ORIGINAL ARTICLE

Estimation of Mandibular Bone Density Loss in Diabetes Mellitus Using Cone Beam Computed Tomography

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ABSTRACT

Objective: The study's goals were to use cone beam computed tomography (CBCT) to estimate the percentage of bone density loss in individuals with type 2 diabetes mellitus (T2DM) that is observed in the condyles, angulus, and symphysis. It will also analyze the differences in mandible bone density between T2DM and Non-Diabetes Mellitus (DM).

Study Design: An analytical observational study used a cross-sectional research design.

Place and Duration of Study: Dental Radiology Installation of the Dental and Oral Hospital, Universitas Sumatera Utara, Medan City, North Sumatra Province, and the Pramita Medan Clinical Laboratory from 2 October – 22 December 2023.

Materials and Methods: The study included fifty CBCT radiographs from T2DM patients and fifty non-DM patients aged between 25 and 60. Bone density measurements were taken from a 10x10 region of interest (ROI) at the symphysis, angulus, and condyle. These measurements were assessed in axial, sagittal, and coronal planes. On-Demand, 3D software was used for radiograph analysis. Data processing included univariate and bivariate analyses, with an independent T-test applied for comparative purposes.

Results: The study estimated bone density reduction in T2DM patients as 40.922% at the condyle, 32.686% at the angulus, and 26.957% at the symphysis. A significant difference in mandibular bone density between T2DM and non-DM patients was found (*p-value* <0.05). For non-DM patients, the bone density values were 264.087 HU at the condyle, 630.717 HU at the angulus, and 554.600 HU at the symphysis.

Conclusion: T2DM patients had lower mandibular bone density than non-DM patients. The condyle showed the highest percentage loss, followed by the angulus and symphysis.

Key Words: *Bone Density; Cone-Beam Computed Tomography; Diabetes Mellitus; Mandible.*

Introduction

Diabetes is a chronic illness with various underlying causes.[1] According to the International Diabetes Federation (IDF), it is estimated that 537 million people worldwide will have diabetes in 2021.[2,3] Ninety-five percent of those with diabetes have type 2, which is the most common form of the disease.[4] Hyperglycemia in type 2 diabetes can lead to lower bone mineral density and increased risk of fractures due to increased calcium excretion and inflammatory response triggered by advanced glycation products.[5] This reduces insulin-like growth factor 1 levels, impacting bone development and synthesis.[4] Ongoing debate exists on the impact of type 2 diabetes on bone mineral density (BMD). Some studies suggest reduced BMD, while others show normal or enhanced BMD.[5] For instance, a study by Xu Y found increased osteoporosis and osteopenia frequency over four survey cycles among type 2 diabetes patients. The study examined BMD decline at the femoral neck in both type 2 diabetes patients and non-diabetic individuals from 2005 to 2014.[6]

The density of the lower jawbone affects implant integration and orthodontic treatment. Evaluating bone quality is crucial during dental implant therapy, and BMD is just one of several factors that influence integration.[7] Due to its benefits in providing anatomical as well as three-dimensional (3D)

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information in the coronal, sagittal, and axial viewing directions from images of the root, bone, nerves, and significant structures at the implantation site, cone beam computed tomography (CBCT) has been used extensively in implant dentistry. Because one of the functions of CBCT is to look at bone quality linked with BMD, it thus aids in dental implant planning to improve treatment outcomes by providing crucial information regarding the ideal implant dimensions and position according to the available bone.[8,9] Compared to CT, CBCT provides imaging findings with a lower radiation dosage and a higher resolution (submillimeter resolution).[10-12]

The studies that have been conducted usually only measure bone density in areas adjacent to the teeth or the apical region of the teeth, even though this study will obtain bone density values in T2DM patients, especially in the condyle, angle, and symphysis areas, which are susceptible to fractures. In addition, bone density values also affect implant osseointegration, healing after extraction, or other surgical procedures. Previous studies on bone density values typically only measure the apical region of the teeth, but the areas in this study often experience fractures. In addition, the results of this study will add to the existing literature.[13] The investigation's goal was to determine the percentage of bone loss in people with type 2 diabetes mellitus observed at the condyle, angulus, and symphysis by comparing T2DM and non-DM mandibular bone density using CBCT analysis.

