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Comparative evaluation of the buccal and lingual bone height in the mandibular posterior region before and after porcelain fused to metal crowns: A prospective cone beam computed tomography study

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Abstract
Background and Objective: This study investigates the relationship between porcelain-fused-to-metal (PFM) crowns and peri-abutment bone, focusing on restoration success and abutment tooth health. It highlights the role of effective occlusal force transfer and bone remodeling. Cone Beam Computed Tomography is emphasized for its precise post-placement monitoring and diagnostics, improving care standards.
Methodology: The research evaluates buccal and lingual bone height changes around abutments with PFM crowns. Selected patients received single crowns, with CBCT scans taken before (P0) and six months after (P1) crown placement. Measurements from the root apex to buccal and lingual alveolar bone were recorded using CBCT software. Comparative analysis aims to optimize single crown treatments by assessing the impact on bone structures.
Results: Pre- and post-treatment comparisons showed no statistically significant difference in buccal bone height (p>0.05). For lingual bone height, although post-treatment values were higher, the difference was not statistically significant (p<0.01).
Conclusion: The study concludes that PFM crowns do not significantly alter peri-abutment bone height within six months, providing insights for optimizing single crown treatments and understanding bone remodeling in response to prosthodontic interventions.

Keywords*:* PFM crowns, peri-abutment bone, CBCT, buccal and lingual bone height, treatment plan, single crowns, fixed partial denture.

Introduction

The placement of porcelain-fused-to-metal (PFM) crowns in the posterior region is crucial for restoring function and aesthetics, given their need to endure significant masticatory forces. Understanding the adaptive responses of peri-abutment bone is vital for the restoration's longevity and the health of the abutment tooth and surrounding structures. Stress and strain redistributions in bone from prosthodontic treatments are complex and not fully understood [1]. Single crowns, which alter local biomechanics, induce bone remodeling or resorption to accommodate new loading conditions [2]. The success of these crowns hinges on how occlusal forces are managed by the root abutments, periodontal ligament, and bone [3]. Post-placement, PFM crowns can trigger an inflammatory response, leading to bone resorption by osteoclasts, followed by bone formation to adapt to new forces [4]. The metal substructure and porcelain overlay of PFM crowns can cause stress mismatches due to differences in elasticity. Cone Beam Computed Tomography (CBCT) enhances the assessment of bone changes, offering detailed three-dimensional imaging to monitor alterations in bone density and resorption, thus improving diagnostic precision [5, 6, 7].

Materials & Methodology

This *in vivo* analytical experimental study, approved by the Research Ethics Committee under opinion report No MVGU/ADM/2022/144(XI), aimed to evaluate the impact of Porcelain-Fused-to-Metal (PFM) crowns on bone height.

The study's objectives were to record and compare the buccal bone height and lingual bone height before and after 6 months of PFM crown placement, and to assess the changes in these measurements post-cementation.

The study at Jaipur Dental College, MVGU, conducted by the Department of Prosthodontics, assessed buccal and lingual bone changes around abutments treated with PFM crowns. Twenty-three patients seeking single crowns in the lower molar region underwent tooth preparation and CBCT scans before (P0) and six months after (P1) crown placement, with measurements from the apex to the buccal and lingual bone compared using Carestream viewer 3D. A detailed clinical examination and case history were obtained from all the participants.

Procedure

During the patient evaluation phase, a comprehensive review of each patient's medical history, oral health, and systemic factors was conducted to ensure adherence to inclusion criteria for single crowns. Special attention was given to matching the shade and characteristics of adjacent teeth to achieve optimal esthetics. [Figure 3] Cone Beam Computed Tomography (CBCT) using a Carestream CS 9300 (6cm field of view, 90 kV, 4.0 mA, 20s exposure) was employed for detailed imaging. A pre-operative CBCT scan (P0) captured measurements from the root apex to the buccal and lingual cortical bones in axial, sagittal, and coronal planes, focusing on the distal root in the mandible [Figure 1, Figure 2].

