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Review Article

Tooth-Implant Connection: A Review

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Connecting teeth to osseointegrated implants presents a biomechanical challenge. This is due to the implant being rigidly fixed to the bone and the tooth being attached to the bone with a periodontal ligament. In order to overcome this problem, various connection types such as rigid and nonrigid have been proposed. However, the mechanism of attachment and the perceived problem of the differential support provided by the implant and the tooth have been discussed by many authors, and the ideal connection type is still controversial. The aim of this study was to carry out a review of all available literature addressing the tooth-implant connection and evidence-based understanding of the management of tooth-implant-retained restorations.

1. Introduction

Multiple missing teeth may possibly be restored with a conventional tooth-supported bridge, with a tooth-supported bridge with cantilevers, with a resin-bonded bridge, with implant-supported single crowns, with an implant-supported bridge or with a combined tooth-implant-supported bridge. However, the combination of teeth and implants for the support of fixed partial dentures has been investigated in many studies but remains controversial. Nevertheless, in some cases because of anatomic limitations or a lack of osseointegration which may affect the planning, they may be associated with natural tooth abutments in the same prosthetic restoration.

Several long-term clinical and laboratory studies have concluded that a tooth-implant relation should provide a desired success if relevant factors were taken into account by the clinicians [1–3]. The objective of this literature review was to investigate the long-term outcomes of restorations supported by implants and natural teeth with regard to complications associated with implants, teeth, and restorations, as well as the influence on these parameters of the connector type used.

2. Differences between Dental Implants and Teeth

Primary function of dental implants is to support the prosthetic restorations as a root of natural teeth. Dentists make an effort to assimilate the form and structure of implant-supported prosthesis to natural teeth. Nevermore, it has to be take in account that between these systems which supports prosthesis, have notable differences.

Kim et al. [4] and Misch [5], compared natural teeth and implants and main differences between these two structures were summed up in Table 1.

3. Comparison of Biomechanics of Implants and Teeth

Relation of natural teeth with bone tissue; is designated to minimize the forces which will distribute to crestal bone with different mechanisms [6]. Biomechanical designation of periodontal membrane, elastic modulus, nerve-blood vessels complex, occlusal material, and type of supportive bone are effective in determination of load amount which is transmitted to supportive tissues. Tissue that covers the natural teeth

Table 1: Differences between dental implants and teeth [5].

	Natural teeth	Implant
Junction	Periodontal ligament.	Osseoentegration and functional ankylosis.
Junction epithel (JE)	Hemidesmosomes ve basal lamina.	Hemidesmosomes and basal lamina.
Connect tissue (CT)	13 group: vertical surfaces and tooth surface.	2 group: parallel ve circuler fibers. No attachment on implant and bone surface.
Biological width (BW)	JE: 0.97–1.14 mm CT: 0.77–1.07 mm BW: 2.04–2.91 mm	JE: 1.88 mm CT: 1.05 mm BW: 3.08 mm
Blood supply	High	Low
Probing depth	3 mm in healthy tissue.	2.5–5.0 mm according to soft tissue depth.
Pressure sensivity	High	Low
Axial movability	25–100 nm	3–5 nm
Movement type	Two phased. Primary: compelex and nonlinear movement. Secondary: linear and elastic movement.	Linear and elastic movement.
Movement forms	Primary: urgent movement. Secondary: proggressive movement.	Gradual movement
Hinge point in lateral movements	1/3 apex region of the root.	Crestal Bone
Property of freightening	Shock absorpbtion mechanism and stress distrubition.	Concentration and stress increase in crestal bone.
Overload findings	Widening in periodontal ligament, movement, abrasion surface, fremitus, and pain.	Loss of screw or fracture, fracture in abutment or prosthesis, bone loss, and implant fracture.

acts as a viscoelastic shock absorber. Especially specified, this tissue lessened the amount of stress which was inbound to bone structure in crestal region [5, 6].

Furthermore, direct conduction of implant and the surface of bone is not flexible as much as natural teeth. That's why an energy formed by occlusal load may not be distributed entirely. Thus, overloading on the bone which counterparts the implant region is fatal [6, 7].

Resistance of a titanium implant is calculated 10 to 100 times higher than a tooth. Besides, loading duration and magnitude of force have important effects on the stress of bone which lay around the teeth. This is due to the fact that, periodontal ligament and tissue resilience is the result of viscoelastic nature [8].

