

A Cone Beam Computed Tomography (CBCT) Based Comprehensive Assessment of Early Marginal Bone Loss Adjoining Mandibular Posterior Dental Implants Placed with Parallel and Tilted Strategies: An Original Research Study

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Abstract

Aim: This study aims for a comprehensive assessment of early marginal bone loss around mandibular posterior dental implants, which were placed using both parallel and tilted strategies via cone beam computed tomography (CBCT).

Materials and Methods: This study examined the outcomes of dental implants in 60 patients with aesthetic and functional challenges due to the loss of their mandibular first molar. Among these, 40 patients preferred implants with implant-supported prostheses. Participants, aged 35 to 60, were selected based on strict inclusion criteria, which required implants measuring 4.2 by 11.5 mm and sufficient alveolar bone confirmed via cone beam computed tomography (CBCT). The focus was on posterior implants in the mandible, using both conventional parallel (Group 1) and tilted placements (Group 2, angles of 15° to 30°) for enhanced stability. Successful osseointegration was mandated with a healing period of 3 to 6 months, followed by functional loading for 6 to 12 months to assess marginal bone loss. Both groups underwent evaluations using CBCT to measure marginal bone loss. Implants followed a delayed loading protocol, with functional loading beginning 3 to 4 months post-implantation and follow-ups at least 12 months later. The study ensured high imaging accuracy with a standardized CBCT machine, carefully monitoring marginal bone loss with specialized software.

Statistical Analysis and Results: Among the participants missing mandibular first molars, they were divided into two groups for evaluating implant strategies. Group 1 had 20 individuals with parallel implants positioned at 0° to the occlusal plane, while Group 2 included 20 with implants tilted between 15° and 30°. Marginal bone loss was assessed via Cone Beam Computed Tomography (CBCT) at three and six months post-operation. Group 1's findings (Table 2) showed three-month mesial and distal marginal bone loss averaging 1.20±1.02 mm and 1.28±1.57 mm, respectively. In contrast, Group 2 had lower losses, with mesial at 0.56±0.24 mm and distal at 0.86±1.05 mm. At six months, Group 1's loss increased (Table 4) to 3.10±1.75 mm (mesial) and 3.04±1.56 mm (distal), while Group 2 (Table 5) showed better outcomes, with losses of 1.02±0.75 mm (mesial) and 1.29±0.56 mm (distal). The results emphasize the advantages of tilted implants in preserving bone integrity. Table 6 provides a one-way ANOVA analysis, highlighting the significant differences in marginal bone loss between the two groups.

Conclusion: This study concluded that while tilted implants may initially show more bone loss than parallel ones, both methods exhibit high success rates and good long-term outcomes.

Keywords: Cone Beam Computed Tomography (CBCT), Dental Implants, Marginal Bone Loss, 3D Imaging, Titanium, Bone Volume, Bone Density, Osseointegration, Abutment

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Introduction

A dental implant is a sophisticated dental solution designed to replace the root of a missing tooth.

Typically made from biocompatible materials such as titanium or zirconia, a dental implant takes the

form of a small screw that is surgically inserted into the jawbone. This implant serves as a secure foundation for artificial teeth, including crowns, bridges, or dentures, helping to restore both functionality and aesthetics to the patient's smile. The process of obtaining a dental implant begins with a comprehensive consultation, during which the dentist evaluates the patient's oral health.^{1,2} Utilizing advanced 3D imaging technology, the dentist examines the jawbone and gums to determine their condition. This assessment helps identify if there is sufficient bone density to support an implant. If any deficiencies are detected, additional procedures may be required before the implant placement, such as a bone graft to build up the jawbone or a sinus lift to allow for the proper positioning of an implant in the upper jaw. Once the initial evaluation is complete and any necessary preparatory treatments have been conducted, the actual implant placement can proceed. An oral surgeon performs this procedure under local anaesthesia to ensure the patient's comfort.^{3,4} The surgeon will carefully make an incision in the gum tissue to expose the jawbone, where a precise hole is drilled to accommodate the titanium or zirconia implant. After the implant is inserted, the gum tissue is closed around it to promote healing. Following the surgical placement of the implant, a critical phase known as osseointegration begins. This biological process lasts between 3 to 6 months, during which the bone cells grow and fuse with the surface of the implant, establishing a strong bond that creates a durable and stable anchor for the artificial tooth.^{5,6} The success of osseointegration is vital, as it ensures that the implant can withstand the forces exerted during normal chewing and biting. Once the osseointegration process is completed, the next step involves placing a component known as an abutment on top of the implant. The abutment serves as a connector between the implant and the custom-made artificial tooth (crown). The dentist takes impressions and measurements of the patient's mouth to fabricate a crown that matches the size, shape, and color of the surrounding natural teeth, ensuring a seamless integration into the patient's smile. Cone Beam Computed Tomography (CBCT) is an essential tool in the planning and assessment of dental implants.^{7,8} This advanced imaging technique provides detailed, three-dimensional views of the jaw structures, allowing clinicians to obtain accurate measurements of the bone volume and density. Furthermore, CBCT imaging helps identify important anatomical landmarks, such as the location of nerves and sinuses, which is critical for minimizing surgical risks and enhancing procedural predictability. With CBCT, dentists can evaluate crestal bone height and detect potential defects that may not be visible on traditional two-dimensional X-rays. This level

