Research Article

The Morphology of Peri-Implantitis Bone Defects: A Retrospective Study on Periapical Radiographs

Alice Alberti,1,2 Benedetta Morandi,1,2 Caterina Frascolino,3 Nicolo Cavalli,2 Luca Francetti,1,2 and Stefano Corbella1,2

1Department of Biomedical, Surgical and Dental Sciences, Università degli Studi di Milano, Milan, Italy
2IRCCS Ospedale Galeazzi—Sant’Ambrogio, Milan, Italy
3Private Practitioner, Geneve, Switzerland

Correspondence should be addressed to Stefano Corbella; stefano.corbella@unimi.it

Received 28 December 2022; Revised 8 April 2024; Accepted 17 April 2024; Published 30 April 2024

Academic Editor: Hua-Hong Chien

Copyright © 2024 Alice Alberti et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Objectives. The aims of this study were to assess the morphologic features of peri-implant defects, as measured on 2D intraoral radiographs, and to investigate the possible correlation between such morphology and other parameters related to the position and characteristics of the implant or the implant-supported prosthesis. Materials and Methods. Implants with peri-implantitis were included in this retrospective study. Data collected were related both to the patients and to the position/characteristics of the implants and the implant-supported prosthesis. Measurements of the morphologic defects were performed by two operators on digitalized intraoral periapical radiographs. Results and Conclusion. In total, 73 implants in 27 patients were included. The measurements of the periapical radiograph suggested that the most common defect configuration was crateriform, with both intraosseous and horizontal components. An inverse correlation was found between the extension of the peri-implant lesion and the time between the radiographic assessment and the implant placement. The total lesion area was strongly correlated to oral hygiene levels. No correlations between lesion extension and smoking, diabetes, history of periodontal were found. In conclusion, the results from this 2D radiographic study showed the prevalence of crateriform peri-implant defects, with a hygiene-correlated extension, perceptible on the mesial and distal aspects; 3D imaging could be used when available for further research and clinical investigation.

1. Introduction

The morphology of peri-implant lesions influences both the choice of the surgical approach and the implant prognosis. It was demonstrated that the clinical success of surgical regenerative therapy of peri-implantitis also depends on the morphological features of the peri-implant lesions: in particular, contained circumferential peri-implant defects (also referred to as Class Ie) [1] registered better results in terms of probing depth (PD) reduction and clinical attachment level gain as compared to other types of defects [2].

In 2007, Schwarz et al. [1] classified the configurations of the peri-implantitis defects on the basis of clinical examination in Class I (intraosseous defects) and Class II (horizontal bone loss). Class I defects were then divided into five different configurations (a, b, c, d, and e) in relation to the position of the bone defect compared to the implant body. The authors found that the most common defect configuration was the circumferential one (Class Ie), with a frequency of 55.3% in humans [1]. Similarly, Serino et al. [3] showed that 66% of the implants showed a similar extent of bone resorption throughout the implant circumference, while in 34% of them, bone loss was larger on the buccal aspect than on other surfaces.

Another study found that 25% of the defects were circumferential combined with a buccal dehiscence, while 30% of the defects were Class Ie [4]. Probably, the fact that peri-implantitis evolves in a more aggressive and severe way in the buccal sites is due to the proximity of the dental implants to the cortical bone and the bone architecture [4–6]. In a more recent study, Monje et al. [7] proposed a new classification of peri-implantitis defects according to their morphology and severity, assessed...
through tridimensional radiographic examination. As for defect morphology, three major categories were identified, namely intrasosseous (Class I), supracrestal (Class II), and combined defects (Class III). Class I defects were further classified as A (with buccal dehiscence), B (2- or 3-wall defect), or C (circumferential defect). The severity of the peri-implant lesion was graded as slight if not exceeding 25% of the implant length, moderate if varying between 25% and 50%, and advanced if more than 50% of the implant length [7].

