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Retrospective radiographic evaluation of the marginal bone level changes around dental implants in posterior regions of the maxillary bone

A thesis submitted in partial satisfaction

of the requirements for the degree Master of Science

in Oral Biology

by

Emil Sebastian Pais

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ABSTRACT OF THE THESIS

Retrospective radiographic evaluation of the marginal bone level changes around dental implants in posterior regions of the maxillary bone

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Master of Science in Oral Biology

University of California, Los Angeles, 2019

Professor Perry Klokkevold, Co-Chair

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This retrospective research was performed to evaluate the marginal bone level changes around dental implants with various types of prosthetic restorations in the posterior regions of the maxillary bone that were placed by clinicians at an academic institution. Intraoral radiographs were used to evaluate the peri-implant bone level changes. The results demonstrated that there were significant differences between implants restored by platform-switching vs. platform-matching on the mesial and distal at the prosthetic restoration and the 1-year visits, and between implants in patients with diabetes vs. non-diabetes on the distal at the 1-year visit. This study complemented the present scarce literature on this topic through the identification of patient-related and implant-related characteristics that may contribute to peri-implant bone loss.

The thesis of Emil Sebastian Pais is approved.

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1. Introduction

Since the ancient times, humans have been searching for various ways to replace their missing teeth, with the purpose of restoring esthetics and function. There is evidence that the origin of oral implantology has its roots over 9,000 years ago when a tooth had been replaced by a single element that was not a human or an animal natural tooth. It was in fact a small-sized bone inserted in jaw bone without bonding (Riaud, 2017). The first evidence of dental implants appears to be dated around the year 600 when the Mayan population was using pieces of shells as implants to replace teeth, and radiographs of the Mayan jaws showed compact bone formation around the inserted implants that closely resembled the one seen around blade implants. Moreover, Ambroise Pare – perhaps anticipating futuristic methods of replacing teeth – famously stated in 1575: "A princess who had had a tooth pulled, immediately received another from another young woman. The tooth grew and became solid as before" (Abraham, 2014). Per-Ingvar Branemark revolutionized the field of oral implantology when he presented a root-form implant made of titanium as a result of an effort on developing a dental implant system using pure titanium fixtures (Branemark, 1983). While some dental implant types that followed had a modified titanium surface to increase the bone-implant interface area, others contained a mobile element to duplicate the mobility of natural teeth, and other dental implant systems were plasma-sprayed designed to be inserted in a one-stage surgical procedure to reduce the number of surgical procedures required.

The concept of *osseointegration* represented a starting point toward implant treatment improvement and predictability (Messias et al., 2019). Light and electron microscopy analyses of the bone-implant interface performed on pure titanium dental implants that were left unloaded for over three months and then connected to fixed prostheses have showed that vital peri-implant bone becomes actively remodeled in a regular manner, presumably according to the stress forces applied, allowing the entire masticatory load to be carried by the implants (Hansson et al., 1983). Some of the recent advances in implant dentistry include the use of various growth factors such as bone morphogenetic proteins (BMPs), transforming growth factors (TGFs), platelet-derived growth factors (PDGFs) in a quest to decrease the healing time and promote peri-implant bone formation. Increased implant surface roughness has been shown to stimulate the production of growth factors such as transforming growth factor beta (TGF-β), thus facilitating peri-implant osteogenesis. With the advent of the three-dimensional treatment planning, increased precision of implant placement and improved clinical outcomes benefitted oral implantology by thoughtfully implementing technological innovations in this field.

This retrospective research was performed to evaluate the marginal bone level (MBL) changes around dental implants placed in posterior regions of the maxillary bone in a diverse patient population. Patients in this population included smokers as well as patients with systemic conditions such as diabetes. The tested null hypothesis was that implant-related and/or patient-related characteristics do not adversely affect the MBL changes around dental implants placed in the posterior regions of the maxillary bone in humans. Furthermore, this study sought to complement the present scarce literature on this topic through the identification of the various factors that may contribute to peri-implant bone loss. It was expected that the findings from this study would offer a better understanding of the factors that influence the MBL changes around dental implants placed in the posterior maxilla, thus paving the way for a more detailed research in this direction.

2. Literature Review and Significance

Marginal bone loss is affected by the location of the dental implants, as it is higher in the maxillary posterior regions compared to the anterior regions (Ozgur et al., 2016). Periodontitis, smoking, and external prosthetic connection are among the factors that negatively influence bone maintenance around dental implants inserted in maxillary native bone or grafted maxillary sinuses (Galindo-Moreno et al., 2014). A recent study on bone loss around submerged and non-submerged implants in diabetic and non-diabetic patients has demonstrated that there is increased peri-implant bone loss around non-submerged implant-supported restorations in diabetic patients, which may be due to the inflammatory response (Al Zahrani & Al Mutairi, 2018). Biological complications associated with dental implants are mostly inflammatory conditions of the soft tissue and bone around implants and their restorative components, which are induced by the accumulation of bacterial biofilm (Renvert et al., 2018). Immediate or early placement of dental implants after tooth extractions may be a viable treatment with long-term survival rates and marginal bone level conditions matching those for implants placed conventionally in healed bone ridges, including the posterior maxilla (Schropp & Wenzel, 2016). It has been documented that early implant crestal bone loss during the healing period and the first year of function is often greater than bone loss occurring at subsequent years, being generally observed irrespective of dental implant types, and that surgical trauma, microgap, biologic width, occlusal overload and peri-implantitis are among the factors that may cause early implant bone loss (Oh et al., 2002). A recent study showed that peri-implant marginal bone loss rates are considerably affected by bone substratum, with a higher marginal bone loss rate associated with increased smoking consumption for grafted versus pristine bone (Galindo-Moreno et al., 2015). Regarding the composition, oxidized and acid-etched titanium mini-implants exhibit less epithelial downgrowth and longer connective tissue seal around them as compared to machined titanium mini-implants (Glauser et al., 2005). In addition, dental implants with relatively smooth and acid-etched surfaces have increased extracellular matrix components around them as compared to implants with machined surfaces (Ramaglia et al., 2013). When inserted in the atrophic posterior maxillae with sinus membrane elevation without bone grafting, rough surfaced implants have a high probability of short-term survival (Park & Yoon, 2018). Tapered soft tissue level implants inserted in maxillary sinus augmentation sites show a promising long-term survival and success rates and a low peri-implant bone resorption (Schiegnitz et al., 2016). Compared with implants with self-tapping thread design/sandblasted surface, implants with a knife-edge thread design/nanostructured calcium-incorporated surface appear to increase the peri-implant endosseous healing properties in the posterior maxilla during immediate loading conditions (Mangano et al., 2017). Dental implants restored according to the platform-switching method experience significantly less marginal bone loss than implants with matching implant-abutment diameters (Canullo et al., 2010). Also, long-term radiographic follow-up of wide-diameter dental implants restored with platform-switching demonstrates a smaller than expected vertical change in the crestal bone height around implants restored with this platform (Lazzara & Porter, 2006). The current trend is that short dental implants may be a preferable choice to bone augmentation because the treatment is faster, cheaper, less invasive, and associated with less morbidity (Bechara et al., 2017; Gastaldi et al., 2018; Bolle et al., 2018); there is also less surgical risk of sinus perforation, with an overall reduction in surgical complexity (Misch et al., 2006). Various recent studies have illustrated that short dental implants have excellent success rates when compared to long implants placed in the posterior maxilla (Felice et al., 2015; Pohl et al., 2017; Yu et al., 2017; Taschieri et al., 2018). Moreover, treatment with short dental implants proves reliable when it is used to support splinted crowns in the posterior maxilla (Han et al., 2018). In contrast, and despite the fact that there is still no consensus about the length of a dental implant for it to be considered short, a recent systematic review and meta-analysis comparing short implants (equal or less than 8 mm in length) versus standard-length implants (longer than 8 mm) placed in posterior regions of the maxillary bone and evaluating survival rates of implants, marginal bone loss, complications, and prosthesis failures, has shown that short implants with lengths between 4-7 mm should be used with caution because they present greater risks to failures compared to standard implants (Lemos et al., 2016). It was recently demonstrated that the failure risk is higher for dental implants inserted in extremely atrophic posterior maxillae of periodontally compromised patients when implants measuring 8 mm in length are placed using osteotome sinus floor elevation (Nedir et al., 2017). Narrow-diameter dental implants (less than 3.5 mm) are claimed to be an alternative to bone augmentation procedures. In this regard, a recent meta-analysis comparing the implant survival of narrow-diameter implants and standard-diameter implants revealed that narrow-diameter implant therapy is a possible solution with promising survival rates (Schiegnitz & Al-Nawas, 2018). Furthermore, it was reported in the literature that one-piece narrow-diameter selective laser sintered implants can be used in fixed prosthetic rehabilitations in the posterior maxillary regions with a predictable positive outcome (Mangano et al., 2013).

