

Assessment of the Peri-implant Bone Density Following Bicortical Anchored Corticobasal Implants Placement in the Maxillary Arch: A Cross-sectional Prospective Study

Anita Doshi¹, Jayantilal Patel², Vivek Gaur³, Gabriela Fernandes⁴, Fadia Awadalkreem⁵

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ABSTRACT

Aim: The aim of this cross-sectional prospective study was to evaluate the bone density changes around the bicortical corticobasal implant placed in the maxilla over 18 months of follow-up using cone-beam computed tomography (CBCT), focusing on the comparison between the anterior and posterior teeth and regions.

Materials and methods: Thirty-five subjects (20, 53.26%, were males, and 15, 46.73%, were females) received 380 implants (Basal Cortical Screwable implant, BCS®) at Narsinhbhai Patel Dental College and Hospital, India. Implant survival and success were assessed using Albrektsson criteria for implant success. The peri-implant bone density values were measured using CBCT (Vatech PaX-i 3d Smart) and *InVivo* software (Anatomage, San Jose, California, USA) at the baseline (immediate postoperative) and at the 18-month follow-up visit. For standardization purposes, the bone density values for only the maxillary implants were measured at the level of the second implant thread in four sites: buccal, mesial, distal, and palatal, respectively. The recorded data were tabulated and grouped according to the tooth's region (anterior/posterior) and sites (mesial, distal, buccal, and palatal).

Results: The implant's survival rate was 100%. After 18 months, the bone density increased significantly ($p < 0.05$) in all the sites in both anterior and posterior regions. The study's findings revealed a higher bone density increase in the posterior region compared to the anterior region after 18 months of follow-up, except for the palatal site.

Conclusion: Within the limitations of this study, an increase in the peri-implant bone density has been associated with the use of corticobasal implants over time, with reported anterior/posterior regional variations.

Clinical significance: This study provides valuable insights into the bone density changes associated with bicortical corticobasal implants and emphasizes the importance of CBCT in evaluating bone density, as well as the significance of regional considerations in implant dentistry. By integrating these findings into clinical practice, clinicians can improve treatment outcomes and ensure long-term implant survival.

Keywords: Bicortical implants, Bone density, Cone-beam computed tomography, Corticobasal implant, Peri-implant bone density.

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INTRODUCTION

Corticobasal implantology represents a paradigm shift in dental implantology with a high reported success rate and improved patient satisfaction, especially in compromised ridge support and maxillofacial patients.¹⁻¹¹ It provides the patients with a fixed treatment modality without a bone grafting procedure and the associated consequences, including treatment delaying.⁸⁻¹¹

This modern technology has been developed on the basis of dental demands through the application of orthopedic principles and the method of osseofixation.^{12,13} Implants utilize the basal bone for macromechanical anchorage of the horizontal plates of the implants, resulting in immediate high primary stability with integration of the vertical shaft of the implant over time.^{12,13} A stiff prosthetic framework splints the anchored implants together, a characteristic that improves the biomechanical force distribution, reduces the force per implant, and directs and transmits the multidirectional masticatory load to the strongest cortical basal bone.^{1,5,8,11-14} Hence, understanding the bone response and the associated changes following corticobasal implants is crucial for optimizing the treatment outcomes and ensuring long-term survival.

Numerous investigators have highlighted the use of corticobasal implant-supported prostheses with high survival/success rates,

^{1,3}Department of Prosthodontics, Sankalchand Patel University, Visnagar, Gujarat, India

²Department of Health Sciences, Sankalchand Patel University, Visnagar, Gujarat, India

⁴Department of Periodontics and Endodontics, SUNY Buffalo, New York, United States of America

⁵RAK College of Dental Sciences, RAK Medical and Health Sciences University, Ras Al Khaimah, United Arab Emirates

Corresponding Author: Anita Doshi, Department of Prosthodontics, Sankalchand Patel University, Visnagar, Gujarat, India, Phone: +91 9320030735, e-mail: dranitagala@gmail.com

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fewer reported complications, acceptable esthetic, masticatory, and phonetic outcomes, as well as significant improvements in patient

satisfaction and quality of life.^{1–4,6,8,11} A recent study conducted by Awadalkreem et al.¹ in 2022 reported a 100% survival rate when corticobasal implants were used in rehabilitating patients with compromised ridge support after 18 months of follow-up. In a study by Pałka Ł and Lazarov A,³ 1019 polished surface bicortical screw implants were used in 87 patients with and without a history of periodontitis. The survival rates after 12-, 24-, and 35 months were 99.3%, 98.6%, and 97.0%, respectively.

Current guidelines for implant success recommend the use of intraoral radiographs, such as periapical radiography and cone-beam computed tomography (CBCT), in assessing the peri-implant bone health.^{15–25} Cone-beam computed tomography serves as a valuable tool for monitoring bone remodeling dynamics and bone density surrounding implants by providing a detailed three-dimensional image and facilitating precise measurement of bone density.^{15–25}

Several investigators studied^{15–25} the change in the bone density following conventional implant insertion; however, there is limited data regarding the effect of corticobasal implant anchorage on the peri-implant bone density.

This study aimed to evaluate the change in the bone density around bicortical corticobasal implants placed in the maxilla over 18 months of follow-up using CBCT, focusing on the comparison between the anterior and posterior regions.

