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Peri-Implant Bone Loss in Fixed Full-Arch Implant-Supported Mandibular Rehabilitation: A Retrospective Radiographic Analysis

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Abstract: Background: the aim of the study was to assess, through orthopantomograms (OPGs), the existence of peri-implant bone loss of distal implants in implant-supported full-arch mandibular restorations. A comparison between full-arch implant-supported rehabilitations performed in the inter-foraminal region and full-arch rehabilitations that include implant insertion distal to the mental foramen was conducted. Methods: a retrospective observational analysis of 17,950 OPGs from 2010 to 2020 was conducted. The presence of fixed implant-supported prostheses in a fully edentulous mandible was the inclusion criteria of the study. OPGs were divided according to the number of implants (four, six, and eight), position of the implants (mesial or distal to the mental foramen), and positioning patterns (models 1, 2, 3, 4, and 5). Results: a total of 51 OPGs were included in the study, 19 of which showed peri-implant bone loss. In particular, 16 belonged to the six-implant rehabilitation group and 3 to the eight-implant rehabilitation group; none of the four-implant-supported rehabilitations were affected by peri-implant bone loss. In all rehabilitations affected by peri-implant bone loss, the distal implant was the most involved, in particular the implant in positions 36 and 46. Conclusions: implants distal to the mental foramina are more susceptible than mesial implants to bone resorption in full-arch fixed implant-supported prostheses. This significant difference should be investigated further for the presence and synergy of biomechanical factors that could act predominantly in this area, such as mandibular flexure and occlusal loading.

Keywords: peri-implant bone loss; mandibular flexure; mandibular rehabilitation; fixed full-arch

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1. Introduction

The condition known as edentulism has a substantial impact on both oral health and social connections [1]. In Europe, it affects between 15% and 78% of adults over the age of 65 and, if not restored, negatively impacts the quality of life, influencing daily activities like eating and speaking, as well as psychological and cognitive functions [2]. For several years, patients who were fully edentulous could only be treated with traditional removable dentures. The development of osseointegration implantology has made it possible to restore fixed prostheses to edentulous patients, including all the complications that could affect an implant, from the amount of bone for its insertion to the development of pathologies such as peri-implantatitis [3,4]. The initial indication of osseointegrated dental implants was for completely edentulous patients [3,5].

Over the years, different methods have been developed with various implant numbers, sites, loading times, for prosthodontic superstructures up to computer-guided implant placement [6,7]. The distribution and the axial position of implants throughout the arch is a crucial factor in a full-arch rehabilitation [8]. Previous research has suggested that dental implants should be parallel to one another when supporting full-arch prostheses [9,10].

Branemark's arrangement required the implants' placement in the anterior area, parallel to one another, and splinted by a passively fitted full-arch fixed prostheses in number 5 for the mandible and 6 for the maxilla. The results of this model were encouraging and, in fact, the survival rates have exceeded 90% after 10 years [5,9].

Subsequently, Branemark et al. conducted a retrospective analysis in which they compared full-arch rehabilitations sustained by four versus six implants [9]. In a total of 156 patients with a ten-year follow-up, the results showed a comparable success rates and no significant differences in terms of bio-mechanical behavior were found between the two types of treatment [11]. In this scenario, other authors have investigated the efficiency of full-arch rehabilitations with a reduced number of implants and have effectively proved that these combinations allow for an easier passive fit of the metal frameworks and better at-home hygienic maintenance, thanks to the smaller number of implants and the greater distance between them [12].

However, the real challenge in full-arch rehabilitations of edentulous patients is the management of a bone quantity, which is not always compatible with the placement of dental implants, particularly in the maxillary and mandibular posterior sectors, and especially when associated with systemic disease or smoking habit [13–15]. In this way, grafting techniques can be used to enhance the amount of bone jaw that might support additional implants and improve the biomechanical distribution, ensuring the survival and long-term success of implants [16–19]. However, the disadvantages of this technique consist of an increased working time, cost, and potential complications [20]. As a result, researchers and clinicians are exploring alternative protocols. As an alternative to grafting, the concept of intentionally tilted implants has been proposed. According to Rangert and Krekmanov, these methods may assist to minimize cantilevers and enhance the antero-posterior distribution of implants inside an arch [21,22]. This approach has gained popularity among clinicians in recent years and could also reduce the number of implants needed to support a fixed complete-arch prosthesis. Following these considerations, the "All on 4" technique was proposed by Malò and Rangert with the aim of rehabilitating patients with extensive bone loss in the posterior mandibular/maxillary regions and also reducing the distal cantilever extension [23]. This protocol consists of the placement of two axial implants in the incisor area and another two implants just before to the mental foramen (for the mandible) or the maxillary sinus anterior wall (for the maxilla) which are slightly tilted distally to the occlusal plane with the implant plate closer to the second premolar [23]. However, from a prosthodontic point of view, this protocol involves the construction of an implant-supported fixed prosthesis with distal cantilever zones, and according to various research, this condition may put excessive stress on the implant and the peri-implant bone due to the unfavorable cantilever [24,25].