Currently, it is widely accepted that accurate cone-beam computed tomography (CBCT) images collected at an early stage before dental implant surgery offer superior implant outcomes and patient satisfaction as compared to traditional radiographic methods. In most cases when CBCT is employed, a planned dental implant site is visualized in three views (cross-sectional, axial, and sagittal). Thus, dental implant simulations can be performed in a three-dimensional space instead of a two-dimensional view, offering a high degree of precision in placement (Angelopoulos & Aghaloo, 2011). Additionally, CBCT overcomes a major limitation of conventional intraoral, cephalometric, and panoramic radiographs, providing many advantages over two-dimensional imaging (Mallya & Tetradis, 2015). CBCT also offers an accurate method for identifying and measuring important anatomical structures that are necessary to the presurgical diagnosis and planning of dental implant cases, and can be useful in measuring dimensions of potential implant sites and assessing post-surgical bone augmentation as well as implant placement; the bone density in potential implant sites is of particular importance (Klokkevold, 2015). Posterior maxillary regions exhibit the lowest cancellous bone density and the thinnest crestal cortical bone thickness among the four regions of the jaws, also having the lowest success rate of dental implant surgery (Ko et al., 2017). Together with mesio-distal (horizontal) and crestal-apical (vertical) measurements, intraoral radiography provides useful information on bone structure (Harris et al., 2012). While periapical radiographs can accurately detect more advanced defects as compared to initial bony defects, it fails to identify the correct morphology of the intra-bony component of the peri-implant defects in peri-implantitis (Garcia-Garcia et al., 2016). Moreover, it was recently reported that periapical radiographs overestimate the level of peri-implant marginal bone compared with surgical measurements, and the timing of implant placement does not influence deviation between the intraoperative peri-implant MBL measurements and the radiographically determined MBL (Cassetta et al., 2018). As a comparison, panoramic radiographs show worse results than periapical radiographs because of their lower spatial resolution and non-linear distortions (Lam et al., 1995). Furthermore, assessing radiographic bone levels around single Branemark dental implants involves specific differences in interpretation related to radiographic brightness, examiner accuracy, and implant characteristics, among other factors. Thus, measurement reliability, consistency, and accuracy are central to providing the profession with precise data (Walton & Layton, 2018).

The main objectives of this research were to assess the influence of dental implant characteristics on the peri-implant MBL changes using intraoal radiographs and to evaluate the influence of patient characteristics such as systemic health and diseases (diabetes) together with periodontitis and smoking on the peri-implant MBL changes in posterior maxillae. In addition, the author performed an evaluation of the influence of the dental implant restoration type on the MBL changes around dental implants inserted in posterior maxillary regions using intraoral radiographs.

3. Research Design and Methods

This retrospective research has been chosen because it was anticipated that the available data would describe in detail the role of various factors and their possible interrelationships leading to the bone loss around dental implants placed in human posterior maxillary regions by Postgraduate Periodontics residents at the University of California, Los Angeles, School of Dentistry. According to the availability of intraoral radiographs at the time of implant placement, prosthetic restorative phase, and 1-year follow-up, this research included a number of 59 patients (32 males and 27 females) with the age between 30 and 86 years that received 119 dental implants placed in the posterior maxillary bone (premolar and molar sites). Based on their length, the implants have been divided into two categories: implants measuring 10 mm and longer, and implants measuring less than 10 mm.

Data from the dental records collected for the patients with dental implants included: age, gender, systemic conditions (diabetes), smoking habits (non-smokers, smokers), parafunctional habits (clenching, bruxism), dental implant characteristics and restoration types, opposing dentition after implant placement, along with histories of periodontal disease (periodontitis) and peri-implant diseases (peri-implant mucositis, peri-implantitis). The influence of dental implant characteristics such as: brand, design, surface morphology, dimensions (length, diameter), along with the surgical procedure (one-stage/non-submerged, two-stage/submerged), maxillary bone substratum (native, grafted), and the presence or absence of maxillary sinus augmentation on the marginal bone of dental implants restored by a crown, bridge or prosthesis was considered for evaluation.

A desktop computer available in the Section of Periodontics, Division of Constitutive and Regenerative Sciences at the University of California, Los Angeles, School of Dentistry was used to retrieve available de-identified intraoral radiographs (periapical, bitewing) used in this study by accessing the XDR imaging software within the AxiUm software application to evaluate the peri-implant bone level changes. Thus, the author measured the vertical bone level around each dental implant on the immediate post-surgical radiographs, final implant restoration radiographs, and 1-year follow-up radiographs of the restored implants; the entire data collected was stored on the desktop computer mentioned above. To measure the peri-implant MBL on radiographs, the author marked the distance as a line from the dental implant-abutment interface until the first contact of the bone with the implant at the mesial and distal aspects (along an axis parallel to the dental implant) together with a measurement of the dental implant width at its neck (perpendicular to the dental implant); all radiographs had grids applied to them to guide with taking the measurements. These measurements were presented in millimeters (mm) and performed by the author on radiographs that were stored as distinct image files (along with a set of duplicates of the original radiographs stored as image files) on the aforementioned desktop computer located in the same room where the author was surrounded by both natural and artificial light while performing the measurements using a 1920 x 1080 resolution monitor connected to the same desktop computer. In addition, the measurements are useful for determining the dimensions of the dental implants on distorted radiographic images based on known implant dimensions. Also, to determine the MBL changes at the prosthetic restorative phase and at the 1-year follow-up, the MBL values obtained at the surgical procedure were subtracted from the MBL values obtained at these two subsequent intervals. The same desktop computer mentioned above was utilized to obtain the mean MBL values using the Microsoft Excel software. Two-tailed t-Test analysis was used to compare the mean MBL values in smoker vs. non-smoker group, diabetes vs. non-diabetes group, platform-switching vs. platform-matching group at both the prosthetic restorative phase and the 1-year follow-up. The data was presented as mean ± standard deviation.

The main limitations of this research consisted of an insufficient number of intraoral radiographs available for each dental implant placed in maxillary posterior regions at different post-surgical visits, and that there were radiographs showing horizontal overlapping along with image distortions, artifacts, or partial visualization of the dental implant and the peri-implant bone (e.g., cone-cut, blurring). Another limitation consisted of difficulty in obtaining measurements as described above due to various radiographic factors. Adjusting the measurements was made according to each particular situation (e.g., a measurement was taken from the dental implant-crown interface until the first contact of the bone with the implant on the mesial and distal aspects in cases of unclear demarcation of the abutment; different labeling was used to mark the marginal bone level). Also, variations in follow-up times, accuracy of the dental records data within the AxiUm software, and the fact that evaluating radiographic peri-implant bone levels involves certain differences in interpretation represented other study limitations.