of detail is key for analyzing local bone density prior to implant placement, which is crucial for anticipating the longevity of the implant and ensuring optimal bone health around the area.^{9,10} Research has shown that careful planning is paramount for successful implant outcomes. For instance, studies evaluating marginal bone loss (MBL) around mandibular posterior implants have highlighted that tilted implants may experience more significant localized buccal bone loss compared to those positioned parallel to the jaw axis.^{11,12} This finding underscores the importance of precision in the placement techniques and the strategic selection of implant angles to mitigate risks and promote long-term success of dental implants. Ultimately, a well-executed dental implant procedure not only enhances the patient's oral function but also significantly improves their quality of life.¹³ This study aims on a comprehensive assessment of early marginal bone loss around mandibular posterior dental implants, which were placed using both parallel and tilted strategies via cone beam computed tomography (CBCT).

Materials and Methods

This study explored the outcomes of dental implants in a cohort of 60 patients who faced both aesthetic concerns and functional challenges stemming from the loss of their mandibular first molar. Out of these participants, 40 individuals indicated a strong preference for receiving dental implants alongside implant-supported prostheses to restore their dental functionality and appearance. The patients, ranging in age from 35 to 60 and representing both genders, were meticulously selected based on precise inclusion criteria designed to ensure the suitability for implant placement. Among the essential criteria was the requirement for implants measuring 4.2 by 11.5 mm, alongside the stipulation that candidates be at least 18 years old. Additionally, sufficient residual alveolar bone to adequately support the implants was necessary, typically confirmed through cone beam computed tomography (CBCT) scans indicating bone densities between 350 and 850 Hounsfield Units. The focus of the study was on patients receiving posterior implants in the mandible, utilizing both conventional parallel placements and strategic tilted placements for enhanced stability and support. The protocol mandated that the implants achieve successful osseointegration, which involves a healing period of 3 to 6 months, free from any complications. Following this healing phase, the implants underwent functional loading for a minimum duration of 6 to 12 months, allowing for the assessment of measurable marginal bone loss, a critical factor in evaluating implant success. Exclusion criteria were stringent, filtering out candidates with uncontrolled systemic health