The primary aim of the present radiographic study was to assess the morphologic features of peri-implant defects, as measured on 2D intraoral radiographs, which are used as a standard routine for monitoring peri-implant health. Secondarily, the study aimed at investigating the possible correlations between such morphology and other parameters related to the position and characteristics of the implant or the implant-supported prosthesis. The null hypothesis is that such parameters do not affect the peri-implant defect morphology.

2. Materials and Methods

This retrospective study was conducted in accordance with the declaration of Helsinki on human studies, and it was part of a research project that was approved by the Internal Board of the IRCCS Istituto Ortopedico Galeazzi (number of approval L4153/2020). The study was reported here according to the STROBE statement.

2.1. Study Population. All patients treated with dental implants and attending the Department of Dentistry of IRCCS Istituto Ortopedico Galeazzi, Milan, from January 2005 to September 2021, were screened for inclusion, and patients with a diagnosis of peri-implantitis were considered.

Peri-implantitis was defined following the consensus report of the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions [8]. In particular, when previous clinical and radiographic examinations were present, peri-implantitis was defined as follows:

(i) Presence of bleeding and/or suppuration on gentle probing;
(ii) Increase in PD with reference to previous clinical examinations;
(iii) Radiographic loss of the peri-implant bone.

Conversely, when the patient did not attend the regular follow-ups and no clinical or radiographic data were present, a case of peri-implantitis was defined following these parameters:

(i) Presence of bleeding and/or suppuration on gentle probing;
(ii) PD ≥6 mm;
(iii) Peri-implant bone level ≥3 mm apical to the most coronal portion of the intraosseous part of the implant.

All data were treated anonymously following the current privacy norms.

2.2. Eligibility Criteria. The inclusion criteria were as follows:

(i) Patients treated with implant-supported single-crowns, fixed partial dentures, or full-arch prostheses;
(ii) Age ≥18 years;
(iii) Diagnosis of peri-implantitis;
(iv) Complete radiographic and clinical documentation, together with data about smoking habits and systemic disease.

The following exclusion criteria were applied:

(i) Intraoral radiographs with insufficient quality to perform radiographic measurements;
(ii) Intraoral radiographs which were not performed with the parallel technique with Rinn intraoral sensor holder with paralleling system rings;
(iii) Radiographic control performed with radiographic examinations other than intra-oral periapical radiograph;
(iv) Patients who did not attend to the maintenance program for more than 1 year.

2.3. Data Collection. The following parameters were recorded: age, sex, gender, smoking habit, history of periodontitis, diabetes, drugs assumption, presence of systemic diseases, frequency of professional oral hygiene recalls, hygiene levels according to the Simplified Oral Hygiene Index (John G. Greene D.M.D., M.P.H. *, Jack R. Vermillion M.P.H. The Simplified Oral Hygiene Index. The Journal of the American Dental Association Volume 68, Issue 1, January 1964, Pages 7–13).

The following data related to the implant treatment were retrieved from clinical records: age of the patient at the time of implant placement, length and diameter of the implant, implant brand, whether guided bone regeneration (GBR) was performed and, eventually, with which material, type of implant-supported prosthesis, time of provisional prosthesis placement, and time of definitive prosthesis placement.

The following measurements were then performed by two operators on digitalized intraoral periapical radiographs (Table 1; Figures 1 and 2):

(i) Maximum radius of the peri-implant lesion, as measured from the center of the implant platform to the most distant coronal bone crest level;
(ii) Mesial and distal depth of the lesion;
(iii) Mesial and distal width of the lesion;
(iv) Mesial and distal distance between the implant and the adjacent tooth or adjacent implant;
(v) Residual bone crest level (mesial and distal);
(vi) Area of the lesion on the mesial side and area of the lesion on the distal side in mm².

The operators who performed the measurements were calibrated on the first five radiographs.