Materials and Methods

The cross-sectional study design utilized in this analytical observational study was authorized by the Health Research Ethics Committee of the Universitas Sumatera Utara under letter number 1024/KEPK/USU/2023. This study was carried out in phases, including field surveys and CBCT radiographic tests, and began on 2 October 2023 and ended on 22 December 2023. The study was completed at the Pramita Medan Clinical Laboratory and the Dental Radiology Installation of the Dental and Oral Hospital, Universitas Sumatera Utara, Medan, North Sumatra Province. Patients with managed diabetes mellitus and intact mandibular cortical bone met the inclusion criteria for CBCT radiography. The radiographic device used is Orthopantomograph® OP300. Cliniview™ software for processing and viewing digital X-ray images. Open architecture and DICOM® format images for planning software and 3D viewing. DICOM® is the registered trademark of the National Electrical Manufacturers Association for its standards publications relating to digital communications of medical information. The image detector is a complementary metal-oxide semiconductor (CMOS), the field of view (FOV) is 13x15 cm, the image voxel size is 85 µm–300 µm, the scan time is 10–20 s, the exposure time is 8,1 s, pulsed X-ray image volume sizes (HxW) 61mm x 78mm, 90 kV, 5 mA, and 771 mGycm^2.

CBCT radiography was used in this investigation on Bataknese patients, aged 25–60 years, including 25 women and 25 men with T2DM and non-DM patients categorized by gender. The sample comprised 50 non-DM patients aged 25-35 years, and 50 T2DM patients, including 12 patients aged 35-40 years and 38 patients aged 41-60 years. The sampling technique employed in this study was purposive sampling. The American Diabetes Mellitus Association's methodology was used to establish the patient's diabetes status, with the HbA1C number serving as a proxy for the patient's three-month cumulative glycemic history.[14] Lesions, fractures, or using a fracture fixation device were considered exclusion criteria. According to Creswell and Creswell (2018), a sample size of 100 is often chosen because it provides a good balance between analytical capability and practical constraints in research, such as time and cost.[15] Therefore, this study used 100 samples, consisting of 50 CBCT radiographs from T2DM patients and 50 CBCT radiographs from non-DM individuals.

CBCT radiographs were performed on patients due to clinical indications that required detailed anatomical assessment. The questionnaire provided identified several patients with non-DM and T2DM. Radiation exposure of 771 mGycm^2 was justified by clinical need and research value, with doses managed according to As Low As Reasonably Achievable (ALARA) principles to ensure safety while improving diagnostic and research outcomes. A digital sensor system, a PC running Microsoft Windows XP Professional OS, Cliniview software version 10.1.2, and OnDemand 3D software are the equipment and supplies used in this study.

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The condyle, angulus, and symphysis bones on both sides of the mandible were used to identify the ROI (region of interest) for the research method (Figure 1). On CBCT, the decision is made in a sagittal orientation. A vertical line that touches the most posterior area of the ramus and condyle is drawn to determine the measurement area on the condyle bone. A vertical line tangent to the most anterior region of the condyle is drawn; both lines are made parallel. A horizontal line perpendicular to the vertical line in the condyle neck or the most concave area is drawn. An ROI of 10x10 is created. The determination is made from the sagittal direction of view. Following that, measurements were made in the axial, sagittal, and coronal viewing orientations. Create a horizontal line in the middle of the angulus perpendicular to the vertical line; create an ROI of 10x10; and determine the measurement area on the angulus bone by drawing a vertical line that touches the most posterior area of the ramus and angulus. The determination is made from the sagittal direction of view. Following that, measurements were made in the axial, sagittal, and coronal viewing orientations. Draw a perpendicular line through the center of the symphysis bone to get the measuring area; the resulting ROI is 10x10.