Biomechanical factors have a significant impact on the predictability and long-term success of any implant-supported rehabilitations, independent of the number and position of the inserted implants [26]. Peri-implant bone is, in fact, a structure that is subjected to continuous cycles of remodelling, and a review conducted by Kim et al. showed that phenomena of marked resorption may occur more frequently when the implant is exposed to biomechanical overload [27]. The human jaw shows a complicated biomechanical behaviour under functional load that is shared by all the long bones in the body, namely, elastic deformation under stress. The intricate structure of the bone, which is an elastic, anisotropic and non-homogeneous tissue, and its anatomical horseshoe form, which is in close contact with ligaments and muscles of the head and neck, particularly the masticatory ones, are the major causes of this phenomena.

In particular, median mandibular flexion (MMF) is a factor that can influence the success rate of dental implants in totally edentulous patients [28].

It is a complicated process of mandibular deformation caused by the contraction of the masticatory muscle system, primarily the inferior head of the lateral pterygoid muscles, which occurs mainly during opening and protrusion movements and less so during lateral movements [29,30]. MMF causes a width reduction in the mandibular arch [13]. The negative effects of mandibular flexure can cause peri-implant bone loss in cases of implant rehabilitations [31].

Therefore, from these considerations, it follows that the number and arrangement of implants required to support a fixed full-arch prosthesis is a crucial factor to consider in the planning of implant-supported rehabilitations for edentulous patients. Consequently, the aim of this study was to evaluate the presence of peri-implant bone loss in different mandibular implant-supported full-arch fixed rehabilitations through a radiographic retrospective analysis. A comparison between implant-supported rehabilitations performed in the inter-foraminal region and rehabilitations that included implant insertion distally to the mental foramen was conducted. As a secondary outcome, we aim to evaluate the presence of a possible correlation between bone loss and specific risk factors associated with the number and position of implants, in order to help clinicians in the appropriate choice of implant-supported full-arch mandibular rehabilitation for each individual case.

2. Materials and Methods

2.1. Study Design

A retrospective observational study was conducted on digital panoramic radiographs (OPGs) of 17,950 subjects taken between January 2010 and December 2020. The OPGs were acquired in a private dental clinic based in Salerno, Italy, through Orthophos Sirona radiographic device use (Sirona Dental Systems GmbH, Bensheim, Germany) and analysed through GALILEOS® imaging viewer software version 1.9 (Sirona Dental Systems GmbH, Bensheim, Germany). All the images were visualized within the same room with appropriate lighting characteristics and on the same 27-inch 4k resolution monitor (UltraSharp, Dell Inc., Round Rock, TX, USA). All the radiographs were transferred anonymously.

The radiographs included in the study had to be characterized by the presence of fixed full-arch implant-supported mandibular rehabilitation in a fully edentulous jaw with a minimum follow-up of 5 years and up to a maximum of 10 years.

Instead, exclusion criteria were the following:

- dental elements in the mandible;
- completely edentulous jaws;
- mandibles rehabilitated with dental implants supporting removable dentures;
- mandibles rehabilitated with dental implants in support of fixed prostheses with horizontal bone resorption
- full-arch rehabilitations with follow-up of less than 5 years;
- full-arch rehabilitations with follow-up more than 10 years.

Furthermore, when the OPGs had poor quality, which did not allow for the exact assessment of peri-implant bone size, these were excluded.

Two trained examiners (A.A. and V.R.) with a good level of experience in radiographic evaluation and implantology independently analysed the OPGs.

According to the number and position of the implants, the sample was divided into five models, as shown in Figure 1. The division was performed relying on full-arch rehabilitations supported by four, six, and eight implants characterized by implants placed exclusively mesial to the mental foramen or even distal to it.