2.4. Statistical Analysis. Descriptive statistical analysis was presented in terms of means and standard deviations for
3. Results

A total of 73 implants belonging to 27 patients were included in the study. Thirteen subjects were males (accounting for 30 implants), while 14 were females (43 implants), and the mean age at surgery was 56.5 ± 7.84 years. Most of the implants were positioned in native bone, while in 20 cases, GBR procedures were performed before or simultaneously with implant placement. As for implant position, the majority of the implants were placed in the posterior areas, both mandibular and maxillary, being 2.5 and 2.4 the most frequent positions (10.9% and 9.6%, respectively), followed by site 4.6 (8.2%). The type of prosthesis placed was AllOn4® in more than half of the cases, partial prosthesis on two or three implants in 23 cases, and single crowns in 9 cases. Most of the implant-supported prostheses were screw-retained. Among all implants, four failed and were extracted.

As for parameters related to well-known peri-implantitis risk factors, it was registered that 32 out of 73 diseased implants belonged to 12 smoking patients, three implants to one subject with diabetes, and 45 implants to 17 subjects with a history of periodontitis. As for oral hygiene level, patients had poor, fair, and good plaque control, respectively, in nearly 35%, 45%, and 20% of the cases (implant-level), with a recall frequency of 6 months in almost 60% of the cases. Table 2 summarizes patient- and implant-related data, while Table 1 shows the results of the registered parameters related to the peri-implant lesion morphology.

Strong correlations were highlighted between some of the evaluated parameters, in particular the mesial and distal height of the lesion \( r = 0.88, p < 0.001 \); the distal area and the mesial area \( r = 0.792, p < 0.001 \); the height of the distal lesion and the mesial area \( r = 0.719, p < 0.001 \); the width of the mesial lesion with the distal area \( r = 0.412, p < 0.001 \) and the distal height \( r = 0.381, p = 0.001 \); the width with mesial area \( r = 0.424, p < 0.001 \), mesial height \( r = 0.411, p < 0.001 \), and mesial width \( r = 0.437, p < 0.001 \). The distance of the distal element is correlated with the width of the distal lesion \( r = 0.492, p = 0.001 \); the distance of the mesial element with the mesial residual bone \( r = 0.657, p < 0.001 \) (Figure 3) and the width of the medial lesion \( r = 0.409, p = 0.003 \); the distal residual bone with the distance of the distal element \( r = 0.697, p < 0.001 \) (Figure 4). A strong correlation was also found between the total area of the peri-implant lesion and the implant brand 3i; however, the analysis was performed only on three implants from this brand, belonging to the same patient. The total lesion was strongly correlated to oral hygiene levels, with an inverse direction (Figure 5). This was confirmed by Student’s \( t \) test \( p < 0.001 \). An inverse statistically significant correlation was found between the extension of the peri-implant lesion...
and the time between the radiographic assessment and the implant placement (Figure 6). Correlations between the lesion extension and various risk factors such as smoking, diabetes, and history of periodontal disease were also explored, but no correlation was found in the investigated population.

4. Discussion and Conclusion

A careful interpretation of the results regarding the registered radiographic parameters is needed to make some clinical considerations. While some of the registered linear correlations between radiographic parameters are simply