Mobility of a natural tooth may increase with the occlusal trauma. With this action, stresses either distribute or conduct to prosthetic components and bone interface. Tooth may become its original occasion, after eliminating occlusal trauma in spite of the size of tooth movement. Mobility of an implant may be formed in same way under occlusal trauma. After elimination of the factor, implant frequently returns into its original rigid position. Alternatively, mobility of implant may continue, health of surrounding tissues become worse, and commonly implant is lost in a short time period [6, 7].

4. Kinds of Connection of the Natural Teeth and Implant

4.1. Rigid Connected Designs. Metal superstructure is formed in a rigid way [9]. Wise [10] accentuated especially passive seating and gave information for this type of designs with metal-supported ceramic applications in his study.

Skalak [11] noted that use of rigid connections in implant-tooth supported fixed partial denture design may be unfavorable. The main reason of their thought was, implants would expose to much more occlusal loads than natural teeth, and this may cause tissue atrophy around the natural teeth and desimantation problems [10].

4.2. Rijid Designs. Since some researchers thought that rigid designs are unfavorable, and suggested connection with non-rigid structures for implant-natural teeth supported bridges, they used different connection types (for this aim). For this purpose, the most widely used precious attachment types;

(i) Bolt-type precious attachments.

(ii) Vertical or horizontal screwed precious attachments.

(iii) Coping applications.

(iv) A Connection.

(v) Intramobil Component.

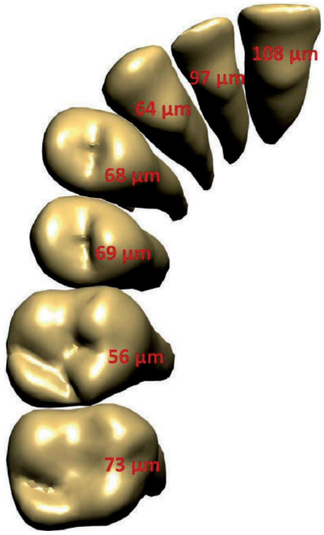


Figure 1: Amount of lateral movement of intact teeth.

5. Principles of Implant and Natural Teeth Connection

It is specified that pronounced decrease in mobility is observed when mobile teeth which are located in same arch are splinted with fixed partial dentures. Splinting of teeth will decrease the complication which may occur in long term, if contacts in posterior region are not hindered with prosthesis or skeletally in lateral movements. In addition, connection of natural teeth abutments decreases the incoming load on each support by dissipation [12, 13].

Increase in number of teeth which are connected decreases the movement of prosthesis. In dental assessment, the principles of procedures for decreasing mobility of prosthesis to 0 with connecting mobile natural teeth should be lean on the following:

(i) Terminal tooth should not be mobile.

(ii) Terminal tooth should be retantive enough [5, 14].

It is possible to say same principles in teeth-implant connections. Natural tooth which is splinted rigidly to implant, must be in retantive form without any mobility. These 2 simple rules and demand of increasing abutment numbers as much as possible, must be remembered while planning teeth-implant supported fixed partial dentures [5].

General fact in prosthetic dentistry, "the less stable tooth must be planned as a terminal tooth, because destructive tension occurs on intact teeth" concept is valid for teeth-implant connection, too [14]. In such cases it must be known, mobile tooth will add on extra load on intact teeth instead of eliciting support. Tooth with a mobility value 0, can be connected to osseointegrated implant. Implant, bone, and prosthesis will compensate the minor teeth movements. According to literature, implants can be connected easily to stabile rigid tooth [2, 9]. Barely, occlusal contacts must be modified to direct loads to natural teeth and abstain in overloading on implant. That is why; immobile abutment requirement is one of the important criterias in connecting implant to natural teeth in clinical practice [12, 15].

Other criteria is, avoiding possible lateral loads on abutment while designating a prosthesis. Lateral movements increase teeth movements while decrease the movement of implants. Lateral movements of natural teeth, cause more stresses than vertical movements [7]. As such, stress is increased in crestal bone area with the horizontal forces which affects implant.

Intact tooth has 8–28 μm physiological vertical movement while this movement is 0–5 μm for implant. Horizontal moves are excessive than vertical ones. Teeth make moves 56–108 micron even with small forces like 500 gram (Figure 1). This moving changes between 97–108 μm while moving in posterior teeth is between 56–73 μm. So that, lateral loads are conducted to implants in anterior teeth connected designs than posterior teeth connected designs in teeth-implant supported designs. In such a case, it is possible to get excessive load on implant biomechanically with the connecting of an implant to its mesial neighboring [5]. Lateral forces increase the amount of stresses on the bone that is around the implant with conducting to implants. So that, connecting implants to posterior teeth may increase the success in implant-tooth supported restorations (Figure 2).