4. Results

The author found that according to the dental records 25 patients had a history of smoking (smoker group), 25 patients did not have a history of smoking (non-smoker group) and a history of smoking could not be identified in 9 patients. While a history of diabetes was identified in 8 patients (diabetes group), there was one patient without a history of diabetes, while a history of diabetes could not be identified in 50 patients. In addition, 13 patients had a history of parafunctional habits (clenching and bruxism – either single or combined forms), and 46 patients could not be identified for having any parafunctional habits. Most patients had a history of periodontitis, three patients were diagnosed with peri-implant mucositis and six patients were diagnosed with peri-implantitis.

Radiographically, only a few of the inserted dental implants exhibited vertical MBL values up to 3.77 mm on the mesial aspect and up to 4.39 mm on the distal aspect at the prosthetic restorative phase, and up to 4.47 mm on the mesial aspect and up to 3.88 mm on the distal aspect at the 1-year visit.

The average peri-implant vertical MBL values irrespective of the groups analyzed were the following:

a) Prosthetic restorative phase: 1.58 mm at the mesial aspect and 1.54 mm at the distal aspect;
b) 1-Year follow-up: 1.52 mm at the mesial aspect and 1.57 mm at the distal aspect.

Comparing the non-smoking vs. smoking, non-diabetes vs. diabetes, and platform type (matching vs. switching) groups, the following were the average vertical MBL values:

a) Prosthetic restorative phase:

    i. Non-smoking vs. smoking: 1.65 mm at the mesial aspect and 1.38 mm at the distal aspect in the non-smoking group; 1.52 mm at the mesial aspect and 1.65 mm at the distal aspect in the smoking group;

    ii. Non-diabetes vs. diabetes: 1.74 mm at the mesial aspect and 2.26 mm at the distal aspect in the non-diabetes group; 1.81 mm at the mesial aspect and 1.83 mm at the distal aspect in the diabetes group;

    iii. Platform-matching vs. platform-switching: 1.66 mm at the mesial aspect and 1.72 mm at the distal aspect in the platform-matching group; 1.36 mm at the mesial aspect and 1.17 mm at the distal aspect in the platform-switching group.

b) 1-Year follow-up:

    i. Non-smoking vs. smoking: 1.52 mm at the mesial aspect and 1.15 mm at the distal aspect in the non-smoking group; 1.44 mm at the mesial aspect and 1.58 mm at the distal aspect in the smoking group;

    ii. Non-diabetes vs. diabetes: 2.17 mm at the distal aspect in the non-diabetes group; 1.07 mm at the mesial aspect and 1.04 mm at the distal aspect in the diabetes group;

    iii. Platform-matching vs. platform-switching: 1.85 mm at the mesial aspect and 1.82 mm at the distal aspect in the platform-matching group; 1.06 mm at the mesial aspect and 1.09 mm at the distal aspect in the platform-switching group.

The exception for obtaining an average MBL value is the non-diabetes group at the 1-year follow-up due to the fact that there was only one measurement performed (i.e., mesial aspect showed a vertical MBL value of 1.97 mm).

At the time of prosthetic restorative phase, and regardless of gender and age, patients with a history of diabetes lost up to around 3 mm of peri-implant bone, while a non-diabetic patient lost up to around 4 mm of marginal bone according to the radiographic measurements. In addition, patients with a history of smoking lost approximately 4 mm of marginal bone around the implants placed, while non-smokers lost up to around 4 mm. At the 1-year follow-up, patients with a history of diabetes experienced less than 2 mm of radiographic peri-implant bone loss, while there was up to around 2.5 mm of bone loss in a non-diabetic patient. Also, patients with a history of smoking exhibited marginal bone loss of up to approximately 3 mm, while non-smokers lost up to approximately 4.4 mm of marginal bone, irrespective of age and gender.

According to the AxiUm dental records, there were 40 Biomet 3i implants, 38 Straumann implants, 10 Astra Tech implants, 8 Nobel Biocare implants, 5 BioHorizons implants, 3 AnyRidge implants, 1 Genesis implant, 1 ST implant, 1 Southern Trimax implant, while 12 brands were unknown. There were 3 narrow-diameter implants and 99 standard-diameter implants, along with 93 implants measuring 10 mm and above in length and 9 implants measuring less than 10 mm in length. The dental implant restoration type was represented by 58 single and 42 splinted implant-supported crowns, implant-supported bridges (4 implants), and fixed implant-supported hybrid (metal-resin) prostheses (3 implants). Concerning the implant platform used, 44 implants were restored by the platform-matching and 47 implants by the platform-switching methods. In relation to the surgical procedure, there were 29 non-submerged implants and 25 submerged implants. Native posterior maxillary bone substratum was identified in 44 implant sites, while bone grafting was found in 46 implant sites. Moreover, maxillary sinus augmentation was found in 14 maxillary regions. The radiographic analysis of the opposing dentition (i.e., mandibular posterior regions) showed that 91 of the inserted dental implants were opposed by natural teeth, 19 of the implants were opposed by other dental implants, and 1 implant was opposed by a dental bridge.

When considering the bone loss based on implant characteristics, while three Biomet 3i tapered implants measuring 10 mm and 11.5 mm in length and 4 mm in diameter that were part of fixed hybrid prostheses exhibited bone loss ranging from 2.76 mm to 2.91 mm at the mesial aspect and from 0.89 mm to 2.76 mm at the distal aspect at the prosthetic restorative phase, four tapered submerged implants (two Biomet 3i implants each measuring 11.5 mm in length and 6 mm in diameter, and 10 mm in length and 4 mm in diameter – one of which was restored by platform-matching; two Nobel Biocare implants each measuring 8 mm in length and 5 mm in diameter, and 10 mm in length and 4 mm in diameter restored by platform-matching) experienced bone loss ranging from 0.35 mm to 2.07 mm at the mesial aspect and from 0.71 mm to 2.48 mm at the distal aspect at the same time interval; these implants were placed in patients with a history of periodontitis, with both native and grafted bone with or without maxillary sinus augmentation. However, platform-switching method and non-submerged implants experienced better marginal bone preservation as compared to their counterparts, but implants restored using internal prosthetic connections experienced marginal bone loss at early stages post-surgery. Furthermore, the OsseoSpeed implant offered good outcomes in terms of marginal bone levels. Peri-implant mucositis was identified in one Biomet 3i submerged implant measuring 10 mm in length and 4.1 mm in diameter with Osseotite surface placed with maxillary sinus augmentation and part of a restoration using splinted crowns, and in two Straumann implants measuring 12 mm in length and 4.1 mm in diameter restored by a wide 6.5 mm platform-matching and part of a restoration using splinted gold crowns. Peri-implantitis was found in the same Straumann implants mentioned above, along with one BioHorizons implant measuring 12 mm in length and 4.6 mm in diameter restored by a porcelain-fused-to-metal crown (PFM), one Biomet 3i non-submerged implant measuring 13 mm in length and 4 mm in diameter restored by platform-switching that was included in a dental bridge, and in two submerged Nobel Biocare implants (one measuring 10 mm in length and 4 mm in diameter and another measuring 8 mm in length and 5 mm in diameter) restored by platform-matching and single PFMs.

A 62 year-old non-smoker female patient with a history of periodontitis, parafunctional habits (clenching), and peri-implantitis that received one Nobel Biocare tapered and submerged 8-mm-long implant with a diameter of 5 mm in native bone and restored by platform-matching and PFM crown experienced over 1 mm of peri-implant marginal bone loss (MBL measurements were 1.67 mm at the distal aspect at the restoration phase, and 4.38 mm at the mesial aspect and 2.47 mm at the distal aspect at the 1-year follow-up).