Models	Implants site
Model 1	45 42 32 35
Model 2	46 44 42 32 34 36
Model 3	46 44 43 33 34 36
Model 4	47 46 44 42 32 34 36 37
Model 5	47 46 44 43 33 34 36 37

Figure 1. Models identified according to implant placement sites.

A mesial and distal-to-implant bone level measurement was carried out on all implants of the selected OPGs using the Sydexis XG software version 4.0 (Dentsply Sirona, Charlotte, NC, USA). The implant shoulder and the bone ridge were used as reference points. The distance between the implant shoulder and the bone crest mesial and distal to the implant was measured with the ruler function after calibration using the known implant diameter. The degree of accuracy was 0.05 mm. The presence of peri-implant bone defect was determined by the percent of bone loss related to the length of the implant; the chosen cut-off was 25% (Figure 1).

2.2. Statistical Analysis

Data from selected OPGs were quantitively summarized by a descriptive statistical analysis using Microsoft Excel software version 16.60 (Microsoft Corporation, Redmond, WA, USA), and frequencies and percentages were computed for implants position, number of implants, and models. A χ^2 test was performed to assess if peri-implant bone loss was influenced by the number, position of implants, and models above defined. To perform this test, initially the observed and expected frequencies of peri-implant bone loss for each model were computed. All tests with a p-value < 0.05 were considered statistically significant. Statistical analyses were performed with SPSS software version 22.0 (IBM SPSS, Armonk, NY, USA).

Then, the null and alternative hypothesis were defined:

H0: *There is no association between per-implant bone loss and models.*

H1: *There is an association between per-implant bone loss and models.*

3. Results

A total of 51 OPGs met the eligibility criteria and therefore were included in the present study.

According to number of implants, the sample included 30 (58.8%) full-arch rehabilitations on six implants, 15 (29.4%) on four implants and 6 (11.8%) on eight implants.

Based on models division, the sample consisted of 15 (29.4%) full-arch rehabilitations that followed pattern 1, 22 (43.1%) that followed pattern 2, 8 (15.7%) that followed pattern 3, 4 (7.8%) that followed pattern 4, and 2 (3.9%) that followed pattern 5.

The descriptive statistics of the frequencies and percentages related to the implants' position are shown in Table 1.

Table 1. Frequencies and percentage of implants' position.

Implant Position	Counts	% of Total
3.2	41	14.2%
3.3	10	3.5%
3.4	36	12.5%
3.5	15	5.2%
3.6	36	12.5%
3.7	6	2.1%
4.2	41	14.2%
4.3	10	3.5%
4.4	36	12.5%
4.5	15	5.2%
4.6	36	12.5%
4.7	6	2.1%

The presence of a peri-implant bone defect was detected in 19 (37.2%) of the 51 OPGs. Specifically, 16 (84.2%) belonged to the six-implant rehabilitation group and 3 (15.8%) belonged to the eight-implant rehabilitation group; none of the four-implant rehabilitations were affected by peri-implant bone loss. Instead, regarding the division into models, bone loss was obtained in 12 (63.2%) OPGs, in which full-arch rehabilitation followed pattern 2, affecting the implants in position 3.6 and 4.6, 4 (21.1%); with pattern 3 affecting the implants in position 3.6 and 4.6, 2 (10.5%); with pattern 4 affecting the implant in position 3.7, 1 (5.3%); with pattern 5 affecting the implant in position 4.7; and no one with full-arch rehabilitation that followed pattern 1. Distribution of implants with bone loss according to division into models was shown in Figure 2.

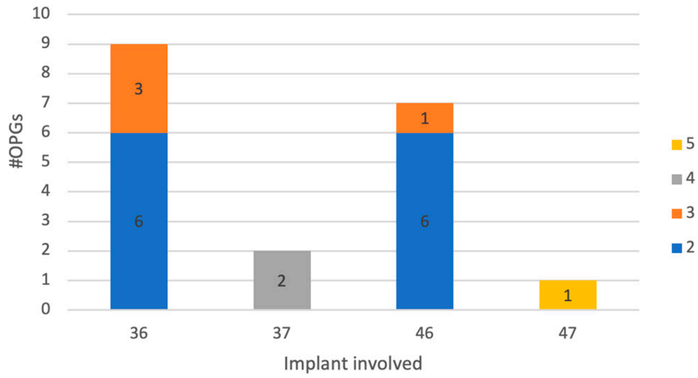

Figure 2. Distribution of implant involved in different models.