Tooth preparation involved using a high-speed air motor and dental loupes (3.5x magnification), with effective moisture control maintained through an air-water syringe and saliva ejector [Figure 4]. For impression making, a two-stage technique was utilized: a stock tray coated with adhesive was filled with putty and light body materials to capture detailed impressions [Figure 5]. Gingival retraction was achieved by isolating the prepared teeth with cotton rolls and saliva ejectors, followed by the application of a knitted retraction cord dipped in 2% Aluminum Chloride, which was gently packed into the sulcus [Figure 6]. The impression was then checked for accuracy, with the putty tray loaded with light body material and placed in the patient's mouth for 6 minutes. A temporary crown was fabricated using tooth-colored acrylic via an indirect-direct technique and cemented with temporary cement to protect the prepared tooth and maintain aesthetics during the interim [11]. Communication with the dental laboratory included detailed instructions on shade, margin design, and specific preferences for the final restoration. The metal coping of the PFM crowns was evaluated for margin integrity, stability, occlusion, and substructure design, with adjustments made as necessary. The bisque evaluation stage assessed the marginal integrity, stability, porcelain contours, shade, texture, and glaze [12].

The final PFM crown was cemented with glass ionomer cement, with meticulous occlusal checks performed using articulating paper to ensure optimal fit and patient comfort. [Figure 7] Follow-up appointments were scheduled to evaluate the final restoration's adaptation, occlusion, and overall patient satisfaction [13]. After a 6-month interval, a follow-up CBCT scan (P1) was performed to assess any changes or adaptations in bone structure, with precise measurements taken as in the pre-operative scan [Figure 8].

Results

Comparison of buccal and lingual bone height before and after PFM single crowns before and after 6 months measured with CBCT. The study utilized a paired t-test to compare pre- and post-treatment measurements of buccal and lingual bone heights from the apex in patients treated with Porcelain-Fused-to-Metal crowns. The paired t-test was chosen due to its effectiveness in evaluating the differences between two related groups. [Table 1] The results showed no statistically significant difference in buccal bone height from the apex (mean difference = -0.1567 mm, P=0.082) between pre- (P0) and post-treatment (P1) measurements. For lingual bone height, although there was a higher mean post-treatment value, the difference was also not statistically significant (mean difference = -0.1100 mm, P=0.060, which is greater than the chosen significance level of $p<0.05$).

The graph [Table 2] displays an intra-group comparison of the buccal bone height from the apex in millimeters (mm) before and after a certain treatment or intervention.

- **Pre-treatment buccal bone height:** The average buccal bone height before the treatment was 10.757 mm.
- **Post-treatment buccal bone height:** The average buccal bone height after the treatment increased to 10.913 mm.

This indicates a slight increase in the buccal bone height from the apex following the treatment or intervention.

The graph [Table 3] shows an intra-group comparison of the lingual bone height from the apex in millimeters (mm) before and after a certain treatment or intervention.

- **Pre-treatment lingual bone height:** The average lingual bone height before the treatment was 11.140 mm.
- **Post-treatment lingual bone height:** The average lingual bone height after the treatment increased to 11.250 mm.

Following the dental treatment, lingual bone height increased from 11.140 mm to 11.250 mm, and buccal bone height rose from 10.757 mm to 10.913 mm. These changes indicate that the intervention had a positive impact on bone structure, with a more noticeable improvement in lingual bone height. This suggests that the treatment supported bone remodeling and enhanced the structural integrity of the peri-abutment bone, contributing to the stability and longevity of dental restorations like PFM crowns.

Figures

Fig 1: Pre-operative CBCT scan showing the measurement of buccal bone height from the root apex in the mandibular posterior region

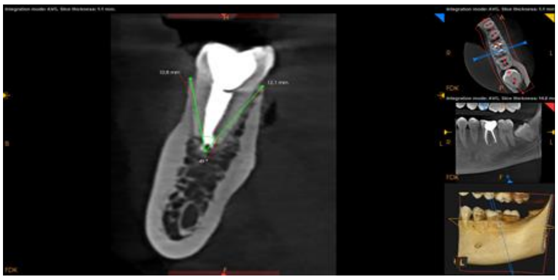


Fig 2: Pre-operative CBCT scan showing the measurement of lingual bone height from the root apex in the mandibular posterior region

Fig 3: Visual representation of the shade-matching process for porcelain-fused-to-metal (PFM) crowns to achieve aesthetic alignment with adjacent teeth

Fig 4: Tooth preparation process using high-speed air motor and dental loupes, ensuring precise cutting and moisture control