MATERIALS AND METHODS

A cross-sectional prospective study was conducted at the Department of Prosthodontics, Narsinhbhai Patel Dental College and Hospital, Visnagar, Gujarat, India, between 2021 and 2023. The study protocol was approved by the Ethics Committee of the Narsinhbhai Patel Dental College and Hospital, Visnagar, IEC. No: NPDCH/IEC/2021/45, prior to the commencement of the study. The procedure adhered to the ethical guidelines of the Declaration of Helsinki. Each participant was informed about the study protocol and asked to participate voluntarily. Written informed consent for participation in the study and publication of the acquired data were obtained for all the participants before enrollment.

Sample Selection

A convenient sample size, including all the patients who approached the Department of Prosthodontics, Narsinhbhai Patel Dental College, and Hospital for implant treatment at the time of the study within the inclusion and exclusion criteria.

Inclusion and Exclusion Criteria

The inclusion criteria included patients with partial or full edentulism in the upper jaw or both the upper and lower jaws. However, to ensure standardization, the study measurements only included the maxillary implants. Additionally, the patient should be in good periodontal health, have no history of progressive periodontitis, be under 18 years old, and be suitable for implant surgery (ASA type I patients).²⁶

The exclusion criteria included the following: patient presented with uncontrolled diabetes mellitus and hypertension or any systemic condition that contradicts any surgical procedure; history of radiotherapy or chemotherapy within the last year; pregnancy; patient presented with oral lesions, such as tumors, bone diseases, and progressive periodontitis; and patient who refused to sign the informed consent.

The Surgical and Prosthetic Procedures

Preoperative CBCT scans (Vatech PaX-i 3d Smart) were obtained for all patients using a standardized technique with exposure parameters of 70 kV and 8 mA for 12 s, using the same scanner and by the same radiologist with 9 years of experience.

Before the operation, patients were instructed to rinse their mouths with Betadine 10% for 10 minutes. For standardization purposes, the implants were inserted by the same maxillofacial surgeon with vast experience in corticobasal implant treatment, and the prostheses were constructed by the same prosthodontist. Flapless technique was followed under infiltration local anesthesia (Lidocaine 2% with adrenaline 1:100,000). Implant osteotomy was carried out using the sequential order of calibrated drills recommended by the manufacturer, cooled with saline solution in external mode at a speed of 27,000 rpm. Implants (Basal Cortical Screw, BCS® implant design) were distributed following the 16 standard clinically proven methods for placing corticobasal implants.²⁷ Postoperative instructions regarding antibiotic and analgesic medication and maintenance of proper hygiene were given to the patients. Immediate postoperative CBCT (baseline) was obtained by the same radiologist for each patient. Impression was taken using Addition Silicon Aquasil (Dentsply), and the prostheses were constructed using the same standard technique and delivered within 3 days. The final prostheses were cemented using Fuji cement (GC Corporation, Tokyo, Japan). Occlusal adjustment was performed, and patients were scheduled for the follow-up program after 1-, 3-, 6-, 12-, and 18 months. In each follow-up visit, patients were examined clinically and radiographically, and complaints were reported (Fig. 1).

Grouping of the Sample and the Study Design

According to the implant position, the sample of the study ($n = 380$) was divided into two groups (Fig. 2):

- Group A ($n = 190$): Anterior implants.
- Group B ($n = 190$): Posterior implants.