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Result (patient-level) (n = 27)</th>
<th>Result (implant-level) (n = 73)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at surgery (years)</td>
<td>—</td>
<td>56.5 ± 7.84 (24–69)</td>
</tr>
<tr>
<td>Sex</td>
<td>M: 13; F: 14</td>
<td>M: 30; F: 43</td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smokers</td>
<td>12 (44.4%)</td>
<td>32 (43.8%)</td>
</tr>
<tr>
<td>Nonsmokers</td>
<td>15 (55.6%)</td>
<td>41 (56.2%)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1 (3.7%)</td>
<td>3 (4.1%)</td>
</tr>
<tr>
<td>History of periodontitis</td>
<td>17 (63.0%)</td>
<td>45 (61.6%)</td>
</tr>
<tr>
<td>Hygiene level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>4 (14.9%)</td>
<td>14 (19.2%)</td>
</tr>
<tr>
<td>Fair</td>
<td>12 (44.4%)</td>
<td>22 (45.2%)</td>
</tr>
<tr>
<td>Poor</td>
<td>11 (40.7%)</td>
<td>26 (35.6%)</td>
</tr>
<tr>
<td>Recall frequency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>15 (55.6%)</td>
<td>43 (58.9%)</td>
</tr>
<tr>
<td>4 months</td>
<td>7 (25.9%)</td>
<td>13 (17.8%)</td>
</tr>
<tr>
<td>3 months</td>
<td>5 (18.5%)</td>
<td>15 (20.5%)</td>
</tr>
<tr>
<td>Implant brand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NobelBiocare™</td>
<td>—</td>
<td>70 (95.9%) (Speedy Groovy™: 55 (75.3%); Replace™: 12 (16.4%); Branemark: 3 (4.1%))</td>
</tr>
<tr>
<td>3i</td>
<td>—</td>
<td>3 (4.1%)</td>
</tr>
<tr>
<td>Prosthetic rehabilitation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AllOn4®</td>
<td>—</td>
<td>41 (56.2%)</td>
</tr>
<tr>
<td>Fixed partial prosthesis</td>
<td>—</td>
<td>23 (31.5%)</td>
</tr>
<tr>
<td>Single crown</td>
<td>—</td>
<td>9 (12.3%)</td>
</tr>
<tr>
<td>Implant length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 mm</td>
<td>—</td>
<td>25 (34.2%)</td>
</tr>
<tr>
<td>15 mm</td>
<td>—</td>
<td>21 (28.8%)</td>
</tr>
<tr>
<td>10 mm</td>
<td>—</td>
<td>14 (19.2%)</td>
</tr>
<tr>
<td>11.5 mm</td>
<td>—</td>
<td>12 (16.4%)</td>
</tr>
<tr>
<td>8.5 mm</td>
<td>—</td>
<td>1 (1.4%)</td>
</tr>
<tr>
<td>Implant diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤3.5 mm</td>
<td>—</td>
<td>8 (10.9%)</td>
</tr>
<tr>
<td>&gt;3.5 and &lt;5 mm</td>
<td>—</td>
<td>64 (87.7%)</td>
</tr>
<tr>
<td>≥5 mm</td>
<td>—</td>
<td>1 (1.4%)</td>
</tr>
<tr>
<td>Prosthetic retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screw</td>
<td>—</td>
<td>61 (83.6%)</td>
</tr>
<tr>
<td>Cemented</td>
<td>—</td>
<td>11 (15.1%)</td>
</tr>
<tr>
<td>Regeneration</td>
<td>—</td>
<td>20 (27.4%)</td>
</tr>
<tr>
<td>Implant position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper anterior</td>
<td>—</td>
<td>15 (20.6%)</td>
</tr>
<tr>
<td>Lower anterior</td>
<td>—</td>
<td>10 (13.7%)</td>
</tr>
<tr>
<td>Upper molar and premolar area</td>
<td>—</td>
<td>26 (35.6%)</td>
</tr>
<tr>
<td>Lower molar and premolar area</td>
<td>—</td>
<td>22 (30.1%)</td>
</tr>
</tbody>
</table>