The mean MBL values on the mesial aspect of the dental implants at the prosthetic restorative phase in smoker patients (1.13 ± 0.85) vs. non-smoker patients (0.77 ± 1.04) with p-value=0.059 showed that this difference is considered to be not quite statistically significant. This was also the case when comparing the mean MBL values on the mesial aspect of the implants at the 1-year visit in smoker patients (1.12 ± 0.85) vs. non-smoker patients (0.76 ± 1.04) with p-value=0.059 that showed that this difference is considered to be not quite statistically significant. When comparing the mean MBL values on the mesial aspect of the implants at the prosthetic restorative phase in patients with diabetes (0.51 ± 0.99) vs. non-diabetes patients (1.16 ± 0.82) with p-value=0.29, the difference is considered to be not statistically significant; the same situation was encountered while comparing the mean MBL values on the mesial aspect of the implants at the 1-year visit in patients with diabetes (0.57 ± 0.64) vs. non-diabetes patients (0.98 ± 0.98) with p-value=0.41 when this difference is considered to be not statistically significant. Nevertheless, statistically significant difference was found in the mean MBL values on the mesial at the prosthetic restorative phase between implants restored by platform-switching (0.57 ± 0.83) vs. platform-matching (1.21 ± 0.99) with p-value=0.0013. Similarly, the mean MBL values on the mesial at the 1-year visit between implants restored by platform-switching (0.50 ± 0.68) vs. platform-matching (1.44 ± 1.16) with p-value=0.0001 showed that this difference is considered to be extremely statistically significant. On the distal aspect at the prosthetic restorative phase, the mean MBL values comparing implants inserted in smoker patients (1.10 ± 1.00) vs. non-smoker patients (0.84 ± 0.87) with p-value=0.17 demonstrated that this difference is considered to be not statistically significant. Similarly, this was also the case at the 1-year visit when comparing the mean MBL values at the distal aspect of the implants placed in smoker patients (1.09 ± 0.90) vs. non-smoker patients (1.04 ± 1.06) with p-value=0.79 when this difference is considered to be not statistically significant. In addition, the mean MBL values at the distal aspect at the prosthetic restorative phase comparing implants inserted in patients with diabetes (0.61 ± 0.82) vs. non-diabetes patients (1.50 ± 1.11) with p-value=0.10 showed that this difference is considered to be not statistically significant. In contrast, at the 1-year follow-up, a statistically significant difference was found when comparing the mean MBL values at the distal aspect of the dental implants inserted in patients with diabetes (0.76 ± 0.66) vs. non-diabetes (2.16 ± 0.33) with p-value=0.0024. Also, statistically significant difference was found both at the prosthetic restorative phase on the distal when comparing the mean MBL values between dental implants restored by platform-switching (0.63 ± 0.73) vs. platform-matching (1.23 ± 0.98) with p-value=0.0014 and at the 1-year follow-up with the mean MBL values at the distal aspect of the implants restored by platform-switching (0.61 ± 0.66) vs. platform-matching (1.61 ± 0.99) with p-value=0.0001.

The following radiographs are representative for this study.

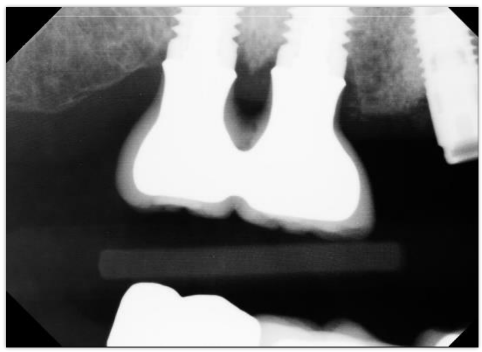

Figure 1. Two dental implants placed in maxillary molar sites, restored by splinted crowns, in a non-smoker patient with histories of periodontitis and diabetes (1-Year follow-up). Note the bone level extending below the shoulder of both restored implants.

Figure 2. Two dental implants inserted in maxillary bone, restored by platform-matching and single crowns, in a smoker patient with history of periodontitis, without diabetes (1-Year follow-up). Observe the peri-implant bone level at the second thread of the implant on the left side.

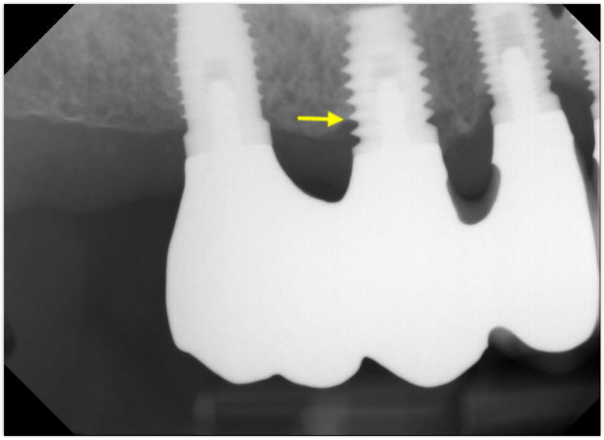

Figure 3. Dental implants inserted in maxillary native bone (molar and premolar sites) that were restored by platform-matching and splinted crowns, in a patient with a history of periodontitis (1-Year follow-up). The arrow indicates the bone level that extends to the second thread around one of the implants.

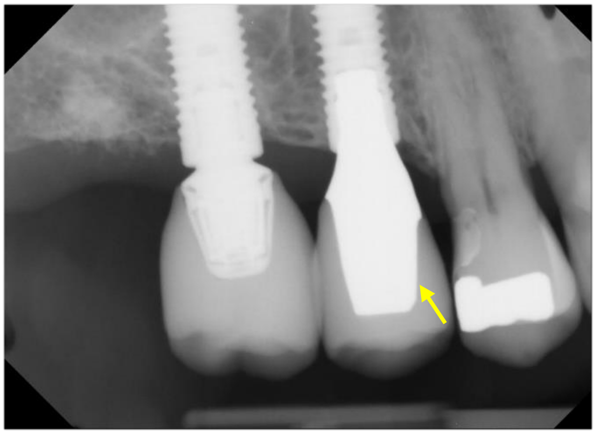

Figure 4. Two dental implants placed in maxillary molar and premolar native bone, restored by platform-switching (arrow) and single crowns, in a non-smoker patient with a history of periodontitis (1-Year follow-up). Observe the bone level at the shoulder of the implant restored by platform-switching.

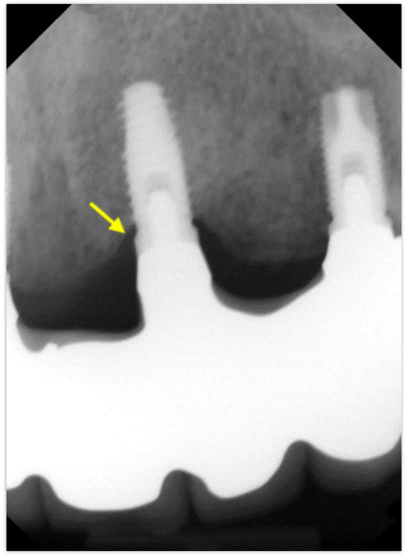

Figure 5. Dental implant (left side) placed in a maxillary premolar grafted site, restored by platform-matching (1-Year follow-up). Note the marginal bone level extending well below the implant shoulder (arrow) as compared to the adjacent implant (right side).