The Investigated Study Outcomes and Variables

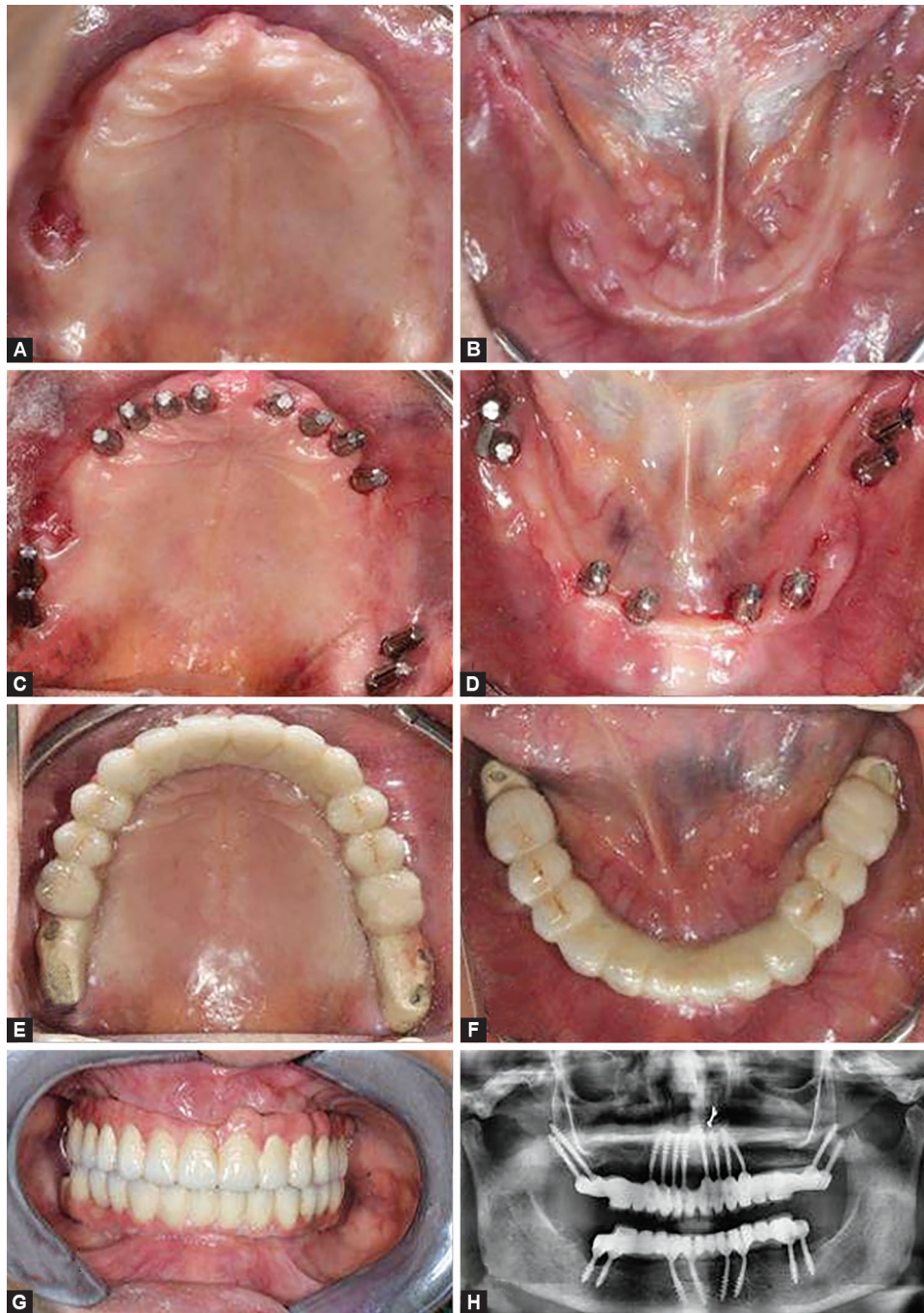
Implant Survival, Success, or Failure

- Implant survival rate was determined by the presence of the implant inside the mouth at the time of examination.²⁸
- Implant success/failure was determined based on the Albrektsson criteria with slight modification.²⁹ An implant was considered failed if the following were detected: The existence of discomfort or persistent pain, peri-implant infection or suppuration, vertical mobility of the implant, and bone loss apical to the shaft of the implant.
- The patient's complaints were reported according to Clavien–Dindo classification.³⁰

Bone Density Evaluation

The peri-implant bone density values were measured and analyzed using CBCT and *InVivo* software (Anatomage, San Jose, California, USA) at the baseline (immediate postoperative) and at the 18-month follow-up visit. Two examiners, including the main investigator, a radiologist and a periodontist, performed the analysis.

For standardization purposes, the bone density values for all the implants were measured at the level of the second implant thread in four regions: buccal, mesial, distal, and palatal, respectively (Fig. 2). All images were evaluated on a high-definition liquid crystal



Figs 1A to H: The clinical and radiographic presentation of the patient code 014. (A) Intraoral view of the patient showing maxillary edentulous arch; (B) Intraoral view of the patient showing mandibular edentulous arch; (C) Intraoral view of the maxillary jaw presenting implant distribution; (D) Intraoral view of the mandibular jaw presenting implant distribution; (E) Intraoral view showing maxillary fixed corticobasal implant-supported prosthesis; (F) Intraoral view presenting the mandibular fixed corticobasal implant-supported prosthesis; (G) Intraoral view presenting the maxillary mandibular fixed corticobasal implant-supported prosthesis; (H) The post-implant insertion panoramic radiograph showing the distribution of the maxillary and the mandibular BCS implants

display using *Invivo* software. The area of interest was selected using the spatial coordination tool (x, y). The y-coordinate, which varies vertically, was kept constant, and tangentially positioned the x-coordinate, which varies horizontally, at the level of the edentulous space included in the study.

The software automatically calculated the Hounsfield units (HU) using its built-in density measuring tool.¹⁹ As the HU

measurement tool showed three intensity values at each implant site (minimum, mean, and maximum), only the mean value was considered for the analysis. The collected data included the peri-implant bone density measurements recorded immediately following implant insertion (baseline) and at the 18 month follow-up visit. The data was tabulated and grouped according to the tooth's region (anterior/posterior) and sites (mesial, distal,