Continuous variables are presented in terms of mean ± standard deviation (minimum—maximum). Discrete variables are presented in terms of absolute value (percentage).
coherent with the geometry of the lesion (e.g., the height of the mesial lesion with the mesial area), some others are specifically associated with the morphologic conformation: in particular, linear correlations between mesial and distal parameters can be translated clinically in peri-implant defects involving contemporarily the mesial and distal side of the implant. For example, there was a strong correlation between the distal and mesial areas, the distal height and the mesial area, the mesial height and the distal height, the width of the mesial lesion with the distal area and the distal height, and, conversely, the distal width and the mesial area, mesial height, and mesial width. These results suggest the most common defect conformation was crateriform, with both intraosseous and horizontal components, which is in accordance with the results of Schwarz et al. [1], who most frequently observed Ie defects (55.3%), which were often combined with Class II defects. Data related to the mean total area of the lesions present a high standard deviation, which can be explained by the presence of a single
patient with a huge peri-implant lesion, which led to the extrac-
tion of the implant itself. The results regarding oral hygiene 
show how peri-implantitis is a plaque-correlated disease. Actu-
ally, the total area of the peri-implant lesion was correlated to 
oral hygiene levels. This must be considered clinically, since 
larger lesions present a challenging complexity to treatment 
and less chance of successful treatment outcome. Therefore,
it is of paramount importance to frequently monitor patients 
with poor hygiene levels, in order to timely diagnose peri-
implantitis before the development of advanced lesions.

Although this study includes only diseased implants and 
is not designed to identify factors associated with peri-
implantitis, some considerations can be made on the ana-
alyzed sample: first, only 18.9% of the implants belong to

![Figure 5: Box plot graphic showing the influence of oral hygiene on the extension of the peri-implant lesion (mm²). Despite the high variability of measures, the figure clearly shows that poor oral hygiene is associated with larger lesions.](image5)

![Figure 6: Graphic showing the correlation between the total area of the peri-implant lesion (mm²) and the time elapsed from implant placement. In this graphic too, results were stratified by oral hygiene level in order to better visualize its effect on the progression of peri-implant pathology.](image6)
patients with good oral hygiene. Moreover, two thirds of the
diseased implants were in the posterior areas, which is more
difficult to access for oral hygiene maneuvers. Similarly, more
than 80% of the prostheses supported by implants affected by
peri-implantitis were of the AllOn4
type and of the partial
multi-unit type; it can be hypothesized that the presence of the
prosthetic superstructure may have prevented patients from
cleaning properly around the neck of the implant.

As for risk factors like diabetes, smoking, and history of
periodontitis, the present study revealed a lack of correlation.
Nevertheless, this could be due to the size of the sample and the
insufficient variability of these parameters throughout the
sample. Actually, there is consistent evidence from longitudi-
nal studies and longitudinal and cross-sectional studies that
both smoking and a history of periodontitis constitute a risk
factor/indicator of peri-implantitis. For example, a 10-year
cohort study by Karoussis et al. [9] found that 18% of all
implants in smokers developed peri-implantitis, while only
6% of implants in nonsmokers were affected. Similarly, in
one study evaluating 218 patients up to 14 years after implant
therapy, implants placed in patients with a history of peri-
donitis were significantly more likely to develop peri-
implantitis compared to non-periodontal patients, with an
reported similar results after examining 109 subjects with
1–16 years of follow-up (OR = 6). One large 10-year longitudi-
nal study by Rocuzzo et al. [12] followed 101 patients with
implants and classified them as (1) periodontally not com-
promised, (2) moderately compromised, and (3) severely
compromised. The authors reported that both the frequency
of implant sites with PD ≥6 mm (2%, 16%, and 27%, respec-
tively) and bone loss ≥3 mm (5%, 11%, and 15%, respectively)
differed significantly between groups. An inverse statistically
significant correlation was found between the extension of the
peri-implant lesion and the time between the radiographic
assessment and the implant placement, which again can be
explained by the small size of the sample. In fact, peri-
implantitis is a worsening pathology, which, therefore, wors-
sens with the passage of time. An example of this is the study
by Fransson et al. [13], who evaluated 182 patients with a total
of 419 implants who presented with progressive bone loss. For
these implants, bone levels were assessed using intraoral
radiographs obtained at the 1-year examination and a
follow-up period of 5–23 years (mean: 11.1 years). The
mean bone loss was 1.7 mm, and the cumulative rates of
implants with ≥1, ≥2, or ≥3 mm bone loss were 68%, 32%,
and 10%, respectively. A multilevel growth curve model
revealed that the bone loss model was not linear and demon-
strated an increase in variance over time that was attributed to
the heterogeneity of the subjects.

