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Assessment and Correlation of Gingival Biotype and Bone Density Using Digital Diagnostic Aids

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KEYWORDS

Bone dentistry, Gingival biotype, Dynamic navigation, Digital diagnostic methods

ABSTRACT:

Background: Sufficient crestal mucosal thickness is extremely crucial for good peri implant health and minimum bone loss. Its importance has been highlighted in several articles. Cone Beam Computed Tomography offers a non-invasive approach to conduct this study which checks for the possible correlation between crestal mucosal thickness and hard tissue density on a CBCT.

Aim: To assess the correlation between the mucosal thickness and density of the underlying bone.

Materials and methods: CBCT images of partially edentulous patients treated at Saveetha Dental College were evaluated. 15 patients with 15 edentulous sites were examined. Demographic records were collected from Dias (Dental Information Archival System, Saveetha Dental College, Chennai). Cross sections at the center of edentulous sites were used to measure crestal mucosal thickness and hard tissue. Pearson's correlation was applied to evaluate the correlation between mucosal thickness and bone density.

Results: the results show an insignificant relation between the gingival thickness and the bone density. Pearson correlation of 0.120 | p value 0.408 for medullary density.

Pearson correlation of 0.097 | | p value 0.502 for cortical density.

Conclusion: Further studies are required in this field to prove a significant relation between gingival biotype and bone density.

1. Introduction

Dental implantology has emerged as the newest treatment modality in the field of prosthetic dentistry. The success rate depends majorly on the planning of the surgery based on the quantity and quality of the bone available prior to the placement of the implant. This is possible with the help of Cone Beam Computed Tomography (CBCT) which helps in the assessment of the bone availability and density. Based on two basic principles, bone density can be evaluated with CT scans- The attenuation coefficient of the x-ray beam is first calculated in order to determine the radiological density of the tissue. Thus, CT embodies the second essential principle by producing a more comprehensive two-dimensional representation of an object based on its three-dimensional reality.

Measurements are expressed using the Hounsfield scale, a quantitative scale that gives a precise density value for each tissue type, in order to evaluate the radiological density using CT.[1] Bone exhibits values ranging from

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+700 for spongy bone to +3000 for dense bone (cochlea), whereas air has a value of −1000 (black on the grayscale) on the Hounsfield scale. This is a crucial component of the imagistic analysis needed to determine bone density. Similarly, there is a significant difference between soft tissue values and air, which makes it possible to analyze maxillary sinuses and other anatomical features clearly. As a result, using values for air, water, and bone density, the Hounsfield scale calibrates a grayscale to reflect the relative density of the tissue.

The stomatognathic apparatus, which is made up of the periodontium, which includes the gingiva, periodontal ligament, cementum, alveolar process, and tooth, is a complex system that functions harmoniously to adapt to constantly changing functional demands and protect itself from a variety of harmful factors. Gingival phenotype and bone morphotype together make up periodontal phenotype. The phenotypes are classified as "thin - scalloped," "thick - scalloped," and "thick - flat". There are numerous techniques for measuring the phenotypic, including non-invasive techniques like CBCT and the periodontal probe transparency method. A dental implantologist is very interested in these aspects because the information they provide can be used to arrange treatments more effectively.

The size of the peri-implant mucosa varies depending on the tissue biotype. In order to keep the implant site healthy, at least some peri-implant mucosa must be established; otherwise, bone loss would result. In thin biotype, an angular flaw is observed, while in thick biotype, a horizontal defect is noted. Furthermore, placing an implant supracrestal, particularly in thin tissue types, might result in increased bone loss, even in cases when switching platforms did not improve results. When the peri implant mucosa dimensions in restored implants were measured using the bone sounding method, it was discovered that thicker biotypes had larger peri implant mucosa dimensions than thin biotypes. Furthermore, it has been observed that the most important criterion in evaluating papillary fill is the distance between the tip of the papilla and the underlying bone; in thin biotypes, this distance is 4 mm, but in thick biotypes, it is 4.5 mm.[2]

The quantity and quality of bone present would be another crucial component. According to Herrmann et al., the primary risk factors for implant failure are inadequate bone quantity and poor bone quality. Although, not all studies show a correlation between bone density and primary stability.[3] Lechkom and Zarb have thoroughly classified the variations into different types, with type one being the most cortical and type four being the most cancellous, and types two and three having the ideal proportion of both. Bone quality has been thought to be the basic cause of this difference. The alveolar process of the jaws contains both cortical and cancellous portions. In comparison to the mandible, the posterior maxilla typically has more trabecular bone and thinner cortical bone. It has been demonstrated that implants inserted into type 1 bone had a greater failure rate, and that it is challenging to achieve optimal primary stability in low-density bone. Additionally, it was found that implant survival is correlated with the surgeon's subjective evaluation of the quality of the bone at the osteotomy site at the time of implant insertion.