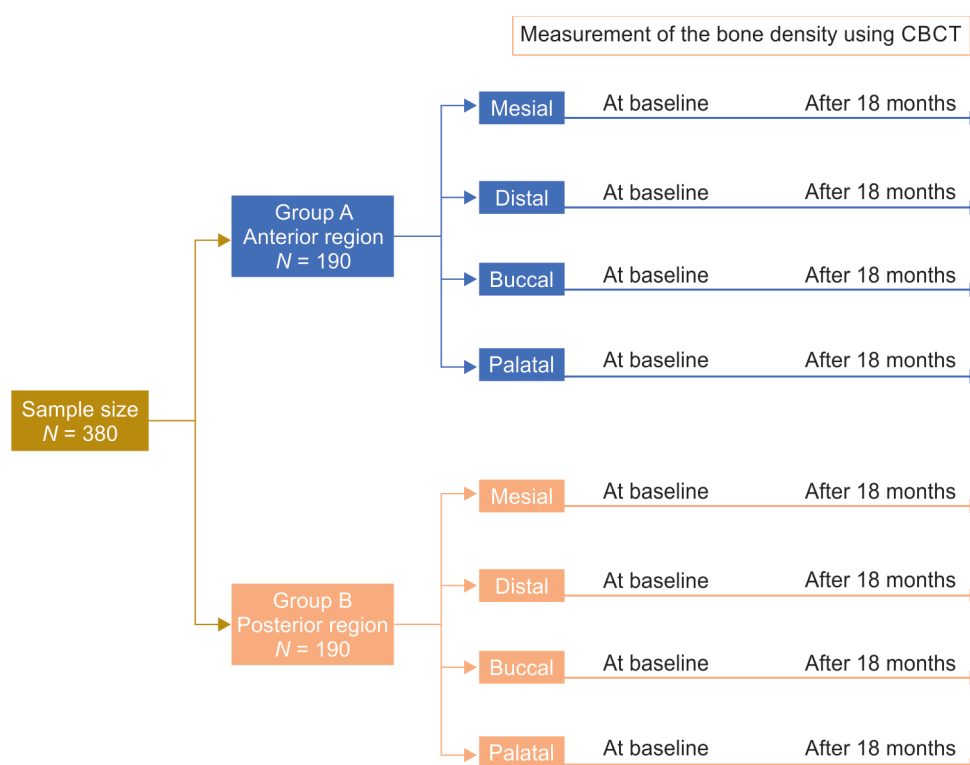


Fig. 2: Flowchart diagram of the study design

buccal, and palatal). The anterior region included data from the central, lateral incisors, and canine areas, while the posterior region included the premolars, molars, and tubero pterygoid areas. The change in bone density was the sum difference between the volumes measured immediately after implant placement (baseline) and at the 18-month follow-up visit.

The Inter- and Intra-examiner Reliability

The inter- and intra-examiner reliability for the investigators was assessed using repeated measurements at intervals performed over a varying number of days' period and found to be 0.91 and 0.92, respectively.

Statistical Analysis

Analysis of the data was achieved using the Statistical Package for Social Sciences software (SPSS®, version 15, IBM, Chicago, IL, USA). Means, standard deviations (SDs) and percentages were used for descriptive data and calculated for each group. A one-way ANOVA test was used to analyze the bone density measurements. The significance level was set at $p \leq 0.05$.

RESULTS

Descriptive Data

The study sample included 35 subjects (20, 53.26%, were males, and 15, 46.73%, were females). The patient's mean age was 55.0 (52.79 + 16.77; age range: 21–97 years), and 380 implants were included in the study.

Implant Survival, Success/Failure Outcomes

- After 18 months of function, the implants showed a 100% survival rate.²⁸

- 0% of the implant being considered failed.²⁹
- All of the reported complaints were found to be grade one, according to Clavien–Dindo classification,³⁰ and dealt with.

The Bone Density Outcomes

The bone analysis measurements are reported and summarized in Table 1, including the bone density change and differences in the basal bone surrounding the implant.

The one-way ANOVA test revealed significant differences in the bone density in all the sites (mesial, distal, buccal, and palatal) between both anterior and posterior region implants ($p < 0.05$) (Table 1, Figs 3 to 10).

For the mesial sites, the bone density was increased in the anterior and posterior implants by 281.2 ± 82.03 HU and $309.7 \text{ HU} \pm 48.83$, respectively (Table 1, Fig. 7), whereas it increased by 200.9 ± 58.58 HU and 286.0 ± 45.10 HU in the maxillary distal sites. (Table 1, Fig. 8).

In the maxillary buccal site, the anterior and posterior density gains were 319.5 ± 59.23 (Table 1, Fig. 9) and 337.3 ± 59.16 , respectively (Table 1, Fig. 9). While in the maxillary palatal sites, the anterior and posterior bone density gains were 319.5 ± 61.98 and 337.3 ± 51.50 , respectively. (Table 1, Fig. 10).

The study's findings revealed a higher bone density increase in the posterior region compared to the anterior region after 18 months of follow-up, except for the palatal site (Table 1).