Interestingly, there was no correlation between the total
area of the defect and sites regenerated with GBR techniques.
Similarly, a systematic review by Salvi et al. [14] did not reveal
any differences in the prevalence of peri-implantitis involving
implants inserted in the native and regenerated bone.

One limitation of the study consists of the use of 2D
intraoral radiographs: such radiographs exhibit some grade
of geometric distortion, they do not give any information
about the pattern of bone resorption on the bucco-lingual
dimension, they do not allow the distinction between buccal
and lingual plates [15], and, because of the superimposition
of anatomical structures, may have masked the real maximum
depth of the defect and the marginal bone levels. Although
cone beam computed tomography (CBCT) is able to provide
more information about the configuration and extension of
the peri-implant defect in all three dimensions, intraoral
radiographs exhibited higher accuracy compared to CBCT
for the measurement of its mesiodistal width, as recently
demonstrated by Steiger-Ronay et al. [16]. Actually, in their
experimental setting, CBCT always led to an overestimation
of the known defect width, especially when zirconium dioxide
implants were considered [16].

In any case, it must be noted that the use of intraoral
radiographs in the present study is linked to its retrospective
design, since periapical radiographs are routinely used in daily
practice to monitor the health of peri-implant hard tissues,
while 3D imaging is used in more complex cases where infor-
mation about the bucco-lingual dimension is needed.

Assessment of the bone level in implants with buccal
defects remains problematic, and data from intraoral radio-
graphs tend to overestimate the bone anchoring of these
implants [17]. It has been observed that intraoral radiographs
can show a resolution of 10–25 line pairs per mm, panoramic images show 3–5 line pairs, and CBCT only 1–2.
In fact, the highest likelihood ratios were found for intraoral
radiographs, indicating the best performance for intraoral
radiographs in detecting peri-implant bone defects, while
the lowest specificity was found with CT [18].

The amount of keratinized mucosa was not considered,
which is crucial for its role as a coronal seal and in maintain-
ing hygiene. Prosthetic misfit has not been considered in the
present study. Although it can be hypothesized that prosthetic
misfit may lead to a higher prevalence of peri-implantitis, a
recent review by Katsoulis et al. [19] concluded that the asso-
ciation between prosthetic misfit and a higher rate of biologi-
cal complications cannot be confirmed due to currently scarce
information on this topic. Surprisingly, a recent analysis of
193 implants with peri-implant defects found that implant-
abutment misfit was associated with slight peri-implant bone
loss (2–3 mm). The authors explained these results, hypothe-
sizing that the presence of prosthetic misfit could have actu-
ally been the peri-implant bone resorption, but once a certain
distance has been established between the prosthetic gap and
the marginal bone, the misfit itself stops contributing to fur-
ther disease progression [20].

The primary limitation of this study is the small sample
size. Future research with a larger sample size would be
valuable to validate our findings in this study.

In conclusion, the results from this 2D radiographic
study showed the prevalence of crateriform peri-implant
defects, with a hygiene-correlated extension, perceptible on
the mesial and distal aspects. Since 3D imaging of the peri-
implant tissues is not part of the clinical routine and is not
always available, our description does not take into consid-
eration bone defects that are not appreciable on 2D exam-
inations, such as dehiscence.
Further studies, possibly based on 3D imaging, are desirable to investigate any correlations that did not emerge in this analysis.

Data Availability
Data can be requested from the corresponding author.

Ethical Approval
This research was approved by the Internal Board of the IRCCS Istituto Ortopedico Galeazzi (number of approval L4153/2020).

Conflicts of Interest
The authors declare that they have no conflicts of interest.

Authors’ Contributions
Alice Alberti has done the conceptualization, methodology, writing—original draft, project administration, and data curation. Benedetta Morandi has done the writing. Alice Alberti has done the conceptualization, methodology, validation, review, and editing. All authors have read and agreed to the published version of the manuscript.

References