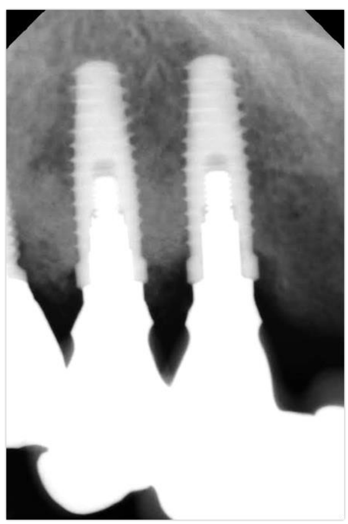

Figure 6. Two dental implants inserted in premolar sites with maxillary sinus augmentation, restored by platform-switching and part of a dental bridge, in a smoker patient, diagnosed with peri-implantitis (1-Year follow-up). Note the bone level situated well below the shoulder of both implants.

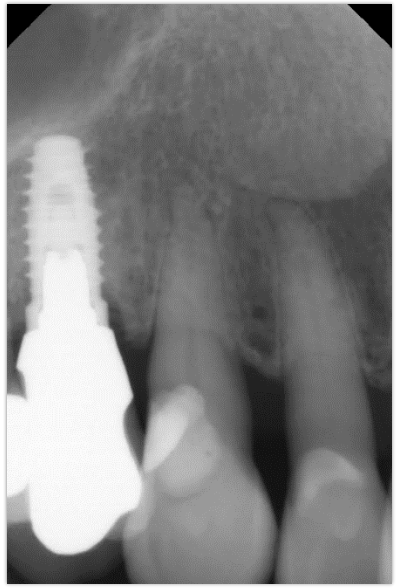

Figure 7. Dental implant inserted in a maxillary premolar site, restored by platform-matching and a single crown, in a smoker patient with a history of periodontitis (1-Year follow-up). Note the bone level extending below the implant shoulder.

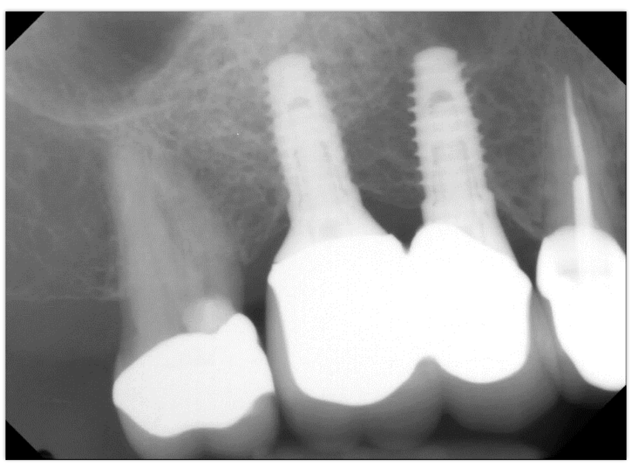

Figure 8. Two dental implants placed in molar and premolar sites with maxillary sinus augmentation, restored by platform-matching and splinted crowns, in a smoker patient, diagnosed with peri-implant mucositis (1-Year follow-up). Observe the bone levels extending below the shoulder of both implants.

5. Discussion

This research has demonstrated that the implant outcomes achieved by novice clinicians at an academic institution were comparable to those obtained by more experienced clinicians that were reported in the specialty literature. In addition, this study is the first to consider for analysis a multitude of implant-related and patient-related characteristics.

A long-term retrospective study conducted by Ozgur et al. (2016) analyzed the effect of dental implant brand, location, size, occlusal table width, cantilever, and smoking on marginal bone loss during a 6-year period, and reported that radiographic bone loss in posterior maxillary region was higher than in anterior region. Moreover, there were no significant associations between smoking history and non-smoking groups, and there was no significant relationship between smoking and marginal bone loss. The authors also reported that the implant diameter and length do not affect the peri-implant bone loss. In the present research, the author found that at the time of prosthetic restorative phase, smoker patients experienced average MBL values of 1.52 mm at the mesial aspect and 1.65 mm at the distal aspect, while at the 1-year follow-up, smoker patients had average MBL values of 1.44 mm at the mesial aspect and 1.58 mm at the distal aspect. In non-smoker patients, the average MBL values were 1.65 mm at the mesial aspect and 1.38 mm at the distal aspect at the prosthetic restorative phase, and 1.52 mm at the mesial aspect and 1.15 mm at the distal aspect at the 1-year visit. These values were consistent with those reported in the literature within the first year of function.

Research performed by Galindo-Moreno et al. (2014) has indicated that cumulative radiographic marginal bone loss values may reach 3.9 mm after 3 years of functional loading of implants placed in both maxillary native bone and grafted maxillary sinuses in posterior regions. Smoking independently influenced bone loss at both mesial and distal aspects. An association between history of periodontitis and increased marginal bone loss was also observed in that study, except on distal aspects at 2 years and 3 years. Increased marginal bone loss was also associated with advanced age. At the same time, history of periodontitis, smoking, and age demonstrated that peri-implant marginal bone loss was higher in grafted (1.09 mm) than in pristine (0.71 mm) bone. Marginal bone loss was significantly higher around implants with external (1.30 mm) than with internal (0.50 mm) prosthetic connections. As a comparison, the author found in the present study that a few MBL values at the 1-year of function were equivalent to the 3-year values reported by Galindo-Moreno and colleagues. Histories of periodontitis and smoking, and advanced age might have contributed to increased marginal bone loss at early stages post-surgery, along with restorations using internal prosthetic connections. Nevertheless, patients with a history of periodontitis receiving seven Biomet 3i implants measuring 10 mm and longer in length (10 mm and 11.5 mm) and 4 mm in diameter that were restored with external connections, platform-matching, and either splinted crowns or hybrid prosthesis lost from 0.76 mm to 2.91 mm of bone at the mesial aspect and from 0.27 mm to 2.56 mm at the distal aspect at the prosthetic restorative, the bone loss at the 1-year visit ranged from 0.57 mm to 1.16 mm at the mesial aspect and from 0.46 mm to 1.54 mm at the distal aspect.

Recently, a 7-year observational study conducted by Al Zahrani & Al Mutairi (2018) has indicated that non-submerged dental implants express more bone loss in diabetic patients as compared to non-diabetic patients, and that peri-implant bone loss is significantly greater in diabetic patients than in non-diabetic patients. Particularly, peri-implant bone loss varied from 0.53 mm at the 1-year visit to 1.1 mm at the 7-year visit in diabetic patients and from 0.23 mm at the 1-year visit to 0.58 mm at the 7-year visit in non-diabetic patients. The authors concluded that the unfavorable peri-implant bone level changes may be due to the inflammatory response in diabetic patients. In this study, non-diabetic patients experienced average MBL values of 1.74 mm at the mesial aspect and 2.26 mm at the distal aspect, while the diabetic group exhibited average MBL values of 1.81 mm at the mesial aspect and 1.83 mm at the distal aspect at the prosthetic restorative phase. At the 1-year follow-up, non-diabetic patients had average MBL values of 2.17 mm at the distal aspect, while the diabetic group had 1.07 mm at the mesial aspect and 1.04 mm at the distal aspect. These values were higher than those reported by Al Zahrani & Al Mutairi between the 1-year and the 7-year visits. At the 1-year follow-up, a statistically significant difference was found when comparing the mean MBL values at the distal aspect of the dental implants inserted in patients with diabetes (0.76 ± 0.66) vs. non-diabetes (2.16 ± 0.33) with p-value=0.0024.

Renvert et al. (2018) have showed that biological complications associated with dental implants are mostly inflammatory conditions of the soft tissue (peri-implant mucositis) and bone (peri-implantitis) around implants and their restorative components, which are induced by the accumulation of bacterial biofilm. Within the limitations of this study, the author found that there were very few patients with peri-implant diseases post-surgery according to only a retrospective dental record review.