According to a study published in 2023, it was found that 33.42% had D2 bone density in the lower posterior region; 13.98% had D3 density in the lower posterior region. Primary stability of 30-40 Ncm was seen in the majority of the subjects; 32.64% who had primary stability of 30-40 Ncm had D2 bone density. It was reported that there was a significant correlation between the primary stability and bone density.[4-5] If the primary stability is adequate then immediate loading can be considered.

The relationship between gingival biotype and bone density is a critical factor in the success of dental implants. Understanding this relationship can provide valuable insights into implant planning and outcomes. This study aims to assess and correlate gingival thickness and bone density using advanced digital diagnostic tools.

Conventionally dynamic navigation softwares has been used for precise implant placement, but for this study we have explored the software for its diagnostics tools and planning capabilities.[6-10]

A computer-assisted implant placement system (CAIS) can be either dynamic or static, and it was launched in recent years. The literature claims that the CAIS method is more accurate than the freehand method.[11]

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2. Materials and Methods

2.1 Study Design

This study was conducted at the Department of Implantology, Saveetha Dental College and Hospital, Chennai, from October 2023 to April 2024. This study was approved by the Institutional Committee (Approval number: SRB/SDC/MSIMPLANT-2304/24/030). The Institutional Human Ethical Committee approved the study protocol (Approval number: IHEC/SDC/MSIMPLANT-2304/24/030). The patients requiring a dental implant and had undergone Cone Beam Computed Tomography scans were selected according to the inclusion and exclusion criteria. Data was acquired using the Dental Information Archival System of Saveetha Dental College, Chennai.

2.2 Selection Criteria

Inclusion Criteria:

(i) Patients willing to participate in the study.

(ii) Non-smokers.

(iii) Aged between 18 and 60 years.

(iv) No systemic diseases affecting mucosal thickness and bone.

(v) No previous surgeries affecting mucosa or bone density (except extraction).

(vi) Completely healed posterior edentulous sites with no infection or remaining tooth structure.

Exclusion Criteria:

(i) Smokers.

(ii) Patients with acute or chronic periodontal disease.

(iii) Patients with systemic diseases.

2.3 Measurements

Patients who had CBCT scans for dental implants in the Implantology clinic were selected. The CBCT scans were performed using the Kodak 9500 Cone Beam 3D System *(Carestream Health, Rochester, NY, USA)* with 150 microns voxel size, tube voltage 120 KV, tube current 4mA for 15s.

Intraoral scans or alginate impressions were taken. Casts were poured out of the diagnostic impressions which were later scanned using a table top scanner *(3shape, Copenhagen, Denmark)*[12]. They were superimposed on the CT scan using dynamic navigation software *(Navident, ClaroNav)*. CT scan sections were analyzed with reference points marked on the CT slice. Gingival thickness was measured from the crest of the ridge to the surface of the mucosa on the superimposed impression scan. Bone density measurements were taken at various points:

(i) C: Crestal Cortical Density

(ii) M1: Medullary Density at Point 1

(iii) M2: Medullary Density at Point 2

(iv) L1: Cortical Density at Point 1

(v) L2: Cortical Density at Point 2

(vi) R1: Cortical Density at Point 3

(vii) R2: Cortical Density at Point 4

(viii) AM: Average Medullary Density

(ix) AC: Average Cortical Density

No measurements were taken intraorally. All the measurements were recorded using digital diagnostic tools.

2.4 Statistical Analysis

Data were analyzed using IBM SPSS software version 23. Descriptive analysis was performed, followed by Pearson Correlation assessment between gingival thickness and the various bone density measurements.

