.29	29	−6.66	5.64	23	−11.14	4.87	6	−25.48	1.67
	Total	**45**	**−3.34**	**6.20**	**68**	**−7.08**	**5.88**	**48**	**−13.17**	**4.83**	**13**	**−18.06**	**7.66**
Masseter muscles													
Left	Females	22	−1.89	7.51	39	−12.99	7.95	25	−19.51	4.81	7	−9.79	10.23
	Males	23	−5.30	4.67	29	−10.95	4.14	23	−17.80	3.72	6	−36.77	7.43
	Total	**45**	**−3.64**	**6.39**	**68**	**−12.12**	**6.63**	**48**	**−18.69**	**4.36**	**13**	**−22.24**	**16.47**
Right	Females	22	−3.35	10.25	39	−14.85	8.80	25	−19.09	4.51	7	−14.77	4.18
	Males	23	−5.20	5.90	29	−13.31	4.77	23	−17.66	3.37	6	−34.32	7.31
	Total	**45**	**−4.30**	**8.27**	**68**	**−14.19**	**7.35**	**48**	**−18.40**	**4.03**	**13**	**−23.79**	**11.57**

The DAB-Bluetooth Instrument was interfaced with a computer which presented the data graphically and recorded it for further analysis. The EMG signals were amplified, digitized, and digitally filtered.

Muscle fatigue was evaluated on the basis of a maximum effort test. The test was performed during a 10-second maximum isometric contraction (MVC) of the jaws. Analysis of the mean power frequency (MPF%), as a variable independent of the complex impedance of the measurement system, did not require the use of a normalization process.

The asymmetry between the activity of the left and the right jaw muscles was quantified by the Asymmetry Index (As). It ranges from 0% (total symmetry) to 100% (total asymmetry) [18–20]:

$$\mathrm{As} = \frac{\sum_{i=1}^{N} |R_i - L_i|}{\sum_{i=1}^{N} (R_i + L_i)} \cdot 100. \quad (1)$$

The Kruskal-Wallis test, the median, and the Mann-Whitney U test were used to verify the hypotheses relating to the existence or absence of differences between the mean values of the independent variables. The statistical significance for verifying all the hypotheses was set at $P = 0.05$.

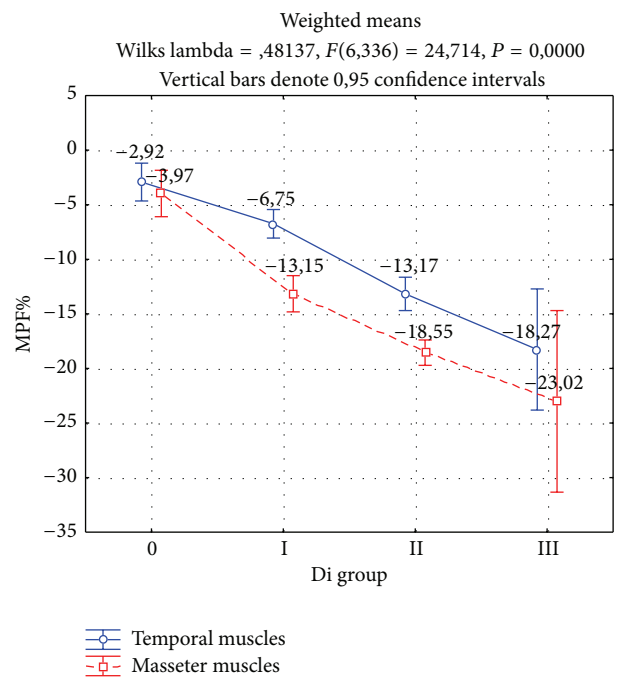

Figure 1: Changes in mean power frequency (MPF%) of muscles during 10 s of maximal voluntary contraction in intercuspal position depending on the temporomandibular dysfunction.

3. Results

The analysis of changes in the mean power frequency of the two pairs of temporal and masseter muscles (MPF%) showed significant differences in the groups with varying severities of temporomandibular dysfunction according to the Di index ($P < 0.0000$, Table 4, Figure 1). There was a significant tendency to increased fatigue in the tested muscles in direct proportion to the severity of the temporomandibular dysfunction according to the Di.

Resistance to muscle fatigue was modified at the level of the type of muscles examined ($P < 0.0000$). There was always greater depletion of the interference signal in the case of the masseter muscles relative to the temporal muscles.

Changes in the mean power frequency (MPF%) of temporal muscles during 10 s of maximum voluntary contraction were the lowest in the group with no symptoms of temporomandibular dysfunction (−2.92%). Significantly higher

depletion of the interference signal was observed in the group with mild dysfunction (−6.75%, $P < 0.0004$), moderate dysfunction (−13.17%, $P < 0.0000$), and severe dysfunction (−18.27%, $P < 0.0223$) according to the Di index. There were no significant differences in the fatigue of the right and left temporal muscles in each group of temporomandibular dysfunction according to the Di index ($P < 0.0784$).

Similar to the temporal muscles, changes in the mean power frequency of masseter muscles were the lowest in the group with no symptoms of dysfunction (−3.97%). Significantly higher muscle fatigue, as evidenced by a greater reduction in the mean power frequency, was found in groups with mild dysfunction (−13.15%, $P < 0.0000$), moderate dysfunction (−18.55%, $P < 0.0000$), and severe dysfunction (−23.02%, $P < 0.0341$) according to the Di index. As in the case of the temporal muscles, the impact of dysfunction on the differences in fatigue between the right and left masseter muscles has not been confirmed ($P < 0.0937$).

4. Discussion

Electromyography (EMG) is one of the few diagnostic tools that enable direct and objective assessments of muscle function. Practitioners dealing with functional disorders of the masticatory motor system are particularly interested in global electromyography (*surface electromyography* (SEMG)) because of the noninvasive nature of measurements that it provides [21–25].

Assessing susceptibility to muscle fatigue is a crucial element in the analysis of electromyographic examinations. Fatigue is usually defined as the point beyond which a particular level of force can no longer be maintained. Mean power frequency (MPF) and its changes linked to function are a reliable and objective indicator of muscle resistance to fatigue. Thus, changes in the frequency of the electrical activity of muscles, being a component of interference signal depletion, are a major predictor of susceptibility to muscle fatigue in EMG recordings. Muscle fatigue can also be determined by an increase in the EMG activity of muscles involved in generating a constant force. This is consistent with the view that generating a constant force as muscle fatigue increases must be associated with an increase in the electrical activity of muscles [26].

Our own examinations showed significant differences with regard to the type of muscles examined. There was a significantly greater depletion of the interference signal in respect of the changes in mean power frequency of the masseter muscles than the temporal muscles during 10 s of maximum isometric contraction in the intercuspal position.

Changes in the interference signal with respect to the mean power frequency of muscles during maximum isometric contraction were also a strong predictor of functional disorders in the masticatory motor system. Resistance to fatigue in the temporal and masseter muscles was significantly higher in the group with no symptoms of temporomandibular dysfunction than in the group of patients with symptoms of dysfunction according to the Di index. There was a significantly greater depletion of the interference signal for masseter and temporal muscles in the group with TMD.

Measurements of the mean power frequency of temporal and masseter muscles also showed high discriminatory efficiency for subjects with varying severities of temporomandibular dysfunctions according to the Di index. There were significant differences in terms of fatigue between the groups with varying severities of dysfunction for both temporal and masseter muscles.

The results of the study were based on the clinical index of temporomandibular dysfunction (Di). This index is simple and easy to use and is extensively used in research [27]. Although there are some limitations in using the Di, it represents a valid tool which correlates with the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) in identifying patients with symptoms of TMD [16, 28].

In studies of masticatory muscle fatigue conducted by Sforza et al. [26] a muscle force sensor was used, which was located on one side between the dental arches of ten healthy subjects. This made it possible to terminate the effort test at the precise moment when the subjects could no longer produce the required bite force (127 N). As in previous studies, the endurance time ranging between 79 and 470 s in a group of ten examined subjects was a prognostic factor for muscle fatigue. An analysis of mean power frequency at the beginning and at the end of the test showed a significant decrease in the masseter muscles, which was not confirmed with regard to the temporal muscles. There was a significant decrease in the mean power frequency of both masticatory muscles after one minute on the side where the force sensor was placed.

Hori et al. [29] recorded mean power frequency (MPF) shift during fatigue and recovery of 46 healthy subjects and 46 patients with craniomandibular disorder at the beginning and the end of fatiguing clenching and then 3, 8, 13, and 18 min following the fatiguing clenching. The reference clenching force was 80% of each subject's maximal voluntary contraction (MVC). The results of the study showed significance between the healthy group and the group with craniomandibular disorder in the three following points, such as the mean of MPF values of the masseter muscles at the end of fatiguing clenching; the recovery pattern of the temporal muscles; and MPF shift induced by fatiguing clenching. These results therefore suggest that measuring fatigue and recovery MPF could be useful in the screening of craniomandibular disorders.

In studies conducted by Gay et al. [30] surface EMG recordings were made for both the masseter and anterior temporal muscles while the subject held an incisal bite force level of 10 N for as long as possible. The sample consisted of 18 patients with symptoms of TMD and 15 patients with no symptoms of TMD. The results showed that the endurance times were significantly shorter for the TMD patients; the masseter was not active in three of 17 TMD patients; and decreases in MPF over time were significantly greater for the TMD patients than normal subjects.

A study by Castroflorio et al. [31] concerned 20 healthy volunteers and 18 patients with TMD. An intraoral compressive-force sensor was used to measure the voluntary contraction forces close to the intercuspal position and to provide visual feedback of submaximal forces to the subject. Surface EMG signals were recorded with linear electrode

arrays during isometric contractions at 20%, 40%, 60%, and 80% of the maximum voluntary contraction force, during an endurance test and during the recovery phase. The analysis of the results revealed that the temporal anterior and masseter muscle show the same myoelectric manifestations of fatigue and recovery and the initial values of the mean power frequency were lower in patients with muscle-related TMD.

Liu et al. [32] found significant differences in the mean power frequency of masseter and temporal muscles in a group of 24 subjects who had at least one objective or subjective symptom of masticatory system dysfunction compared to a group of 20 healthy people. Although an analysis of the results in both the examined groups showed a similar mean power frequency both at the beginning and at the end of maximum contraction in the intercuspal position over 30 s, there was a significantly greater decrease in the mean power frequency of the temporal muscles (right: 24.1 and left: 22.9) and masseter muscles (right: 19.2 and left 22.3) in the group with symptoms of TMD in comparison to the group with no symptoms of TMD (temporal muscles: right 13.4 and left 15.3; masseter muscles: right 10.5 and left 10.9).

The studies presented, whose observations are consistent with the results of our own findings, provide justification for using the analysis of muscle fatigue in the identification and discrimination of subjects with symptoms of masticatory system dysfunction.

5. Conclusions

(1) The results of the presented study showed an increase in the fatigue of temporal and masseter muscles in direct proportion to the severity of symptoms of temporomandibular dysfunction in the examined patients.

(2) The use of surface electromyography in the assessment of muscle fatigue is an excellent diagnostic tool for identifying patients with temporomandibular dysfunction.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Review Article

Psychoeducation Program on Strategies for Coping with Stress in Patients with Temporomandibular Joint Dysfunction

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Lack of educational projects in the available literature was an inspiration to develop a psychoeducational program. The objective was to provide patients with basic information on the contribution of stressors in the occurrence of temporomandibular joint dysfunction and educate on methods for coping with stress most commonly used in psychology. In the course of three meetings, patients are familiarised with the issue of experienced stress as a potential source of psychosomatic illnesses (in particular, temporomandibular joint dysfunction). Preliminary patients' opinions, expressed through self-report methods, indicate significant usefulness of the developed psychoeducational program for the process of treatment and the quality of patients' lives.

1. Introduction

Stress, as indicated by numerous data in the literature, is one of the main etiological factors of functional disorders of the masticatory system [1–11]. More than half of this group of patients experiences high-frequency stress, that is, the number of life events having features of difficult events [2], and even extremely traumatic events. Authors of available publications indicate that this may be the group that did not develop the appropriate skills to cope with stress at a physiological level. In the future, PTSD (posttraumatic stress disorder) symptoms may develop in some of these patients [12–16].

The results of neuroimaging studies, mainly using magnetic resonance imaging, have provided valuable information regarding the role of experienced stress in the formation of parafunctions, consequently leading to persistent morphological and functional disorders of the masticatory system [17–21]. Information about stressors is transmitted by the corticobulbar tract to the brainstem structures which, in turn, activates the neurotransmission in the central pontospinal structure of the reticular formation, as a result stimulating the γ loop. γ cell bodies are placed in anterior horns of the spinal cord, and their fibres reach muscle sensory receptors-neuromuscular spindle, regulating excitability of the latter [22–29] (Figures 1 and 2). Hence, the release of strong emotions accompanying experiencing stress results in the activation of mandibular adductor muscles' activity. Prolonged psychophysical tension contributes to excessive activity of the mandibular adductor muscles, especially superior lateral pterygoid muscle, which has its attachment, among others, in the area of the front part of the articular disc. Its pathological displacement results in lack of coordination of the articular head and disc during the mandible movements, causing acoustic symptoms in the form of glitches. Negative effects of excessive muscle tension triggered under the influence of psychological stress include damage to dental hard tissues in the form of cracks in the enamel of clinical crowns, emergence of wedge-shaped lesions, or pathological tooth wear. Moreover, there are also pathological changes in periodontal

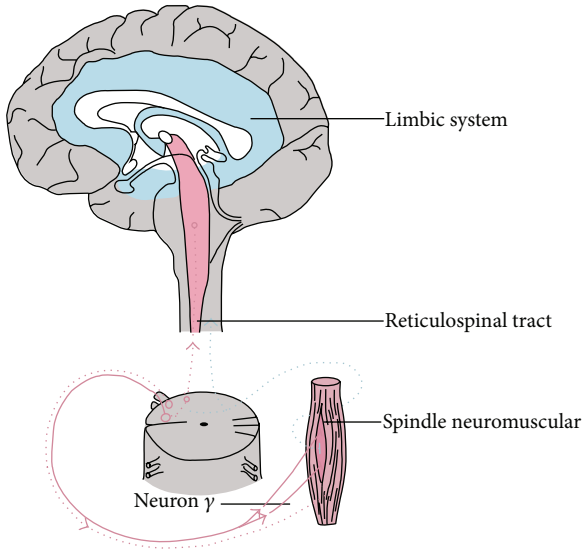

Figure 1: Wiring diagram of the limbic system, gamma loop, and chewing muscle.

tissues and uncontrolled bone atrophy, along with damage to the structures of temporomandibular joints and masticatory muscle overload and growth.

The main purpose of the paper is to describe the psychoeducation program dedicated to patients with temporomandibular joint dysfunction. It will also provide information on the impact of stress on the development of the illness, educating on how to cope with stress and increasing the sense of control over their emotional response.

2. The Role of Stress in the Temporomandibular Joint Dysfunction

The long-term impact of the stressor leads to a state of severe mental and physical tension [30, 31] that is relieved by movement reactions of parafunctions nature, such as bruxism [32, 33]. Parafunctional habits of masticatory system muscles, with and without associated chronic pain, long-term treatment requiring numerous visits to specialists, rehabilitation exercises, as well as changes of habits are the source of secondary stress for the patient [34–38]. Stress experienced in such a way, together with other daily stressors with which the patients cope in an ineffective way, intensifies the pain. The effect is further intensified by potentially comorbid sleep disorders [39, 40]. All of these factors significantly reduce the quality of life for patients, negatively affecting their motivation to continue the functional disorders of the masticatory system therapy.

The term "coping" can be viewed in two ways: through the collection of relatively fixed characteristics of the individual (so-called coping styles) and in relation to activities undertaken by him/her in a particularly difficult situation (so-called coping strategies) [41, 42]. Coping, according to the firmly established psychology theory created by Lazarus and Folkman [43], performs two basic functions: (1) task (problem-oriented, instrumental), aiming at improving the unfavourable relations of situational requirements to the individual's abilities, and (2) being associated with emotional self-regulation, oriented to reduce the unpleasant tension and to ease negative emotional states. Studies indicate that patients with temporomandibular joint dysfunction are a group that significantly and more frequently uses nonadaptive strategies for coping with stress, which is general avoidance or wishful thinking [4, 43]. At the same time, in this particular group of patients, the negative impact of such strategies on physical and mental wellbeing was confirmed [44]. Subjects only partially [45, 46] maintain consistency between diagnosed coping style and the content of chosen strategies, or this phenomenon does not occur at all [47]. It may indicate certain dynamism of coping, as well as its flexibility; we can, therefore, expect the undertaking of different activities, depending on the actual characteristics of a person (including his/her knowledge and well-being) and the characteristics of the situation.

At the same time, the main characteristics of the stressor are what significantly differentiate the range of coping strategies chosen by the individual, especially the possibility of controlling it [48]. This control is determined by the ability to control the occurrence, course, and consequences of a particular stressor [49]. For example, chronic stress related to the experience of pain caused by the presence of dysfunctions of the stomatognathic system is, for the patient, largely difficult to control. This is the case until the patient is covered by the specialist's care and learns how to diminish the discomfort or prevent the recurrence of symptoms and gain "control" over his/her own illness. When trying to maintain control over the experienced stress situation, the patient is more likely to activate instrumental strategies, aiming at coping with the difficulty. Without such a control, the ability to activate a strategy focused on the regulation of experienced emotions is important.

3. Possibilities for Modification of the Style of Coping with Stress through Psychoeducational Interventions

Following Lazarus and Folkman's assumptions [43] applied to an interactive model of coping with stress, any controlled modification of knowledge and competence of the individual realistically makes it possible for her (to some individually limited degree) to influence the process of coping with stress. In practice, it means that the strategies and styles of coping with stress used by the patient may undergo favourable changes under the influence of deliberate, individually customized psychoeducational activities.

Psychoeducation is defined as a form of psychological help combining psychotherapy with education [50, s.206]. As such, it is inscribed in the holistic model of care for the patient based on the development of specific competencies in the patient.

Meta-analyses examining the impact of psychoeducation on the reduction of stress revealed that shorter psychoeducational interventions, comprising several meetings, give

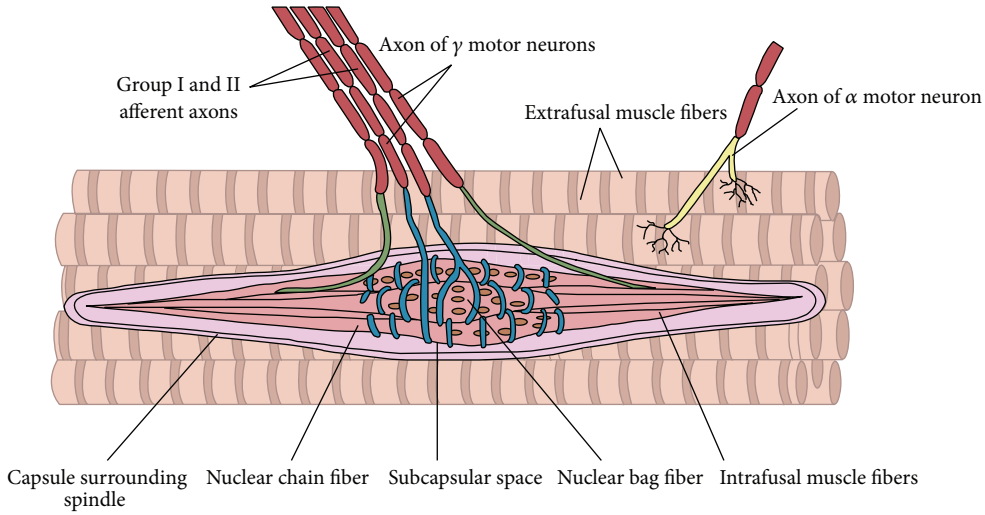

Figure 2: Sketch of afferent and γ motor neurons connection with neuromuscular spindle.

particularly favourable results [51, 52]. This is especially important in the case of psychoeducational intervention designed as multimodal, that is, referring to different techniques within a single program. It is different from targeting one specific way of stress reduction, such as the ability to diminish the effects of stress through specific relaxation techniques; in such cases it is reasonable to schedule more meetings.

4. Materials and Description of the Psychoeducational Program

4.1. Meeting Purpose. The aim of the original psychoeducational program developed in the Consulting Room of Dysfunction of the Masticatory System, Department of Dental Prosthodontics, Jagiellonian University Medical College in Krakow, is to provide patients with basic information about the stressor contribution in the symptoms development of temporomandibular joint dysfunction and education on ways of coping with stress. Moreover, the purpose is to strengthen the sense of control over emotional reactions of patients by choosing the most favourable method of coping with stress for the specific patient. At the same time, the program is a response to the request to enable patients to widen the sense of affecting stressors—not only the disease, but also all others, which may be experienced. This is a particularly important goal of functional disorders of the masticatory system therapy, in which the stress factor is not only somatic and the mental result of experienced illness, but also an important etiologic and dysfunction-supporting factor.

