Perspective
Volume 8:5, 2023

Journal of Forensic Medicine

ISSN: 2472-1026 Open Access

Exploring Mandibular Trabecular Bone Microstructure: An Initial Estimation Study

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Abstract

The purpose of this study has a dual focus: firstly, to establish correlations between the characteristics of trabecular bone microstructure within different boundaries and an individual's chronological age and gender, thus facilitating the assessment of potential age and gender-related changes in TBM boundaries within the mandible. Secondly, the study aims to evaluate how these trabecular microstructural boundaries correspond to categorized age groups. A total of twenty cone-beam computed tomography scans were retrospectively selected from an adult patient dataset, spanning ages from 22 to 43 years. The region of interest in the mandible encompassed the interdental space between the second mandibular premolar and the first mandibular molar, along with the trabecular space beneath and between the apices. The DICOM images from the CBCT scans were pre-processed, transformed, segmented using an intelligent semi-automated thresholding technique, and quantified. Furthermore, TBM characteristics were derived, and a statistical analysis was conducted using a two-tailed Pearson correlation test.

Keywords: Trabecular bone microstructure • Age assessment • Cone shaft CT

Introduction

Bone presentation and regeneration are critical processes that govern the initial and ongoing structural integrity of bone tissue. The latter process, regeneration, is a continuous and ongoing phenomenon. Approximately 10% of the human skeleton undergoes regeneration each year. Age determination through subjective methods is inherently inconsistent, yielding mean and age range estimates for distinct periods of morphological changes within the human skeleton, and as such, is susceptible to substantial errors. The term "bone quality" defies simple definition. While consensus on its precise definition remains elusive, it generally encompasses various facets of bone physiology, including mineralization levels, morphology, and the specific trabecular patterns. In essence, it refers to the intrinsic, material, and cellular characteristics of bone that govern its mechanical competence across varying length scales. Overall bone structure (size and shape), along with its microstructural (trabecular and cortical) and nanostructural arrangements, embody these intrinsic characteristics, particularly in woven and osteonal bone.

Conversely, "bone quantity" is relatively straightforward to define as it pertains to the amount of bone and the width of the alveolar ridge at an edentulous site. Quantitative methods for age estimation necessitate invasive bone sampling but represent a significant improvement over subjective methods that rely solely on bone structure and composition. Evaluation of trabecular patterns from plain film radiographs also relies on surface characteristics and tends to be subjective. Previous studies on age-related changes in the jawbones were predominantly subjective and hinged primarily on macrostructural parameters such as mandibular ramus height, bigonial width, and mandibular angle [1-3].

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Received: 05 September, 2023, Manuscript No. JFM-23-114773; **Editor assigned:** 07 September, 2023, PreQC No. P-114773; **Reviewed:** 19 September, 2023, QC No. Q-114773; **Revised:** 23 September, 2023, Manuscript No. R-114773; **Published:** 30 September, 2023, DOI: 10.37421/2472-1026.2023.8.218

Description

Numerous studies have also concentrated on assessing bone quality for implants, but their findings have been inconclusive. Bone with inadequate cortical thickness and large marrow spaces can result in poor osseointegration, yet even thick cortical bone does not consistently yield favorable outcomes. The entire interface between the implant and the bone is primarily in contact with the trabecular microarchitecture. However, previous investigations primarily focused on bone mineral density, which was once considered the sole factor for assessing bone quality and strength. More recently, most studies have shifted their focus towards evaluating the trabecular microstructural characteristics of bone. However, the assessment of trabecular microstructure requires high spatial resolution from imaging modalities [4].

The assessment, evaluation, and measurement of jaw structure using cone-beam computed tomography (CBCT) would be the most advantageous approach, as it generates a digital imprint that can be revisited, reanalyzed, and further examined by future researchers. This eliminates the need for invasive bone sampling at the sole quantitative assessment site and provides a clear view of the microarchitectural remodeling of trabecular bone. This study was prompted by the discoveries in trabecular microstructural characteristics that were extensively investigated in the axial skeleton (such as the femur, vertebrae, tibia, and radius), although these investigations were primarily conducted on cadaveric samples with a focus on chronological age using various imaging modalities [5,6].

Conclusion

In this comprehensive review, a non-invasive imaging technique was employed to conduct an objective quantitative assessment, focusing on age-related variations in specific trabecular microstructural features within the mandible. The findings from the analysis of 20 CBCT DICOM images in relation to chronological age reveal the potential utility of high-resolution CBCT in discerning differences in mandibular trabecular microarchitectures. Consequently, this study serves as an initial investigation laying the foundation for the development of a predictive model to estimate chronological age based on these trabecular microstructure characteristics. A comprehensive and well-documented dataset spanning various age groups is strongly recommended for future research in this field.

Acknowledgement

None.

Conflict of Interest

None.

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How to cite this article: Yusof, Mohd. "Exploring Mandibular Trabecular Bone Microstructure: An Initial Estimation Study." *J Forensic Med* 8 (2023): 218.