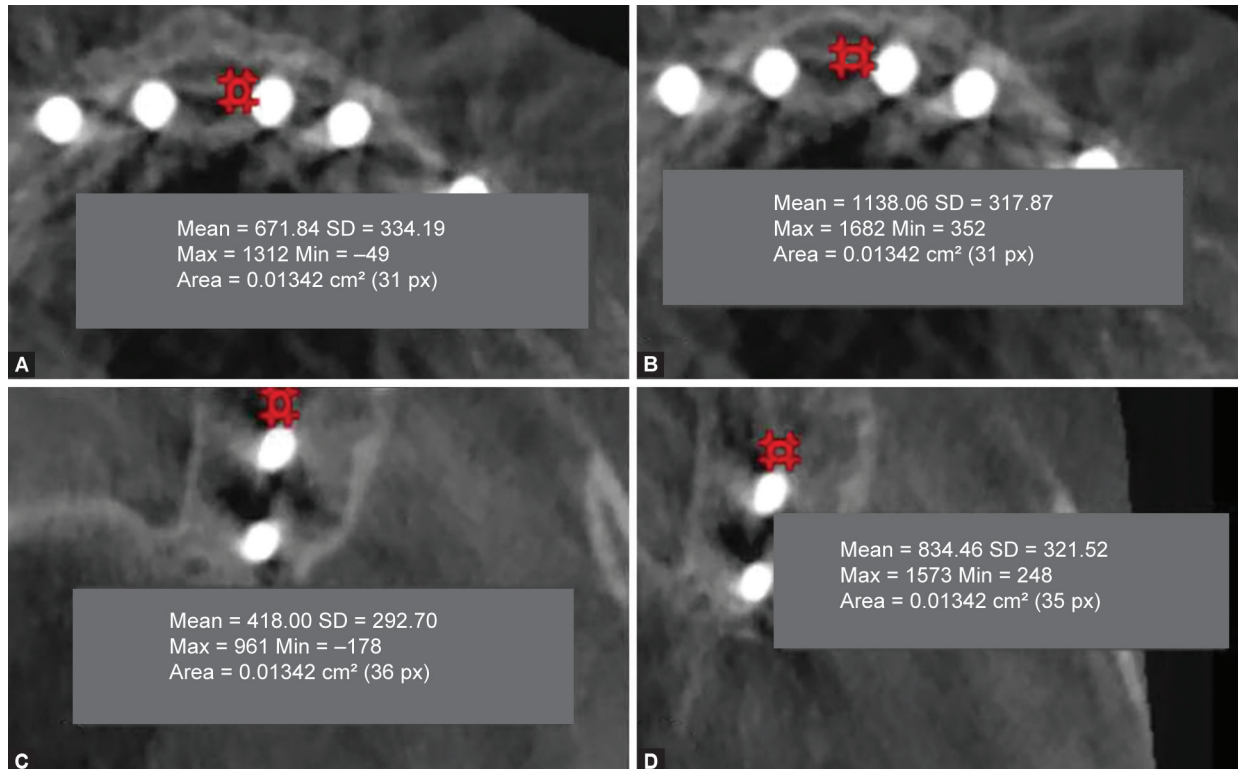
DISCUSSION

Implant stability and peri-implant bone health play a significant role in long-term implant survival, success, and hence prosthesis' outcomes. Therefore, studying the effect of implant anchorage on bone density and its consequences on implant stability is of great importance.^{31,32}

Table 1: Shows the peri-implant bone density measurements according to the different implant sites and regions

Position	Variable	Group A anterior implants mean (HU)	Group B posterior implants mean (HU)	p-value
Mesial	Baseline	807.46	569.46	<0.0001*
	Post 18 months	1088.66	879.2	
	Difference	281.20	309.74	
	SE of difference	82.03	48.83	
	95% CI of difference	120.42–441.98	214.03–405.45	
Distal	Baseline	853.4	533.2	0.0004*
	Post 18 months	1054	819.2	
	Difference	200.9	286.0	
	SE of difference	58.58	45.10	
	95% CI of difference	318.7–83.14	375.7–196.3	
Buccal	Baseline	811.8	591.8	<0.0001*
	Post 18 months	1131	929.2	
	Difference	319.5	337.3	
	SE of difference	59.23	59.16	
	95% CI of difference	439.1–199.8	455.3–219.4	
Palatal	Baseline	757.2	583.4	<0.0001*
	Post 18 months	1081	889.2	
	Difference	324.2	305.7	
	SE of difference	61.98	51.50	
	95% CI of difference	449.3–199.0	408.4–203.0	

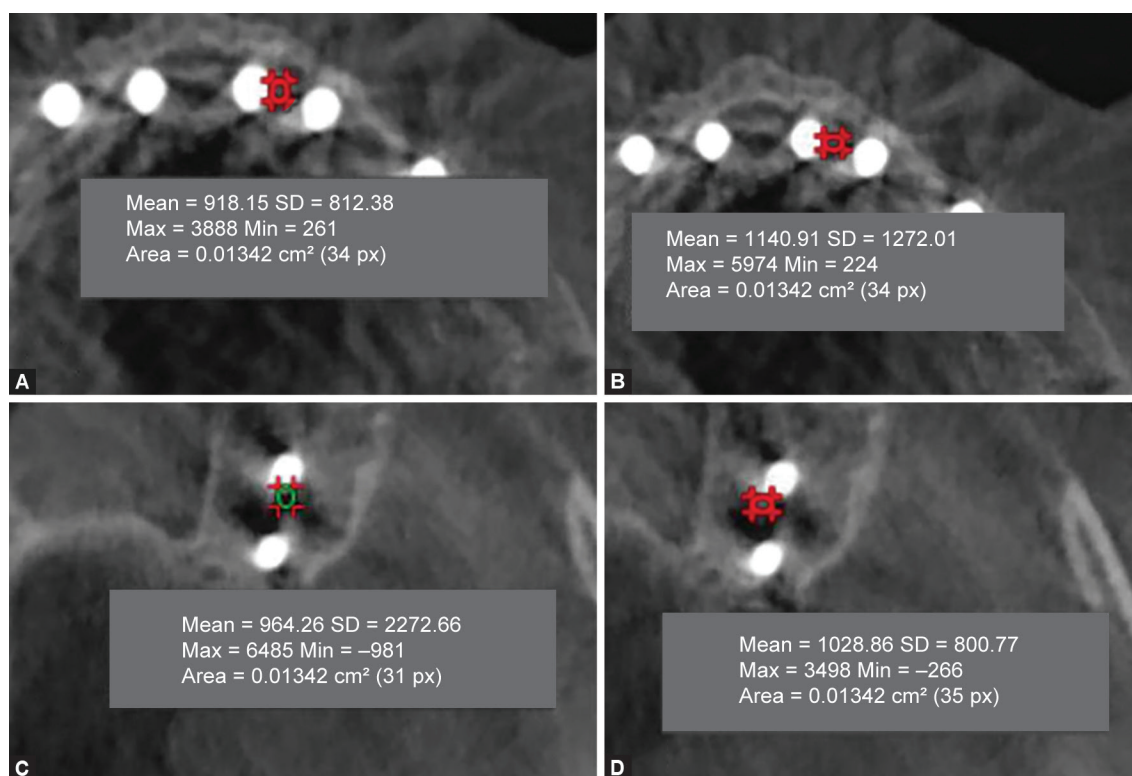
*represents significant, One-way ANOVA test was used