4.2. Participants. The participants are Consulting Room of Temporomandibular Joint Dysfunction patients, 18 years old and above, and interested in the program. The only exclusion criterion is the presence of an organic mental disorder or any somatic illness, which prevents them from effective participation at meetings. They are mostly obtained from their dentists, who briefly inform them about the possibility of participating in the program. Already, a few patients refused to participate in the program, indicating some logistical difficulties (access to the meeting place, busy work schedule). However, all of them expressed their keen interest in the issue. What seems interesting is that few participants underwent psychotherapy. None of the participants has ever participated in any psychoeducational program or been instructed to cope with stress.

4.3. Content and Methods Used. In the course of three meetings with a psychologist, patients gain knowledge on stress and its impact on their bodies. They also discover their style of coping with stress, and, consequently, have the opportunity to consider, together with a psychologist, which ways of coping with stress (customized to their individual style for coping with difficult situations) may be effective for them. In each case, these meetings are customized to the mental and physical capacity and resources presented by the patient. Each meeting, takes from 45 to 90 minutes, depending on patients' needs, capabilities, and knowledge.

During the first meeting, basic knowledge on the mechanisms of the stress response and psychosomatic in the stomatognathic system is transferred to patients. In many cases, patients independently come to the conclusion that such situations are composed of both the positive and negative. With the help of Holmes and Rahe's Social Readjustment Rating Scale (SRRS) [53], patients have the opportunity to estimate the cumulative stress to which they were recently exposed. Using this scale, life stress is measured in Life Changes Units (LCU). The highest value is assigned to the most stressful events. All the data obtained in the questionnaire are analysed quantitatively. The study conducted by the authors of the scale shows an interesting relationship between the amount of stressors and the likelihood of developing a serious illness. For values exceeding 300, it is almost 80%. During the same meeting, patients are familiarized with the characteristics of personality types, which may favour the occurrence of

difficulties in the fight against stress. Personality may be related to stress resistance, as it may determine the quantity and quality of positive social and family relationships, which can further ease the impact of stress and reduce the number of incidences and premature deaths [54]. In contrast to introverts, people who are open and oriented toward contacts with other people (extroverts) may have more people in their environment who are ready to offer help in difficult situations, in this way weakening the negative effects of stress. So-called neuroticism—a tendency to worry and anxiety, especially when connected with a low level of extraversion—is a feature which lowers the overall stress resistance. Further work, during the first meeting with a psychologist, focuses on making patients aware of the prevalence of stressors and difficulties in adequately coping with them, giving special attention to the group of patients with dysfunctions in the stomatognathic system. At this stage patients, during a short lecture, are familiarized with the issue of stress as an etiologic factor of experienced temporomandibular joint dysfunction. Explanations concern a two-way relationship of stress and health [55], pointing to the basic physiological and psychological processes: emotions, behaviours accompanying stress, and coping.

In the last part of the first meeting, the psychologist explains harmful and unfavourable changes occurring in the organism under the influence of stressors, on the example of the mechanisms of developing functional disorders of the masticatory system. Another issue discussed at the first meeting is presenting the possibilities of analysing and avoiding situations that generate experienced stress and enriching types of strategies for coping with stress using potentially the most beneficial methods for the particular patient.

The second psychoeducational meeting begins with the completing of a Brief-Cope survey (Coping Inventory for Stressful Situations, Polish adaptation: Z. Juczyński) on the scale of coping with stress by the patient. The questionnaire consists of 28 statements included in the 14 strategies (two statements for each strategy). It is used to measure dispositional coping and the assessment of the typical ways of responding and emotions in difficult situations. The advantage of this questionnaire is the possibility of quickly summarizing the results and providing patients with feedback during the current meeting. Although the main method of data obtained in the questionnaire analysing was quantitative, it was supplemented by participant statements, analysed qualitatively.

Moreover, possibilities are also discussed to modify the unconstructive behaviour within the frame of strategy for coping with stress preferred by the patient. It occurs during the motivating interview, which is designed to strengthen a patient's involvement in making significant life changes and facilitate the discovery of intrinsic motivation for changes. Motivating interview is a style of work, based on partnership cooperation with a specialist (in this case a psychologist), with the patient striving to transform his/her attitude into a pro-health perspective [56].

The purpose of the third, and last, meeting is to familiarize patients with constructive techniques for coping with stress, consistent with their individual predispositions. They are proposed on the basis of the subjective examination results and the Brief-Cope questionnaire. They include both complex techniques, such as physical self-regulating techniques, relaxation techniques (e.g., Jacobson progressive relaxation training), or self-hypnosis, as well as simple methods based on instruction in physiological breathing in stressful situations. It is a meeting during which the patient is able to practically experience the basics of techniques, which he considered interesting or useful. Moreover, the meeting highlights a significant role of contacts with relatives, regular physical exercise or sleep hygiene, factors which (as revealed in studies) are an important source of dysfunction of stomatognathic system.

5. Results and Discussion

The paper provides a description of the psychoeducational program for patients with temporomandibular joint dysfunction, which may be investigated as replenishment treatment. As a result the exact research, supported with objective measurements, is essential.

Initial patients' opinions indicate the usefulness of psychoeducation in the field of treating functional disorders of the masticatory system and present an important impetus to continue psychoeducational meetings. Patients emphasize the benefits of analyzing their current psychophysical situation, expressing satisfaction of the new knowledge, which is used in everyday life, and they are interested in the possibility of continuing education in specific techniques pointing to stress reduction. Moreover, meetings show that skillfully directed patients demonstrate high creativity in designing techniques, which are appropriate for them. Sometimes patients communicate their knowledge to people within their immediate environment, thereby encouraging collective use of previously acquired knowledge.

The proposition is not without some limitations. Firstly, a significant amount of content to pass on to patients in a small window of time requires considerable and efficient cooperation. Secondly, the construction stage of the program did not include physician participation in meetings and completing the psychological data with some physiological or medical knowledge, strengthening the power and reliability of the transmission. Finally, the personal factor should also be noted; the implementation of the program would require the creation of a consistent training for psychologists having to conduct the meetings with patients. The temporomandibular joint dysfunction issue is still not very popular among the representatives of the profession (at least in Poland).

Developed psychoeducational program is the second proposal of patients' education in techniques for coping with stress. A psychoeducational program project for patients with dysfunction of the temporomandibular joints, created at the Eastman Dental Institute, University College London, seems to produce equally positive results [57]. Psychoeducational interventions used in the project were related to two aspects of psychoemotional functioning of patients and were aimed at developing a sense of control and self-efficacy, as well as self-relaxation (in two independent groups). The main

fundamental difference between these two programs is their form. In the case of the London proposal, it was focused on training in the field of a particular method; thus, patients had the opportunity to be familiarized with this technique for coping with stress, but they did not obtain the knowledge on the mechanisms which justify the importance of undertaken psychoeducational impacts. In the case of this program, the techniques which were a part of psychoeducation were selected with regard to individual characteristics of the patient. In the case of the London program, it was not driven by psychoemotional characteristics of individuals. Comparing the effectiveness of training in order to create the optimal method of impacting patients with temporomandibular joint dysfunction would be an interesting proposition. However, it seems to the authors that the psychological impact on this group of patients should proceed in two stages, combining the proposed psychoeducational program with training in specific techniques for coping with stress.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Evaluation of Pain Regression in Patients with Temporomandibular Dysfunction Treated by Intra-Articular Platelet-Rich Plasma Injections: A Preliminary Report

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Objective. The objective of this study was to evaluate the regression of temporomandibular pain as a result of intra-articular injections of platelet-rich plasma (PRP) to patients with temporomandibular joint dysfunction previously subjected to prosthetic treatment. *Materials and Methods.* The baseline study material consisted of 10 patients, both males and females, aged 28 to 53 years, previously treated due to painful temporomandibular joint dysfunction using occlusal splints. All patients were carried out to a specialist functional assessment of the dysfunction using the Polish version of the RDC/TMD questionnaire axis I and II. Intra-articular injections were preceded by a preparation of PRP. The injection sites were determined by the method used during arthroscopic surgical procedures. Following aspiration, 0.5 mL of plasma was injected into each temporomandibular joint. *Results.* The comparison of the intensity of pain during all examinations suggests a beneficial effect of the procedure being performed as the mean VAS score was 6.5 at examination I, 2.8 at examination II, and 0.6 at examination III. *Conclusion.* Application of the intra-articular injections of platelet-rich plasma into the temporomandibular joints has a positive impact on the reduction of the intensity of pain experienced by patients treated for temporomandibular joint dysfunction.

1. Introduction

A number of conservative methods are used in the treatment of temporomandibular joint dysfunction pain syndrome, including occlusal splints of various designs, supportive physical therapy procedures, rehabilitation involving muscular training, and specialist psychological support [1–10].

Intra-articular administration of medications is an established method of treatment, particularly in orthopedic and rheumatic disorders associated with pain, effusion, inflammation of cartilage, and bone and joint capsules as well as fibrous adhesions. Currently, agents used for intra-articular injection within the temporomandibular joint regions include hyaluronic acid and steroids [11, 12].

Although autogenous platelet-rich plasma (PRP) concentrates were developed in the 1970s, the medical use of these materials was facilitated only by subsequent technological advances, particularly by progress in medical instrumentation. In 1997, Whitman et al. were the first to present a method for preparation and use of platelet-rich plasma to accelerate healing processes. Centrifugation of full autogenous blood yields a platelet concentrate with platelet concentration of ca. 1 million cells per cubic millimeter of plasma. The concentrate is produced in the process of collecting peripheral vein blood (most commonly from the ulnar vein) directly from patients, with blood being centrifuged during the procedure. To date, platelets were demonstrated to contain more than 30 growth factors, the most important of them being the platelet derived growth factor (PDGF), transforming growth factor (TGF), epidermal growth factor (EGF), insulin-like growth factor (IGF), and vasoendothelial growth factor (VEGF) [13–21].

Platelets are anuclear, flat disc-shaped cells formed in bone marrow; about 30% of all platelets are found in the spleen. The life span of platelet cells ranges from 8 to 12 days; cells are eliminated by the mononuclear phagocyte system. When in the interphase, platelets have no thrombogenic potential; thrombin is required for their activation which involves a change in the shape and the release of granules. The main function of the platelets is the control of hemostasis. Platelets form hemostatic plugs at injury sites, participating in blood coagulation processes. Wound healing starts with platelet thrombus formation, platelet degranulation, and the release of growth factors. The next stage involves fibroplasia and angiogenesis followed by the synthesis of structural connective tissue elements. This leads to increased resistance to wound disruption and then to scar remodeling. New collagen is generated owing to chemotactic and mitogenic effects of FGF on fibroblasts, stimulating proliferation and differentiation of keratinocytes thanks to the presence of highly concentrated growth factors [12, 16, 18].

Platelet-derived growth factors contained in the concentrate are peptides that stimulate proliferation, differentiation, and migration of cells. These properties determine the usefulness of growth factors in the healing process. Most growth factors present within the platelet-rich plasma have mitogenic properties leading to an increase in the repair cell counts. Growth factors derived from centrifuged blood were used for the first time by Knighton in patients with chronic skin ulcerations [18].

Platelet-rich plasma contains proteins that are responsible for cell adhesion, namely, fibrin, fibronectin, and vitronectin. It stimulates tissue regeneration processes by stimulating fibroblasts to produce structural proteins for use in formation of new collagen and elastin, support of remodeling and angiogenesis (formation of new vessels), and activation of mesenchymal stem cells. PRP is widely used in surgical procedures, in the treatment of burns and extensive, difficult-healing wounds, orthopedic ligament injuries, and connective tissue injuries. An additional advantage of this method is the safety of the material and a zero possibility of hypersensitivity to injected plasma. It should be kept in mind that blood and plasma may be carriers of pathogens such as HIV, CMV, EBV, or HCV, and therefore precautions should be used consisting of appropriate staff apparel and patient behavior [13–18, 21, 22]. (Consent of the Bioethics Committee Number KBET/125/L/2013.)

The objective of this study was to evaluate the regression of temporomandibular pain as a result of intra-articular injections of platelet-rich plasma to patients with temporomandibular joint dysfunction previously subjected to prosthetic treatment.

2. Materials and Methods

The baseline study material consisted of 10 patients, both males and females, aged 28 to 53 years, previously treated using occlusal splints, who reported at the Consulting Room of Temporomandibular Joint Dysfunctions of the Department of Dental Prosthetics of the Jagiellonian University Medical College in Krakow between 01.09.2013 and 20.05.2014 due to painful dysfunction of the stomatognathic system.

Figure 1: Disposable closed set for blood collection.

All patients were carried out to a specialist functional assessment of the masticatory organ using the Polish version of the RDC/TMD questionnaire axis I and II (examination I). The following parameters were analyzed in detail for the purposes of this study: changes in the intensity of pain as reported by the patients with regard to temporomandibular joints and stomatognathic system muscles, pain intensity characteristics, level of impairment, and grade of chronic pain [23, 24].

The assessment involved also a subjective assessment of pain within the stomatognathic system muscles and temporomandibular joints, evaluation of the range and symmetry of mandible motion, acoustic symptoms within the temporomandibular joints, and the impact of the masticatory organ health on overall well-being [1, 3, 23].

The inclusion criteria included temporomandibular joint dysfunction pain manifested as lack of coordination in operation of articular heads and disc (disc translocation with or without disc blockade/crackling sounds/) and dysfunctions presenting with excessive masticatory muscle tone as the dominant problem and lack of benefits from previous treatment methods. All subjects reported that the pain had sustained for at least 3 months and that they continued the prosthetic treatment.

The exclusion criteria included poor overall health, unwillingness to participate, numerous dental defects, diagnosis of a connective tissue disease, and dysfunctions classified as RDC/TMD groups IIIb and IIIc. Contraindications associated with the use of platelet-rich plasma (platelet function disorders, fibrinogen deficiency, and anticoagulation treatment) were also taken into account [1, 3, 5, 6, 11, 23, 24].

Intra-articular injections of platelet-rich plasma were preceded by collection of peripheral blood from the ulnar vein of the patient in accordance witj the procedures in force using single-use, closed vacuum systems and glass tubes with sodium citrate as an anticoagulant (Figure 1). After mixing the collected blood exactly with the citrate using rotational movements, an even number of tubes were placed in a centrifuge rotor. Centrifugation parameters were set to 3,200 rpm, and the centrifugation time was 12 minutes. After

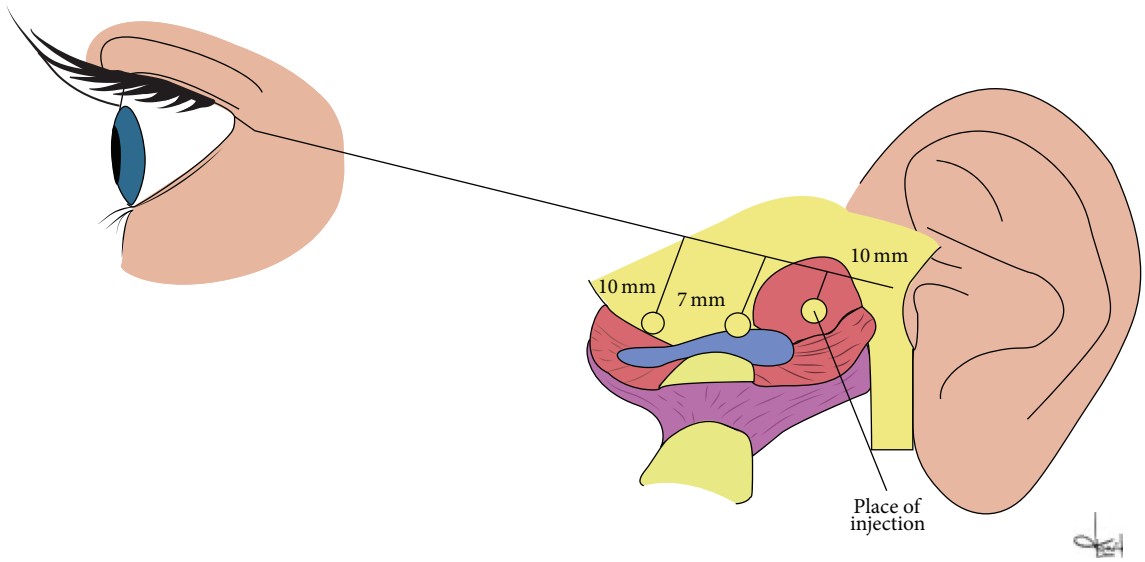

Figure 2: Scheme of place for intra-articular injection.

Table 1: Categories of clinical form according to the RDC/TMD.

Patient	1	2	3	4	5	6	7	8	9	10
Clinical form	IIIa	IIb	IIa	IIIa	IIa	IIIa	IIa	IIIa	IIa	Ia

separation of the erythrocytic mass and the platelet-poor and platelet-rich plasma layered directly above the erythrocytes, the platelet-rich plasma was aspirated with caution into a separate syringe. Thus prepared concentrate was ready for injection into the temporomandibular joint regions [18, 24–27].

The injection sites were determined by the method used during arthroscopic surgical procedures within the temporomandibular joints. Patients were prepared for the procedure by a line being drawn on their skin between the earlobe and the outer eye corner. Three segments were marked at 10 mm intervals starting from the earlobe. The lengths of the lines were 3 mm (first line), 5 mm (second line), and 7 mm (third line). The platelet-rich plasma injection site was marked by the tip of the third line corresponding to the upper compartment and retrodiscal zone (Figure 2). The skin at the injection site was washed with a disinfectant to decontaminate the field. Injections were made in the determined point with the mandible abducted. Following aspiration, 0.5 mL of plasma was injected into each temporomandibular joint. The skin was disinfected once again after the injection. Patients were informed about the possibility of experiencing an unpleasant and transient sensation of fullness or compression in the joint regions. Clinical follow-up was performed 7 days (examination II) and 6 weeks (examination III) after the procedure [18, 28–30].

The following parameters were assessed in the specialist baseline examination and the follow-up examinations using the RDC questionnaire: the presence and intensity of spontaneous and palpation-induced pain within temporomandibular joints and masticatory muscles, the range and symmetry of mandible motion, abduction trajectory, and the presence of acoustic symptoms within temporomandibular joints during all mandible movements and accompanying symptoms such as squeaking sounds and tinnitus in ears. In one case, classified as RDC group IIb, active unblocking of the articular joint was first performed; the patient was subsequently qualified for platelet-rich plasma injection [8, 23].

The results were subjected to statistical analysis using the basic procedures such as determination of means, standard deviations, medians, and post hoc ANOVA Friedmana statistical significance test.

3. Results

The group of patients qualified for the study consisted of two males and eight females. The mean age was 37.6 years. According to the results of baseline examinations, the patients reported for prosthetic treatment for the following reasons: pain within one or both temporomandibular joints, spontaneous or occurring at mandible movements, chewing, tight jaw occlusion, or joint palpation. The pain was located in the joints or the masticatory muscles, radiating into the temporal and cranial region in 2 cases. Joint crackling sounds were heard upon mandible movements by 4 patients, while a reduced range of mandible abduction was observed in 1 patient. The following diagnoses were made on the basis of RDC/TMD questionnaire axis I survey: 1 case of group I a, 4 cases of group II a, case of group II b, and 4 cases of group III a (Table 1).

Table 2: (a) Assessment of pain intensity by VAS Scale during subsequent investigation. (b) Average values of pain scoring in the subsequent studies in the statistical calculation.

(a)

Investigation	Patient									
	1	2	3	4	5	6	7	8	9	10
Invest. I	10	7	6	7	6	7	6	7	5	4
Invest. II	4	4	2	2	3	4	3	4	1	1
Invest. III	0	1	1	0	0	2	1	1	0	0

(b)

ANOVA Friedmana Chi kwad. ANOVA (N = 10, df 2) = 20,0 P = 0,00005 0		
	Mean value	Standard deviation
Invest. I	6.50	1.58
Invest. II	2.80	1.23
Invest. III	0.60	0.70

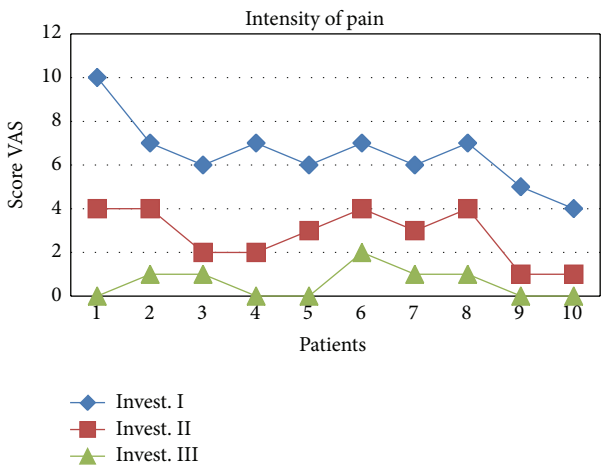

Figure 3: Values of pain scoring in the subsequent studies presented graphically.