Fig 5: Impression-making technique with adhesive-coated stock tray and putty material, capturing detailed impressions for accurate crown fabrication

Fig 6: Gingival retraction using a knitted cord dipped in Aluminum Chloride, facilitating an accurate impression by creating space around the prepared tooth

Fig 7: Cementation of the final PFM crown with glass ionomer cement, followed by occlusal adjustments to optimize fit and comfort

Fig 8: Post-operative CBCT scan taken six months after crown placement, showing the measurement of buccal and lingual bone heights for comparative analysis

Discussion

The placement of porcelain-fused-to-metal (PFM) crowns in the posterior region is crucial in prosthetic dentistry for restoring both function and aesthetics. These crowns must manage significant masticatory forces and evenly distribute occlusal stress to avoid adverse bone responses. Single crowns modify the local biomechanical environment, leading to bone remodeling to accommodate new loading conditions. This process involves bone resorption and formation by osteoclasts and osteoblasts. Initial placement of a PFM crown often triggers an inflammatory response that leads to bone resorption, followed by a phase where osteoblasts work to restore bone structure. The material differences between the metal substructure and natural tooth structure can cause stress mismatches, necessitating careful management to prevent bone changes. Cone Beam Computed Tomography provides detailed 3D imaging, offering insights into peri-abutment bone alterations and enhancing diagnostic precision [1, 14-16].

Understanding the impact of single PFM crowns on alveolar bone requires knowledge of the physiological characteristics of supporting tissues. Effective crown design must ensure compatibility with surrounding tissues, with bone vitality being crucial for crown stability. Studies using CBCT have examined stress and strain distributions in posterior molars before and after crown placement. Mechanical masticatory stimulation is essential for bone health, and crown placement alters local bone morphology and biomechanics. Frost's mechanostat theory suggests that a minimum effective strain (MES) maintains bone turnover equilibrium, with PFM crowns helping to adapt to increased masticatory loads. The masticatory system, involving muscles, teeth, and the periodontium, handles forces and stress distributions, which can be altered by tooth and bone loss. Studies by Sulik and White highlight the increased strains in PFM crown models compared to pre-crown models, while research by Zweers *et al*. discusses stress distribution is high in the cervical region of the abutment teeth [17-22].

PFM crowns combine a durable metal core with a natural-looking porcelain exterior, used to restore damaged teeth and improve appearance. They must handle significant masticatory forces while providing aesthetic benefits. Research by Lehman and Mleyer shows that masticatory forces create high stress near the amelocemental junction, affecting restorations. Clarice Field's study found significant bone mineral density (BMD) loss after fixed partial dentures (FPDs) installation, emphasizing the need for proper design to maintain bone health. Walton's research on jacket crown fractures highlighted the importance of core design in reducing stress. Glickman used photoelastic analysis to study internal stresses, and Field's work on vertical and distributed loads provides recommendations for preventing bone resorption and ensuring long-term success [23-28].

In the present study, the P0 and P1 measurements were marked and recorded using the Carestream 3D imaging software 3.8.7 (Carestream Health, Inc, USA) with 6cm field of view (FOV) using 90 kilovoltage, 4.0 mA and 20.0 s of exposure time in the imaging software, focusing on the distance from the apex of the abutment's root to the buccal and lingual bone. These measurements were taken for both the P0 and P1 phases. The data from a total of 23 samples were compiled into a master chart for analysis. The comparison of pre- and post-treatment values for buccal and lingual bone height from the apex revealed no statistically significant differences between the time intervals. For buccal bone height, the mean pretreatment value was 10.76 mm with a standard deviation of 2.42, while the post-treatment mean was 10.91 mm with a standard deviation of 2.35. The mean difference between pre- and post-treatment values was -0.16 mm, with a standard deviation of 0.48, resulting in a t-value of -1.800 and a p-value of 0.082, indicating non-significance ($p>0.05$). Similarly, for lingual bone height, the pre-treatment mean was 11.14 mm with a standard deviation of 1.62, and the post-treatment mean was 11.25 mm with a standard deviation of 1.63. The mean difference was -0.11 mm, with a standard deviation of 0.21, leading to a t-value of -2.860 and a p-value of 0.060, also indicating non-significance ($p>0.05$). Despite slight increases in post-treatment values, these differences were not statistically significant, suggesting that the placement of PFM crowns did not result in significant changes in bone height measurements within the observed period. Previous studies on fixed prosthodontics often focus on technical issues and stress peaks, with fewer examining the biomechanical responses of mandibular bone. Clarice Field and Qing Li's 3D finite element analysis showed higher stress/strain in mandibles with FPDs, indicating bone remodeling. However, our clinical study of single crown FPDs showed no significant changes over 6 months. Field and Li's study also found increased bone resorption in the buccal region under FPDs, aligning partially with our study's observations of buccal and lingual bone remodeling, though no significant overall changes were recorded. Junro Yamashita's research on 3-unit FPDs found minimal changes in mandibular strain patterns, consistent with our findings. J. Zweers *et al*. reported more marginal bone loss with narrow diameter implants compared to regular ones, but our study found no significant changes but a slight increase in buccal and lingual bone height, suggesting stress from PFM crowns may induce bone growth [6].