3. Results

3.1 Assessment of bone density and mucosal thickness.

The study involved a sample size of 50 participants, ranging in age from 18 to 60 years, with an equal gender distribution of 25 males and 25 females. The average medullary density (AM) was measured to be 350.13 ± 179.15 HU, while the average cortical density (AC) was found to be 728.22 ± 77.36 HU. Additionally, gingival thickness was recorded, with a minimum value of 1.8 mm, a maximum value of 3.7 mm, and a mean value of 2.6240 ± 0.5975 mm. These measurements provide a comprehensive overview of the participant demographics and key density metrics. (Table 1)

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3.2 Correlation between mucosal thickness and bone density at 7 points and the average cortical and medullary density.

The Pearson Correlation Coefficients and corresponding p-values for the correlation between gingival thickness and various bone density measurements are summarized in the table below. (Table 2)

Point C was recorded at the crest of the ridge.

Point M1 was recorded 5mm apical to point C in the medullary bone

Point M2 was recorded 5mm apical to point M1 in the same line in the medullary bone

Point L1, R1 were recorded at 5mm from the crestal most point of the ridge on the left and right side in the corticated bone.

Point L2, R2 were recorded at 10mm from the crestal most point of the ridge on the left and right side in the corticated bone. (Figure 1)

The correlation coefficients indicate weak to moderate correlations between gingival thickness and the various bone density measurements. However, none of these correlations are statistically significant, as indicated by the p-values, which are all above 0.05.

This bar plot shows the correlation coefficients for each density measurement. The p-values are annotated on the bars to provide a quick reference to their significance. (Figure 2)

3.4.2 Scatter Plots

The scatter plots illustrate the relationship between gingival thickness and each bone density measurement. These plots help visualize the data distribution and any potential linear relationships. (Figure 3)

4. Discussion

The statistical analysis indicates that there is no significant correlation between gingival thickness and any of the measured bone densities. Despite the moderate correlations observed in the descriptive analysis, the p-values suggest that these correlations are not statistically significant.

Digital diagnostic methods, such as Cone Beam Computed Tomography (CBCT), have revolutionized dentistry by providing highly detailed 3D images of both soft and hard tissues. CBCT allows for precise measurement and evaluation of anatomical structures, enhancing diagnostic accuracy and treatment planning. This imaging technique offers a comprehensive view of the craniofacial region, which is invaluable for various dental applications, including implant planning, orthodontics, endodontics, and maxillofacial surgery. By accurately assessing bone density, the position of teeth, and surrounding tissues, CBCT enables clinicians to develop more effective and personalized treatment plans, ultimately improving patient outcomes. Additionally, the detailed imagery aids in detecting pathologies and abnormalities that might not be visible with traditional 2D radiographs, ensuring a higher standard of care and facilitating minimally invasive procedures.

In a study published in 2015, it was found that there was a positive correlation between the buccal bone thickness and the gingival thickness.[13]

A novel, noninvasive, CBCT-based technique known as ST-CBCT can also be used to visualize, measure the dimensions, and analyze the relationship of several structures of the periodontium and dentogingival attachment apparatus. In this technique two CBCT scans are taken and in the second scan the patients were asked to wear a plastic lip retractor and to retract their tongues toward the floor of their mouths.[14]

The relationship between bone density and gingival thickness has been a subject of interest in dental research, yet findings have been varied. Our study, which found no significant correlations between gingival thickness and bone density measurements, aligns with some previous studies that also reported weak or non-significant associations. For instance, a study by Vandana et al[15-16] found that while there were variations in gingival thickness, these did not strongly correlate with bone density. Conversely, other studies, such as those by Müller et al.[17], have suggested potential links between gingival thickness and bone quality, emphasizing the role of thicker gingiva in providing better support and protection for the underlying bone. However, these studies often noted that the relationships were complex and influenced by multiple factors including patient age, systemic health, and specific anatomical locations. Our findings contribute to this ongoing discourse by reinforcing the notion that gingival thickness alone may not serve as a reliable indicator of bone density, underscoring the need for a more nuanced understanding of the interplay between soft and hard oral tissues.

Future research should continue to explore these relationships, potentially incorporating advanced imaging techniques and larger, more diverse cohorts to uncover more definitive patterns. These findings highlight the complexity of the relationship between gingival biotype and bone density, suggesting that other factors may also play a crucial role. Further research with larger sample sizes and more comprehensive data may be necessary to draw more definitive conclusions.