The comparison of the intensity of temporomandibular joint and masticatory muscles pain at baseline and follow-up examinations suggests a beneficial effect of the procedure being performed as the mean VAS score was 6.5 at examination I, 2.8 at examination II, and 0.6 at examination III. The result of subsequent investigation differs in the statistically significant way (Tables 2(a) and 2(b), Figures 3 and 4). It should be mentioned that the question regarding the presence of pain within the last 6 months was answered positively by all patients and the minimum score marked at the VAS scale was 5. Acoustic symptoms observed within the temporomandibular joints in 4 cases (group II a) at examination I were experienced by only one patient in the final examination.

Table 3 presents the results of the RDC/TMD (axis II) evaluation of chronic pain in the study group, assessing the characteristics of pain intensity, impairment level, and chronic pain grade. The results showed grade I chronic pain in 2 subjects, grade II chronic pain in 4 subjects, grade III chronic pain in 1 subject, and grade IV chronic pain in 3 subjects.

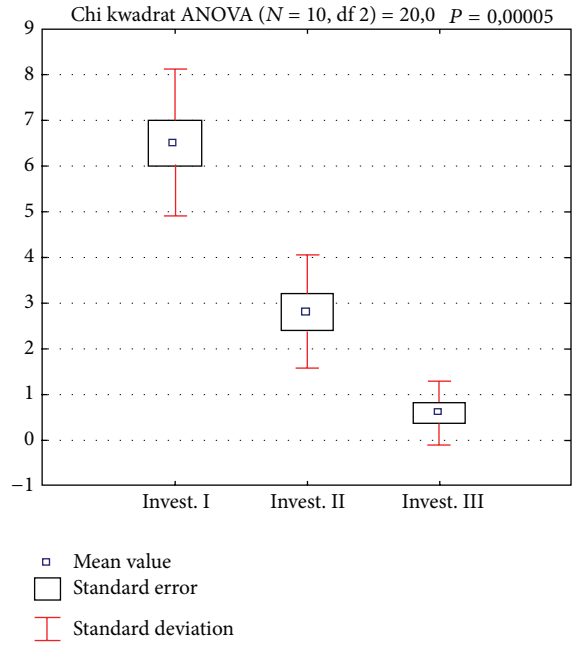

Figure 4: Average values of pain scoring in the subsequent studies in the statistical calculation, presented graphically.

4. Discussion

Chronic facial pain is a common cause of impairment in the everyday activities of patients and requires numerous therapeutic procedures being initiated by physicians of different dental specialties as well as by neurologists, laryngologists, maxillofacial surgeons, and psychiatrists. This suggests a need for interdisciplinary treatment due to the complex character of complaints. Temporomandibular joint pain is a special problem as the mandible motion upon chewing and talking constitutes a stimulus for a significant increase in the pain being experienced [1–10, 24, 29, 31–34].

Acoustic symptoms and tenderness on palpation (associated with hyperactivity) of mandible lifting muscles are an evidence of overloads located within the posterior disc ligament (strain, swelling, and corrugation). The area is poorly accessible for application of healing-promoting drugs and the physical therapy procedures applied in these cases are not always satisfactory.

Many researchers studying PRP treatments highlight the high efficacy of this method of management of musculoarticular disorders and its safety due to the use of autologous material as well as the low costs of treatment [12–22, 25–28, 30, 35–57].

Daif compared the efficacy of intra-articular injections within the upper temporomandibular joint compartment and additional injections in the articular capsule region points out the superiority of the latter method for the treatment

Table 3: The results of scoring protocol for grade chronic pain.

Patient	Characteristic pain intensity (CPI)			Disability points	CPGC [grade]
	I Invest.	II Invest.	III Invest.		
1	100	80	66	5	IV
2	90	73	63	6	IV
3	43	33	30	0	I
4	63	46	40	2	II
5	63	53	43	1	II
6	70	60	53	3	III
7	40	26	23	0	I
8	70	60	50	5	IV
9	66	53	46	3	II
10	60	46	43	2	II

CPGC: chronic pain grade classification.

of dysfunctions involving disc translocation with no disc blocking [58]. PRP is commonly used in dentistry procedures such as filling bone defects with trabecular bone chips mixed with platelet-rich plasma. The results of follow-up histomorphometric examinations performed 12 weeks after the procedure revealed higher bone density in patients having undergone the transplant of trabecular bone transplant combined with PRP [13].

Today, the use of platelet-rich plasma has been expanded no include numerous indications after orthopedic surgeries to treat sports-related injuries. PRP is widely used for tissue healing in many anatomical regions as well as in the treatment of pathological lesions of bone, cartilage, ligament, and muscle tissues. The popularity of this novel treatment method triggered a rapid increase in research. However, differences in application techniques and PRP compositions make comparisons of efficacy results difficult. Potential complications following the procedures involving PRP administration are mild and therefore this method of treatment appears to be safe. It brings various potentially positive effects for the damaged musculoskeletal system tissues. Platelet-rich plasma injection is used with increasing frequency in reconstructive orthopedic procedures (tennis elbow, knee injuries, healing of meniscus, cruciate ligaments, and Achilles tendons), muscle injuries, dental surgeries, and implantations [12–22, 27, 30, 35–40, 45–51]. As highlighted by Middleton et al., PRP injections promote optimization of healing environment and facilitate earlier functional rehabilitation of joints [42]. Studies conducted by Paoloni et al. and Pelletier et al. demonstrated high efficacy of PRP injections in the anterior cruciate ligament region in the knee and food injuries [46, 47]. Filardo et al. reported the use of platelet-rich plasma in the treatment of intra-articular cartilage injuries and knee inflammations; the treatment was reported to cause rapid reduction of pain and quick recovery of functional capability [27]. Studies conducted by Sundman et al. demonstrated significant anti-inflammatory properties of plasma [50]. Proper healing is also influenced by appropriate preparation of platelet-rich plasma, starting from proper collection of peripheral blood and optimum centrifugation parameters and ending at the administration procedure itself [12–22, 25–28, 30, 35–58].

A separate opinion suggesting the lack of confirmed benefits of PRP on musculoarticular tissue healing has been presented by Willits et al., who claim that the review of PubMed and Medline data performed in April 2013 does not warrant any positive opinions on the clinical use of this method [59].

The results of our preliminary research suggest beneficial effects of platelet-rich plasma in intra-articular injections as a supplement to the basic prosthetic treatment of temporomandibular joint dysfunction. The reduction in pain and gradual restoration of functional capabilities of the stomatognathic system as the result of the treatment of interest raises hopes that future studies would lead to establishment of appropriate management algorithms.

5. Conclusion

Conclusions are as follows.

(1) Additional intra-articular injections of platelet-rich plasma into the temporomandibular joints have a positive impact on the reduction in the intensity of pain experienced by patients treated for temporomandibular joint dysfunction.

(2) Determination of appropriate treatment algorithm making use of intra-articular injection in patients with temporomandibular joint dysfunction pain requires further studies and longer follow-up of the study group.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Review Article

Psychosocial Aspects of Bruxism: The Most Paramount Factor Influencing Teeth Grinding

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In clinical practice, patients suffering from an occlusal parafunctional activity have increased. It can be observed that a negative influence of environment aggravates patient's health. The aim of this paper is to present the impact of environment and development of human civilization on the prevalence of bruxism and the correlation between them. The authors grasp the most relevant aspects of psychological and anthropological factors changing over time as well as their interactions and describe a relationship between chronic stress and bruxism. Current literature shows how contemporary lifestyle, working environment, diet, and habits influence the patient's psychoemotional situation and the way these factors affect the occluso-muscle condition.

1. Introduction

Bruxism is an oral habit consisting of involuntary rhythmic or spasmodic nonfunctional gnashing, grinding, or clenching of teeth, unlike chewing movements of the mandible, which may lead to occlusal trauma [1]. The term "la bruxomanie" was used for the first time by Maria Pietkiewicz in 1907 [2].

Research shows that the most dangerous form of this pathology is night bruxism, which has a psychoemotional and occlusal origin [3, 4]. If not treated, it leads to damage of the teeth, periodontium and oral mucosa, pathology of the muscles constituting the masticatory system, headache and cervical pain, temporomandibular, and hearing disorders [5]. Stress related disturbances, including depression and anxiety, are a real problem in a highly developed society. Clinical studies suggest that stress is the main reason for patients to seek medical advice (50–75%) [6–8]. This is also confirmed by the large number of medicines used in order to treat stress related problems in western countries such as antidepressants, anxiolytics, and hypnotics, which decrease arterial blood pressure and the level of cholesterol [9]. Moreover, the number of patients seeking treatment because of temporomandibular disorders and oral parafunctions is increasing, which may confirm a correlation between these conditions and a growing number of chronic stressors in highly developed societies. This type of disorder can also be observed in younger people and it is more common in females [10–13]. It is generally accepted that chronic stressful situations and mental diseases conduct to the development of occlusal parafunctions and temporomandibular disorders without being the only cause. Additional reasons include interceptive occlusal contacts, malocclusions, traumas/microtraumas, hormone disorders, rheumatism, orthopedic problems, and masticatory system inflammations [14–16]. A rapid development of this disease at the turn of the 20th and 21st centuries induced the authors to attempt to find a cause of this process.

The aim of this paper is to show the correlation between chronic stress, development of civilization, and bruxism based on current literature.

2. Materials and Methods

Literature is available from PubMed, PubMed Central, and CINAHL databases that were published between 1955 and

2014. Valuable original and review articles related to the terms bruxism, stress, occlusal parafunctions, temporomandibular disorders, psychology, anthropology, and sociology have been selected for this paper.

3. Results

3.1. Psychological Aspects of Bruxism. According to Selye [24], stress involves a biological strain of an organism, which is caused by various somatic and/or mental stimuli. These stimuli are called stressors. "Being under stress" means that a person is under an influence of unspecified stimuli, which are revealed by specific changes characterizing this situation. Stressors, regardless of their type, stimulate in an organism stereotypical, nonspecific, and complex adaptation reactions. This adaptation is controlled by hormonal and neurohormonal processes. A state of strain of an organism is called stress, and it can be divided into acute and chronic. Chronic stress belongs to the most destructive factors threatening a human organism [25].

Servan-Schreiber et al. [26–29] present the pathophysiology of stress in a different way. They report a so-called "emotional brain," which has a completely separate structure from the neocortex and it functions independently. This "brain" is located in the limbic system, so in the central part of the encephalon, and it consists of three main anatomical elements: the hippocampal gyrus, cingulate gyrus, and amygdala. These elements have a far less complicated structure than the neocortex; that is, they are not arranged in regular bundles of neurons, but the nerve cells are rather mixed here. The "emotional brain" controls vital emotions and reactions. Pathological chronic stress and emotional disorders result from functional disturbances of the "emotional brain," which most often are a consequence of traumas and/or family and professional life. All impressions concerning external environment are processed in the brain. The central nervous system is responsible for their assessment. Signals reach the limbic system and hypothalamus, where they trigger proper emotions and stimulate the sympathetic nervous system releasing adrenaline, which i.a. leads to faster breathing and heartbeat, a higher muscle tension, and an increased sugar level and blood pressure. Any external information which triggers such a response may be recognized as a stressor [30, 31]. Our ancestors usually manifested this analysed biological warning reaction in a form of motor activity. After surviving the danger, their bodies functioned normally again. A contemporary individual, living in a highly developed society, has been deprived of these reaction possibilities. The effects of suppressing emotions and motor activities burden the function of an organism resulting in several neuromuscular disorders [32].

Various pathological emotional experiences more and more often result in the development of a muscular parafunction/bruxism. This can be related to occlusion or can be caused entirely by psychological stimulation. It had been proved that compulsive, controlling, and aggressive persons are more vulnerable to develop bruxism [33]. This disorder involves unconscious teeth clenching and grinding, which leads to gradual damage of the dentition and periodontium, damage of the oral mucosa, increased tension and hypertrophy of masticatory muscles, chronic headaches and cervical pain, and abnormality of the temporomandibular joints as well as hearing problems [18–22]. The most important symptoms related to bruxism are presented in Table 1. Suggestions that teeth grinding is connected with malocclusions do not seem to be true. Dental patients (5–30%) suffer from this type of disorders occurring in the temporomandibular joint, whereas 50–75% of society needs to be treated orthodontically, at least to a moderate degree [23]. Accordingly, this malocclusion is classified as peripheral factor influencing bruxism [2]. Bruxism is a parafunction in which the contraction of the temporal and masseter muscles is responsible for clenching of the dental arches, while the contraction of the pterygoid muscles is responsible for lateral movements, potentially affecting the temporomandibular joints [34]. The most destructive type of this disorder is sleep bruxism [35]. This condition is associated with a rhythmic activity of the masticatory muscles, characterized by a repeated contraction of the masticatory muscles. The highest activity is observed during the phase of sleep called REM (rapid eye movement sleep). In this phase, several parts of the encephalon, including the limbic system, are very active [36]. According to literature, average activity of muscles is several times more intensive in patients with bruxism than in patients showing no bruxism symptoms [36–38]. The intensity of contractions during sleep considerably exceeds a maximum patients' ability to clench their teeth when they are aware of it [39]. Based on the etiology, bruxism can be divided into awake, sleep, occlusion-dependent, psycho-dependent, and a mixed type depending both on the occlusion and psyche. Based on the mandible movements, bruxism is classified as centric, lateral eccentric, anterior eccentric, mixed eccentric, and extra eccentric [40].

A muscle, when passive, stays under constant tension resulting from the alpha neurons stimulation by the central stream of impulses. This tension does not lead to muscle fatigue. The main role in the tension coordination belongs to gamma neurons, which are controlled by higher centers and participate in the development of an abnormal muscle activity (Figure 1) [17]. Chronic stress and warning reactions triggered by it manifest themselves as functional deficiencies of the nervous-muscle system and are the main etiologic factors of psycho-dependent bruxism [41]. When these disturbances appear, attention is drawn by venting the accumulated tensions directly through the dental arches, by means of increased muscle activity, which may lead to headaches. This abnormal activity and increased tension are controlled by the limbic system and hypothalamus, stimulated by chronic stress, which are connected with the cortex. In this way, through the reticular formation of the brainstem occurs a correlation between stimulating awareness, vegetative activities, and affective emotional behavior along with the muscle tension. Central stimulations increase a segment reflex activity mainly over stimulation of gamma motor neurons. The increased reflex activity causes muscle tone, which may vary from a state of higher tension up to rigidity. The gamma loop is activated through the descending reticulospinal tract, which results in increased muscle tone. The possibility of

Table 1: Possible symptoms of bruxism according to medical disciplines [18–23].

Branch of medicine	Symptoms observed
Dentistry	Clenching or grinding of the teeth while asleep (often noticed by sleeping partner); hypersensitivity of teeth to hot, cold, sweet, and so forth; attrition; fractures of teeth; negative consequences in periodontium/gingival recessions; loss of teeth; damages and cracks of fixed and removable dentures (especially dental ceramics); cheek and tongue biting
Otolaryngology	Ear sounds (tinnitus), ear aches (referred pain) with possible hearing loss, ear infections, apnea
Neurology	Constant, dull headache; pain in the temples; sleep disorders (insomnia); anxiety, stress, and depression; dizziness; vertigo
Ophthalmology	Hypersensitivity to light, pain in the eye or around the eye, difficulties in sight focus
Physical Therapy	Sore jaw muscles, facial pain or jaw pain, higher muscle tension, myofascial pain, temporomandibular joint disorders (clicking), trismus, hand and arm tingling
Others	Changes in facial appearance, eating disorders

an influence of the higher centers can lead to an abnormal increase of muscle tone, which explains the occurrence of higher muscle activity triggered by psychological stimuli [42–44].

3.2. Social Aspects of Bruxism. According to Young [45], the rapid development of civilization is an apparent factor conducive to diseases, which do not pose a direct threat to human life. The author describes the changes in the dentition of native inhabitants of Australia, which occurred after contact with western culture. Aborigines' oral hygiene improved considerably, but changes of eating habits and consumption of a large amount of food with high sugar content as well as soft diet caused an unexpected increase of teeth crowding and dental caries. A change in lifestyle and diet prevented the dentition from severe attrition. Occlusal-muscular disorders were quite rare. Because of changes in nutritional habits, for example, softer diet at the expense of raw meat and vegetables, nowadays contemporary inhabitants of Australia use different and less muscle groups than the primitive tribes or the inhabitants in the 19th century. For this reason, contemporary inhabitants suffer from similar functional disorders of the stomatognathic system, regardless of their background. Watson [46] studied the changes in dentition of the inhabitants of north-west Mexico and showed the impact of diet and agricultural factors on the health of teeth tissue. The dentition of this group clearly shows that the development of civilization reduced the physiological wear-and-tear of the teeth, which followed the changes in nutrition. Moreover, the author suggests that psychological factors and a diet of the contemporary people inhabiting this region are causative factors of changes of a different type, that is, caries and noncaries defects.

The studies explicitly revealed that a new form of losing teeth must be connected with a different impact of contemporary environment on the stomatognathic system. Omnipresent chronic stressors, to which a human organism is subjected every day, lead indirectly to various disorders. The study of Bayar et al. [47] proves that occlusal parafunctions are closely connected with psychological disturbances of different degrees of severity, most of which are caused by an inability to accept everyday reality or by exaggeration of experiencing external stimuli. Bayar assumes that the etiopathogenesis of bruxism is complex; nevertheless, he indicates that the most important is the psychological factor, which is also confirmed by other authors [48, 49]. The studies of Bracha et al. [50] and Gungormus and Erciyas [51] distinguish from 3 many emotional disorders those which are accompanied by occluso-muscle disorders, that is, excessively experienced stress, depression, neurosis, phobias, personality disorders, anxiety, and paranoid states. These diseases are common in highly developed societies, in which surrounding environment directly leads to their occurrence. Chronic stress, lack of sleep, rest time, and activities are conducive to the development of psychoemotional disorders, vascular diseases, dermatological problems, gastric disturbances, and neuromuscular disorders [52–55]. Omnipresent chronic stressors in a contemporary society are called civilization stress [56]. Independent of mental disorders, availability and overuse of stupefying agents may result in an increase of parafunctional muscular activity. This problem was proved by Gomez et al. [57], whose study confirms a correlation between drug addiction and an increase of abnormal occluso-muscle function.

Manfredini et al. [58] show that significant factors in the development of occlusal parafunctions are malocclusions and abnormal bites. It should be stressed that an occlusal aspect most often connected with psychological disorders gives the picture of full-blown bruxism. In everyday clinical practice, patients who are diagnosed with occlusal problems often do not show symptoms characteristic of emotional disturbances. Only after taking the patient's medical history are revealed problems often related to the family and/or professional life. It should be emphasized that a properly conducted medical interview as well as a physical examination is an important part of therapy of the temporomandibular disorders.

A change of profile of health threats as well as a longer lifespan in contemporary societies caused dissemination of diseases and treatment methods, which were very rare or even did not exist in the past. An example of such change is the orthodontic treatment, whose rapid development took place in the second part of the 20th century. Chu et al. [59] confirm this thesis in their study, which is based on a group of 240 students, 41% of whom undergo/underwent

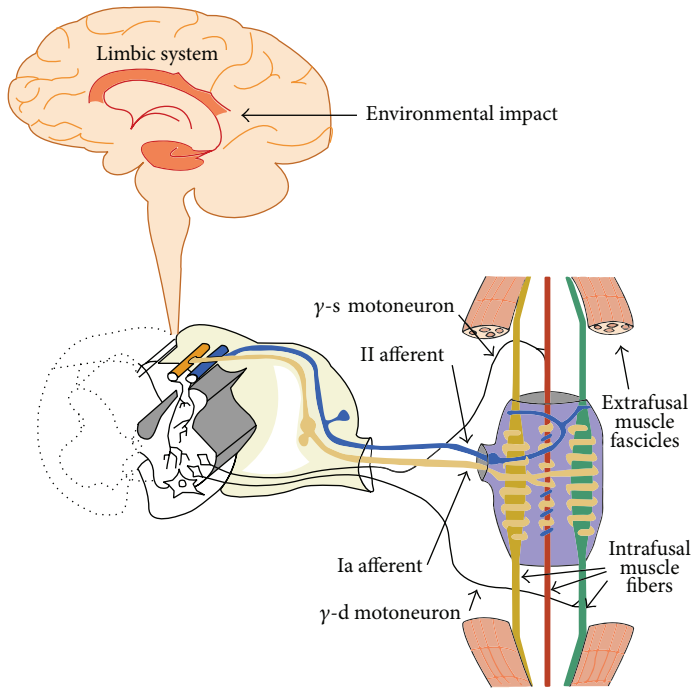

Figure 1: Schematic diagram of the gamma loop, which is permanently stimulated by external impulses in a group of people affected by chronic stress [17].

orthodontic treatment. Nonetheless, occluso-muscle parafunctions belong to a group of disorders, which affect an increasing part of a society. Frequently, these parafunctions are a cause of dental treatment failure. Kinsel and Lin [60] studied the prosthetic complications in 152 patients with implant borne fixed dental prostheses and proved seven times higher odds in bruxers.