When peri-implant bone loss was detected, the most distal implant was affected in all models. In relation to implants' position, there were 17 implants with peri-implant bone defect and specifically 9 (47.4%) in position 3.6; 2 (10.5%) in position 3.7; 7 (36.8%) in position 4.6; and 1 (5.3%) in position 4.7. The distribution of implant position according to bone loss is shown in Figure 3.

Statistical analysis using a χ^2 test showed that there was a statistically significant difference between peri-implant bone loss and the number of implants (p = 0.002), the implant position (p < 0.001), and the models into which the sample was divided (p = 0.013). The distribution of peri-implant bone loss in relation to the number of implants and models is shown in Figure 4.

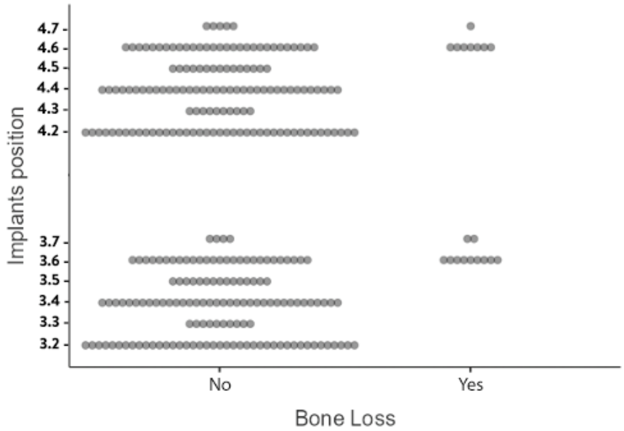

Figure 3. Distribution of implant position according to bone loss.

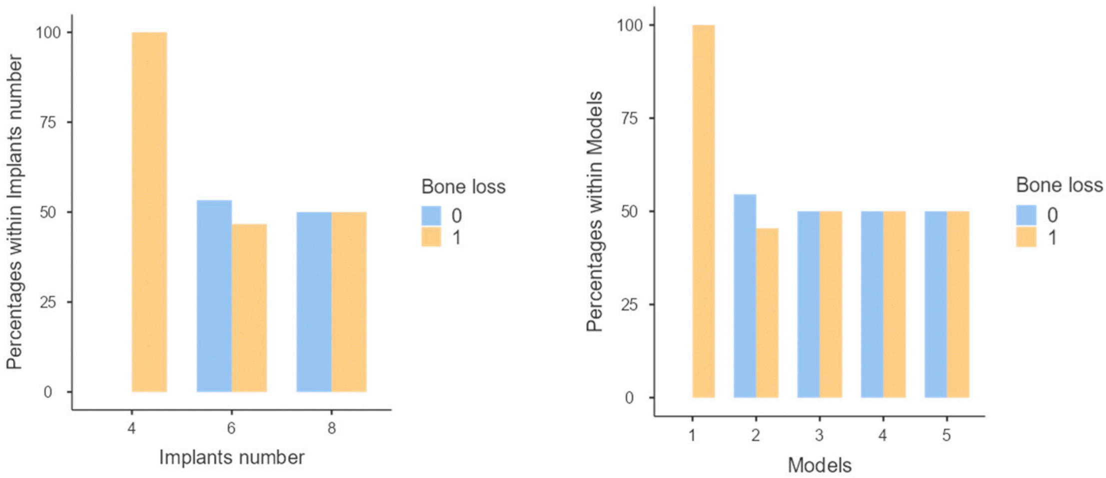

Figure 4. Distribution of peri-implant bone loss in relation to the number of implants and models. When there were 6 or 8 implants or when the implants in full-arch rehabilitation were placed following patterns 2, 3, 4, 5, the failure rate was around 50%.