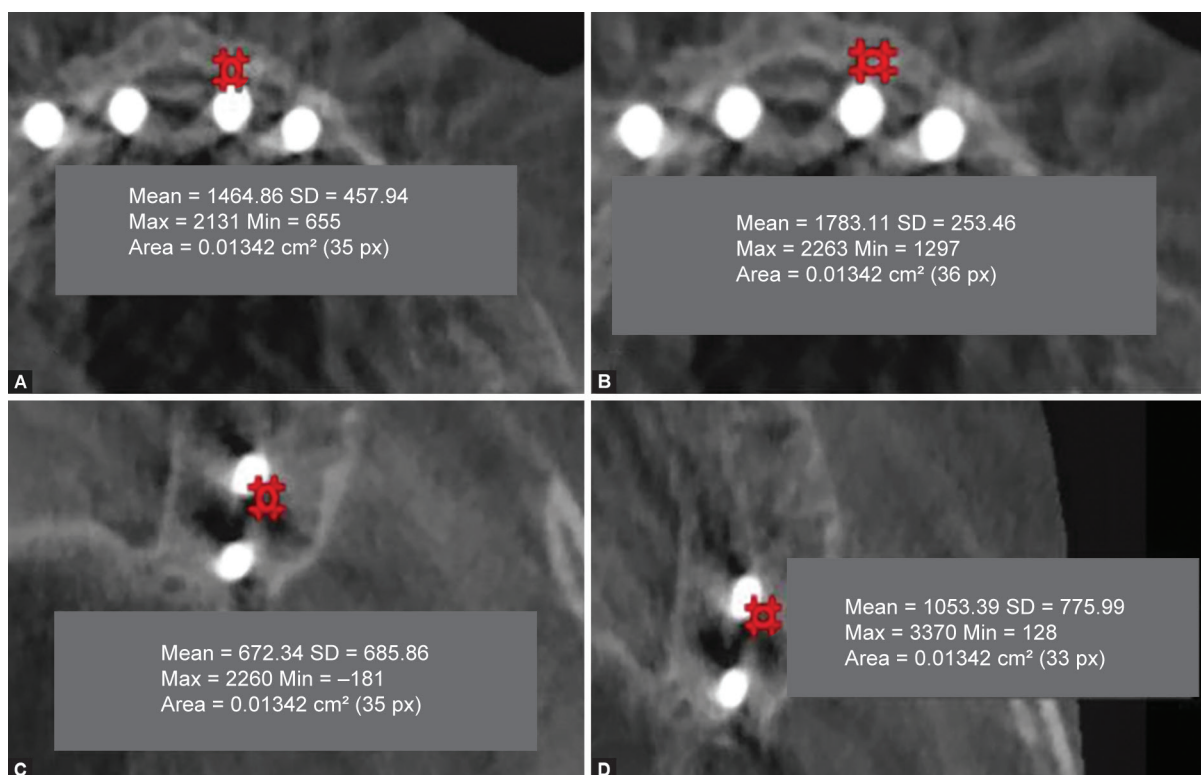
Figs 3A to D: The cone-beam CT showing the measurement of the bone density in the mesial site in the anterior region. (A) At baseline; (B) After 18 months. In the posterior region: (C) At baseline; (D) After 18 months

There is a strong link in the research between the density of the bone around an implant and its primary stability, with many prescribed methods used to evaluate the peri-implant bone density,

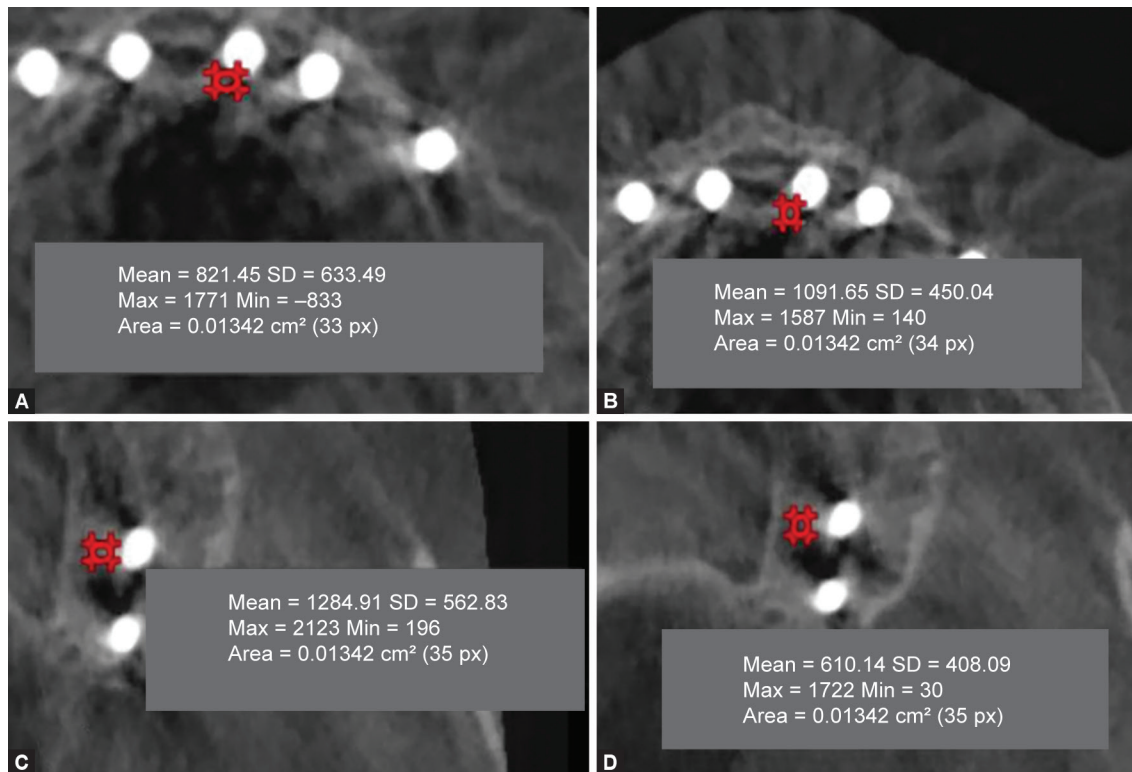
including surgical expertise during torque force and reverse torque technique. Despite the reliability and easy accessibility of these techniques, subjective evaluation may question their accuracy.²¹