Other studies reveal that a frequency of occluso-muscle disorders also depends on ethnic background. Hicks et al. [61] conducted studies concerning the frequency of bruxism among American students of different backgrounds. The results showed higher bruxism prevalence in students of Asian origin, an average among European and Latin-American group and the lowest in the Afro-American group. Several authors proved that psycho-dependent occlusal parafunctions more and more often concern children under 10 years [62–64]. These studies reveal that occluso-muscle disorders affect people of different ages. However, bruxism is more common in females [2].

4. Discussion

The etiology of bruxism is multifactorial. Occlusion abnormalities, chronic stress, and mental disorders are responsible for this condition. It should be highlighted that there is a tendency of more frequent occurrence of oral parafunctions in highly developed societies. Thus, it seems that the occlusal aspect in the development of bruxism is of minor importance. This is confirmed by studies in which bruxism is observed in patients with implant borne restorations, among them there is no impulsation from the periodontium [65]. Symptoms of bruxism may be unnoticeable for a longer period. Only after having experienced a nagging pain does a patient start to seek medical help. Patients often consult doctors of different specialties, especially neurologists or ophthalmologists, but also ENT specialists, since one of the symptoms of severe bruxism can be a sleep apnea, resulting in a long-term state of chronic fatigue and increasing stress related to "not keeping up" with projects. Bruxism functions as a kind of *perpetual motion machine*, as intensifying symptoms resulting from the abnormal functioning of an organism increase a feeling of being stressed, and in consequence leads to an increased muscle tone and teeth grinding [66, 67]. In its stage, this problem is often ignored by patients, which has serious consequences in the form of destruction of the dentition and severe abnormalities of muscles and joints. In this phase, the condition requires at least two-phased prosthetic treatment. It also calls for multidisciplinary treatment, in which specialists like a dentist, psychiatrist, neurologist, psychologist, physiotherapist, and a dental technician should participate. Worldwide discussions and studies of scientists resulted in recognizing sleep bruxism as a disorder, which was then included in the International Classification of Sleep Disorders in 2005 [67].

5. Conclusions

On the basis of the data collected by the authors based on current literature it can be stated that the prevalence of bruxism depends on the development of civilization and the modern lifestyle. In this way the psychological aspect of occluso-muscle disorders becomes more significant. Contemporary environment is full of incessant stress threats and thus

dangerous to our health and life. In recent years, the number of patients suffering from bruxism has increased significantly. For this reason doctors should pay more attention to this parafunction in order to diagnose it at an early stage.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Prevalence and Correlation between TMD Based on RDC/TMD Diagnoses, Oral Parafunctions and Psychoemotional Stress in Polish University Students

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The aim of the study was to assess the prevalence of temporomandibular disorders (TMD) and oral parafunctions, as well as their correlation with psychoemotional factors in Polish university students. The research was conducted in a group of 456 students ($N = 456$). The examination form comprised of two parts: survey and clinical examination. The research diagnostic criteria for temporomandibular disorders (RDC/TMD) was used in order to assess TMD. Symptoms of TMD were observed in 246 (54%) students after clinical examination. The largest group involved students with disc displacement (women: 132, 29%; men: 70, 15%). Women (164; 36%) suffered more frequently than men (82; 18%) from problems related to the stomatognathic system ($P < 0.05$), described themselves as easily excitable and emotionally burdened, and reported symptoms as tightness of the facial and neck muscles ($P < 0.05$). In 289 (64%) students intraoral symptoms concerning occlusal parafunctions were observed. In 404 (89%) examined students, nonocclusal parafunctions were recorded. A significant correlation between TMD and psychoemotional problems could be detected. TMD symptoms more often concern women. Emotional burden and excitability are factors predisposing muscular disorders.

1. Introduction

The temporomandibular disorders (TMD) and oral parafunctions seem to be a frequent problem in modern societies [1–6]. The etiopathology of the temporomandibular joints is related to muscles, teeth arches, and periodontium. Their main causes involve both pathophysiological and psychosocial factors [7, 8]. In the literature, a significant impact of the psychoemotional factor is reported, comparable to the impact of other factors concerning physical health such as systemic diseases, malocclusions, loss of teeth, traumas, and microtraumas [9–12]. Stress, fatigue, anxiety, depression, sleep disorders, and a fast pace of life affect negatively the human psyche [13]. In those patients muscular related TMD is observed more often [14]. Moreover different studies report that TMD coexists with other numerous disorders such as SAPHO syndrome (synovitis, acne, pustulosis, hyperostosis, and osteitis syndrome), fibromyalgia, back- or spine ache, chronic fatigue syndrome, spastic colons, sleep disorders, congenital defects, headaches, and arthritis [11, 12, 15, 16]. Many studies report that the symptoms of the masticatory system disorders are more frequent in women than in men [2–5]. This may result from biological differences, including hormonal ones, and also psychosocial factors [17, 18]. Stallman reports that student population lives more under stress than the general population and develops considerably often TMD and oral parafunctions [19]. The possible stress factors include poor learning achievements, financial problems, unergonomic body position while studying, exams, submitting academic papers, and the necessity to become

independent [19–21]. Another predisposing factor to the occurrence of the masticatory system disorders in students is the age of this population, since the peak of the development of the symptoms is between 20 and 40 years of age [3].

The aim of this epidemiological study is to assess the prevalence of temporomandibular disorders and oral parafunctions among Polish university students and their correlation with psychoemotional factors.

2. Materials and Methods

The study was conducted at the four different Polish universities (Wroclaw Medical University, Wroclaw University of Technology, Wroclaw University of Environmental and Life Sciences, and University of Wroclaw) on a group of 456 students in the years 2012–2014 (N = 456). Inclusion criteria were that the participants should be aged between 19 and 30 years, be Polish university student (both gender were acceptable), and express consent to participate voluntarily in the study. Two hundred sixty four (58%) women and 192 (42%) men were examined. The mean age of participants was 22.01 ± 2.11 years.

The analysis was conducted by the research diagnostic criteria for temporomandibular disorders (RDC/TMD) introduced by Dworkin and LeResche in 1992 [1]. This enables the standardization of the procedures of epidemiological studies, the unification of TMD diagnostic and exploratory criteria, and the comparison of results of other similar studies. The results of the study were based on the RDC/TMD Axis I diagnostic criteria. Mental state of subjects was not assessed according to RDC/TMD Axis II diagnoses.

Before the commencement all researchers have been trained and calibrated in accordance with the adopted norms presented on the official website of the International RDC/TMD Consortium [22]. A simplified version of the examination form was used, which comprised of the survey and the clinical examination, developed on the basis of the RDC/TMD clinical physical examination form and questionnaire [23].

As first part the survey included questions concerning basic demographic data such as gender and age, type of reaction to stress, emotional burden, and occurrence of subjective symptoms of TMD such as fatigue and tightness of the facial muscles, cervical muscle pain, chronic headache, and otologic symptoms. It also included questions concerning the occurrence of nonocclusal parafunctions (habitual gum chewing, lip biting, nail biting and/or skin biting around nails, objects biting, and cheek biting).

During the second part of the clinical examination, patients were given one or more diagnoses according to RDC/TMD Axis I: group I/muscle disorders, group II/disc displacements, and group III/other common joint disorders. The study did not take into account individual unilateral diagnosis of TMD. Over the clinical examination no reliable diagnosis was possible in order to unambiguously group a patient to subgroups IIc, IIIb, or IIIc. Thus, the authors used only groups IIa, IIb, and IIIa. Intraoral symptoms of occlusal parafunctions as teeth attrition, buccal linea alba, gingival recession, crenated tongue, and cracked enamel were systematically documented in an assessment form specially made for the study.

Based on self-report, clinical criteria, and diagnosis, the patients were divided in the following groups.

Group I: Muscle Disorders

Ia Myofascial Pain

Consider the following:

(i) pain or ache in the jaw, temples, face, preauricular area, or inside the ear at rest or during function;

(ii) pain in response to palpation of three or more of the following muscle sides (right and left side count as separate sides for each muscle): posterior temporalis, middle temporalis, anterior temporalis, origin of masseter, insertion of masseter, posterior mandibular region, submandibular region, lateral pterygoid area, and tendon of the temporalis;

(iii) at least one of painful muscle must be homolateral to the reported pain.

Ib Myofascial Pain with Limited Opening

Consider the following:

(i) myofascial pain as defined in Ia;

(ii) pain-free unassisted mandibular opening <40 mm interincisal distance;

(iii) maximum assisted opening (passive stretch) of ≥50 mm/greater than pain-free unassisted opening.

Group II: Disc Displacements

IIa Disc Displacement with Reduction

Consider the following:

(i) clicking in temporomandibular joint (TMJ) (click on both vertical opening and closing/occuring at a point at least 5 mm greater interincisal distance on opening than closing/eliminated on protrusive opening), reproducible on 2 of 3 consecutive trials;

(ii) clicking in TMJ on both vertical range of motion (either opening or closing), reproducible on 2 of 3 consecutive trials and clicking during lateral excursion or protrusion, reproducible on 2 of 3 consecutive trials.

IIb Disc Displacement without Reduction with Limited Opening

Consider the following:

(i) history of locking or catching that interfered with eating;

(ii) unassisted opening (even painful) ≤35 mm interincisal distance;

(iii) contralateral excursion <7 mm and/or uncorrected deviation to ipsilateral side on opening;

(iv) absence of joint sound or presence of joint sounds not meeting criteria for disc displacement with reduction.

Group III: Other Common Joint Disorders
IIIa Arthralgia

Consider the following:

(i) painful joint uni- or bilateral (lateral pole and/or posterior attachment) during palpation;

(ii) one or more painful regions (self-report): pain in the joint, pain in the joint during maximum unassisted opening, pain in the joint during assisted opening, and pain in the joint during lateral excursion;

(iii) coarse crepitus must be absent for simple arthralgia diagnosis.

The intergroup differences were tested using the chi-square test for independence and the test of difference between two proportions as appropriate. Statistical significance level was set at $P < 0.05$. Statistica 10.0 was used in the conducted analysis (StatSoft Inc., Tulsa, Oklahoma, USA).

3. Results

3.1. Results of the First Part-Survey. From 456 examined students 194 (43%) described themselves as easily excitable, 263 (58%) suffered from emotional burden, 139 (30%) reported fatigue and/or tightness of the facial muscles, 214 (47%) cervical muscle pain and 180 (40%) students regular headaches. Significantly more women than men reported the above symptoms ($P < 0.05$). Otologic symptoms are declared by 87 students (19%) (Table 1). Nonocclusal parafunctions were reported from 404 (89%) examined students. In the majority of cases no significant differences in the prevalence of nonocclusal parafunctions between genders could be detected, excluding lip biting, which is more frequent in women (Table 2).

Students who perceive themselves as easily excitable and/or as having chronic emotional burdens also reported more often fatigue and tightness of facial muscles, cervical muscle pain and headaches compared to other participants ($P < 0.05$). The prevalence of those symptoms were, respectively, 77 (17%), 111 (24%), and 88 (19%) in the group of students defining themselves as excitable, while in the group suffering from chronic emotional burdens 111 (24%), 154 (34%), and 126 (28%).

3.2. Results of the Second Part-Clinical Examination. In the second part of clinical examination TMD symptoms were found in 246 (54%) students. More often were detected students with symptoms of disc displacements. Almost one third (147; 32%) of subjects were classified in more than one diagnostic group; no one represented all TMD symptoms (Table 3). Significantly more women (164; 36%) than men (82; 18%) suffered from stomatognathic system problems ($P < 0.05$). The prevalence of TMD symptoms and their correlation to the gender are presented in Table 4.

In group I/muscular disorders a significant higher percentage belonged to students with emotional burden and/or excitability, suffering from fatigue and tightness of facial muscles, cervical pain, and headaches (for all $P < 0.05$; Table 5).

In 289 (64%) students intraoral symptoms concerning occlusal parafunctions were observed (women: 166, 37%; men: 123, 27%). In most cases no differences between men and women were found, with the exception of a higher prevalence of crenated tongue in women ($P < 0.05$). No correlation was recorded between the frequency of the symptoms of occlusal parafunctions and excitability, chronic emotional burdens, fatigue, tightness of facial muscles, cervical muscle pain, and headaches, although a significant correlation between crenated tongue and students with regular headaches was observed ($P < 0.05$).

4. Discussion

Temporomandibular disorders have a multifactorial etiopathogenesis. Several authors underline the influence of local factors on their development, while others underline that of systemic factors [24, 25]. The importance of psychological factors, such as increased psychoemotional activity and stress, is also emphasized in literature describing the etiology of TMD and oral parafunctions [26, 27]. In the presented study we also observed a significant role of psychoemotional factors in the TMD development. Easily excitable and emotionally burdened persons suffered significantly more often from TMD and oral parafunctions. It must be mentioned that the RDC/TMD Axis I protocol includes valid diagnostic criteria for differentiating the patients in this study into two groups, with and without TMD. Although this protocol served the scope of the study, generally enables the diagnosis of a limited number and common TMD.

Stress is also an important factor contributing to the TMD development. The examined student population is particularly susceptible to the influence of this factor [28]. Stressors may include a large number of duties, the pressure of getting a good education, an uncertain future, low income, living far away from home, and functioning in an alien environment. Moreover, students also face social, emotional, physical, and family problems [27]. Over half of the students in this study (58%) identified themselves as emotionally burdened. According current literature this percentage could reach 72% [29] or even 90% [30] in student population. It has been proved that being under stress increases the activity of the masticatory muscles, which consequently results in TMD [31].

Further, some studies underline also the gender influence on TMD development [32, 33]. An intercontinental research in 17 countries on 85052 adults supports that 62% of women and 38% of men suffer from TMD [34]. In similar studies in student populations the respective percentage is 65% for women and 35% for men [32, 34]. In the presented study, a greater disproportion between the different genders (70% women; 30% men) was detected, showing that women are more susceptible to TMD than men. This may result from the hormone level fluctuation, biological differences, social position, or higher sensitivity to pain in women [35]. The peak of the development of the symptoms is between 20 and 40, in a reproductive period [17, 36]. It may be caused

Table 1: Answer distribution in questionnaire-first part/survey.

Gender	Feature											
	Excitability		Emotional burden		Fatigue and tightness of facial muscles		Cervical muscle pain		Headache		Otologic symptoms	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Women	124* (27%)	140 (31%)	168* (37%)	96 (21%)	91* (20%)	173 (38%)	152* (33%)	112 (25%)	138* (30%)	125 (27%)	56 (12%)	208 (46%)
Men	70 (15%)	122 (27%)	95 (21%)	96 (21%)	48 (11%)	144 (32%)	62 (14%)	130 (29%)	42 (9%)	150 (33%)	31 (7%)	161 (35%)
Total	194 (43%)	262 (57%)	263 (58%)	192 (42%)	139 (30%)	31 (7%)	214 (47%)	242 (53%)	180 (40%)	275 (60%)	87 (19%)	369 (81%)

* $P < 0.05$ comparison between women and men; (%) percentage off all respondents.

Table 2: Prevalence of nonocclusal parafunctions in tested population.

Gender	Feature						
	Total	Gum chewing	Lip biting	Nail biting	Skin biting around nails	Objects biting	Cheek biting
Women	238 (52%)	199 (44%)	148 (32%)*	49 (11%)	105 (23%)	95 (21%)	111 (24%)
Men	166 (36%)	133 (30%)	87 (19%)	39 (9%)	63 (14%)	58 (13%)	71 (16%)
Total	404 (89%)	332 (73%)	235 (52%)	88 (19%)	168 (37%)	153 (34%)	182 (40%)

* $P < 0.05$ comparison between women and men; (%) percentage off all respondents; respondents declared more than one parafunction.

Table 3: Distribution of single and combined RDC/TMD diagnoses in the tested population compared to the results of other studies.

Author	Mean age ± SD	Feature							
		Total *n*	I *n* (%)	II *n* (%)	III *n* (%)	I + II *n* (%)	I + III *n* (%)	II + III *n* (%)	I + II + III *n* (%)
Achieved results	22,01 ± 2,11	456	82 (18,0)	202 (44,3)	81 (17,8)	53 (11,6)	42 (9,2)	52 (11,4)	0
Karibe et al. [38]	17 ± 0,9	167	59 (48,8)	56 (46,3)	6 (4,9)	—	—	—	—
Miyake et al. [39]	20,4 ± 2,1	3557	—	1483 (41,7)	569 (16)	—	—	—	—
Poveda-Roda et al. [40]	40,5 ± 18,7	850	299 (35,2)	436 (51,3)	115 (13,4)	—	—	—	—
Manfredini et al. [41]	32,7 ± 14,5	243	9 (4,5)	24 (12,1)	38 (19,1)	4 (2)	38 (19,1)	43 (21,6)	43 (21,6)
Guarda-Nardini et al. [42]	41,7 ± 17	383	16 (12,6)	27 (21,3)	78 (61,4)	—	—	—	—

n number of examined; (%) percentage of examined; "—" not included in the study.

Table 4: Prevalence of TMD symtpoms according to the gender.

Gender	Feature						
	GROUP I Muscle disorders			GROUP II Disc displacements			GROUP III Arthralgia
	I (total)	Ia	Ib	II (total)	IIa	IIb	IIIa
Women	63 (14%)*$	52 (11%)*$	11 (2%)	132 (29%)*$	116 (25%)	16 (4%)*$	62 (14%)*$
Men	19 (4%)	16 (4%)	3 (<1%)	70 (15%)	68 (15%)	2 (<1%)	19 (4%)
Total	82 (18%)	68 (15%)	14 (3%)	202 (44%)	184 (40%)	18 (4%)	81 (18%)

* $P < 0.05$ comparison between women and men; $ $P < 0.05$ comparison between the percentage of women with the percentage of men in RDC/TMD groups; (%) percentage off all respondents.

Table 5: Comparison of answers to selected questions of the questionnaire in the group of students exhibiting muscle disorders.

Selected question	Selected RDC/TMD diagnoses GROUP I Muscle disorders		
	I (total)	Ia	Ib
Emotional burden			
Yes	58 (13%)*$	48 (11%)#$	10 (3%)
No	24 (5%)	20 (4%)	4 (<1%)
Fatigue and tightness of the facial muscles			
Yes	44 (10%)*$	38 (8%)#$	6 (1%)
No	38 (8%)	30 (7%)	8 (2%)
Cervical muscle pain			
Yes	55 (12%)*$	43 (9%)#$	12 (3%)^$
No	27 (6%)	25 (5%)	2 (<1%)
Headache			
Yes	50 (11%)*$	39 (9%)#$	11 (2%)^$
No	32 (7%)	29 (6%)	3 (<1%)

* $P < 0.05$ comparison between group I (total) and students without muscle disorders; # $P < 0.05$ comparison between group IIa and students without muscle disorders; ^ $P < 0.05$ comparison between group Ib and students without muscle disorders; $ $P < 0.05$ comparison between percentage of "yes" answers with percantage of "no" answers in the RDC/TMD group; (%) percentage off all respondents.

by a greater number of estrogen and progesterone receptors in intra-articular cartilage in women with TMD. Thorn et al. refers that women report even slight pain during clinical examination, while men only when it is intensified, which could in a way contribute to achieving the above results [37]. This study has also indicated women as a group in which TMD is more frequent in all three diagnostic groups (I–III).

The most frequent disorder of TMJ in the examined population is disc displacement (44%). Similar results were obtained by Karibe et al. [38] in patients aged between 16 and 18 (46.3%), Miyake et al. [39] in patients with mean age 20 years (41.7%) and Poveda-Roda et al. [40] in a group of people with mean age 40 years (51.3%). The study of Manfredini et al. [41] in patients with mean age 32 years did not get a clear result stating a dominance of one of the disorders, while Guarda-Nardini et al. [42] in a group with average age of 41 reported a higher prevalence of pain in TMJ (61.4%). Only Karibe et al. [38] assessed the frequency of type I disorders on the same level as type II in a group of subjects aged between 16 and 18. Stress, which is the main cause of the stomatognathic system disorders, is characteristic for young people up to 20 years old and for patients who are in their 40's, but the reasons of tension in each age group vary [38]. The comparison of data obtained in this and the above referred studies are presented in Table 3.

Not everyone is equally susceptible to the development of oral parafunction. For example, genetic factors affect the development of bruxism, since the significant influence of genetic polymorphism of receptor gene 5HT2 and particularly the presence of allele C rs6313 has been proved [43]. Further, the psychological factor and stress play also a significant role [44]. Each person perceives the world objectively and deals with stress differently depending on its psyche. Neurotic persons often relieve stress by straining the stomatognathic system through teeth clenching, contracting the masticatory muscles, and teeth grinding [14]. Consequently, an interdisciplinary approach from both dental clinicians and psychologists is prerequisite for a successful therapy in patients suffering from stomatognathic system disorders. Any therapeutic effort should exclude the cause, which in case of TMD and oral parafunctions is a failure to deal with stress effectively in everyday life.