The important points that must be taken in account in natural teeth-implant connection can be summed up with the light of all these informations, below;

(1) The distance between the natural teeth and implant increases, rotational movement of implants with vertical and horizontal forces decreases [10, 16].

(2) Natural teeth must have low mobility clinically [5].

(3) If two or more implants are supports, there is pressing stress on the implant that is nearest to pontic, while flexion stress will be formed on the furthest implant to pontic [10].

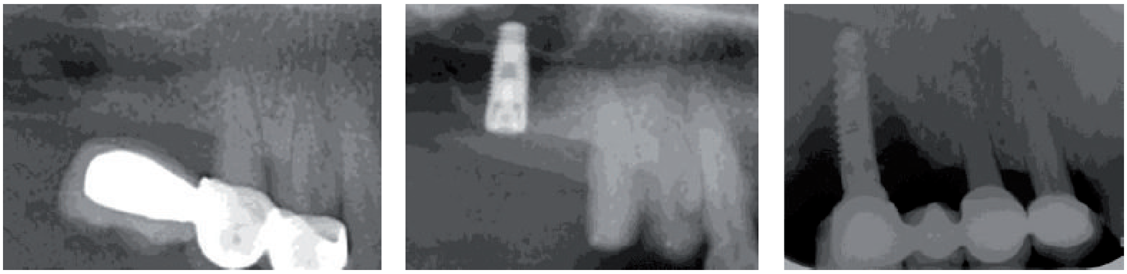
(4) When molar teeth are used as a support, they have more resistance to horizontal rotational movements which can occur on implant abutment with lateral forces so as to number of root and root surface area [5, 10].

(5) When precision connections are localized to natural teeth area, they may cause intrusion of opposite teeth with axial forces [10].

(6) Eliminating occlusal forces in lateral direction or application of posterior disclussion will decrease the effect of lateral forces [10].

(7) Precision connections which are located on to implant support will permit the lateral movement of natural teeth with lateral forces.

(8) Load distribution in implant or natural teeth supported prosthesis is related with geometry of implant or natural teeth, flexibility of supports, and rigidity of prosthesis. Rigid prosthesis distributes forces between abutments more moderately. Nonrigid designated prosthesis condensed the forces to the nearest abutment [10].



(a) (b) (c)

Figure 2: Anterior teeth can move more than posterior teeth. Implant which is connected to anterior teeth will be affected by loads biomechanically, consequently bone resorption will increase.

(9) Short pontic, short wing designations in mandible can be applied while general principle in maxilla is placing maximum number of implants as much as anatomy allows [10].

6. Advantages and Potential Problems in Connection of Natural Teeth and Dental Implant

It was believed that natural teeth and dental implants had been used as a supports in same prosthesis many years ago, however, different movement types of implant and teeth, it was noted that there was an increasing bending movement in implant lately. This increasing stress formed the idea of being successful with implant-implant supported denture than teeth-implant supported dentures. However, it was shown that potential problem could be acceptable [17].

It cannot be ignored that dental implants and natural teeth connections are advantageous like increasing the treatment. The other advantages of connection of natural teeth and implant are explained by Greenstein et al. (2009) [17] as follows:

(1) Increasing the treatment options for splinting teeth for implants.

  (a) Cases with anatomical restrictions (maxillary sinus, mental foramen).
  (b) When insufficient bone exists and placement of implant is not possible.
  (c) When patient does not agree to have augmentation.

(2) Splinting mobile teeth with an implant.

(3) Eliciting teeth proprioception.

(4) Reducing cost.

(5) Additional support against load which affects teeth.

(6) Reducing the numbers of implants for restoration.

(7) Avoiding cantilever bridge.

(8) Protection of papilla for functional or esthetical concern.

Instead of advantages told above, there is some situations that must be taken in account when connecting dental implants with natural teeth. For example, when applying 0.1 N force, natural teeth with healthy ligament moves 200 microns as a reaction, while dental implants change place only less than 0.1 micron [18]. This movement is primarily, related to the flexibility of bone. For this reason, teeth can intruse in alveol socket because of the difference in mobility of natural teeth and implant in 3-unit implant-teeth connection, and, prosthesis moves on the implant as a cantilever bridge. Theoretically, this causes increase in stress of implant and technical and biological complications [18, 19].

