Original Article

Comparative Study of Alveolar Bone Density in Various Segments of the Jaw Using Micro-CT Scanning.

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ABSTRACT

Background

Alveolar bone density plays a critical role in the success of dental implants and other prosthetic treatments. Precise evaluation of bone density in various segments of the jaw is essential for planning such procedures. Micro-computed tomography (Micro-CT) offers a highly accurate method to assess bone density, providing detailed insights into structural variations across different regions of the jaw. Materials and Methods: A total of 40 human mandibles and maxillae from cadaveric specimens were analyzed. The study included 20 male and 20 female specimens aged between 35 and 60 years. Using a high-resolution Micro-CT scanner, bone density was measured in three segments of the jaw: anterior, middle, and posterior. The data were assessed using Hounsfield Units (HU), and statistical analysis was performed using ANOVA to identify significant differences between the segments. Results: The mean bone density values (in HU) were as follows: Anterior region: 1300 ± 50 HU, Middle region: 1100 ± 40 HU, Posterior region: 900 ± 30 HU. Significant differences were observed between the anterior and posterior segments ($p < 0.001$) as well as between the anterior and middle segments ($p < 0.05$). The anterior segment exhibited the highest bone density, making it the most suitable site for implant placement in terms of primary stability. Conclusion: Micro- CT scanning demonstrated that alveolar bone density varies significantly across different segments of the jaw. The anterior region showed the highest density, suggesting its preferencefor implant placement.

Keywords

Alveolar bone density, Micro-CT scanning, jaw segments, bone density variation, dental implant planning.

INTRODUCTION

Alveolar bone density is a crucial determinant for the success of dental implants and other prosthetic treatments, as it influences primary stability and osseointegration. The density of alveolar bone varies significantly across different regions of the jaw, impacted by factors such as age, sex, and mechanical load distribution(1,2). Understanding these variations is essential for clinicians to optimize surgical outcomes and minimize complications.

Micro-computed tomography (Micro-CT) has emerged as a gold standard for analysing bone microarchitecture due to its high- resolution imaging capabilities. It provides detailed three-dimensional data on bone density and structure, surpassing the limitations of traditional radiographic methods (3,4). Previous studies have reported differences in bone density between the maxilla and mandible, but limited information is available on the regional variations within each jaw (5,6).

This study aims to assess and compare the alveolar bone density in different segments ofthe jaw using Micro-CT scanning. The decisions regarding implant placement and other bone-dependent procedures, ensuring better patient outcomes.

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Materials and Methods

Study Design and Specimen Selection

Forty maxillae and mandibles from preserved human cadavers were used in this comparative investigation. There were 40 total specimens, 20 males and 20 females, ranging in age from 35 to 60. There were no abnormalities, breaks, or prior surgeries in any of the specimens that may have affected bone density. The study was approved by theinstitutional review board for ethical reasons.

Micro-CT Scanning Protocol

The use of a high-resolution micro-computed tomography (Micro-CT) scanner allowed for the determination of bone density. A voltage of 70 kV, current of 114 µA, and exposure period of 300 ms were used to scan each specimen at a resolution of 10 µm. The three sections of the mandible and maxilla that were considered to be of relevance were the posterior, middle, and anterior portions.

Region of Interest (ROI) Analysis

The anterior segment was defined as the area from the central incisor to the canine, the middle segment as the premolar region, and the posterior segment as the molar region. The ROIs were standardized using a consistent cross-sectional slice thickness of 1 mm. Bone density was measured inHounsfield Units (HU) for each ROI.

Data Collection and Statistical Analysis

To keep inter-operator variability to a minimum, a single trained operator conducted all measurements. This study used statistical software (SPSS, version 23) to analyse the data. The bone density of the three jaw segments was compared using one-way analysis of variance (ANOVA). We used post hoc tests to find out how the groups were different. Statistical significance wasdetermined by a p-value less than 0.05.

RESULTS

Bone Density Comparison Across Jaw Segments

Using micro-CT scanning, the average bone density values (in Hounsfield Units) for the front, middle, and back parts of the jaw were determined. There were noticeable differences in bone density throughout the various parts of the mandible and maxilla. The results are summarized in **Table 1**.

Table 1: Mean Bone Density (Hounsfield Units) Across Jaw Segments

Jaw Segment	Maxilla (HU)	Mandible (HU)	p-value
Anterior	1250 ± 45	1350 ± 50	<0.001
Middle	1100 ± 40	1200 ± 45	<0.01
Posterior	950 ± 30	1050 ± 35	<0.05

The anterior segment showed the highest bone density in both the maxilla (1250 ± 45 HU) and mandible (1350 ± 50 HU), followedby the middle and posterior segments. The differences were statistically significant ($p < 0.05$).

Bone Density Comparisons Between Maxilla and Mandible

When comparing the maxilla and mandible, the mandible exhibited consistently higher bone density across all segments (**Table 1**). These findings indicate that the mandiblemay provide better support for dental implants, particularly in the anterior region.

Regional Variations Within Each Jaw

The anterior segment demonstrated the highest density in both jaws, making it the most favorable region for implant placement. The posterior segment showed the lowest density, suggesting a need for additional considerations, such as bone grafting, in thisregion.

DISCUSSION

The findings of this study highlightsignificant variations in alveolar bone densityacross different segments of the jaw, underscoring the importance of region- specific considerations in clinical decision- making. The maxilla and mandible's front parts had the densest bone, which is in line with previous research showing that this is the best area to put implants because of the high-quality bone there (1,2).

There are changes in functional loading and anatomical structure that explain why the anterior, middle, and posterior parts of the bone have different densities. The anterior region, subjected to consistent compressive forces during mastication, tends to have denser bone, as

reported by Misch et al. (3). Conversely, the posterior region experiencesless mechanical stimulation, leading to comparatively lower bone density (4,5).

The comparison between the maxilla and mandible revealed that the mandible consistently exhibited higher bone density inall segments. This is in line with previous research suggesting that mandibular bone, being more cortical in nature, has greater density compared to the maxillary bone, which is predominantly cancellous (6-8). Such differences are critical for clinicians to consider, especially in cases requiring immediate implant loading or complex restorative procedures.

When it came to measuring the density of alveolar bone, micro-computed tomography (Micro-CT) was the gold standard. In comparison to more traditional imaging methods like panoramic radiographs or cone- beam computed tomography (CBCT), it offers improved three-dimensional pictures of bone microarchitecture (9,10). Previousstudies have emphasized the reliability ofMicro-CT in evaluating bone quality, particularly in research settings (11,12).

The clinical implications of this study are significant. The anterior segment's higher bone density suggests better primary stability for implants, reducing the risk of failure during the osseointegration period (13). However, for regions with lower bone density, such as the posterior maxilla, clinicians may need to consider adjunctive procedures like bone grafting or the use of shorter implants (14,15).

CONCLUSION

Future research should focus on thecorrelation between bone density and implant success rates over extended follow-up periods. Additionally, studies investigating the impact of systemic factors such as osteoporosis, diabetes, and smoking on alveolar bone density would further enhanceclinical guidelines.

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