5. Conclusions

(1) The prevalence of TMD in studied Polish student population is 54%.

(2) TMD symptoms more often concern women.

(3) Emotional burden and excitability are factors that predispose to muscular disorders.

(4) The results based on RDC/TMD diagnoses are in accordance with current literature.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Incidence of Otolaryngological Symptoms in Patients with Temporomandibular Joint Dysfunctions

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The functional disorders of the masticatory organ are the third stomatological disease to be considered a populational disease due to its chronicity and widespread prevalence. Otolaryngological symptoms are a less common group of dysfunction symptoms, including sudden hearing impairment or loss, ear plugging sensation and earache, sore and burning throat, difficulties in swallowing, tinnitus, and vertigo. The diagnostic and therapeutic problems encountered in patients with the functional disorders of the masticatory organ triggered our interest in conducting retrospective studies with the objective of assessing the incidence of otolaryngological symptoms in patients subjected to prosthetic treatment of the functional disorders of masticatory organ on the basis of the analysis of medical documentation containing data collected in medical interviews. *Material and Methods*. Retrospective study was conducted by analyzing the results of medical interviews of 1208 patients, who had reported for prosthetic treatment at the Functional Disorders Clinic of the Department of Dental Prosthetics of Jagiellonian University Medical College in Cracow between 2008 and March 14, 2014. *Results*. Otolaryngological symptoms were observed in 141 patients. The most common symptoms in the study group were earache and sudden hearing impairment; no cases of sudden hearing loss were experienced.

1. Introduction

Temporomandibular joint dysfunctions are the third stomatological disease to be considered as a populational disease due to its chronicity and widespread prevalence. The disorders occur in more than 10% of population, restricting individuals' capability to perform everyday functions at home and work. According to epidemiological data, the number of patients with the painful form of the disorders is increasing (to about 40%) while the age of patients with temporomandibular disorders is being lowered. The problem is more common in females than in males [1].

Functional disorders of the masticatory organs are often manifested by acute or chronic pain symptoms in the temporomandibular joints and/or masseter muscles. Impaired dynamics of mandibular movements is manifested as restricted or enhanced range of jaw openings, deviations in the course of abduction and adduction of the mandible, and lack of symmetry of mandibular lateral movements. Acoustic symptoms within the joints, manifested as popping and cracking sounds, are an evidence of the lack of coordination between the articular head temporomandibular joint articular discs during mandible movements [2]. Otolaryngological symptoms are a less common group of dysfunction symptoms, including sudden hearing impairment or loss, ear plugging sensation and earache, sore and burning throat, difficulties in swallowing, tinnitus, and vertigo [3–5]. Due to the latter symptom, patients may experience fear when moving around. Tinnitus is acoustic sensations heard in one or both ears or inside the patient's head when no acoustic stimuli are coming from the outside. Tinnitus may be experienced as squeaks, whistles, chirps, bubbling sounds, pulsations, howls, paper rustle, or sea humming [6].

Facial pains and headaches are one of the symptoms of the painful form of the functional dysfunction of the masticatory organ, commonly misdiagnosed and treated as pain of some

other etiology [7–9]. The impact of the emotional factors in the development of temporomandibular joint dysfunction and common concomitance of otolaryngological symptoms should also be noted. Tinnitus, chronic facial pains, and dysfunctions were commonly reported in depressive patients [9–11].

Other symptoms of the dysfunction include disorders of the visual organ, neck and shoulder girdle muscles, spinal muscles, and even upper limbs and chest muscles. In such cases, differential diagnostics is the key element of the diagnostics and treatment process; however, it is not an easy task [12, 13].

Subjective hearing organ symptoms that accompany the functional disorders of the masticatory organ are broadly reported in the literature [14–18]. The incidence of these symptoms is in the range of about 5 to 30% for earache and about 30% for tinnitus [19–22]. The reported causes for otolaryngological symptoms include common embryonic origin of the ear and the masseter muscles and the compression of vessels, nerves, and ligaments by posteriorly translocated articular heads of the mandible in the middle and inner ear regions [3, 4]. This is due to missing teeth not being replaced, particularly in the support zones, as well as to pathological teeth attrition, promoting the reduction in occlusal height and posterior translocation of articular heads in central occlusion [23, 24].

Occlusal parafunctions are responsible for the hyperactivity of masticatory muscles, including lateral superior pterygoid muscles, with one of the attachments located within the articular disc. Contractures of these muscles occurring upon pathological motor habits translocate the disc towards the front and lead to posterior location of mandibular heads. Many authors report a relationship between otolaryngological symptoms, particularly earache, and masticatory muscle disorders [8, 11, 16, 25].

Patients reporting for prosthetic treatment had often undergone otolaryngological consultations previously, with results suggesting that the complaints were of an origin other than being located within the middle or inner ear. Another much smaller group of patients with otolaryngological disorders are patients reporting for prosthetic treatment of otolaryngological symptoms constituting an indication of specialist consultation. In most cases, the results of such consultations are negative [19, 24].

The diagnostic and therapeutic problems encountered in patients with the temporomandibular joint dysfunction triggered our interest in conducting retrospective studies with the *objective* of assessing the incidence of otolaryngological symptoms in patients subjected to prosthetic treatment of the functional disorders of masticatory organ on the basis of the analysis of medical documentation containing data collected in medical interviews.

2. Material and Methods

Retrospective study was conducted by analyzing the results of medical interviews of 1208 patients, both males and females, aged 19 to 50 years, who had reported for prosthetic treatment at the Consulting Room of Temporomandibular Joint Dysfunction, Department of Dental Prosthetics of the Jagiellonian University Medical College in Cracow between 2008 and March 14, 2014. Each patient was subjected to specialist examination of the masticatory organ function. The first part of the examination consisted of medical interview. Based on the specialist diagnostics including the assessment of the range and symmetry of mandibular movements and pain upon palpation of temporomandibular joints and masseter muscles, patients were diagnosed with dysfunctions of the stomatognathic system. The following symptoms were taken into consideration when analyzing the results of medical interviews: sudden hearing impairment or loss, earache or sore throat, burning throat, tinnitus (squeaks, swishes, bubbling sounds, pulsations, whistles, chirps, and sea humming), and vertigo. The number of otolaryngological symptoms in individual patients and the total number of all symptoms in the study group were also assessed. The duration of the incidence of otolaryngological symptoms ranged from 3 weeks to 14 months before the commencement of prosthetic treatment, and the reported otolaryngological complaints were experienced every day. No history of otolaryngological procedures within the three preceding years was reported in the medical interview.

3. Results

Retrospective analysis was conducted on 1208 case report forms from 952 women (78.8% of all patients) and 256 men (21.2% of all patients) treated between 2008 and March 14, 2014, in the Laboratory of Functional Disorders of the Masticatory Organ of the Department of Dental Prosthetics of the Jagiellonian University Medical College in Cracow. Medical documentation included the results of medical interviews containing information on the reason for patient's reporting for the treatment, subjective symptoms, duration of symptoms, intensity of symptoms, and precious or subsequent otolaryngological verification of the reported complaints. It should be mentioned that examination results in patients undergoing otolaryngological consultation prior to reporting for prosthetic treatment were negative.

The symptom most commonly reported in medical interviews was earache, experienced by 69 out of 1208 subjects. In 58 cases it was a one-sided located pain. In 21 cases, the pain was an acute, persistent pain lasting for several hours during the day; in the remaining patients, the intensity of pain was considered mild. In seven cases, the earache was accompanied by the sensation of compression and fullness in the ear. No increase in body temperature or intensification of pain in horizontal position, usually accompanying acute or chronic otitis, was observed. In addition, of symptoms manifesting within the ear region, 14 cases of hearing impairment were reported, while none of the assessed patients experienced sudden hearing loss. The second most common otolaryngological symptom was tinnitus, experienced by 45 and manifesting as squeaks (in 21 patients), sea humming (11 patients), whistling (8 patients), and ticking sounds (5 patients). In 26 patients tinnitus was unilateral whereas in

Table 1: Incidence of individual otolaryngological symptoms reported in medical interviews.

The number of analyzed interviews	1208 patients					
Otolaryngological symptom	Earache	Hearing impairment	Sudden hearing loss	Tinnitus	Sore/burning throat	Vertigo
Number of symptoms reported in medical interviews	69	14	0	45	4	9
Skip on the amount of the tested-‰	5.71‰	1.16‰	0	3.72‰	0.33‰	0.75‰

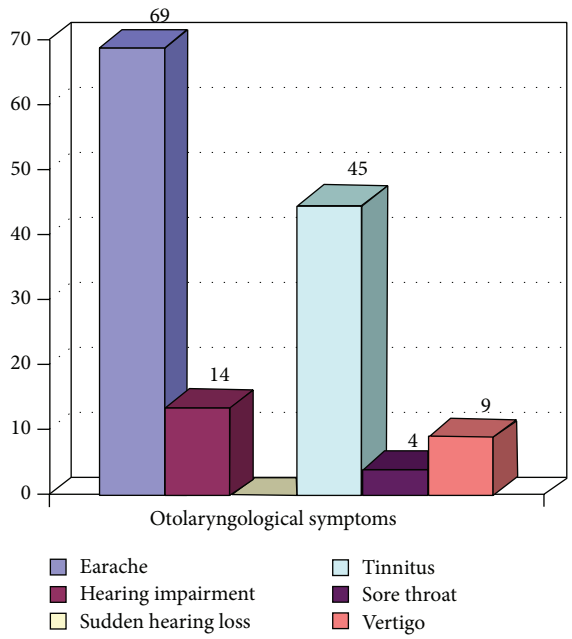

Figure 1: Graphic presentation of the incidence of individual otolaryngological symptoms in the study group.

the rest of the respondents it was bilateral. In 4 cases, a sensation of the presence of a foreign body (worm) within the ear canal was reported. Patients reported high persistence of tinnitus that interfered with their normal occupational and social activities; each of the patients highlighted that the sensations were perceived as louder and more troublesome during the night's rest periods. In four patients, tinnitus was accompanied by the ear plugging sensation, thus leading to concomitance of 2 otolaryngological symptoms in the same patient. Other otolaryngological symptoms included in the analysis were sore throat, reported by 4 patients, and vertigo, reported by 9 patients. Vertigo was described as the sensation of whirling, swaying, and instability of patients' surroundings. In 4 patients, vertigo was accompanied by nausea. All patients reporting vertigo upon medical investigation were previously consulted by otolaryngologists, with otolaryngological treatment being initiated for this reason in some of them, not leading to resolution of the complaints.

The results of the analysis of otolaryngological symptoms in the group of patients undergoing prosthetic treatment for functional disorders of the masticatory organ are presented in Table 1, while graphical representation of these results is provided in Figure 1.

4. Discussion

Otolaryngological symptoms accompanying pathological posterior translocation of the mandible were first observed in 1920 by Monson who reported a case of sudden hearing loss due to abnormal location of mandibular heads [26]. Five years later, Decker described a series of hearing loss and impairment cases in patients with deep occlusion and posterior location of mandibular heads within the temporomandibular joints. In 1933, Goodfriend observed the relationship between the incidence of tinnitus and dysfunction of the stomatognathic system [22, 24]. It is wrongly assumed that the first physician to associate the hearing disorders with masticatory organ dysfunction was Costen. He published his observations as late as in 1934, and therefore he was the fourth researcher who paid attention to the concomitance of tinnitus, vertigo, and earaches with complaints related to the stomatognathic system [27]. As highlighted by several authors, common phylo- and ontogenetic development of masseter muscles, facial muscles, and ear muscles (tensor palati and tensor tympani muscles), originating from the first pharyngeal arches, is not unimportant for the concomitance of otolaryngological symptoms and masticatory organ dysfunction. In addition, posteriorly translocated mandibular head (due to missing teeth, pathological teeth attrition, or trauma) may compress the tympanic artery and vein, leading to blood supply disorders within the middle ear and constituting an important cause of hearing disorders. At the same time, compression by the articular head may damage the tympanic cord, leading to contracture of the stapedius muscle in a reflex mechanism transmitted via the facial nerve. In addition, the course of the auriculotemporal nerve in the temporomandibular joint region promotes its compression by the mandibular head, generating an impulse for reflexive contracture of the tensor tympani muscle and leading to hearing impairment or tinnitus symptoms. Anatomical fissures between the articular cavity and the middle ear, such as petrotympanic or petrosquamous fissures, are routes for transmission of inflammatory infections. Another possible reason for the concomitance of both types of symptoms is the transmission of excess mechanical forces by the discomalleolar ligament or direct compression on the auriculotemporal nerve [3, 4].

The analysis of the obtained results suggests that otolaryngological symptoms are important element of the symptomatology of the functional disorders of the masticatory apparatus, particularly in cases of negative results of consultations pertaining to the condition of the middle or inner ear or tinnitus. Ear-related symptoms may accompany neoplastic growths in the region (Reichert syndrome, i.e., tympanic

neuralgia accompanying glossal tumors) or may be due to injuries or contusions of face or head [13].

The fact that tinnitus may be a symptom of other diseases, not related to the stomatognathic system, such as otosclerosis, Ménière's disease, tumors within the cerebellopontine angle, and acoustic neuroma, should be taken into account in differential diagnostics [6].

It is difficult to identify the leading causal relationship theory for the symptoms in question; in difficult cases of functional disorders accompanied by auriculovestibular symptoms, numerous possible causes for the dysfunction of the middle and the inner ear as well as the functional disorders of the masticatory organ should be taken into account [22, 24].

5. Summary

In cases when otolaryngological origin of symptoms such as earache or sore throat, hearing impairment, tinnitus, or vertigo is excluded, functional disorders of the masticatory organ should be taken into consideration [1, 4, 5, 9, 10, 14–25, 27].

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgment

The study has been approved by the Bioethics Committee, Approval no. KBET/31/B/2014, dated February 27, 2014.

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Clinical Study

Myorelaxant Effect of Bee Venom Topical Skin Application in Patients with RDC/TMD Ia and RDC/TMD Ib: A Randomized, Double Blinded Study

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The aim of the study was the evaluation of myorelaxant action of bee venom (BV) ointment compared to placebo. Parallel group, randomized double blinded trial was performed. Experimental group patients were applying BV for 14 days, locally over masseter muscles, during 3-minute massage. Placebo group patients used vaseline for massage. Muscle tension was measured twice (TON1 and TON2) in rest muscle tonus (RMT) and maximal muscle contraction (MMC) on both sides, right and left, with Easy Train Myo EMG (Schwa-medico, Version 3.1). Reduction of muscle tonus was statistically relevant in BV group and irrelevant in placebo group. VAS scale reduction was statistically relevant in both groups: BV and placebo. Physiotherapy is an effective method for myofascial pain treatment, but 0,0005% BV ointment gets better relief in muscle tension reduction and analgesic effect. This trial is registered with Clinicaltrials.gov NCT02101632.

1. Introduction

Apitherapy is the use of bee products, such as honey, pollen, propolis, royal jelly, bee venom, wax, and apilarnil (atomized drone larva) to prevent or treat illness and promote healing [1]. The roots of apitherapy can be traced back more than 6000 years to medicine in ancient Egypt. The Greeks and Romans also used bee products for medical purposes. This is described by Hippocrates (460–370 BC), Aristotle (384–332 BC), and Galen (130–200 AD) [2, 3].

Bee venom called apitoxin is a mixture of proteins: melittin (main component 52%), apamin, adolapin, phospholipase A2, hyaluronidase, histamine, dopamine, and protease inhibitor. It is a bitter, colorless liquid of density 1,1313 g/cm^3 and pH 5,0–5,5 [4]. It has been used for at least 22 centuries, especially in Eastern Asia [3]. A honey bee (*Apis mellifera* L.) can inject 0,012–0.1 mg of venom via its stinger. The main component is melittin comprising 52% of venom peptides [4, 5]. Apamin is a mild neurotoxin that selectively blocks SK channels, a type of Ca^{2+}-activated K^+ channel expressed in the central nervous system. Dry bee venom consists of 2-3% of apamin [6]. Adolapin comprising 2–5% of the peptides acts as an anti-inflammatory and analgesic agent because it blocks cyclooxygenase. The most destructive component of apitoxin is phospholipase A2 (10–12%), because it degrades the phospholipids, which cellular membranes are made of. It also causes decreased blood pressure and inhibits blood coagulation. Hyaluronidase comprising 1–3% of peptides dilates the capillaries causing the spread of inflammation. Histamine (0,5–2%) is involved in the allergic response. Dopamine and noradrenaline (1-2%) increase pulse rate and protease inhibitors (2%) act as anti-inflammatory agents and stop bleeding [7, 8].

Bee venom therapy, also acupuncture (apipuncture), is used by some as a treatment for rheumatism and joint diseases, due to its anticoagulant and anti-inflammatory properties [6, 9–12]. BV also has an antiarthritic effect in patients with rheumatoid arthritis [4]. Anti-inflammatory and analgesic effect of BV may be explained by process of counterirritation, which increases pain thresholds sensitivity and

reduces pain rating [3]. In Asia similar methods are used for pain reduction, for example, moxibustion (method of burning herbs to stimulate acupoints) [3]. Bee venom is also used to desensitize people allergic to insect stings and even for SAPHO syndrome treatment [13]. The treatment use of honey bee venom therapy is based on the long-known fact that bee keepers (who often get stung) very rarely develop arthritis or problems with their joints and muscles [1]. Bee venom therapy can also be delivered in the form of a balm, although this may be less potent than using live bee stings. Bee venom can be found in numerous beauty products. It is believed to increase blood flow therefore plumping the applied area, producing collagen.

The aim of the study was the evaluation of myorelaxant and analgesic effect of bee venom in patients with RDC/TMD Ia and RDC/TMD Ib.

2. Material and Methods

A parallel group, randomized double blinded trial was performed including 79 patients with painful RDC/TMD Ia and RDC/TMD Ib. Patients were allocated into one of two groups: 37 in experimental group and 42 in control group, by picking up an even or odd number from the envelope. Of these, 4 patients were excluded because of positive allergic reaction to bee venom substance (1 in experimental group and 3 in control group). Five patients did not attend control visits and two patients did not accept bee venom substance. The experimental group consisted of 34 subjects (males = 6 and females = 28) and the control group consisted of 34 subjects (males = 4 and females = 30) aged 22–34 years (average = 23 years).

The patients were examined using the RDC/TMD clinical and physical examination form and asked to fill in Oral Behavior Checklist and VAS scale. One person enrolled participants in the study and another dental practitioner assigned them to the interventions and control visits.

The main eligibility criteria for the participants were a temporomandibular disorder-positive RDC/TMD examination for groups RDC/TMD Ia and RDC/TMD Ib and patient agreement to participate in the experimental study. Exclusion criteria were bee venom allergy, hyperactivity to bee products, positive anamnesis of anaphylactic reaction after bee bites, skin wounds with skin surface discontinuation, RDC/TMD II, and RDC/TMD III.

Masseter muscle tension [μV] at rest and in maximal contraction was measured in previously determined points. The points were marked on paper template and were repeatable.

Bee venom is collected by electric stunning, without harming honey bees. To obtain pure BV it is necessary to remove impurities and lyophilize it. There are different methods of preparing pure BV, for example, capillary zone electrophoresis [14]. During one stung a honey bee injects one International Unit of Bee Venom (approximately 0,012 mg of liquid bee venom, after drying 10 μg of pure bee venom). BV patients' group was given 0,0005% bee venom ointment for topical skin application in region of masseter muscle at the right and left side. Placebo group patients were given only ointment vehicle (Vaseline) in the same containers. Containers in both groups had even or odd number written on it (to allocate patient in one of the two groups). Patients were asked to perform allergic test first, by applying a small amount of the ointment (placebo or BV) on their forearm skin 24 h before therapy. In case of swelling, itching, or skin redness patients were asked to quit therapy. Each patient had been taught earlier how to perform simple physiotherapy with bee venom or placebo ointment. Patients were supposed to massage their masseter muscles 3 times a day during 2 weeks before control visit. Electromyography of both masseter muscles with Easy Train Myo EMG (Schwa-medico, Version 3.1) was performed (Figure 1). Rest muscle tonus and maximal muscle contraction values [μV] were evaluated. Participants' skin was cleaned and rubbed with cotton ball moisture with alcohol. Six adhesive electrodes were applied symmetrically, directly over both masseter muscles insertions. Reference electrodes (two) were placed on the neck.

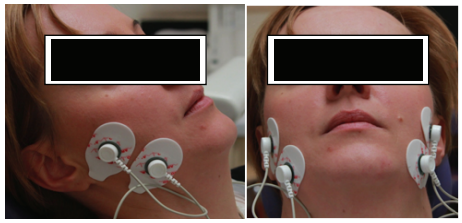


Figure 1: EMG Easy Train Myo (Schwa-medico, Version 3.1).

Data collected during electromyography were noted in Excel file. The results were analyzed with Statistica 7.0 for each group and Wilcoxon test analysis was performed ($P <$ 0,05000).