Digital diagnostic tools significantly enhance convenience and precision in research related to bone, mucosa and dental implants as compared to conventional methods. Technologies such as cone-beam computed tomography (CBCT) provide detailed three-dimensional imaging of bone structure and density, crucial for drawing accurate correlations between any two findings. They are also helpful in planning the surgery to assess the availability of bone and the anatomic structures near it.[18] Intraoral scanners capture precise digital impressions, eliminating the discomfort, anxiety and potential inaccuracies associated with physical molds.[19] These digital tools streamline workflows, offer immediate and accurate measurements, and facilitate virtual seamless planning, improving the accuracy of study. Overall, digital diagnostics improve efficiency, accuracy, patient comfort, and treatment outcomes in implant dentistry.

5. Conclusion

Understanding the correlation between gingival thickness and bone density can enhance implant treatment outcomes. However, this study found no significant correlation between these variables in the sample analyzed digitally. Future studies with larger and more diverse populations are needed to validate these findings.

6. Clinical Significance

The clinical significance of a study correlating gingival biotype and bone density in implantology is substantial. Understanding this relationship can guide implantologists in selecting appropriate implant types and placement techniques, ensuring better integration and stability. For instance, patients with a thin gingival biotype and low bone density may benefit from specific implant designs or adjunctive procedures to enhance bone density and ensure successful outcomes. This knowledge also aids in risk assessment, allowing for the identification of patients who may be at higher risk of implant failure and who might require additional interventions or careful monitoring. Ultimately, such insights can lead to more personalized and effective implant treatments, improving patient satisfaction and long-term success rates.

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Table:

Variable	**Mean ± Std. Deviation**
Mucosal Thickness	2.62 ± 0.59
C	435.98 ± 107.28
M1	344.52 ± 189.69
M2	355.74 ± 175.03
L2	941.96 ± 169.05
L1	865.00 ± 134.83
R1	860.12 ± 109.30
R2	916.12 ± 106.04
Average Medullary Density (AM)	350.13 ± 179.15
Average Cortical Density (AC)	728.21 ± 77.35

Table 1: Mean and standard deviation values of mucosal thickness, crestal most point, Medullary point 1 and 2, Cortical point 1,2,3,4, average medullary and cortical density.

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Measurement	Pearson Correlation Coefficient	p-value
Crestal Cortical Density (C)	0.005	0.97
Medullary Density at Point 1 (M1)	0.057	0.692
Medullary Density at Point 2 (M2)	0.182	0.205
Cortical Density at Point 1 (L1)	0.176	0.222
Cortical Density at Point 2 (L2)	-0.062	0.667
Cortical Density at Point 3 (R1)	0.222	0.121
Cortical Density at Point 4 (R2)	-0.135	0.35
Average Medullary Density (AM)	0.12	0.408
Average Cortical Density (AC)	0.097	0.502

Table 2: Pearson Correlation Coefficients and p-values for Density Measurements

Figures:

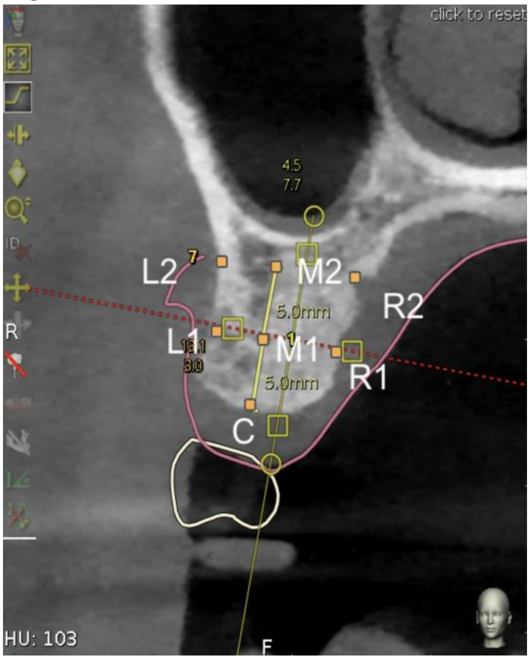

Figure 1: Reference points for bone density calculation

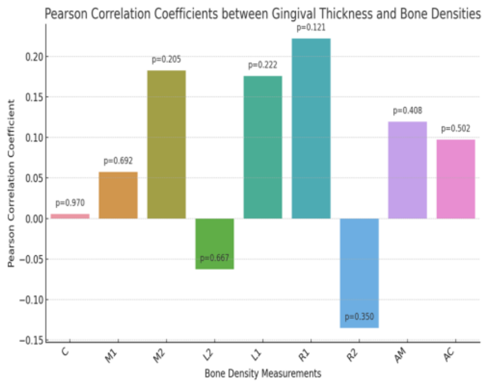

Figure 2: Bone Density Measurements

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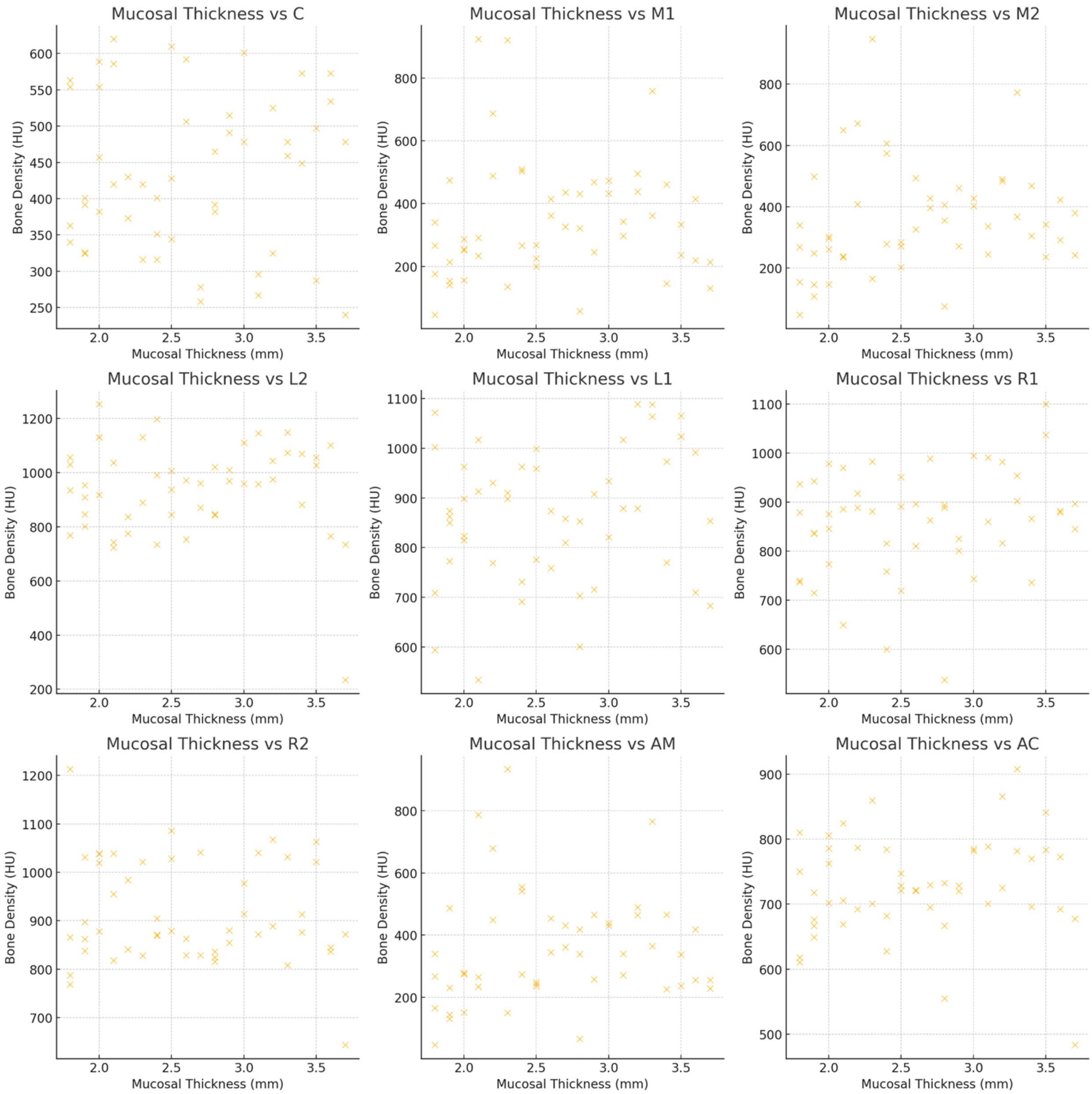

Figure 3: Scatter plot graph of Correlation between the various points and bone density.