A review performed by Oh et al. (2002) has demonstrated that early dental implant crestal bone loss during the healing period and the first year of function is often greater than bone loss occurring at subsequent years, being generally observed irrespective of dental implant types. It was reported that etiologic factors causing early implant bone loss include, among others, surgical trauma, occlusal overload, peri-implantitis, and microgap. For instance, the authors found that occlusal overload may often lead to marginal bone loss or deosseointegration of successfully osseointegrated implants. There is also minimal peri-implant bone loss (equal or less than 0.2 mm) annually after the first year of function. As a comparison to the study performed by Oh and colleagues, the results of the present research demonstrated that peri-implantitis that occurred in a few implants within the first year post-surgery was one of the causative factors of marginal bone loss. In addition, the microgap found in a few implant restorations might have been associated with the peri-implant diseases, thus leading to the marginal bone loss. Nevertheless, irrespective of the factors identified, the average MBL values were consistent with those published in the literature concerning the amount of bone loss in the first year of implant function.

Research conducted by Galindo-Moreno et al. (2015) has shown that at 18 months following dental implant placement, 96% of the implants had a marginal bone loss over 2 mm, losing 0.44 mm or more at 6 months post-loading, and that marginal bone loss rate was higher with increased smoking consumption for grafted versus pristine bone. While marginal bone loss was more related to the prosthetic phase as compared to the post-surgical bone healing and remodeling process, a history of periodontitis was not significantly related to the marginal bone loss. In the present research, the author also found similarities with those reported by Galindo-Moreno and colleagues in that a few implants exhibited MBL values higher than 2 mm at the 1-year visit post-surgery in both smokers and non-smokers, but irrespective of the maxillary bone substratum.

A light-microscopic overview and histometric analysis on peri-implant soft tissue barrier (term used interchangeably with biologic width/seal) at experimental one-piece titanium mini-implants (10 mm in length and 2.3 mm in diameter) with different surface topography placed in posterior human jaws conducted by Glauser et al. (2005) revealed an overall height of the biologic width of approximately 4-4.5 mm consisting of an epithelial and a supracrestal connective tissue barrier. Glauser and colleagues concluded that oxidized and acid-etched mini-implants exhibited less epithelial downgrowth and longer connective tissue seal than machined mini-implants and, strikingly, that there was a slightly increased height of the peri-implant soft tissue barrier compared to animal studies and natural teeth, suggesting that a specific tissue response is important in protecting the soft tissue-implant interface from bacterial invasion and biomechanical challenges. In a similar manner, Ramaglia et al. (2013) showed that dental implants with relatively smooth and acid-etched surfaces have increased extracellular matrix components around them as compared to implants with machined surfaces. Particularly, Ramaglia and colleagues demonstrated that the microtopography of a double acid-etched rough surface may induce a greater collagen and fibronectin production, thus conditioning the biological behavior of human gingival fibroblasts during the process of peri-implant soft tissue healing. In the present research, while the author was not seeking to evaluate the peri-implant biologic seal or the extracellular matrix, it was demonstrated that the OsseoSpeed implant provided good outcomes in terms of marginal bone levels. Additionally, peri-implant mucositis was identified in one Biomet 3i submerged implant measuring 4.1 mm in diameter and 10 mm in length with Osseotite surface placed with maxillary sinus augmentation and part of a restoration using splinted crowns, and in two Straumann implants measuring 4.1 mm in diameter and 12 mm in length restored by a wide 6.5 mm platform-matching and part of a restoration using splinted gold crowns.

Park & Yoon (2018) have conducted a study to compare the clinical and radiographic outcomes of two types of rough surfaced implants after placement in the atrophic posterior maxilla with sinus membrane elevation without bone grafting. The length of all two-piece, non-submerged implants placed in the study was 10 mm. CBCT images were taken to evaluate the amount of bone gain in the maxillary sinus, while standardized periapical digital radiographs were used to evaluate the changes in the crestal peri-implant bone level and peri-implant fixture radiolucency. Their results revealed that the full length of both types of rough surfaced implants measuring 10 mm in length was covered with bone after the sinus floor elevation without bone grafting procedure during the 2-year follow-up period.

A clinical and radiological evaluation of the long-term success of tapered soft tissue level dental implants placed transgingivally and supracrestally that was conducted by Schiegnitz et al. (2016) revealed a lower marginal bone loss in patients receiving maxillary sinus augmentation compared with patients having alveolar ridge augmentations. In spite of these findings, the osseointegrated dental implants placed following a two-stage approach showed predominantly healthy tissue conditions (61.3%) versus peri-implant mucositis (28%) and peri-implantitis (10.7%), while the implant diameter showed no significant influence on implant survival. These findings are consistent with the author's results that revealed a very low proportion of peri-implant diseases (3 patients with peri-implant mucositis and 6 patients with peri-implantitis).

Mangano et al. (2017) have compared implants with self-tapping thread design/sandblasted surface versus implants with a knife-edge thread design/nanostructured calcium-incorporated surface and found that the latter appear to increase the peri-implant endosseous healing properties in the posterior maxilla during immediate loading conditions. The one-piece, transitional transmucosal implants used in their study were all made of titanium grade 4, with dimensions of 3 mm in diameter and 6 mm in length, but were different in the macro- and micro/nanotopography. In the present research, the author found that the OsseoSpeed implant provided good outcomes in terms of marginal bone levels.

It was demonstrated by Canullo et al. (2010) that dental implants restored according to the platform-switching concept experienced significantly less marginal bone loss than implants with matching implant-abutment diameters over a period of almost 3 years. In three patients, radiographic evaluation demonstrated that a 4.3-mm-diameter implant had slightly less bone loss than a 4.8-mm-diameter implant with wider platform, and in one patient, a 4.3-mm-diameter implant showed slightly more bone loss compared to a 3.8-mm-diameter control implant; all abutments measured 3.8 mm in diameter. The authors also found that platform-switching may increase the distance between the abutment-associated inflammatory cell infiltrate and the marginal bone level, resulting in a decrease in its bone-resorptive effect. It was concluded that the findings could possibly be attributed to a wider space for horizontal repositioning of the biological width and/or a better distribution of loading stress at the bone-implant interface. In a similar fashion, Lazzara & Porter (2006) reported that long-term radiographic follow-up of wide-diameter dental implants restored using the platform-switching method demonstrates a smaller than expected vertical change in the crestal bone height around implants restored with this platform. Both studies conducted by Canullo and colleagues and Lazzara & Porter show similarities with the author's present research observations in that the platform-switching method and non-submerged implants experienced better marginal bone preservation as compared to their counterparts.

A study conducted by Bechara et al. (2017) evaluated whether short (6 mm in length) dental implants (test group) could be an alternative to sinus floor elevation and placement of standard-length (10 mm or longer in length) implants (control group) in the posterior maxilla. All implants were tapered and loaded after 4 months of healing. Mean marginal bone loss was significantly higher in the control group than in the test group, both at 1 year (0.14 mm versus 0.21 mm) and at 3 years (0.20 mm versus 0.27 mm). The authors concluded that the results for short implants were similar to those for standard-length implants in augmented bone. As a comparison, the author found in the present research that the MBL values for implants measuring less than 10 mm in length were between 0.72 mm and 4.38 mm post-surgery.

Gastaldi et al. (2018) have reported that patients with prostheses restorations on maxillary submerged short implants (5 mm in length) lost on average 1.04 mm of peri-implant bone at 3 years and patients with 10 mm or longer maxillary implants lost 1.43 mm, demonstrating that longer implants show a greater bone loss up to 3 years after loading as compared to short implants. The author found in the present research that the MBL values for submerged implants measuring less than 10 mm in length were between 0.89 mm and 4.38 mm post-surgery.