Hypothesis, technical and physiological problems and functionality of natural teeth and implant connection and advantageous results of analysis teeth and implant cause the need of investigation in another point [17].

Researchers bet that the lifetime of the fixed partial prosthesis is short when implant and the natural teeth are connected. For the explanation, it can be said that there are biomechanical, design, and mechanical differences between implant and teeth. In consequence of these differences;

(i) Intrusion of teeth.

(ii) Periodontal problems in teeth.

(iii) Decementation of the bridge.

(iv) Secondary caries.

(v) Lost in implant-abutment screw.

(vi) Fracture of bridges.

(vii) Osteoentegration problems in implants can be mentioned.

Theoretical problems are thought under the light of the clinical cases and help avoiding the complications related to the mobility of teeth-implant [20]. For this purpose, it will be better to consider the most common complication which is bone loss around the implant/teeth and intrusion of natural teeth.

6.1. Bone Loss. Biomechanical differences between tooth and implant were displayed by theoretical models and supported by most of scientific research which were published. As a result of these studies, excessive load is accumulated around the teeth and implants and as such the risk of marginal bone loss complications have been reported to be higher. The types of connections used in a rigid connection showed fewer complications are specified, but not completely emphasized. As well as implant-implant supported prosthesis, for the natural teeth-implant prostheses, the amount of bone loss around the abutments is a critical determinant for the evaluation of the abutment has been used as an expression [5].

Occlusal forces may affect the bone around the implant in some cases. However, it is hard to explain the reason of this effect that is why there are various factors [17].

Jemt et al. [21] concluded that existing teeth supports move as a pontic on the osseointegrated abutment and make an increase in bone loss around the collar of implant because of their peridontium. For this reason, flexibility of implant, tooth, and bone should be similar for distrubiting stresses equally and it was emphasized that periodontal ligaments of existing teeth have to be healthy when planning teeth-implant supported prosthesis.

Akça et al. (2006) [22], concluded that marginal bone surface resorption amount is negligible in rigid connection of fixed prosthesis. There are lots of researches to refer and describe rigid implant-tooth connection in the current literature [12, 23]. Teeth-supported prosthesis with rigid connection have similar mobility with implant-tooth supports bridge. However, this type of design is preferred for teeth-supported restorations mostly. There would be much more movement in the side of implant in tooth-implant-supported bridges with rigid connectors. It was shown that the implants are exposed to much more loading during photoelastic and finite element analysis [8, 24]. Especially, the load on the implants show rise with the increase of pontic number. This is the proof of supportation of the prosthesis by the implants [12, 24]. Short-term clinical success in tooth-implant-supported and implant-supported prosthesis is similar. As a result of the 24-month followup, there was no resorption in the level of marginal bone of implants despite the load increase on the implant [22].

6.2. Intrusion of Teeth. Intrusion incidence in implant-tooth-supported prosthetic designs may varies. The rate of intrusion is between 3% and 5.2% in the survey studies [17]. Rieder and Parel reported [25] that the ratio of intrusion is nearly 50% in patients with parafunctional habits. It is also concluded that there was intrusion in rigid-connection is well. Many researchers pointed that, intrusion is more common in patients with nonrigid connected restorations than rigid connected restorations, and it is explained that the cause of intrusion is the use of natural teeth as a female part of stress breaker [5, 25].

Other researchers did not report any intrusion about rigid connectors [17, 26]. However, intrusion was reported in restorations which was supported with telescopic crowns. As a result, intrusion potential of abutment cannot be ignored however connection between tooth and implant should not be considered as a disincentive connection. To avoid this dilemma, Clarke et al. [27] has advised;

(i) Selection of the appropriate patient.

(ii) The use of rigid connections.

(iii) Avoid making coping on teeth which will be used as an abutment.

(iv) Preparing the abutment to ensure maximum retention and resistance.

(v) Permanent cementation of prostheses [27].

The use of nonrigid connection is advised for homogenous load distrubition. The basic of this approach is the movement of teeth apart from implants [28]. In contrast, finite element analysis show successful results for nonrigid connections. These results are also supported by photoelastic studies however it should be kept in mind that in vitro studies cannot be imitated in the vivo conditions. For that reason in clinical studies, an intrusion of teeth was observed [29].