Data normality was assessed with the Kolmogorov-Smirnov test, while homogeneity was evaluated using the Levene test. Subsequently, the data were analyzed with the Independent T-test. Parametric tests were employed in this study because of the data gathering the assumptions of normal distribution and homogeneity of variances. The coronal viewing direction is used to calculate the measuring area. Following that, measurements were made in the axial, sagittal, and coronal viewing orientations. By comparing the mean bone density of T2DM and non-DM patients, the estimated percentage of bone density decline can be calculated.

Results

The individuals in the study sample ranged in age from 25 to 60 years. There were 25 women and 25 men among the T2DM patients furthermore to those without DM according to gender. Drawing from the two declared children, it may be concluded that all samples are Bataknese. The study's findings demonstrated a substantial (p<0.05) difference in bone density between those with DM 2 and those without (Table I). T2DM patients' average cone density value was 108.07 HU lower than that of non-DM patients. T2DM patients had an average angular density of 206.157 HU, which was lower than that of non-DM patients. Compared to non-DM, symphysis density in T2DM had a lower average value of 149.503 HU. T2DM patients had a lower average bone density than non-DM individuals based on the total average bone density value. These findings indicate that DM patients have less bone density. According to Table II, the condyle had the largest percentage drop in bone density (40.922%), followed by the angulus (32.686%) and the symphysis (26.957%) in T2DM patients.

Table I: The Difference in Mandibular Bone Density Values on CBCT Radiographs Between T2DM and Non-DM Patients

Bone Density		Mean (HU)**	Standard Deviation	p-value	95% Confidence Interval	
					Lower	Upper
Condyle	DM*** Non-DM	156.017 264.087	51.924 109.394	<.0.001*	-70.429	1.053
Angulus	DM Non-DM	424.560 630.717	43.927 298.337	<0.001*	- 357.007	- 291.305
Symphysis	DM Non-DM	405.097 554.600	45.912 225.426	<0.001*	- 474.882	- 411.674

*Independent T-Test; significant $p < 0.050$ is considered
**Hounsfield Unit (HU)
***Diabetes Mellitus

Table II: The Percentage of DM Patients' Decreased Bone Density

Bone Density		Mean (HU)*	Percentage $(\frac{Mean\ DM}{Mean\ Non\ DM} \times 100\%)$	Percentage decreases $(100\% - x\%)$
Condyle	**T2DM****	156.017	59.078%	40.922%
	Non-DM	264.087		
Angulus	**T2DM**	424.560	67.314%	32.686%
	Non-DM	630.717		
Symphysis	**T2DM**	405.097	73.043%	26.957%
	Non-DM	554.600		

*Hounsfield Unit (HU)
**Diabetes Mellitus

Discussion

This study revealed a significant difference (p<0.050) in bone density between the T2DM and non-DM groups, with the T2DM group showing markedly lower bone mineral density (BMD) compared to the non-DM group. Among the numerous regions examined, the condyle exhibited the highest density at 40.922%, followed by the angle at 32.686%, and