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issues, such as diabetes and bleeding disorders, which could impede proper bone healing. Other disqualifying conditions included bone metabolism disorders like osteoporosis or Paget's disease, habits such as severe bruxism that might compromise the integrity of the implants, and lifestyle choices characterized by heavy smoking or alcohol consumption—factors known to correlate with increased rates of implant failure. Furthermore, any cases of active infections or untreated periodontitis affecting adjacent teeth, as well as anatomical challenges demanding complex grafting procedures, were grounds for exclusion from the study. The 40 patients with missing mandibular first molars were organized into two distinct groups for the purpose of implant placement. Group 1 consisted of 20 individuals who received implants positioned in a parallel manner, aligned at a precise 0° orientation perpendicular to the occlusal plane. Conversely, Group 2 also encompassed 20 patients, but these implants were tilted at angles ranging from 15° to 30° relative to the vertical axis, allowing for variation in implant placement strategies. To assess the clinical outcomes of these different approaches, both groups underwent evaluations through cone beam computed tomography (CBCT), which meticulously measured marginal bone loss on the mesial and distal surfaces of the implants. The implantation conveyed the use of implants measuring 4.2 by 10 mm following a delayed loading protocol; the implants were loaded 3 to 4 months post-implantation. Evaluative follow-ups took place at least 12 months following the commencement of loading, with marginal bone levels precisely assessed using the intersection of the polished and rough surfaces of the implant as reference points. In a bid to maintain imaging accuracy, a standardized CBCT machine was employed, specifically utilizing a restricted field of view confined to the posterior mandible, thus minimizing unnecessary radiation exposure. The acquisition settings were fine-tuned to between 85–90 kVp and 8–12 mA, with a voxel size ranging from 0.15 to 0.30 mm, ensuring high spatial resolution for effective bone assessment. Baseline scans were obtained immediately following implantation. For analytical purposes, the DICOM data extracted from the scans were carefully processed using specialized software. To calculate marginal bone loss (MBL), the study measured the vertical distance from the implant shoulder to the first bone-to-implant contact. Statistical comparisons between follow-up and baseline scans evaluated net MBL, utilizing SPSS for independent and paired t-tests. Intra-observer reliability was ensured through Kappa correlation methods.

Statistical Analysis

In this research study, we conducted all statistical analyses using SPSS version 31.0, a robust

software package specifically designed for statistical computing and data analysis within the social sciences. To assess the significance of our findings, we employed the chi-square test, which is especially effective for exploring differences in proportions among various groups. This evaluation was performed utilizing Pearson's chi-square method, allowing us to draw meaningful conclusions from the data.

Results

The study conducted involved a total of 40 individuals, all of whom expressed a strong preference for the restoration of their dental health through dental implants paired with implant-supported prostheses. This specific combination was chosen as it effectively addresses both the functional needs of chewing and speaking, while also enhancing the aesthetic appearance of their smiles. The participants in this study ranged in age from 35 to 60 years, ensuring a diverse representation that incorporates various life stages and experiences related to tooth loss. The gender distribution among the participants was also varied, reflecting a broad cross-section of the population affected by edentulism, which allows for more generalizable findings. For further insights, comprehensive demographic information about each participant is meticulously detailed in Table 1. This table provides a thorough statistical breakdown categorized by age and gender, facilitating a clearer understanding of the demographic distribution within the study cohort. Additionally, Graph 1 offers a clear visual representation of these demographics, illustrating the proportionate distribution of the participants across different age groups and genders. This graphical depiction adds valuable context to the study's findings, enhancing the interpretation of how diverse demographics may influence preferences for dental restoration options. Among the 40 patients specifically noted for missing mandibular first molars, the cohort was systematically divided into two distinct groups to allow for an in-depth evaluation of different implant placement strategies. Group 1 consisted of 20 individuals whose dental implants were positioned in a parallel alignment, specifically at a precise orientation of 0°, which is perpendicular to the occlusal plane. Conversely, Group 2 comprised another 20 participants whose implants were positioned at an angle varying between 15° and 30° relative to the vertical axis. This strategic grouping facilitated a meaningful comparative analysis of the efficacy of the different implant placement approaches. The effectiveness of these implant placements was meticulously assessed by examining marginal bone loss, utilizing Cone Beam Computed Tomography (CBCT) at two critical post-operative intervals: three months and six months. The findings from Group 1 are

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thoroughly detailed in Table 2, revealing that the patients who received the parallel implants (N=20) experienced mesial marginal bone loss averaging 1.20 ± 1.02 mm and distal marginal bone loss averaging 1.28 ± 1.57 mm at the three-month mark following surgery. In contrast, Table 3 outlines the results for Group 2, where the 20 individuals who received tilted implants demonstrated a significantly more favourable outcome, with a mesial marginal bone loss of only 0.56 ± 0.24 mm and a distal marginal bone loss of 0.86 ± 1.05 mm at the same three-month post-operative evaluation. Subsequent evaluations were performed six months after the implants were placed. The data for Group 1, presented in Table 4, indicated that patients with parallel implants experienced a marked increase in marginal bone loss over this period. The mesial marginal bone loss was recorded at 3.10 ± 1.75 mm, while distal marginal bone loss reached 3.04 ± 1.56 mm. Table 5 offers an insightful summary of the findings for Group 2 at the six-month follow-up mark. It reveals that participants with tilted implants experienced a marginal bone loss characterized by a mesial measurement of 1.02 ± 0.75 mm and a distal measurement of 1.29 ± 0.56 mm. These results highlight the significant advantage of tilted implant orientation in preserving bone integrity when compared to traditional placements. To further synthesize and elucidate the findings across the different study groups while evaluating the statistical significance of these observed differences, Table 6 showcases a detailed analysis utilizing one-way ANOVA. This rigorous analysis presents a comprehensive overview of marginal bone loss patterns across both groups, enhancing our understanding of how the orientation of dental implants can significantly influence bone preservation outcomes after surgical intervention.