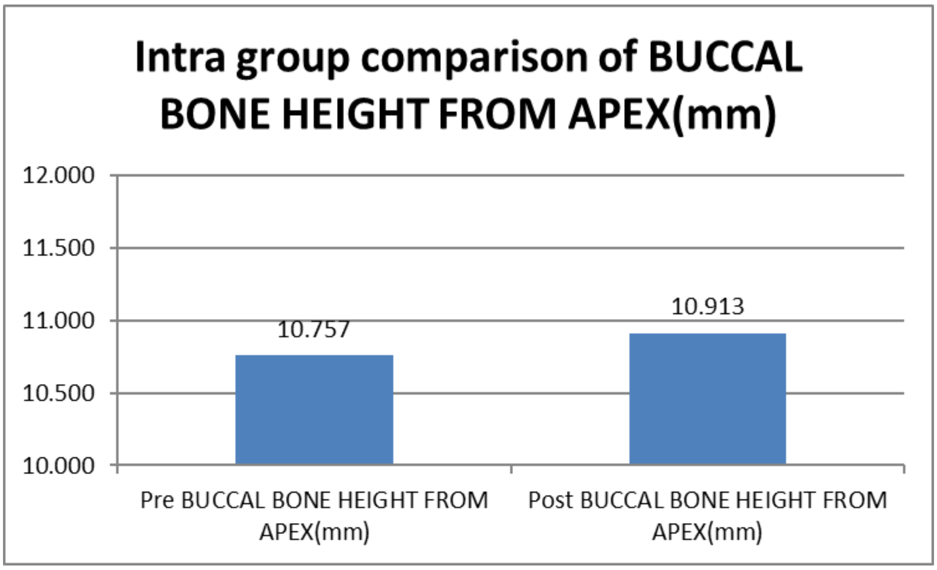
We observed no statistically significant bone growth, which may be attributed to the limited number of subjects. To provide a more definitive conclusion, further clinical studies with larger sample sizes are necessary. These additional studies could confirm the potential for bone regrowth due to the use of PFM crowns in patients. It is important to consider the possibility of measurement errors in our study, further emphasizing the need for more precise and expansive research. Notably, changes observed in bone growth could be explained by Frost's mechanostat theory and Wolff's law. Frost's mechanostat theory suggests that bone adapts its strength in response to the mechanical loads it experiences. According to this theory, when bone is subjected to increased stress, it responds by growing stronger to accommodate the load. Conversely, reduced stress leads to bone resorption. Wolff's law posits that bone in a healthy person will adapt to the loads under which it is placed. If loading on a bone increases, the bone will remodel itself over time to become stronger to resist that sort of loading. These principles suggest that the observed bone changes could be a response to the mechanical environment created by the PFM crowns. Therefore, larger, more precise studies are essential to validate these findings and understand the underlying mechanisms better. The study on the impact of porcelain-fused-to-metal crowns on buccal and lingual bone heights has several limitations. The small sample size of 23 subjects limits generalizability and statistical power, potentially missing subtle changes. The six-month follow-up may not be long enough to capture long-term bone remodeling effects. Measurement errors, despite using Cone Beam Computed Tomography (CBCT), could affect results. Additionally, the study did not account for variables like bone density, masticatory forces, or oral hygiene, which could confound results. A lack of comparative analysis with other prosthetic devices limits understanding. Future research should include larger samples, longer follow-ups, and control for additional variables to confirm findings and compare PFM crowns with other restorations.