Figs 4A to D: The bone-beam CT showing the measurement of the bone density at the distal in the anterior region. (A) At baseline; (B) After 18 months. In the posterior region: (C) At baseline; (D) After 18 months



Figs 5A to D: The cone-beam CT showing the measurement of the bone density at the buccal site in the anterior region. (A) At baseline; (B) After 18 months. In the posterior region: (C) At baseline; (D) After 18 months



Figs 6A to D: The cone-beam CT showing the measurement of the bone density at the palatal site in the anterior region. (A) At baseline; (B) After 18 months. In the posterior region; (C) At baseline; (D) After 18 months

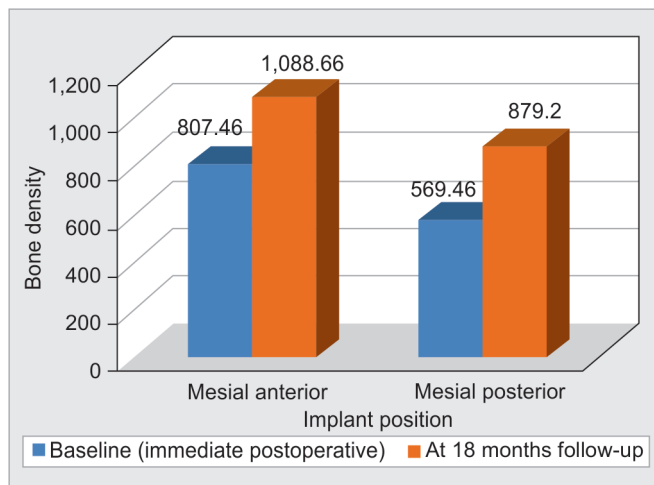


Fig. 7: Displays the peri-implant bone density at the mesial site in the anterior and posterior regions at the baseline and 18-month follow-up visits

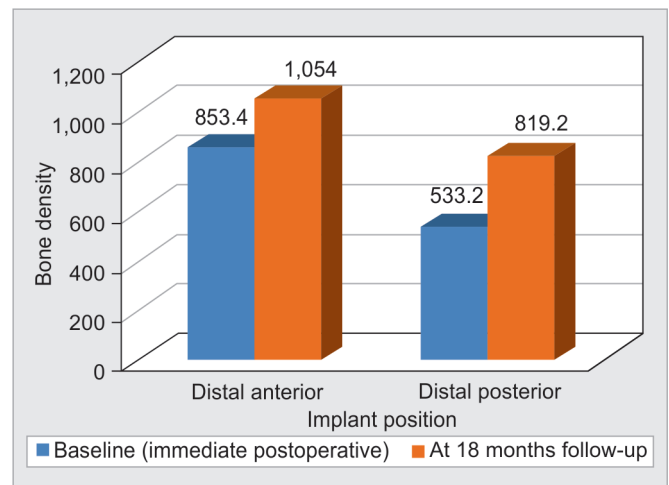


Fig. 8: Displays the peri-implant bone density at the distal site in the anterior and posterior regions at the baseline and 18-month follow-up visits

In the present study, the use of CBCT has been emphasized due to its ability to provide more accurate and precise information regarding the peri-implant bone structure, including bone quality and quantity. This choice aligns with the findings of numerous other researchers.^{17-20,22-25} Hussaini et al.²⁵ conducted a recent study that highlighted the significance of using CBCT as an adjunct to panoramic radiography during the diagnosis and treatment planning phases, as it reduces the likelihood of misdiagnosis by 7%. While Park et al.¹⁷ reported the high accuracy, linearity, and

uniformity of CBCT images in evaluating the bone mineral density at the implant site, In the same line, Sennerby et al.²² emphasized the role of CBCT for bone density examination to predict implant primary stability in patients.

The present study reports an increase in bone density after 18 months of follow-up, which can be attributed to the ongoing bone remodeling processes surrounding the implants, an explanation that aligns with the principles of Wolff's Law, which emphasized the ability of the bones to adapt to mechanical loading. Such an increase

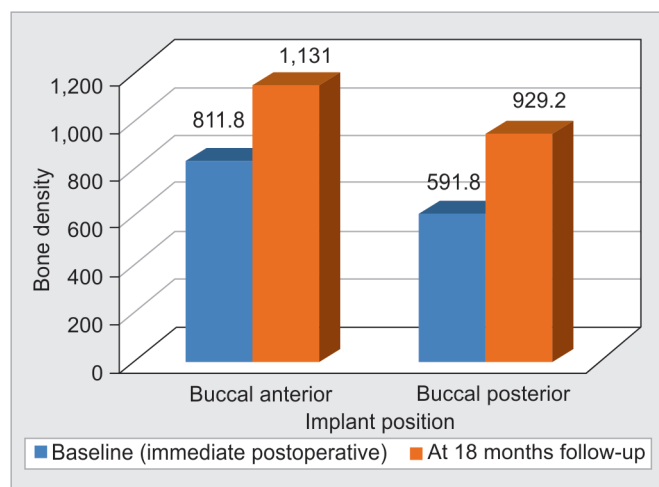


Fig. 9: Displays the peri-implant bone density at the buccal site in the anterior and posterior regions at the baseline and 18-month follow-up visits