Table 1: Age & gender based statistical description of contributing patients

Age Group (Yrs)	Male	Female	Total	P value
35-40	5	4	9	0.06
41-45	5	3	8	0.40
46-50	3	4	7	0.04*
51-55	4	4	8	0.80
56-60	5	3	8	0.40
Total	22	18	40	*Significant

***p<0.05 significant**

Graph 1: Patients demographic distribution and associated details

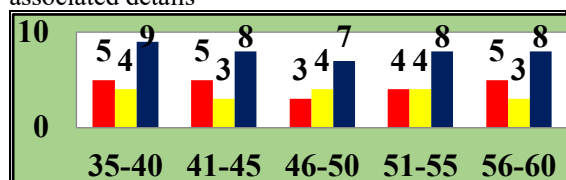


Table 2: Group 1 (N=20) Individuals who received implants positioned parallelly, aligned at a precise 0° orientation perpendicular to the occlusal plane, had marginal bone loss evaluated by CBCT three months post-operatively

Parameters	Mean +SD	Std. Error	95 % CI	Pearson Chi-Square Value	Df	P Value
Mesial Marginal Bone Loss	1.20 ± 1.02	2.043	2.78	2.374	1.0	0.02*
Distal Marginal Bone Loss	1.28 ± 1.57	1.281	2.32	2.081	2.0	0.40

***p<0.05 significant**

Table 3: Group 2 (N=20) Individuals who received tilted implants at angles ranging from 15° to 30° relative to the vertical axis, allowing for variation in implant placement strategies, had marginal bone loss evaluated by CBCT three months post-operatively

Parameters	Mean +SD	Std. Error	95 % CI	Pearson Chi-Square Value	Df	P Value
Mesial Marginal Bone Loss	0.56 ± 0.24	0.089	1.50	1.056	1.0	0.06
Distal Marginal Bone Loss	0.86 ± 1.05	0.063	1.17	1.063	1.0	0.56

***P<0.05 Significant**

Table 4: Group 1 (N=20) Individuals who received implants positioned parallelly, aligned at a precise 0° orientation perpendicular to the occlusal plane, had marginal bone loss evaluated by CBCT six months post-operatively

Parameters	Mean +SD	Std. Error	95 % CI	Pearson Chi-Square Value	Df	P Value
Mesial Marginal Bone Loss	3.10 ± 1.75	2.032	2.09	2.05	1.0	0.09

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Distal Marginal Bone Loss	3.04±1.56	1.108	2.03	2.02	1.0	0.70
*P<0.05 Significant						

Table 5: Group 2 (N=20) Individuals who received tilted implants at angles ranging from 15° to 30° relative to the vertical axis, allowing for variation in implant placement strategies, had marginal bone loss evaluated by CBCT six months post-operatively

Parameters	Mean ±SD	Std. Error	95 % CI	Pearson Chi-Square Value	Df	P Value
Mesial Marginal Bone Loss	1.02±0.75	1.06	1.09	1.04	1.01	0.01*
Distal Marginal Bone Loss	1.29±0.56	1.10	1.06	1.02	1.02	0.08
*P<0.05 Significant						

Table 6: Estimation amongst all studied groups using one-way ANOVA

Variables	Degree of Freedom	Sum of Squares Σ	Mean Sum of Squares mΣ	F	Level of Sig. (p)
Between Groups	5	3.982	2.870	1.2	0.02*
Within Groups	78	2.745	2.054		—
Cumulative	894.14	4.563	*p<0.05 significant		