3. Results

3.1. Changes in Muscle Tonus [μV] and Muscle Pain Intensity in VAS Scale after Bee Venom Skin Topical Application

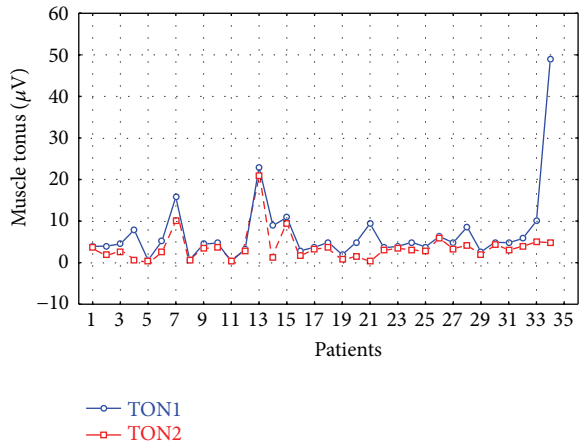
(1) Changes in rest muscle tonus [μV] at the right side before and after 2 weeks of skin topical bee venom application are shown in Figure 2.

(2) Changes in rest muscle tonus [μV] at the left side before and after 2 weeks of skin topical bee venom application are shown in Figure 3.

(3) Changes in maximal muscle contraction [μV] at the right side before and after 2 weeks of skin topical bee venom application are shown in Figure 4.

(4) Changes in maximal muscle contraction [μV] at the left side before and after 2 weeks of skin topical bee venom application are shown in Figure 5.

(5) Changes in VAS scale before (VAS1) and after 2 weeks (VAS2) of bee venom skin application are shown in Figure 6.

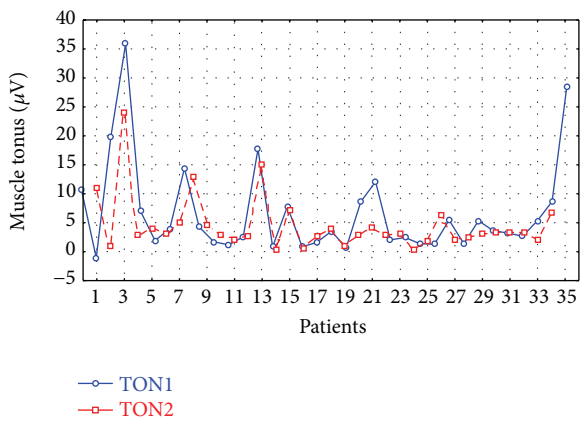


Wilcoxon test (bee venom), statistically significant with $P < 0{,}05000$.

	N	T	Z	P
Rest muscle tonus right side TON1 and TON2	34	0	5,011926	0,000001

Changes in rest muscle tonus: masseter muscle at the right side, statistically relevant $P = 0{,}000001$.

Figure 2: Changes in rest muscle tonus at the right side before (TON1) and after 2 weeks (TON2) with bee venom [μV].



Wilcoxon test (bee venom), statistically significant with $P < 0{,}05000$.

	N	T	Z	P
Rest muscle tonus right side TON1 and TON2	34	38,50000	4,427997	0,000010

Changes in rest muscle tonus: masseter muscle at the right side, statistically relevant $P = 0{,}000010$.

Figure 3: Changes in rest muscle tonus at the left side before (TON1) and after 2 weeks (TON2) with bee venom [μV].

3.2. *Changes in Muscle Tonus [μV] and Muscle Pain Intensity in VAS Scale after Placebo Skin Topical Application*

(1) Changes in rest muscle tonus [μV] at the right side before and after 2 weeks of skin topical placebo application are shown in Figure 7.

(2) Changes in rest muscle tonus [μV] at the left side before and after 2 weeks of skin topical placebo application are shown in Figure 8.

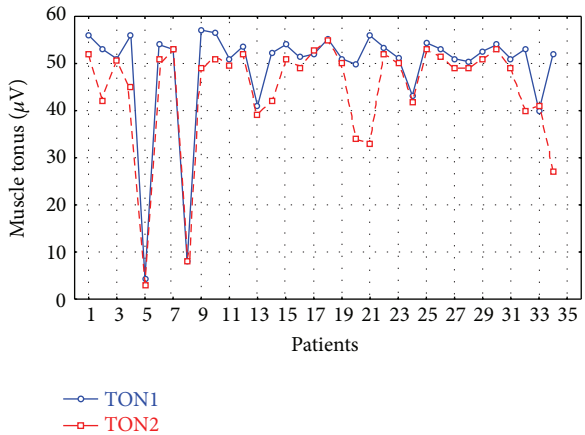
(3) Changes in maximal muscle contraction [μV] at the right side before and after 2 weeks of skin topical placebo application are shown in Figure 9.

(4) Changes in maximal muscle contraction [μV] at the left side before and after 2 weeks of skin topical placebo application are shown in Figure 10.

(5) Changes in muscle pain intensity in VAS scale before (VAS1) and after 2 weeks (VAS2) with placebo are shown in Figure 11.

3.2.1. Rest Muscle Tonus Median Values [μV]. Rest muscle tonus values before physiotherapy with topical application of bee venom (BV) are TON1BV right = 4,8 [μV] and TON1BV left = 4,75 [μV].

Rest muscle tonus values before physiotherapy with topical application of placebo are TON1 PLACEBO right = 4,55 [μV] and TON1PLACEBO left = 4,45 [μV].

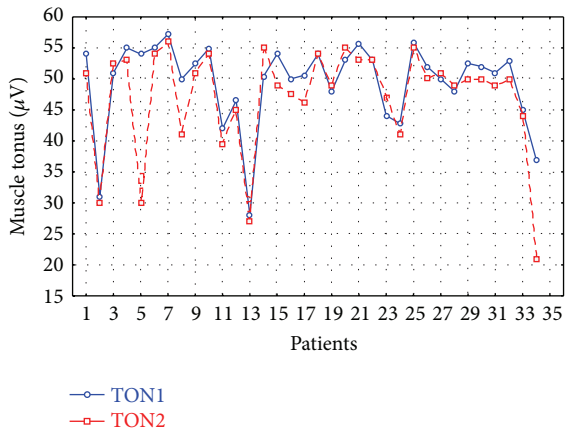


Wilcoxon test (bee venom), statistically significant with $P < 0{,}05000$.

	N	T	Z	P
Max. muscle contraction right side TON1 and TON2	34	8,000000	4,786929	0,000002

Changes in maximal muscle contraction: masseter muscle at the right side, statistically relevant $P = 0{,}000002$.

Figure 4: Changes in maximal muscle contraction at the right side before (TON1) and after 2 weeks (TON2) with bee venom [μV].



Wilcoxon test (bee venom), statistically significant with $P < 0{,}05000$.

	N	T	Z	P
Max. muscle contraction left side TON1 and TON2	34	100,5000	3,057277	0,002234

Changes in maximal muscle contraction left side, statistically relevant $P = 0{,}002234$.

Figure 5: Changes in maximal muscle contraction at the left side before (TON1) and after 2 weeks (TON2) with bee venom [μV].

Rest muscle tonus values after 2 weeks of physiotherapy with topical application of bee venom (BV) are TON2 BV right = 3,05 [μV] and TON2 BV left = 3,1 [μV].

Rest muscle tonus values after 2 weeks of physiotherapy with topical application of placebo are TON2 PLACEBO right = 4,3 [μV] and TON2 PLACEBO left = 3,95 [μV].

In both BV (Table 1) and placebo groups (Table 2) a decrease in muscle tension [μV] was observed; it was statistically relevant for BV group, on both left and right sides (right $P = 0,000001$ and left $P = 0,000010$). For placebo group only on the left side, in rest muscle tonus, a statistically relevant decrease in muscle tonus was observed (right $P = 0,421366$ and left $P = 0,005169$).

3.2.2. Maximal Muscle Contraction-Median Values [μV]. Maximal muscle contraction values before physiotherapy with topical application of bee venom (BV) are TON1BV right = 52,4 [μV] and TON1BV left = 51,5 [μV].

Maximal muscle contraction values before physiotherapy with topical application of placebo are TON1 PLACEBO right = 51,95 [μV] and TON1PLACEBO left = 51 [μV].

Maximal muscle contraction values after 2 weeks of physiotherapy with topical application of bee venom (BV) are TON2 BV right = 49,25 [μV] and TON2 BV left = 50 [μV].

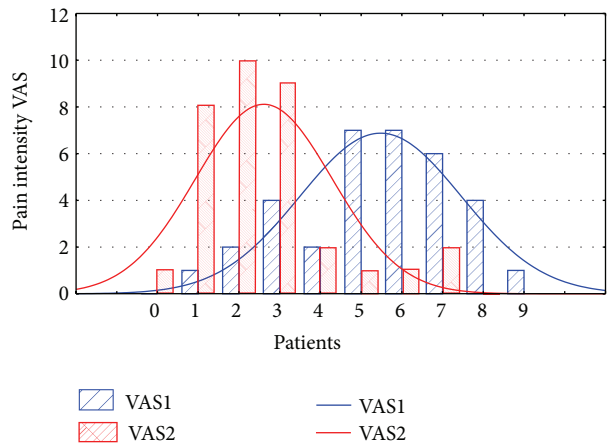
Maximal muscle contraction values after 2 weeks of physiotherapy with topical application of placebo are TON2 PLACEBO right = 50,4 [μV] and TON2 PLACEBO left = 49,5 [μV].

Table 1: Median values of muscular tonus before (TON1) and after 2 weeks (TON2) of topical skin application of bee venom.

Median values BV	Rest muscle tonus right side [μV]	Rest muscle tonus left side [μV]	Maximal muscle contraction right side [μV]	Maximal muscle contraction left side [μV]	VAS
TON1	4,8	4,75	52,4	51,5	VAS1 = 6
TON2	3,05	3,1	49,25	50	VAS2 = 2

Table 2: Median values of muscular tonus before (TON1) and after 2 weeks (TON2) of topical skin application of placebo.

Median values placebo	Rest muscle tonus right side [μV]	Rest muscle tonus left side [μV]	Maximal muscle contraction right side [μV]	Maximal muscle contraction left side [μV]	VAS
TON1	4,55	4,45	51,95	51	VAS1 = 5
TON2	4,3	3,95	50,4	49,5	VAS2 = 4

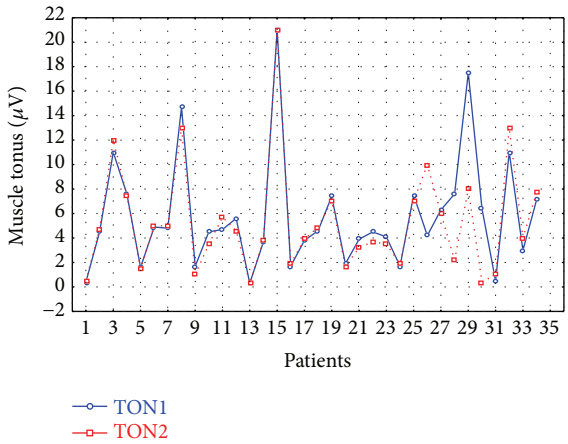


Wilcoxon test (bee venom), statistically significant with $P < 0{,}05000$.

	N	T	Z	P
VAS1 and VAS 2	34	10,00000	4,749531	0,000002

Changes in VAS scale before (VAS1) and after 2 weeks (VAS2), statistically relevant $P = 0{,}000002$.

Figure 6: Changes in VAS scale before (VAS1) and after 2 weeks (VAS2) of bee venom.

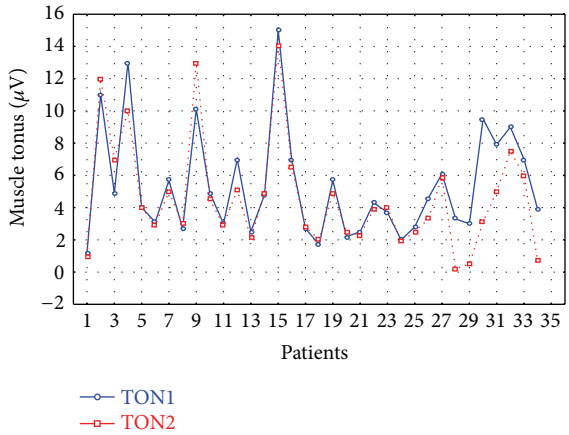


Wilcoxon test (placebo), statistically significant with $P < 0{,}05000$.

	N	T	Z	P
Rest muscle tonus right side TON1 and TON2	34	221,0000	0,804054	0,421366

Changes in rest muscle tonus: masseter muscle at the right side, statistically irrelevant $P = 0{,}421366$

Figure 7: Changes in rest muscle tonus at the right side before (TON1) and after 2 weeks (TON2) with placebo [μV].

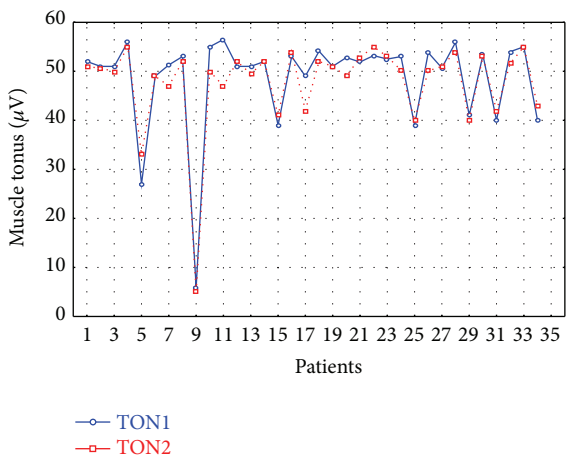


Wilcoxon test (placebo), statistically significant with $P < 0{,}05000$.

	N	T	Z	Poziom P
Rest muscle tonus left side TON1 & TON2	34	124,0000	2,796315	0,005169

Changes in rest muscle tonus: masseter muscle at the left side, statistically irrelevant $P = 0{,}005169$.

Figure 8: Changes in rest muscle tonus at the left side before (TON1) and after 2 weeks (TON2) with placebo [μV].



Wilcoxon test (placebo), statistically significant with $P < 0{,}05000$.

	N	T	Z	P
Max. muscle contraction right side TON1 and TON2	34	144,0000	1,820298	0,068715

Changes in maximal muscle contraction: masseter muscle at the right side, statistically irrelevant Z $P = 0{,}068715$.

Figure 9: Changes in maximal muscle contraction at the right side before (TON1) and after 2 weeks (TON2) with placebo [μV].

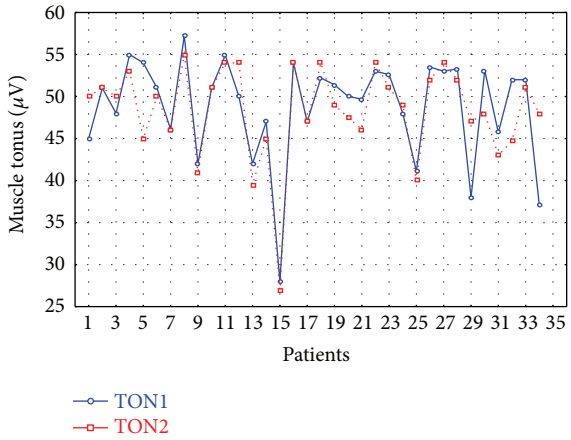
Reduction in maximal muscle contraction [μV] was statistically relevant for BV group (Table 1) for both sides (right $P = 0,000002$ and left $P = 0,002234$). For placebo group (Table 2) maximal muscle contraction was reduced, but the change was not statistically relevant (right $P = 0,068715$ and left $P = 0,113249$).

3.2.3. Muscle Pain Intensity Changes in VAS Scale. In both BV (Table 1) and placebo (Table 2) groups a decrease in muscle pain intensity (VAS scale) was observed (VAS1 = 6, VAS2 = 2); it was statistically relevant for BV group ($P = 0,000002$). For placebo group reduction in muscle pain intensity was also observed, but it was not so significant (VAS1 = 5 and VAS2 = 4), statistically relevant ($P = 0,000024$).

4. Discussion

Lee performed a review of the literature (11 RCTs) and confirmed the effectiveness of bee venom acupuncture, compared to acupuncture without any additional agents, in the treatment of musculoskeletal pain [4, 9, 10].

Efficacy of BV in myofascial pain therapy can depend on anti-inflammatory effect, which is a well-known fact for centuries [1, 6]. In our study patients evaluated their muscle

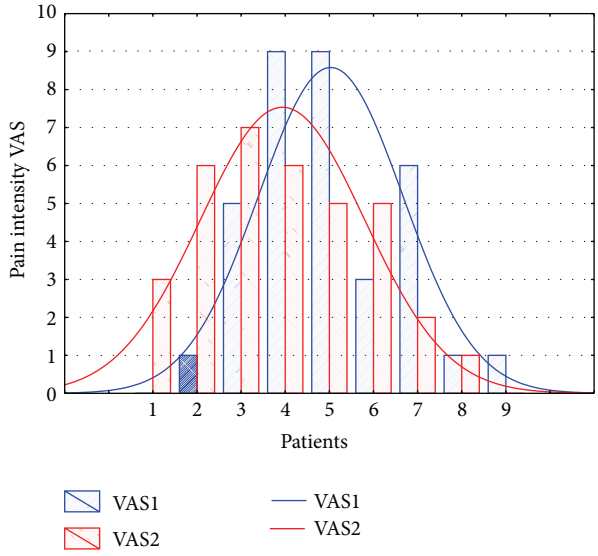


Wilcoxon test (placebo), statistically significant with $P < 0{,}05000$

	N	T	Z	P
Max. muscle contraction left side TON1 and TON2	34	155,5000	1,583762	0,113249

Changes in maximal muscle contraction: masseter muscle at the left side, statistically irrelevant $P = 0.113249$

Figure 10: Changes in maximal muscle contraction at the left side before (TON1) and after 2 weeks (TON2) with placebo [μV].



Wilcoxon test (placebo), statistically significant with $P < 0{,}05000$.

	N	T	Z	P
VAS1 and VAS2	34	9,000000	4,228763	0,000024

Changes in VAS scale before (VAS 1) and after 2 weeks (VAS2) with placebo, statistically relevant $P = 0{,}000024$.

Figure 11: Changes in VAS scale before (VAS1) and after 2 weeks (VAS2) of placebo skin application.

pain intensity decrease in both groups; VAS BV decreased from VAS1 = 6 to VAS2 = 2 (Figure 6) and VAS placebo from VAS1 = 5 to VAS2 = 4 (Figure 11), which is probably the effect of local muscle irritation reduction and BV healing properties [4, 6, 11]. Intensive and long lasting muscle effort, when muscle expends more energy, evokes anaerobic exercise, probably in the mechanism of glycolysis (lowering pH and acidosis), which can be harmful for muscle cells and painful for a patient [8]. Research is needed to establish any relation between BV anti-inflammatory effects and glycolytic muscle irritation.

Day or nighttime bruxism produces great muscular damage and delayed onset muscle soreness one to two days after training, the reason of myalgia. Muscle effort in this case incorporates eccentric, concentric, or both muscular contractions; muscle soreness depends also on the way and direction of strength application [15]. All those changes can occur in patients with RDC/TMD Ia and RDC/TMD Ib

during bruxism and muscle effort. Muscles undergoing heavy eccentric loading suffer greater damage when overloaded as compared to concentric loading [15].

Next possible mechanism of anti-inflammatory and analgesic effect of BV may be explained by process of counterirritation and pain threshold regulation, which increases pain thresholds sensitivity and reduces pain rating [3]. VAS changes in our study may be also connected with pain threshold sensitivity increase.

As a result of the study we have observed a reduction of muscle tension (rest and maximal contraction tonus) in both groups: BV and placebo. In BV group the reduction was statistically relevant on both sides, in rest muscle tonus (Figures 2 and 3) and maximal muscle contraction (Figures 4 and 5). In placebo group only the reduction of rest muscle tonus observed on the left side was statistically relevant ($P = 0,005169$) (Figure 8). Other parameters in placebo group were not statistically relevant (Figures 7, 9, and 10). On the basis of these data we can conclude that physiotherapy (masseter muscle massage) is an effective method of muscular tension reduction. Miernik et al. also have shown the physiological effect of different massage techniques applied in myofascial pain treatment [16]. Physiotherapeutic massage and muscle elongation induces blood perfusion and blood flow increase in muscle tissue [17–19]. It is a useful method for muscle tension and muscle pain reduction, but the efficacy of physiotherapy in our study was considerably increased by BV ointment (median BVTON reduction was 1,75; 1,65; 3,15; and 1,5 and median PLACEBOTON reduction was 0,25; 0,5; 1,91; and 1,5). Muscle tension can also be regulated by some BV proteins, for example, melittin. This peptide induces two-phase changes in rat papillary muscles: first it evokes an increase in the force of muscle contraction (15 min) and after that it inhibits muscle contraction for 30–45 min [20]. The effect is dose-dependent that is why further research is needed to evaluate influence of melittin on muscle cells contraction. That could be one of the possible mechanisms of bee venom healing properties on muscle tissues.