Table

Table 1: Distribution of mean and standard deviation and comparison of pre-op and post op measurement

	Mean	Std. Deviation	Std. Error Mean	Mean diff	SD of diff	T-Value	P-Value of paired t-test
Pre buccal bone height from apex(mm)	10.756667	2.4197012	.4417750	-.1566667	.4768310	-1.800	.082#
Post buccal bone height from apex(mm)	10.913333	2.3506028	.4291594				
Pre lingual bone height from the apex(mm)	11.140000	1.6221739	.2961671	-.1100000	.2106640	-2.860	.060#
Post lingual bone height from the apex(mm)	11.250000	1.6281468	.2972576				

Table 2: Comparison of pre vs post buccal bone values in bar graph



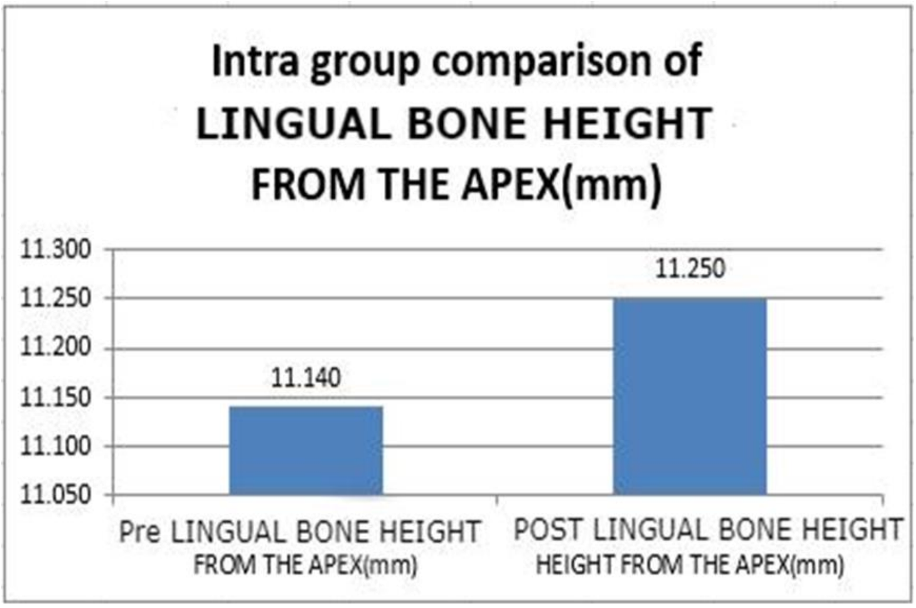


Table 3: Comparison of pre vs post lingual bone values in bar graph

Conclusions

This study evaluated the impact of Porcelain-Fused-to-Metal (PFM) crowns on buccal and lingual bone heights using Cone Beam Computed Tomography (CBCT) in a controlled clinical setting. By adhering to a patient evaluation process and employing precise measurement techniques, the research aimed to determine whether the placement of PFM crowns influenced peri-abutment bone stability over a six-month period. The investigation included detailed pre- and post-operative CBCT scans and utilized advanced statistical analyses to ensure accurate findings. The results showed no statistically significant differences in buccal bone height (mean difference = -0.1567 mm, P=0.082) and lingual bone height (mean difference = -0.1100 mm, P=0.060) from the apex before and after the placement of PFM crowns. These results suggest that PFM crowns do not adversely affect peri-abutment bone heights within the first six months post-cementation, indicating that they maintain peri-abutment bone stability. The study's comprehensive methodology, including careful tooth preparation, accurate impression making, and precise crown placement, contributed to these findings, underscoring the importance of clinical protocols in achieving successful outcomes. The absence of significant changes in bone heights post-cementation highlights the effectiveness of PFM crowns in preserving bone integrity, making them a reliable option for restorative dental procedures but also further clinical studies with larger sample sizes are necessary to confirm the potential for bone regrowth due to PFM crowns, considering principles like Frost's mechanostat theory and Wolff's law, which suggest bone adapts to mechanical stress.. This research contributes valuable insights into the long-term stability and success of PFM crowns, providing a foundation for future studies to explore longer-term impacts and further refinements in restorative dental practices.

Conflict of Interest
Not available

Financial Support
Not available

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