There are lots of theories to explain intrusion phenomenon. One of the hypothesis is “Effect of Rachet” [29]. It is referred that Rachet effect is, not returning to its original position of the teeth after occlusal loading due to the friction resistance of the parts of attachment between the rigid connectors. One other theory is debris impingement. Microjamming of food particles at the bottom of the matrix is said to cause a similar intrusion as impaction of particles will prevent the tooth from reconnecting to its original position. However, this theory is not fully explained.

Intrusion as a result of the atrophy of the periodontal ligaments was popular in the past. However, tooth may be extrused rather than being intrused in hypofunction [30].

Use of telescopic copings and overdentures is alternative to tooth-implant connections [31, 32]. Theorically, the stress caused by occlusal trauma trigger osteoclastic activity according to intrusion, The solution is to integrate a vertical lock screw into the cemented doping [33].

In recent studies with long term followups, intrusion has been reported even in cases with rigid attachments [26, 34] and the rate of bone loss was reported higher in implants with nonrigid attachments than rigid attachments [2, 34].

6.3. Other Complications in Tooth-Implant Attachments. Other causes for complications include planning of the restoration and preparations, dentition in the opposing arch and the type of implant and screws used. Therefore, it is not possible to talk about a set of technical complications that may arise in a certain case, as these factors vary according to the case and the dentist [17].

Several studies have shown that tooth-implant supported prosthesis show more technical complications compared to implant supported prosthesis [2]. Naert et al. [2] noted that there is 5% and 10% complication risk in tooth-implant supported prosthesis. Many researchers have studied about tooth-implant supported prosthesis despite these complications and researchers concluded with varying results (Table 2). Several studies have shown that natural tooth-implant supported prosthesis cause more technical problems compared to those that are implant-implant supported [2].

In recent literature, it has been reported that the use of tooth-implant supported prosthesis significantly reduce mechanical complications risk when compared to implant

Table 2: Success rate of Implant and tooth-implant supported prosthesis.

Author	Type of case	n	Time	Observation
Akça et al. [22]	3-unit bridge	34	24 months	Success rate: 100% The bone level is stable
Block et al. [26]	3-unit bridge	60	5 years	Success rate: 90.6% abutment loss Rigid results are better than nonrigid There are no differences between bone loss around the implants
Brägger et al. [18]	Various	18	4-5 years	Success rate: 97.5% (implant supported) Success rate: 95% tooth-implant supported prosthesis
Clarke et al. [27]	3-unit bridge	1	32 months	Success rate: 100%
Ericsson et al. [35]	Various	10	6–30 months	Success rate: 100%
Gunne et al. [23]	3-unit bridge	20	10 years	Success rate: 85.1% (tooth-implant supported prosthesis) There is no difference between implant-implant and tooth-implant supported prosthesis
Jemt et al. [21]	Various	20	15 years	Success rate: 98.7%
Kindberg et al. [34]	Various	41	14 weeks–9 years	Success rate: 92.85%
Lindh et al. [36]	Various	123	more than 15 years	Success rate: 98.4% (implant supported) Success rate: 94.9% (tooth-implant supported prosthesis) There are more technical problems at tooth-implant supported prosthesis

supported prosthesis. However, none of these studies include a long-term follow-up period [17].

Excessive loading on implants and/or the supporting bone is risky. When implant components are exposed to excessive stress continiously, this phenomenon leads to affecting implant components or fracture of components due to metal fatigue [9].

7. Conclusions

In dental literature reported that intrusion can be prevented with using rigid connectors, bone resorption can be reduced with using nonrigid connector in tooth-implant connection. As a result, undesirable cases can be avoided with some precautions;

(i) Using with the teeth which have healthy periodontium and dense bone.

(ii) When connecting tooth and implant, using stress breakers instead of one-piece castings which increase rigidity.

(iii) A rigid connection should be used for preparation of implant and tooth, and parallelism should be taken in account.

(iv) Permanent cementation should be preferred.

(v) Usage of the short bridges. When using a long bridge, tooth-implant connections should be avoided as much as possible.

(vi) Occlusal forces must be distributed to all supported teeth in occlusion as evenly as possible.

(vii) Generally, use of implant-tooth connection should be avoided when the patients have parafunctional habits. If we have to, maximum implant must be used.

(viii) Cantilever extensions must be avoided.

(ix) Should be noted that the fixed prostheses which have minimum abutment support have high failure rate.

(x) Implant supported restorations were preferred.

(xi) Tooth-implant connection should be established with using the posterior tooth support as far as possible.

(xii) Using more than one natural tooth support increases the achievement rate tooth-implant connection.

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