A 1-year follow-up study performed by Bolle et al. (2018) evaluating whether 4-mm-short dental implants could be an alternative to augmentation in the maxilla and placement of at least 10-mm-long implants in posterior atrophic maxillary regions revealed that 1 year after implant loading, 4-mm-short implants achieved similar results, if not better, than 10 mm or longer inserted implants, but were affected by fewer complications. The results showed that at 1-year post-loading, average peri-implant bone loss was 0.63 mm at short maxillary implants and 0.72 mm at long maxillary implants restored with prostheses. In contrast, the average peri-implant bone loss presented by the author in this study ranged between 1.04 mm and 2.26 mm following implant placement. Also, the MBL values for implants measuring less than 10 mm in length were between 0.72 mm and 4.38 mm at both the restorative and the 1-year visits.

A recent short-term follow-up study was performed by Felice et al. (2015) to evaluate the efficacy of submerged short (5 or 6 mm in length) dental implants versus 10 mm or longer dental implants placed following crestal sinus lifting and grafting in posterior atrophic maxillae. The authors demonstrated that the bone loss was less than 1 mm around both short and long implants 1 year post-loading. As a parallel, the author found in the present research that the MBL values for submerged implants measuring less than 10 mm in length were between 0.89 mm and 4.38 mm post-surgery.

Comparing the 2-year outcomes of 6.5-mm-long hydrophilic dental implants placed with osteotome sinus floor elevation versus standard implants (11-12.5-mm-long) placed with lateral sinus floor elevation in patients with a severely atrophic posterior maxillae, Yu et al. (2017) found that of the 80 inserted implants, one in the standard implant group failed because of abscess formation; the failed implant was removed and reinserted after a 3-month healing period. Rupture of the maxillary sinus membrane occurred in two of the short implant cases and in one of the standard implant cases. Other complications included nasal bleeding and postoperative headache in four of the short implant cases and in five of the long implant cases. In addition, within 2 years after implant loading, two prosthetic complications appeared in the standard implant group and one in the short implant group. Their results suggest that short implants with a hydrophilic surface can be successfully loaded after 8 weeks, and that placement of dental implants of 6.5 mm in length with osteotome sinus floor elevation is an effective alternative for the rehabilitation of severely atrophic posterior maxillae compared to 11-12.5-mm-long dental implants. As a parallel to the results reported by Yu and colleagues, the author found in this study that dental implants measuring less than 10 mm in length lost less than 1 mm of marginal bone at both prosthetic restorative phase and 1-year follow-up with the exception of one Nobel Biocare tapered and submerged 8-mm-long implant with a diameter of 5 mm inserted in native bone and restored by platform-matching and PFM crown, 62 year-old non-smoker female patient with a history of periodontitis, parafunctional habits (clenching), and peri-implantitis (MBL measurements were 1.67 mm at the distal aspect at the restoration phase, and 4.38 mm at the mesial aspect and 2.47 mm at the distal aspect at the 1-year follow-up). Additionally, the OsseoSpeed implant provided good outcomes in terms of marginal bone levels.

Taschieri et al. (2018) have performed a study comparing short dental implants (6.5-8.5 mm in length) versus standard implants (equal or longer than 10 mm in length) and maxillary sinus augmentation procedure for the rehabilitation of edentulous posterior maxilla, and observed a mean marginal bone loss of 0.82 mm for short implant group and 0.99 mm for standard implant group at 1-year after loading. After 3 years of function, the peri-implant marginal bone level did not change substantially from the 1-year observation in both groups. Throughout 3 years of follow-up there were no biological or mechanical complications in both groups. Most of the short implants were splinted together or splinted with 10 mm or 11.5 mm in length implants. All implants had a micro-rough acid-etched surface and were bioactivated with pure platelet-rich plasma prior to insertion. As a comparison, the author found in this study that two Biomet 3i submerged implant measuring 4.1 mm in diameter and 10 mm in length with Osseotite surface placed with maxillary sinus augmentation and part of a restoration using splinted crowns exhibiting marginal bone loss between 0.89 mm and 4.39 mm post-surgery, and two Straumann implants measuring 4.8 mm in diameter and 12 mm in length with a wide 6.5 mm platform-matching and part of a restoration using splinted gold crowns lost between 1.13 mm and 1.59 mm of marginal bone post-surgery. MBL values for implants measuring less than 10 mm in length were between 0.72 mm and 4.38 mm at both the restorative and the 1-year visits.

In a recent study assessing clinical and radiographic outcomes of dental implants measuring 4 mm in diameter and 6 mm in length and applying an early loading protocol, Han et al. (2018) have showed that short implants restored by splinted crowns represent a viable treatment option in posterior maxilla, having low marginal bone resorption. Most study patients were non-smokers and had a history of periodontitis. Thirty-one implants were placed in posterior maxillae using a one-stage surgical procedure and loaded with splinted fixed dental prostheses 6 weeks later. At 3-year after implant placement there was a mean marginal bone loss of 0.04 mm. Their results proved that the treatment using implants measuring 6 mm in length is successful in posterior regions when it is used to support splinted crowns. In the present research, two Biomet 3i submerged implant measuring 10 mm in length and 4.1 mm in diameter with Osseotite surface placed with maxillary sinus augmentation and part of a restoration using splinted crowns exhibiting marginal bone loss between 0.89 mm and 4.39 mm post-surgery, and two Straumann implants measuring 12 mm in length and 4.8 mm in diameter restored by a wide 6.5 mm platform-matching and part of a restoration using splinted gold crowns lost between 1.13 mm and 1.59 mm of marginal bone post-surgery. MBL values for implants measuring less than 10 mm in length was between 0.72 mm and 4.38 mm at both the restorative and the 1-year visits.

A systematic review and meta-analysis performed by Lemos et al. (2016) compared short implants (equal or less than 8 mm in length) versus standard-length implants (longer than 8 mm in length) placed in posterior regions of human jaws and found that there was no significant difference between short implants and standard implants in terms of marginal bone loss. Despite the fact that the authors considered short implants as a predictable treatment for posterior jaws, it was concluded that short implants measuring between 4-7 mm in length should be used with caution because they present greater risks to failures when compared with standard implants. As mentioned above, the author found in this research that dental implants measuring less than 10 mm in length lost less than 1 mm of marginal bone at both prosthetic restorative phase and 1-year follow-up with the exception of one Nobel Biocare tapered and submerged 8-mm-long implant with a diameter of 5 mm inserted in native bone and restored by platform-matching and PFM crown, 62 year-old non-smoker female patient with a history of periodontitis, parafunctional habits (clenching), and peri-implantitis (MBL measurements were 1.67 mm at the distal aspect at the restoration phase, and 4.38 mm at the mesial aspect and 2.47 mm at the distal aspect at the 1-year follow-up).

Discussing the implant failure risk, Nedir et al. (2017) have reported that the risk is higher for dental implants inserted in extremely atrophic posterior maxillae of periodontally compromised patients when implants measuring 8 mm in length are placed using osteotome sinus floor elevation. Measured radiographic bone data revealed a mean crestal bone loss of 0.6 mm in the test group (8-mm-long dental implants) and 0.4 mm in the control group (8-mm-long dental implants with grafting material) at 1-year interval after implant placement, while a mean crestal bone loss of 0.6 mm in the test group and 0.7 mm in the control group was observed at 5-year interval after implant placement. The authors concluded that the mean bone loss was limited, without a significant difference between the groups, and that high bone loss was noticed in patients with a history of periodontal disease prior to the implant treatment. Moreover, the authors demonstrated that osteotome sinus floor elevation procedure without grafting material allows a decrease in treatment cost, duration of surgery and treatment, and patient morbidity related to graft infection. As a comparison, the author found in this research that dental implants measuring less than 10 mm in length lost less than 1 mm of marginal bone at both prosthetic restorative phase and 1-year follow-up with the exception of one Nobel Biocare tapered and submerged 8-mm-long implant with a diameter of 5 mm inserted in native bone and restored by platform-matching and PFM crown, 62 year-old non-smoker female patient with a history of periodontitis, parafunctional habits (clenching), and peri-implantitis (MBL measurements were

1.67 mm at the distal aspect at the restoration phase, and 4.38 mm at the mesial aspect and 2.47 mm at the distal aspect at the 1-year follow-up).