5. Conclusion

Physiotherapy is a very important and effective element of masticatory muscles myalgia treatment (RDC/TMD Ia and RDC/TMD Ib). Topical application of BV ointment provides excellent therapeutic effects: it reduces muscular tonus and muscle pain intensity and gives better relief to a patient than placebo (Vaseline). Local, topical BV application helps to minimize harmful side effects (as anaphylaxis) and teaches patients how to deal with muscle spasm, self-control, and biofeedback. Further research in that field is necessary to establish optimal dose (International Units of BV, %), a way of BV application, frequency, and duration of therapy.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

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Research Article

Correlation between TMD and Cervical Spine Pain and Mobility: Is the Whole Body Balance TMJ Related?

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Temporomandibular dysfunction (TMD) is considered to be associated with imbalance of the whole body. This study aimed to evaluate the influence of TMD therapy on cervical spine range of movement (ROM) and reduction of spinal pain. The study group consisted of 60 patients with TMD, cervical spine pain, and limited cervical spine range of movements. Subjects were interviewed by a questionnaire about symptoms of TMD and neck pain and had also masticatory motor system physically examined (according to RDC-TMD) and analysed by JMA ultrasound device. The cervical spine motion was analysed using an MCS device. Subjects were randomly admitted to two groups, treated and control. Patients from the treated group were treated with an occlusal splint. Patients from control group were ordered to self-control parafunctional habits. Subsequent examinations were planned in both groups 3 weeks and 3 months after treatment was introduced. The results of tests performed 3 months after the beginning of occlusal splint therapy showed a significant improvement in TMJ function ($P > 0.05$), cervical spine ROM, and a reduction of spinal pain. The conclusion is that there is a significant association between TMD treatment and reduction of cervical spine pain, as far as improvement of cervical spine mobility.

1. Introduction

Recent years have seen a significant increase in the number of patients suffering from temporomandibular disorders (TMD) [1]. According to various sources, 8 out of 10 patients coming to the dentist are found to have bruxism or TMD [2].

The issue of relationships between temporomandibular disorders and body posture is still a source of speculations. The knowledge about connections between distant body districts has to be proven by appropriate diagnostic procedures and instruments.

TMD are musculoskeletal disorders needing a multidisciplinary effort to manage with other professionals (e.g., neurologist, laryngologist, and psychiatrist) [3].

Because of the variety of TMD symptoms, many patients had a history of multiple treatments and medications and were treated previously by laryngologists, neurologists, or physiotherapist, but the therapy did not bring the expected, long lasting results. According to currently prevailing theories, temporomandibular dysfunction is considered to be associated with imbalance of the whole body [4].

In addition, the body as a whole operates on the principle of compensation, when it comes to disturbances in the upper quarter, such as increased muscle tension; this will lead to compensatory changes within the muscle tension in the spinal region so as to force the correct position/posture. These adaptive changes occur at all levels, within tolerance of the body [5, 6].

When the body capacity to compensate for the pathological changes progressing in given areas is exceeded, however, imbalance sets in and pathological symptoms will appear. Each individual, obviously, has a unique compensation limit beyond which such symptoms are triggered off.

It was pointed out by many authors that pain in the upper quarter and masticatory motor system may be caused by cervical spine disorders (generally by dysfunction of muscular origin) and vice versa [7–9].

It could be explained by specific functional and morphological connections between the cervical and temporomandibular regions.

2. Materials and Methods

The sample was comprised of 60 individual (30 female, 30 male, age 18–40) and was divided into two groups with randomization. Study and control groups both consisted of 30 people with TMD, cervical spine pain, and limited cervical spine range of movements (ROM). Subjects were directed from Cooperating Orthopaedic Service.

Groups were not different regarding age and gender.

Patients from both groups met the criteria for inclusion and exclusion of studies (Table 1).

Patients from both groups were recruited from cooperating clinics and previously diagnosed by an orthopaedist who excluded morphological and degenerative changes of cervical spine. Cervical spine pain was diagnosed by an orthopaedist according to the Neck Pain Task Force recommendations [10].

Each patient had to have had cervical spine pain for at least 12 months in multiple episodes at a frequency of at least once a week. Patients were included in the study if having pain in the area between occiput and C7.

Subjects gave written consent to participate in the study. The study was approved by the Ethics Committee of the Medical University of Silesia (number KNW/0022/KB1/6/I/10 from 16.03.2010).

Each patient was examined three times. At the 3-week and 3-month evaluations, symptoms of TMD and cervical spine pain and mobility were studied.

The examination included the following:

(1) medical history and physical examination, based on a survey card (according to RDC/TMD);

(2) analysis of pain, using the visual analogue scale (VAS) and the cervical Oswestry scale for the cervical spine;

(3) TMJ functional evaluation by JMA device;

(4) cervical spine motion evaluation with the MCS device.

In order to describe individual TMD symptoms, the entire sample filled out a questionnaire according to research diagnostic criteria for TMD, the translated Polish version (RDC/TMD axis I). The questionnaire focuses on symptoms specifically in the jaw-face, neck, shoulder girdle, intensity of spinal pain, and any other complaints of TMD and spinal origin. Presence of symptoms was marked according to duration, frequency, and intensity. The survey card was completed by each patient 3 times during three consecutive examinations which enabled a comparison of symptoms between groups according to treatment provided in treated group.

On a questionnaire, patients indicated the intensity of spinal pain experienced at the time of examination on a 100 mm visual analogue scale (VAS). Additionally, subjects described symptoms of pain and reduced mobility of cervical spine by filling in the cervical Oswestry scale.

Table 1: Inclusion and exclusion criteria of studies.

Inclusion criteria	Exclusion criteria
(1) Spinal pain	(1) After spine surgery
(2) Women, men	(2) Congenital or degenerative changes of the spine confirmed radiologically
(3) Age between 18 and 40	(3) Neuropathy
(4) Functional changes of the spine, muscle-related	(4) Ongoing medication or physiotherapy
(5) Temporomandibular joint disorder/bruxism	(5) TMJ internal derangement
(6) Patient agreement	

Clinical examination was performed according to RDC/TMD guidelines, too.

Previously trained examiner assessed face symmetry, dentition, and occlusion, as far as "upper quarter" muscle tenderness to palpation with an emphasis on the masticatory muscles, trapezius muscles, suprahyoid muscles, infrahyoid muscles, sternocleidomastoid muscles, and neck muscles in the region of the linea nuchae. Each time the muscle tension was examined by the same examiner.

Mandibular motion was recorded using jaw motion analyzer (JMA) from Zebris, (GmBbH) and the software provided (WinJaw) [11]. The device allows recording mandibular position and movements.

The subjects were provided with an explanation as to the objective of the axiographic examination and its course as well as what types of mandibular movements should be made and how. For each examination, it was necessary to make a paraocclusal clutch mounted on the vestibular surface of the lower teeth and fitted with an electronic sensor. The tool was made of light-cured Multitray (Espe).

The study was based on the performance of patients' movements: opening and closing of the mandible, lateral movements, protrusion, and retrusion. To avoid bias, all subjects performed each trials three times. For each movement, the baseline position was the mandibular rest position. It seems that the rest position should be the starting point when assessing the motor function of the stomatognathic system using instrumental techniques (Figure 1).

The advantages of this system are the ease of use and a positional accuracy of about 100 micrometers. Software allowed creating data report, which consists of graphic diagrams of TMJ function (e.g., Condyle path, maximal opening, and Bennett angle).

Afterwards, the MCS (Zebris, GmbH) ultrasonic-based device was used to collect external kinematic data of the cervical spine movements. Patients with a neutral (comfortably seated) position performed maximal head movements: flexion, extension, rotation to the right and left side, and lateral flexion movements. Each movement was repeated three times in order to minimise measurement errors. The system was calibrated before each measurement. Data were monitored in a real time (Figure 2).

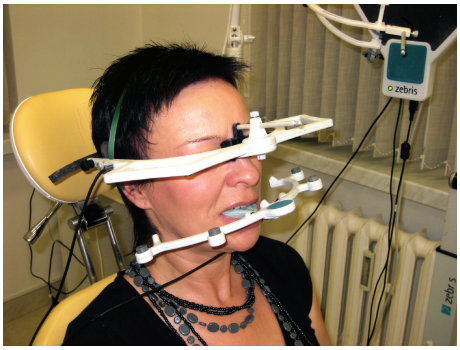

Figure 1: Patient during the mandibular movements' examination (JMA).

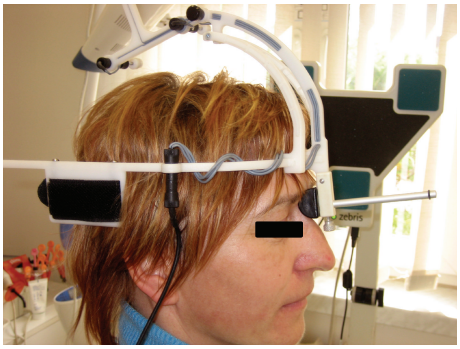

Figure 2: Patient during the cervical spine movements' examination.

Thanks to the repeatable measurements, values were found describing the cervical spine ROMs, presented in the form of relevant graphs.

After the subjects' examination, data containing information about the quality and range of movement in both the TMJ and cervical spine were stored on a personal computer.

After the first examination, each patient selected for the treated (experimental) group was supplied with an occlusal splint. Every patient suffered from TMD of muscular origin (RDC/TMD axis I); therefore, subjects were supplied with an occlusal splint SVED (Sagittal Vertical Extrusion Device). SVED is a removable, flat-plane appliance which makes contact only with the anterior teeth in the opposing arch [12]. It disengages the posterior teeth and thus eliminates their influence in the function of the masticatory system by changing the input signal from proprioceptive fibres contained in the periodontal ligament of the posterior teeth (Figure 3).

The SVED appliance is used in case of hyperactivity of masticatory muscles, without the occlusal reason of TMD [13]. It is usually used to promote jaw muscle relaxation in patients with stress related pain symptoms like headache or neck pain of muscular origin. The splint also obliges the patient to find a new mandibular position, which results in a muscular balance. Patients were ordered to wear the occlusal splint during sleep, but not more than 8–10 hours per day.

Table 2: Characterization of the sample according to age and gender.

Gender	Group		Total
	Treated	Controls	
Female	16	14	30
Male	14	16	30
Mean age in years	32,65	34,87	33,76

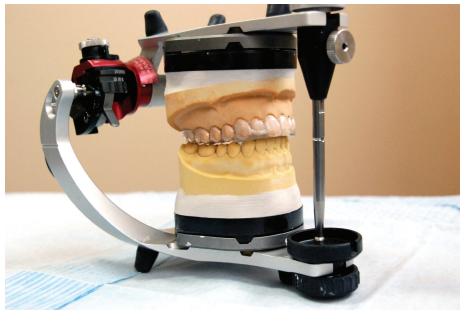

Figure 3: SVED appliance.

According to many researchers, there is no ideal way to handle the problem of control treatment, especially in splint studies. The use of a placebo control group can balance the nonspecific effects in the treatment group and allow for independent assessment of the real treatment effect [14]. In our study control, subjects were instructed to self-control clenching and other parafunctional habits.

The statistical analysis of the results was performed using the statistical package STATISTICA 9.0 (StatSoft). The test probability of $P < 0.05$ was assumed to be significant while the test probability of $P < 0.0001$ was highly significant.

3. Results

60 subjects were examined: 30 belonged to the treated group and 30 to the control group. Patients were randomly admitted to groups. The characteristics of age and gender for both groups are shown in Table 2.

All patients were simultaneously assessed by the same examiner.

3.1. RDC/TMD Diagnoses. Referring to TMD research diagnostic criteria, in patients from both treated and control groups myofascial pain (I) or disc displacement with reduction (DDR, IIa) was diagnosed.

After a three-month therapy with an occlusal splint considerable improvements of TMJ function were found in the experimental group, with 78% of the subjects reporting no DDR symptoms or acoustic phenomena like clicks during mandible movements; the abduction path of the mandible was symmetrical, and there was no pain during the movements (Table 3).

Most interestingly, however, there were changes on the condyle path in the TMJ during the measurements made

Table 3: Symptoms of DDR and myofascial pain during 3 examinations.

	Myofascial pain (treated/control)		Disc displacement with reduction Left side (treated/control)		Disc displacement with reduction Right side (treated/control)	
Examination 1	27	29	13	11	15	12
Examination 2	19	26	8	11	10	12
Examination 3	4	25	3	10	6	12

with a JMA. Deviations within the condylar path which had been noticeable in the first examination (such as lack of symmetry between the length of the path in the right and left TMJ) became reduced in 28 subjects as a result of the treatment, and during the third measurement, the graphs of the condylar paths were asymmetrical on both sides in as few as four subjects. In 24 subjects, there were considerable improvements, which also improved the TMJ function.

In the control group, no changes in the TMJ function were observed in the clinical examination or instrumental check with a JMA in successive examinations.

Muscle tension was examined by palpation by the same examiner. In all subjects, upper quarter muscle tenderness (masticatory muscles, semispinalis muscles, trapezius muscles, sternocleidomastoideus muscles, suprahyoid muscles, and neck muscles in the region of the linea nuchae) was diagnosed during three consecutive examinations. The presence of muscle pain and tenderness during palpation was registered in both experimental and control groups.

During the third examination, the muscle tension of the subjects in the experimental group lowered considerably and they reported lack of pain in the examination by palpation. Out of the 27 subjects in whom intensified tension of the examined muscles had been found, 22 reported no complaints during the third examination. No significant changes were found in the control group.

3.2. Spinal Pain. The whole group showed cervical spine pain. Cervical spine pain according to VAS scale in a treated group significantly improved during three-month therapy (Figure 4).

During treatment, cervical spine pain diminished and after 3 weeks it occurred in 39% of subjects and after 3 months pain was only in 8% subjects from treated group (2 subjects).

The difference between treated and control groups was statistically significant ($P < 0.0001$).

3.3. Cervical Spine ROM. During the first examination, cervical limited ROM at least during one of the tested movements was reported in 60 subjects.

For each measurement, a relevant physiological standard was established, to which the cervical spine ROM results were referred [15]. The norm assumed was dependent on the gender and age of the subject.

Many authors claim that in the ROM examinations of the cervical spine it is not correct to treat an imposed and inflexible range of values within which the ROM should be included as the only indicator. As the resultant data are

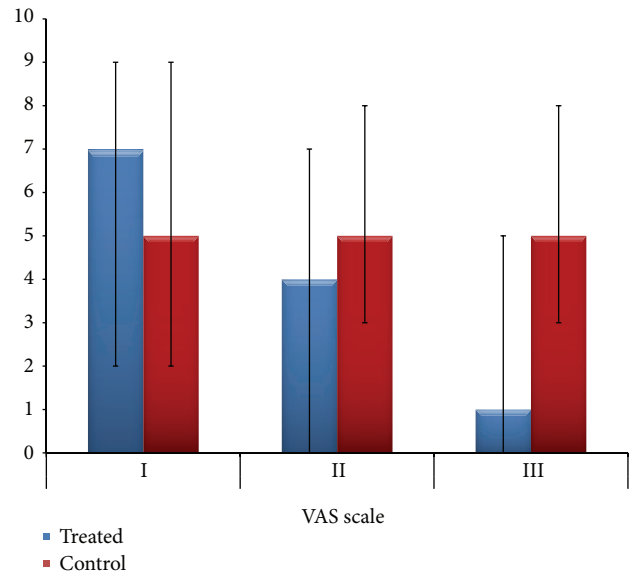

Figure 4: The VAS scale score according to groups during three examinations.

dependent on too many additional factors, in the study we placed special emphasis on the comparison between the results from the first, second, and third examinations and on the assessment whether they have been changed or improved, not merely whether they fell within the standard.

After introducing the occlusal splint therapy, cervical spine mobility improved.

The highest improvement was seen during the flexion movement, which, on the 1st examination only in 22% of patients, was within normative values. During the 3rd examination in 70% of patients from treated group flexion movement conformed the norm (Figure 5).

For the anteflexion movement, the improvement of the results was highly significant ($P = 0.0006$); that is, there were more subjects in the experimental group with the result conforming to the norm.

Likewise, for the retroflexion movement, the results were improved by a highly significant factor ($P = 0.0082$); that is, there were more subjects in the experimental group with the result conforming to the norm.

In the control group, no significant ($P > 0.05$) changes were found; that is, there was no ROM improvement in the cervical spine towards the values in the norm.

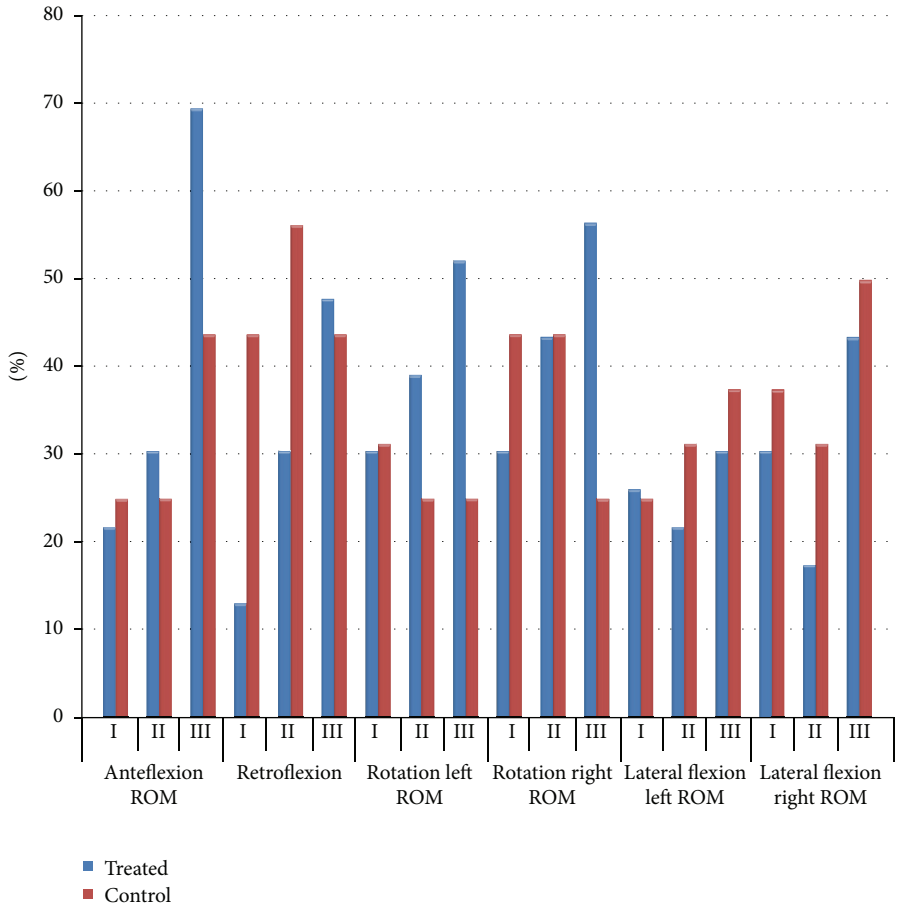

Figure 5: Cervical spine mobility results.

The results of improving the mobility and reduction of cervical spine pain influenced the cervical Oswestry scale score. The average score on the first examination in a treated group was 9.22 points and during therapy, after 3 months, the average score changed to 3.71.

4. Discussion

The results obtained have confirmed a correlation between the pathologies and the positive impact of treatment within the motor aspect of the stomatognathic system on the alleviation of spine pain, even in subjects experiencing such pain for many years.

It is important to understand the complex interrelations between the stomatognathic system and pain and dysfunctions in other areas of the body in order to be able to treat patients more efficiently and effectively at the initial stage, when painful symptoms appear and when curing them is possible as well as much swifter and more efficient. To be able to make successful therapeutic interventions, dental surgeons should cooperate in an interdisciplinary fashion with neurologists, orthopaedists, or laryngologists. They all should also take such interdependencies into account in their diagnostic work with their own patients.

Scientists often note the importance of a holistic approach to therapy. There are many voices in favor of this approach that symptoms of the disorder are usually not isolated and the dysfunction of one region of the body also applies to other regions [16–20].

Although the etiology of cervical spine pain very often remains unexplained, medical specialists in many cases report the comorbidity of dysfunctions in the stomatognathic system and the pain syndrome in the cervical spine [4]. Numerous scientific reports confirm that many researchers have embarked on the examination of the impact of disorders in the "upper quarter" on body posture and pain experienced in various areas of the body [21]. In studies conducted thus far, however, the focus has been mainly to prove the presence or absence of dependence between dysfunction of the stomatognathic system and pain in the cervical spine. The most commonly applied methodology was questionnaires with questions concerning cervical spine pain and complaints of the motor aspect of the stomatognathic system [22]. On that basis, researchers would look for a link between the dysfunction in the motor aspect of the stomatognathic system and the pain felt in the cervical spine. Our study, however, included a therapy with an occlusal appliance, with no other invasive treatment methods used. By applying treatment

with an occlusal splint in the experimental group, a vast majority of the subjects reported improvements and the total disappearance or considerable alleviation of cervical spine pain and TMD symptoms, while the mobility of the cervical spine improved considerably as well.