4. Discussion

This study aimed to evaluate the presence of peri-implant bone defects in different implant-supported full-arch mandibular fixed rehabilitations and assess the correlation between bone loss and specific risk factors associated with the number and position of implants. The detailed breakdown of the study's sample selection and findings provides valuable insights into the prevalence of peri-implant bone loss in different implant-supported full-arch rehabilitations. The initial sample of 17,950 panoramic radiographs (OPGs) indicates the substantial scope of the study. However, it is important to note that not all of these radiographs met the inclusion criteria. The careful selection process that resulted in 51 OPGs for analysis demonstrates the rigor of the study's methodology. This process helps ensure that the final sample is representative and relevant to the research objectives. The identification of peri-implant bone loss in 19 digital radiographs that include implant placement distal to mental foramen is an interesting outcome to analyse. The study's findings showed that implants distal to the mental foramen were more vulnerable to peri-implant bone loss than those mesial to the foramen in fixed full-arch mandibular implant-supported rehabilitations. These results suggest that the number and position of implants may play a significant role on the long-term success of full-arch implant rehabilitation. According to the success criteria of Albrektsson et al., the presence of peri-implant radiotransparency, and marginal bone loss of more than 1.5 mm during the first year of loading and 0.2 mm for each year thereafter, results in implant rehabilitation failure [32]. In the new classification of peri-implant diseases and conditions of 2018, a minimum limit of 2 mm peri-implant bone loss was established in the definition of peri-implant disease, and biomechanical factors were associated with peri-implant bone loss, although the literature shows uneven opinions [33].

In addition to biological considerations, this disparity may be caused by biomechanical variables acting primarily in this region, such as mandibular flexion and load forces [34,35]. This study's results show a bone loss rate greater than or equal to 50% for models that included implant placement distal to the mentor foramen. These results reflect those emerging from the study by Myiamoto. In a research of 2003, Miyamoto et al. found that the main reason for posterior implant failure in mandibular full-arch fixed prostheses on fixed implants was mandibular flexion. Because of the rigid framework's ability to resist mandibular flexion, implants that are tightly connected together are vulnerable to significant vestibulo-lingual force during opening and protrusion [28,36]. Lateral stresses, particularly in the crestal area, may prevent osseointegration and cause peri-implant bone loss [37]. This study's findings are also in accordance with studies that have examined the relative stresses and deformations caused by mandibular bending in various fixed implant prosthodontic restorations (four or six implants, with or without a distal cantilever, a single bar or a bar divided into two or three sections). The most distal implants were affected in all models by the highest stresses.

A review of the literature revealed that the cervical area of distal implants of full-arch rehabilitations, particularly in the molar region, has greater values of the peri-implant bone tension generated by mandibular flexion [38]. According to results of the present study, due to the greater mandibular flexion values of edentulous, it is essential to consider any other factors that would further enforce mandibular flexion in full-arch rehabilitations of edentulous jaws in order to prevent it from negatively influencing implant success.

Several protocols have been proposed for fixed rehabilitation of totally edentulous patients in the mandible, and various bone augmentation techniques have been proposed to increase the volumes needed for implant placement [39,40]. However, to date, no precise number of implants has been established for an ideal rehabilitation.

The All-on-4 technique has been introduced and is generally performed in cases of a lack of bone availability in the posterior sectors [41].

However, based on the results of this study, it could be a valid solution even in the absence of severe bone atrophy of the posterior mandible, so as to avoid the problems associated with implant placement distal to the mental foramen, particularly when mandibular flexion is exacerbated by risk factors, such as patients with brachial facial type, greater jaw length, small gonial angle, and less density, length, and bone surface of the symphysis, during protrusive movements and in the posterior areas of the lower jaw [42].

In the evaluation and planning of a mandibular full-arch implant treatment it is, therefore, essential to consider all risks associated with mandibular flexion.

Limitations of the Study

A limitation of this study is that it employed the retrospective analysis of digital radiographs. The sample could, therefore, be underestimated. In several OPGs it was not possible to identify the time interval in which bone loss occurred, so these orthopantomograms were not included in the analysis. There was no assessment of PD, the presence of bleeding on probing, or signs of inflammation. Another limitation is the lack of standardization of implant type and prosthodontic superstructure.

5. Conclusions

The results demonstrate that implants distal to the mental foramen are more susceptible than mesial implants to bone resorption at the crestal level in implant-supported full-arch rehabilitations. The number and position of implants play a significant role in the long-term success of full-arch implant rehabilitation. The results of this study contribute to the existing body of knowledge on implant-supported full-arch rehabilitations and emphasize the need for further research in this area. Prospective clinical and radiographic observational studies should be carried out to confirm the results and investigate possible causes or co-causes. According to the findings, the placement of dental implants alone in the inter-foraminal region may be a clinical indication for implant-supported full-arch rehabilitations.

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Informed Consent Statement: Not applicable.

Data Availability Statement: Restrictions apply to the availability of these data. Data was obtained from a private dental clinic and are available from the authors through the e-mail contacts with the permission of third party.

Conflicts of Interest: The authors declare no conflict of interest.

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