Discussion

Cafasso E et al reviewed in their study that dental implants are advanced dental solutions designed to replace missing teeth. These implants are typically composed of titanium, a biocompatible material prized for its strength and compatibility with human bone, and they are surgically inserted into the jawbone to serve as artificial tooth roots. Dental implant systems consist of three key components that collaborate to restore both function and aesthetics to a patient's smile. The first component is the implant fixture, commonly known as the "post."^{14,15} Garzon HS et al. reported that this screw-like structure is surgically embedded into the jawbone and is typically made of titanium or zirconia. It undergoes a process called osseointegration, where it gradually bonds with the jawbone, creating a stable base for the replacement tooth. The second component is the abutment, which serves as a connector between the implant

fixture and the prosthetic tooth, or crown. Usually crafted from metal, the abutment is securely attached to the top of the implant post, allowing the crown to be placed on it. The final component is the crown, the custom-made prosthetic tooth that is visible in the mouth.^{16,17} Lin L et al showed in their study that crowns are often made from materials that mimic the appearance of natural tooth enamel, such as porcelain, ensuring they blend seamlessly with surrounding teeth. In the planning phase for dental implants, Cone Beam Computed Tomography (CBCT) is regarded as the gold standard imaging technique. Unlike traditional two-dimensional X-rays that may obscure important anatomical features, CBCT provides detailed three-dimensional views of the oral structures. This technique serves several crucial functions in implant dentistry, including assessing the available bone volume to ensure adequate support for the implant. It also protects vital structures by precisely mapping the paths of nerves and blood vessels, helping to prevent complications during surgery.^{18,19} Elena C et al. reported that CBCT also evaluates the nasal floor and maxillary sinuses before procedures such as sinus lifts, ensuring patient safety. It assists in pre-surgical grafting planning by determining the necessary bone volume and placement for grafting, and it facilitates guided surgery simulations, enhancing the precision of implant placement through the integration of digital data into planning software. Research examining the performance of tilted versus parallel implants over a five-year period indicates that the overall marginal bone loss for both types is quite similar, typically ranging from 1.0 mm to 1.2 mm.^{20,21} Rios HF et al reviewed in their study that however, studies suggest that tilted implants experience slightly greater buccal bone resorption, attributed to variations in how biomechanical stresses are distributed around the implant. Post-implantation, retrospective analyses using CBCT have revealed distinct patterns of bone remodelling. Specifically, parallel (or axial) implants tend to have a lower mean buccal bone loss of about 0.42 mm, in contrast to tilted implants, which exhibit higher resorption, averaging around 0.70 mm. Despite the differences in implant placement strategies, both axial and non-axial techniques exhibit similar clinical manifestations of interproximal bone loss. This observation suggests that the method of implant placement may not have a profound influence on this particular aspect of dental implantology.^{22,23} Many other recent studies have also highlighted similar outcomes and inferences.²⁴⁻³⁶ Vasegh Z et al showed in their study that however, it is important to highlight that patients with thin soft-tissue biotypes may be more susceptible to experiencing significant bone loss, irrespective of whether an axial or tilted implant strategy is utilised. The

choice between axial and tilted implant placements holds considerable importance, as it directly affects the stress distribution on the surrounding bone structures. This stress profile can influence the long-term stability and health of the bone. Cone Beam Computed Tomography (CBCT) plays a crucial role in this context; it not only provides detailed insights into how these stress distributions are organised but also delivers vital metrics that are essential for effectively monitoring and managing any changes that may occur throughout the healing process. This technology is indispensable for practitioners seeking to optimise treatment outcomes and enhance patient care.^{37,38}

Conclusion

In this study, the authors present a detailed analysis of early marginal bone loss associated with mandibular posterior dental implants, utilizing Cone Beam Computed Tomography (CBCT) for a comprehensive assessment. The findings concluded that while implants placed at tilted angles may initially experience slightly greater marginal bone loss when compared to those positioned in parallel, both techniques show impressive success rates and deliver favourable long-term outcomes. Additionally, the study highlights the effectiveness of these methods in avoiding critical anatomical structures, such as the inferior alveolar nerve. However, the authors emphasize that further research is essential to deepen the understanding of these findings and their implications in clinical practice.

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