In case of TMD, there are often large discrepancies between therapists concerning type of occlusal splint most appropriate to use. Many types of splints can be distinguished, for example, stabilization splint, repositioning splint, relaxation splint, or splints only for protecting oral tissues. SVED splint, which is a typical relaxing appliance, was used because of its influence on jaw muscles. No studies about different types of splints used in patients with both TMD and spinal pain were found [23].

5. Conclusions

Our studies as well as the clinical followup suggest that TMD is very frequently present along with pain in the cervical spine. The key aspect of the studies described here is the considerable ROM improvement in the cervical spine and the elimination of cervical spine pain felt there by the subjects in the experimental group. Taking into account the results of our study, it seems obvious that interdisciplinary cooperation between orthopedist, laryngologist, neurologist, and dentist is necessary and essential.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

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Review Article

Differential Diagnostics of Pain in the Course of Trigeminal Neuralgia and Temporomandibular Joint Dysfunction

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Chronic oral and facial pain syndromes are an indication for intervention of physicians of numerous medical specialties, while the complex nature of these complaints warrants interdisciplinary diagnostic and therapeutic approach. Oftentimes, lack of proper differentiation of pain associated with pathological changes of the surrounding tissues, neurogenic pain, vascular pain, or radiating pain from idiopathic facial pain leads to improper treatment. *The objective of the paper* is to provide detailed characterization of pain developing in the natural history of trigeminal neuralgia and temporomandibular joint dysfunction, with particular focus on similarities accounting for the difficulties in diagnosis and treatment as well as on differences between both types of pain. It might seem that trigeminal neuralgia can be easily differentiated from temporomandibular joint dysfunction due to the acute, piercing, and stabbing nature of neuralgic pain occurring at a single facial location to spread along the course of the nerve on one side, sometimes a dozen or so times a day, without forewarning periods. Both forms differ significantly in the character and intensity of pain. The exact analysis of the nature, intensity, and duration of pain may be crucial for the differential diagnostics of the disorders of our interest.

1. Introduction

According to the definition provided by the International Association for the Study of Pain, pain is a subjectively unpleasant and negative sensory and emotional experience occurring following activation of nociceptive stimuli that damage the tissue. The character of pain depends on its location, type of dysfunction of the particular region, and stage of the disease. It is also an observation made during mental interpretation of associated phenomena. Although pain is associated with unpleasant sensations, it also plays a positive forewarning and protective role. Pain is an extremely complex neurophysiological process [1–12]. It appears as the result of a damaging stimulus and the effect of tissue hormones (serotonin, bradykinin, histamine, leukotriene, and accumulation of hydrogen ions) on nociceptors, that is, receptors specialized in the reception of pain and discomfort sensations. Nociceptor excitability depends on physical stimuli, physiochemical milieu, and the quantities of endogenous pain substances being secreted [2–6]. Factors such as microcirculation, dysregulation of the sympathetic nervous system, and excessive muscle tone affect the activity of pain receptors. The process of the development of pain sensation is known as nociception and consists of four stages: transduction, transmission, modulation, and perception. Nociceptive stimuli are transmitted by the neuronal route of the posterior spinal horn and by the spinothalamic routes to cortical centers where perception of pain sensations occurs [1, 2].

The objective of the paper is to provide detailed characterization of pain developing in the natural history of trigeminal neuralgia and temporomandibular joint dysfunction, with particular focus on similarities accounting for the difficulties in diagnosis and treatment as well as on differences between both types of pain.

2. Craniofacial Pain

Chronic oral and facial pain syndromes are an indication for intervention of physicians of numerous medical specialties, while the complex nature of these complaints warrants interdisciplinary diagnostic and therapeutic approach. The incidence of oral and facial pains is estimated at 10% in adults and 50% in elderly patients. Oftentimes, lack of proper differentiation of pain associated with pathological changes of the surrounding tissues, neurogenic pain, vascular pain, or radiating pain from idiopathic facial pain leads to improper treatment. Diseases that involve significant pain, when inappropriately treated, lead to the reduction in the quality of life and to the development of depressive disorders [2–14].

Of the important data provided in medical interviews, particular attention should be drawn to the time of the onset of pain, pain location and characteristic, intensity, frequency and factors that enhance or reduce the intensity of pain. Also important is the radiation of pain to the surrounding organs of anatomical structures [1–15].

Pain within the craniofacial area is one of the most important reasons why patients present at the dentist's office [2–11]. Odontitis, periodontopathies, alveolar osteitis, nerve injuries, atypical facial pains, neoplastic lesions, elongated styloid process syndrome (Eagle's) syndrome, and reflex sympathetic dystrophy of the face should be taken into account. Common causes of pain include trigeminal neuralgia (most commonly of the third branch of the trigeminal nerve, i.e., the mandibular nerve) and temporomandibular joint dysfunction. In the differential diagnostics of facial pains, disease duration of several months or several years required unified diagnostic criteria with consideration of nontypical cases. In the therapy, we use various methods of treatment such as medication, surgery, dental prosthetic, physiotherapy, and psychological support [2–36].

3. Trigeminal Neuralgia

Neuralgia is a symptom of nerve dysfunction present within the brain stem or within the nerve segment running to the trigeminal ganglion located within the base of the middle cranial fossa. The disorder is most common in patients over 60 years of age and more common in women. Main etiological factors responsible for neuralgia include vasculoneural conflict consisting in compression of the nerve by blood vessels at the site of neural connection to the brain stem, within the region of the superior cerebellar artery, the basilar artery, the vertebral artery, and the petrosal vein. In addition, neuralgia may be a result of head injuries or inflammation of nerve within the myelin sheath. The disorder may also be associated with other diseases such as multiple sclerosis (formation of demyelinating plaque in the brain) or tumors that compress the nerve and disturb its function [4, 8–17, 23]. According to the most recent theory of magnetic bioresonance, trigeminal nerve starts oscillating at amplitudes that exceed its natural frequency. The human organs differ in their natural frequencies (8–12 Hz for the head). The nerve is immersed in the cerebrospinal fluid that transmits the vibrations of the surrounding structures [5, 9]. The increase in the amplitude of vibrations damages the permeability of ion channels, leading to nerve injury. The disorder is characterized by recurrent, paroxysmal attacks of sudden, intense, and piercing pain within the region supplied by the trigeminal nerve, comparable to an electric shock [5–7, 9–19, 30].

It might seem that trigeminal neuralgia can be easily differentiated from temporomandibular joint dysfunction due to the acute, piercing, and stabbing nature of neuralgic pain. It should be mentioned that neuralgia may be of either spontaneous (primary) or symptomatic (secondary) form. Both forms differ significantly in the character and intensity of pain. Unexplained etiology of spontaneous neuralgias of the second and third branch of the trigeminal nerve is a cause of significant therapeutic problems [1–8, 10–15]. Both branches may also be affected at the same time. The incidence is 1 in 15,000 cases. The acute, paroxysmal, and piercing pain occurs at a single facial location to spread along the course of the nerve on one side, sometimes a dozen or so times a day, without forewarning periods. Pain episodes may last several seconds to several minutes. As the disease progresses, the number of episodes increases and the remission periods become shorter. The pain is intensified during facial muscle and mandibular movements. Primary neuralgia is often accompanied by facial muscle contractures (*tic douloureux*), increased salivation, lachrymation, running nose, and skin redness. Stimuli that most commonly cause the pain are trivial and everyday causes such as wind gusts, sudden changes in air temperature, bright light, sharp sounds, or delicate touch (e.g., shaving in males). A typical feature of these disorders is the unilateral occurrence of pain and lack of complaints during the night's sleep [3, 5, 7, 9–13, 15].

In contrast to the spontaneous neuralgia, its symptomatic (secondary) form is associated with pain that increases gradually, has different nature, and persists with no interruptions. The pain becomes intensified in heat. It may be a result of numerous local or generalized causes (odontitis, cysts, sharp socket edges, tumors within the mouth, and the maxillo-ethmoidal massif, disorders of the maxillary sinuses or the middle ear). Neuralgia of this type may be a symptom of numerous diseases within the region of the posterior cranial fossa, such as basal tumors or cerebellopontine angle tumors. This type of neuralgia may also be observed in alcohol, mercury, or nicotine intoxication [8–13, 15, 18, 30].

Symptomatic neuralgia should be differentiated from causalgia which may be due to the traumatic injury of nerve, particularly maxillary nerve, or mandibular nerve within the facial region. Causalgia may develop as a result of contusion, fracture, or surgical intervention in this region. As shown by the characteristic of pain, primary neuralgia is substantially different from the secondary form. Therefore, the pain associated with the temporomandibular joint dysfunction may have a characteristic that is similar to the secondary neuralgia and may pose significant difficulties in differential diagnostics [4, 5, 8–10, 13, 14].

Table 1: Differential characteristics of pain in the course of trigeminal neuralgia and temporomandibular joint dysfunction.

Common features of pain in trigeminal neuralgia and temporomandibular joint dysfunctions	Differential characteristics of pain in the course of trigeminal neuralgia and temporomandibular joint dysfunction	
	Trigeminal neuralgia	Temporomandibular joint dysfunctions
Increase in pain as a result of activity of facial or masticatory muscles	Unilateral location of pain (97%)	Bilateral pain
Possibility of pain being located on one side of the face	Characteristics of pain: acute and stabbing	Characteristics of pain: continuous and dull
Possibility of otolaryngological symptoms	Remission of the neuralgic pain during nights	Pain may still be present during the nights
Significant reduction in patients' quality of life and the development of depressive disorders	The duration of pain: very short, lasting several seconds to several minutes with long periods of remission during the day	The duration of pain: long-lasting (several hours) with short intermissions
Pain being radiated into the neighboring regions	Pain accompanied by facial muscle convulsions (tics), skin redness, lachrymation	Lack of such symptoms

4. Temporomandibular Joint Dysfunction

According to WHO report, temporomandibular joint dysfunction is the third stomatological disorder to be considered a populational disease, after dental caries and periodontal diseases. Temporomandibular joint dysfunction consists in a spectrum of changes disturbing the morphological and physiological balance within the musculoskeletal system. The nature of these changes is determined by psychoemotional, environmental, and genetic factors. The changes include abnormalities in the relationship between opposing teeth, and the function of the muscles of the frontal and medial part of the skull and neck, working in a symmetrical manner in physiological conditions of the temporomandibular joints. Increasing stress levels lead to intensification of adverse motion habits within the stomatognathic system and the rapid increase in the number of patients observed in recent years is associated with the drop in the age of patients with dysfunctions manifested with pain symptoms [14, 15, 17, 18].

Functional disorders of the masticatory organ are pathologies of diverse etiology [2]. The incidence of the painful form of the disorders is estimated at about 30% of all cases. Most commonly, pain is located within the temporomandibular joint region or, less commonly, the masticatory muscles (myalgia). It may range from slight tenderness to a very strong discomfort. The pain is either acute and stabbing or chronic, diffuse and radiating into the neighboring structures, that is, eyes, ears, temples, and occiput. It is not associated with inflammation; the intensity of muscle pain is closely related to excessive functional activity of particular muscle groups during occlusal parafunctions. Overburdened muscles are characterized by hypoxia and ischemia and thus with the release of allogeneic substances that determine the resultant pain, such as bradykinin or prostaglandins. Muscle tenderness is a source of deep pain and may lead to protective contractures [2–5, 18, 19].

The articular pain is a result of damage to articular surfaces, degeneration, injuries of articular capsule, or damage of retrodiscal tissue. Arthralgia may develop only as a result of impulsation originating from nociceptors located within the soft tissue. Lack of coordination of mandibular head and disc is manifested by acoustic symptoms within the temporomandibular joints, such as popping and cracking sounds upon mandibular movements. At advanced stages of disc translocation and blockade, acoustic symptoms disappear to be replaced by chronic pain and significant restriction of jaw opening range, complicated by tilting the mandible towards the affected side upon abduction. Temporomandibular pains may also be the result of prolonged overload of articular structures of high intensity, exceeding the adaptational capabilities of the collagen fibers within the posterior disc ligament, which are commonly subject to fragmentation. The nature of the pain observed in temporomandibular joint dysfunction is similar to that in the symptomatic form of neuralgia and significantly different from that in the spontaneous neuralgia [2, 15–28].

5. Common Features of Both Types of Pain

Pains sensations experienced in trigeminal neuralgia and temporomandibular joint dysfunction have both common features and significant differences (Table 1). Common features include pain being radiated into the neighboring regions, and even to distant structures, possibility of pain being located on one side of the face, increase in pain as a result of increased activity of facial or masticatory muscles and the possibility of otolaryngological symptoms (earache and hearing impairment) [16]. In addition, the diffuse pain that lasts for many months in both cases may lead to significant reduction in patients' quality of life and to the development of depressive disorders. Compared to primary neuralgia, pain experienced in secondary neuralgia is much more similar to that observed in functional disorders [2, 15, 17–20].

6. Differences in the Characteristics of Pain

Features differentiating both nosocomial entities include unilateral location of pain in neuralgia (97%) and bilateral pain in myalgia. Also the nature of pain is different, being

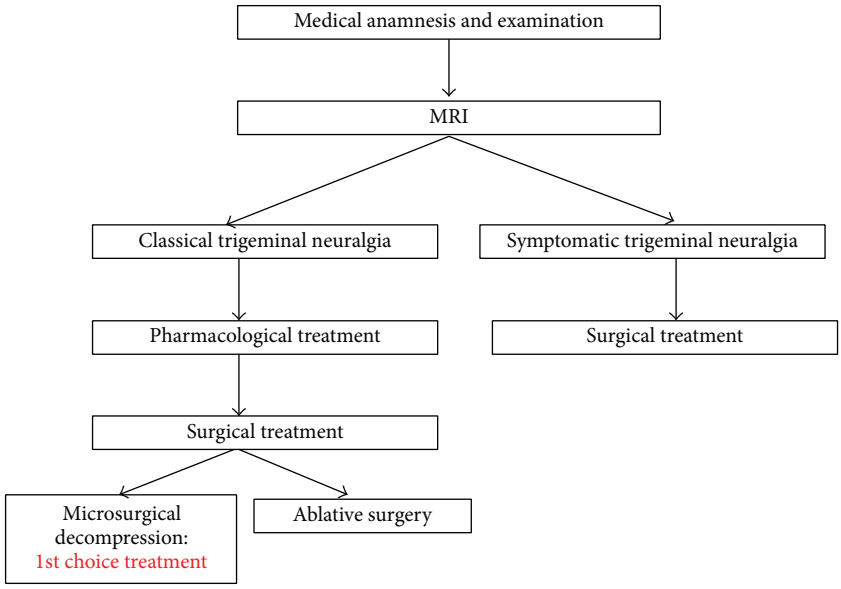

Figure 1: Diagnostic and therapeutic management of patients suffering from trigeminal neuralgia.

acute and stabbing in neuralgia and continuous, dull in temporomandibular joint dysfunction. Night's rest is a period of remission of the neuralgic pain, while temporomandibular joint pain may still be present in this period in case of functional disorders [13–16]. The duration of pain is also different: the neuralgic pain is very short (lasting several seconds to several minutes), with long periods of remission during the day, while the dysfunctional pain is long-lasting (several hours) with short intermissions. Pain episodes in spontaneous neuralgia are induced by triggering stimuli which are usually the same in particular patient. Patients tend to avoid these stimuli and are afraid of them. If neuralgia episodes are induced by chewing, patients fast deliberately, which leads to secondary and multiplanar somatic disorders. Neuralgic pains are often accompanied by facial muscle convulsions (tics), skin redness, lachrymation, which are not observed in temporomandibular joint dysfunction. In neuralgia, pain is intensified by heat, while being alleviated in myalgia [2–5, 9–35].

Thanks to the development of neurophysiological examinations, magnetic resonance imaging, cerebral angiography, and clinical symptoms, trigeminal neuralgia may be correctly diagnosed while excluding other causes for paroxysmal facial pains. The exact analysis of the nature of pain may be crucial for the differential diagnostics of the disorders of our interest [3, 10, 22, 36–48].

Despite similarities of pain symptoms in both types of pathologies, therapeutic management is different in both cases. In trigeminal neuralgia, treatment involves conservative and more or less invasive methods. Usually, the treatment is commenced carbamazepine (100 to 1000 mg/day) pharmacotherapy, in some cases combined with anticonvulsants (phenytoin, clonazepam). One should also keep in mind the ability to achieve long-term remission of neuralgic pains by means of neural blockades of the terminal trigeminal nerve branches using lidocaine or bupivacaine solutions (Figure 1). The next step consists in surgical treatment; however, the use of surgical methods, even in the form of minor procedures such as neurotomy or exeresis, requires that the patient should be qualified for the surgery by both internal medicine specialist and anesthesiologist which constitutes a major problem, considering the commonly elderly age of patients combined with significant burden of concomitant diseases [10, 36–39, 42].

The latest method is stereotactic surgery/gamma knife, making use of electromagnetic gamma radiation from cobalt ^{60}Co isotope sources, corpuscular radiation of protons of heavy carbon ions, or electromagnetic X radiation generated by linear accelerators. The method was developed by professor Lars Leksel and has been known since 1967. The method consists in precise delivery of radiation from 192 collimator sources into intracranial pathological lesions using stereotactic techniques. The first stage of the procedure is the placement of stereotactic frame on patient's head using special screws in local anesthesia. The patient is placed within a gamma knife apparatus, where the irradiation spot location and dose magnitude is determined on the basis of magnetic resonance scan results and the location of the lesion. The usual dose is 90 Gy and is absolutely safe for tissues permeated by radiation. Irradiation lasts about 30 minutes. Factors taken into consideration when qualifying patients for the treatment include the type, size, and location of lesions. Radiosurgery techniques have witnessed an enormous technological progress. At the same time, a model of multidisciplinary teams of oncologists, radiotherapists, neurosurgeons, and other medical specialties has been developed for the radiosurgery purposes. The efficacy of stereotactic radiosurgery is estimated at 80–90%. Due to the minimum

invasiveness of the procedure, it is the method of choice in elderly patients or patients with high concomitant disease load [42, 49].

Due to the poor availability of this treatment in Poland, microvascular decompression (MVD) technique is still in use, consisting of craniotomy followed by elimination of the vasculoneural conflict by means of separating the problematic artery or vain from the nerve using autogenic (muscle fragment) or alloplastic (teflon, goretex) material [5, 8, 10, 14, 32].

The natural history of temporomandibular joint dysfunction most commonly involves changes in the biomechanics of temporomandibular joints connected with the dysfunction of masticatory muscles. The treatment of functional disorders usually involves occlusal splints, characterized by multiple effects. These include elimination or reduction of pain by reducing the load on temporomandibular joints and retrodiscal structures as well as reduction of excessive activity and restoration of symmetry in the tone of masticatory muscles. This is known as reversible occlusal treatment. Prosthetic methods for the treatment of dysfunction include procedures to correct the occlusion system (selective contouring, reconstruction of correct occlusal conditions with fixed or mobile prostheses) [1–3, 5, 8, 18, 25–29, 41, 44, 47, 48].

Physiotherapy plays an important role in the treatment of patients with temporomandibular joint dysfunctions when used as an element of supportive therapy applied simultaneously to the primary treatment. The goal of physiotherapeutic procedures is to eliminate or reduce pain, reduce the excessive tone of overloaded muscles of the head, neck, and shoulder girdle, activate muscles of reduced muscle tone, and mobilize joints of limited mobility. The techniques used in physical therapy affect motor coordination of the musculoskeletal system and have beneficial effect on the increased vascular flow in the treated area. Physiotherapeutic methods used in stomatology include kinesitherapy, laser therapy, manual therapy, massage, light therapy, electrotherapy, and magnetoledtherapy [2, 15, 19, 21, 23, 33, 38].

A new pharmacological approach consists of the use of botulinum toxin type A in the treatment of excessive muscle tone which constitutes a serious problem in the natural history of the temporomandibular joint dysfunction [26, 28, 29]. The mechanism of action of the drug involves suppression of the release of acetylcholine (parasympathetic neurotransmitter) into the synaptic cleft and blockade of the transmission of impulses leading to muscle contracture. Intramuscular injections of the toxin are administered in the region of the largest cross section of the masseter muscle. The duration of the relaxant effect of the drug depends on the dose strength; most usually, it is 6 months [26]. There are several other medicines like Propolis or topical application of Ketoprofen in the area of temporomandibular joints [22, 23, 31].

7. Summary

Chronic oral and facial pain syndromes are an indication for intervention of physicians of numerous medical specialties, while the complex nature of these complaints warrants interdisciplinary diagnostic and therapeutic approach. The precise analysis of characteristic features of pain, its intensity, and duration may be crucial for the differential diagnostics of trigeminal neuralgia and functional disorders of the masticatory apparatus [2–4, 8, 13–15, 19, 50–53].

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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