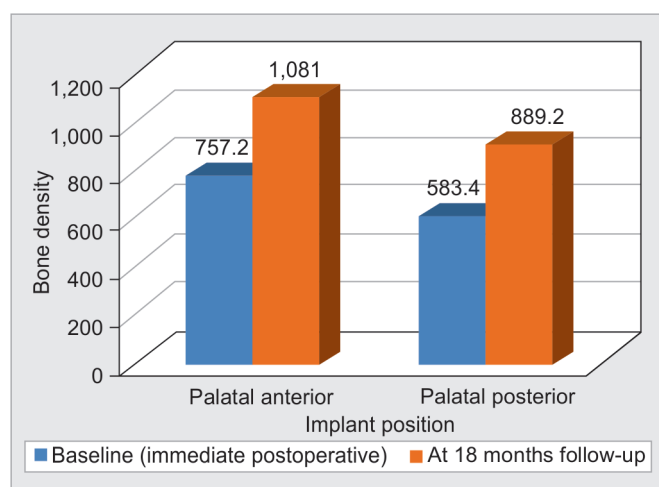


Fig. 10: Displays the peri-implant bone density at the palatal site in the anterior and posterior regions at the baseline and 18-month follow-up visits

in loading will cause the architecture of the internal, spongy bone to strengthen, followed by secondary changes to the external cortical layer.^{33–35}

This observation is in accordance with previous studies, which highlight the role of peri-implant bone remodeling and adaptation in response to implant placement and subsequent loading.^{16,36,37} A result that is in line with Lim et al.,¹⁶ who documented a significant increase in the volumetric bone change 12 months following implant insertion of two different implant designs using computed tomography. Moreover, Issa et al.³⁷ reported a decrease in bone density values during the first month of surgery, which was followed by a gradual increase from the second month and continued until after prosthesis insertion around the implant's apex, body, and neck. However, the present study used cone-beam CT for bone density evaluation, while Issa et al.'s research³⁷ relied solely on a digital periapical radiograph.

Differences in bone quality, anatomical morphology, and biomechanical loading patterns may account for the significant

regional and site variation reported in the present study. As the higher occlusal forces and greater mechanical stress in the posterior maxilla may trigger more pronounced bone remodeling responses than in the anterior region, which aligns with the posterior region's reported higher bone density. According to Şahin et al.³⁸ and Bianchi et al.,³⁵ the changes in the peri-implant bone interface were affected by a number of factors, including the amount, direction, and frequency of the applied force, the design of the implant, how well the bone and implant interface can adapt mechanically, and how the bone reacts to the mechanical loading of the implant. On the other hand, the statistically significant increase observed in the maxillary posterior region highlights the importance of considering regional factors in treatment planning and follow-up care. These findings emphasized the complexity of bone remodeling processes and highlighted the variations based on individual patient anatomy and biomechanical considerations. Understanding these regional variations in bone remodeling is crucial for optimizing treatment outcomes and ensuring the long-term success of implant therapy. The same observation has been documented by De Oliveira et al.,³⁹ who emphasized the importance of a site-specific bone tissue evaluation even prior to implant installation.

In this study, implant splinting by the rigid prosthetic framework plays a key role in improving the force distribution in the bone area around the implant, which may explain the activation of osteogenesis. This explanation is in accordance with Potapchuk et al.,⁴⁰ who reported increased implant bone contact with splinted implants 1.6 times more than non-splinted implants.

Furthermore, the effect of immediate loading and the bone function adaptation mechanism to the load can be another attributing factor resulting in the increased bone density observed in the study. A result that is in line with many investigators.^{41–43} Barros et al.⁴² reported a higher number of osteocytes in the peri-implant bone around immediately loaded implants in comparison to submerged dental implants, while Tumedei et al.⁴³ documented 10–12% higher bone implant contact (BIC) values with loaded implants.

Recent research has highlighted the impact of immediate implant loading as a mechanical stimulus on the osteogenesis process in bone cells, with a reported effect on mechanosensitive ion channels.^{44–47}

The limitation of the study included the small sample size; however, the use of CBCT and software to ensure measurement accuracy strengthens the study result.

CONCLUSION

Within the limitations of this study, an increase in the peri-implant bone density has been associated with the use of corticobasal implants over time, with reported anterior/posterior regional variations. Hence, the anchorage of corticobasal implant has a positive impact on increasing the peri-implant bone density and hence the implant survival rate.

Clinical Significance

This study provides valuable insights into the bone density changes associated with bicortical corticobasal implants and emphasizes the importance of CBCT in evaluating bone density changes, as well as the significance of regional considerations in implant dentistry. By integrating these findings into clinical practice, clinicians can improve treatment outcomes and ensure long-term implant survival.

AUTHOR CONTRIBUTIONS

Doshi A formulated the study design and contributed to the conceptualization, treating the cases, validation, writing, and finalizing the manuscript.

Patel JR formulated the study design and contributed to the conceptualization, treating the cases, data interpretation, and finalizing the manuscript.

Gaur V formulated the study design and contributed to the conceptualization, treating the cases, validation, and finalizing the manuscript.

Fernandes G formulated the study design, contributed to the conceptualization, and finalized the manuscript.

Awadalkreem F formulated the study design and contributed to the conceptualization, writing, editing, validating, finalizing, and submission of the manuscript.

All authors have read and approved the final version of the manuscript.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Research Involving Human Participants and/or Animals

All procedures performed on the patients involved were in accordance with the ethical standards of the institutional and/or national research committee, as well as the 1964 Helsinki Declaration, its later amendments, and comparable ethical standards.

Ethical Approval

The study protocol was approved by the Ethics Committee of the Narsinhbhai Patel Dental College and Hospital, Visnagar (IEC. No. NPDCH/IEC/2021/45), prior to the commencement of the study.

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