Comparing the implant survival of narrow-diameter dental implants with that of standard-diameter dental implants using a systematic meta-analysis, Schiegnitz & Al-Nawas (2018) revealed that narrow-diameter implant therapy is a possible solution with promising survival rates. The authors classified narrow-diameter implants into three categories: Category 1 (implant diameter less than 3.0 mm, “mini-implants”), Category 2 (implant diameter between 3-3.25 mm) and Category 3 (implant diameter between 3.3-3.5 mm). The meta-analysis demonstrated that category 1 implants with a diameter between 1.8 mm and 2.4 mm showed mean marginal bone loss ranging from 0.6 mm to 1.43 mm, category 2 implants exhibited mean marginal bone loss between 0.09 mm and 1.6 mm, while category 3 implants showed that mean marginal bone loss ranged from 0.1 mm to 2.17 mm. In addition, marginal bone loss values were presented in the majority of the studies below 1.5 mm. As a parallel to the research conducted by Schiegnitz & Al-Nawas, the author found in this study that two Straumann dental implants with 10 mm and 12 mm in length and both with a diameter of 3.3 mm restored by crowns and platform-switching method and inserted in grafted maxillary bone (one of which placed in a patient with a history of smoking) lost between 0.86 mm and 1.13 mm at the prosthetic restorative phase and the 1-year visit, being comparable to the outcomes offered by category 3 implants.

Mangano et al. (2013) have performed a study to evaluate the survival and success rate of immediately restored one-piece narrow-diameter selective laser sintered dental implants placed in the posterior human jaws after 2 years of functional loading. A number of 14 implants made of titanium alloy with lengths of 10-13 mm and diameters of 2.7 mm and 3.2 mm were inserted in posterior maxillary regions at the bone crest level. The prosthetic restoration consisted of fixed partial prostheses. At the 2-year follow-up, periapical radiographs revealed crestal bone loss of less than 2 mm from the initial surgery. Nevertheless, two maxillary implants exhibited over 2 mm of bone loss at the same follow-up interval. In addition, there were no prosthetic complications. While in the present research the author could not identify any prosthetic complications, there were three Biomet 3i tapered implants measuring 10 mm and 11.5 mm in length and 4 mm in diameter and part of fixed hybrid prostheses that exhibited bone loss ranging from 2.76 mm to 2.91 mm at the mesial aspect and from 0.89 mm to 2.76 mm at the distal aspect at the prosthetic restorative phase, four tapered submerged implants (two Biomet 3i implants each measuring 11.5 mm in length and 6 mm in diameter, and 10 mm in length and 4 mm in diameter – one of which was restored by platform-matching; two Nobel Biocare implants each measuring 8 mm in length and 5 mm in diameter, and 10 mm in length and 4 mm in diameter restored by platform-matching) experienced bone loss ranging from 0.35 mm to 2.07 mm at the mesial aspect and from 0.71 mm to 2.48 mm at the distal aspect at the same time interval; these implants were placed in patients with a history of periodontitis, with both native and grafted bone with or without maxillary sinus augmentation.

In assessing radiographic bone levels around single Branemark dental implants, Walton & Layton (2018) found that there are specific differences in interpretation related to radiographic brightness, examiner accuracy, and implant characteristics. Thus, the authors mentioned that when evaluating MBL, the agreement within and between examiners is poor. Particularly, disagreement occurred around 25% of the time, potentially affecting consistent disease assessments. While brighter radiographs improved intra-examiner agreement, neither study participant nor implant characteristics have clearly affected agreement. In addition, the authors found that the perceived MBL changes below 1 mm are likely due to human characteristics, and that brighter radiographs improved intra-examiner agreement. Their study mentioned that participants have reviewed radiographs under any external environmental condition. The authors concluded that measurement reliability, consistency, and accuracy are central to providing the profession with precise data. In this research, the radiographic vertical MBL measurements were performed on radiographs with grids applied to them in a room where the author was surrounded by both natural and artificial light, and this aspect might have affected some of the factors involved in accurately assessing peri-implant bone levels on radiographs.

Concerning the peri-implant MBL changes, the author found in this research that the average mesial marginal bone loss at the restorative phase was 1.58 mm and at the distal aspect it was 1.54 mm, while the average mesial marginal bone loss at the 1-year follow-up was 1.52 mm and at the distal aspect it was 1.57 mm. Nevertheless, high values of peri-implant bone loss found in a few patients might have been attributed to interrelations among various factors such as: angled abutments that could have transmitted excessive forces to the peri-implant bone, microgap (recognized by now as a well-known reservoir for bacterial invasion), along with histories of smoking and diabetes that might have contributed to compromising the maxillary bone structure. Additionally, in spite of the study limitations, the average MBL values at both mesial and distal aspects of the inserted dental implants were consistent with those reported in the specialty literature at the 1-year follow-up and beyond, irrespective of the patient-related and/or implant-related characteristics. Platform-switching method and non-submerged implants experienced better marginal bone preservation as compared to their counterparts. In contrast to the scientific literature, this study revealed that a number of implants restored using internal prosthetic connections experienced marginal bone loss at early stages post-surgery. Another significant finding discussed in this research was that the OsseoSpeed implant provided good outcomes in terms of marginal bone levels. Within the study limitations of reviewing only dental records, peri-implant mucositis was identified in one Biomet 3i submerged implant measuring 4.1 mm in diameter and 10 mm in length with Osseotite surface placed with maxillary sinus augmentation and part of a restoration using splinted crowns, and in two Straumann implants measuring 4.1 mm in diameter and 12 mm in length with a wide 6.5 mm platform-matching and part of a restoration using splinted gold crowns. Peri-implantitis was found in the same Straumann implants mentioned above, along with one BioHorizons implant measuring 4.6 mm in diameter and 12 mm in length and restored by a porcelain-fused-to-metal crown (PFM), one Biomet 3i non-submerged implant measuring 4 mm in diameter and 13 mm in length restored by platform-switching that was included in a dental bridge, and in two submerged Nobel Biocare implants (one measuring 4 mm in diameter and 10 mm in length and another measuring 5 mm in diameter and 8 mm in length) restored by platform-matching and single PFMs. It could not be determined if the dental implant restoration type alone had a negative influence on the MBL changes around dental implants inserted in posterior maxilla. Due to the limited sample size represented by dental implants with less than 10 mm in length, a thorough comparison with longer implants could not be made. Radiographic MBL measurements that were performed in a room filled with natural and artificial light might have affected some of the factors involved in accurately assessing peri-implant bone levels on radiographs.

6. Conclusions

This retrospective research that was performed to evaluate the MBL changes around dental implants placed in posterior regions of the maxillary bone in patients with a history of diabetes and in patients with a history of smoking. This research complements the present scarce literature on this topic through the identification of the various factors that may contribute to peri-implant bone loss. Within the limitations, this is the first study that attempted to identify a large number of patient-related and implant-related characteristics that may influence peri-implant bone loss and that demonstrated that novice clinicians at an academic institution may obtain similar implant outcomes as compared to more experienced clinicians. Lastly, the findings from this study offer a better understanding of the factors that influence marginal bone level changes around dental implants placed in the posterior maxilla, thus paving the way for a more detailed research in this direction.

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