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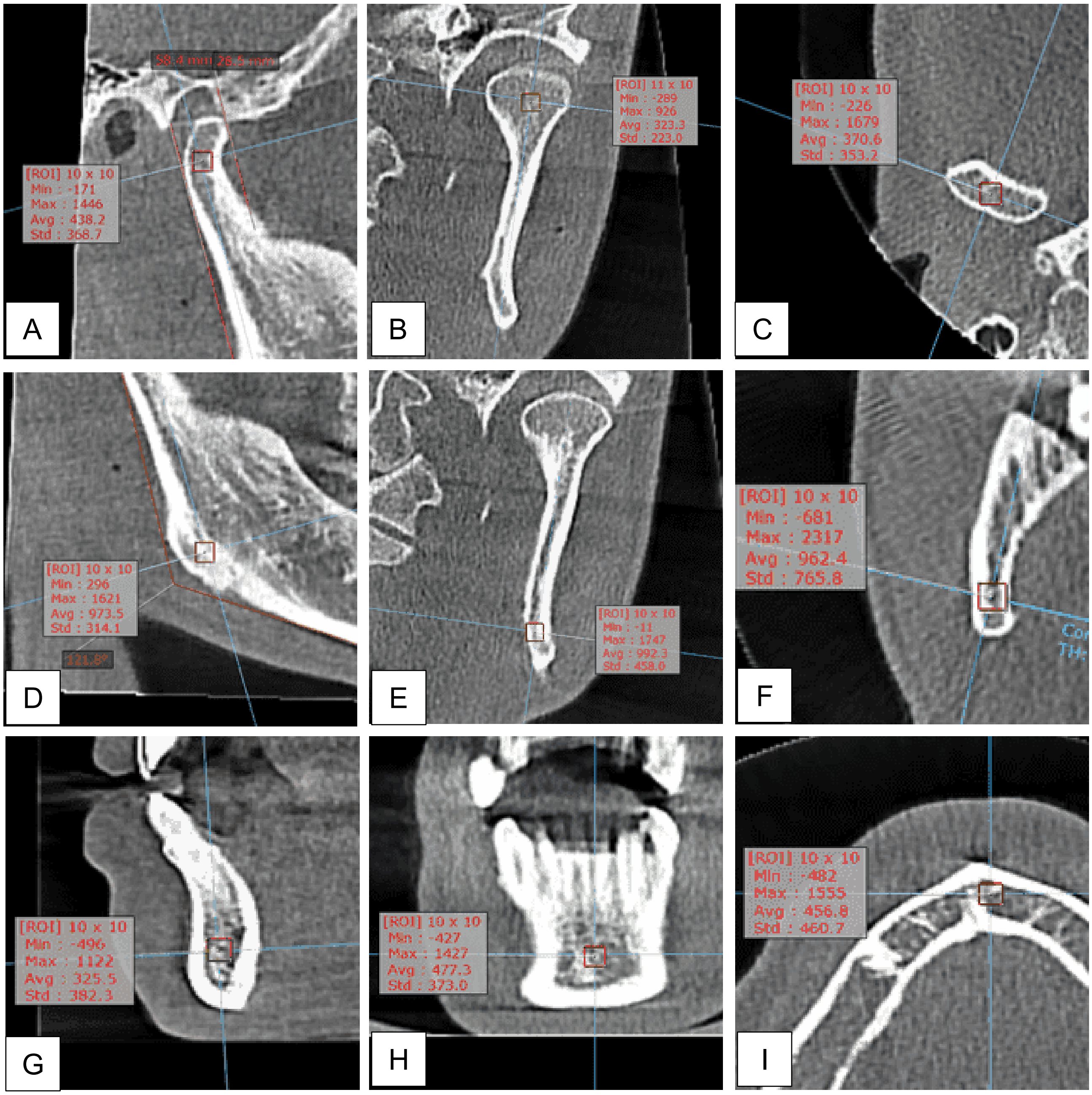

Figure 1. ROI-based density measurement: 10x10 (A) sagittal view at the right condyle; (B) coronal view at the right condyle; (C) axial view at the right condyle; (D) sagittal view at the right angulus; (E) coronal view at the right angulus; (F) axial view at the right angulus; (G) sagittal view at the symphysis; (H) coronal view at the symphysis; (I) axial view at the symphysis

the symphysis at 26.957%. According to David et al.'s analysis of the study's data, patients with type 2 diabetes have significantly lower bone mineral density. Therefore, the primary screening instruments for more accurately assessing the bone mineral density of individuals with diabetes are the Mental Index (MI), Antegonial Index (AI), and Gonial Index (GI).[16] Similarly, an investigation by Al Ansari et al. revealed that compared to implants implanted in non-DM patients, diabetes patients had a significantly increased chance of implant failure and a larger marginal bone loss.[4]

The data supporting a link between poor bone density and diabetes mellitus is insufficient, according to Qiu J's[5] systematic review and meta-analysis. Subgroup analysis revealed no statistically

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significant difference in the probability of low bone density between T1DM and low bone density, nor between women and men in developed or developing nations and T2DM patients. This may be because the etiology of T2DM varies throughout patient populations and can be caused by obesity, aging, diabetes complications, duration of diabetes, and medication. Variable circumstances also arise in osteoporosis and type 2 diabetes.[5] It is anticipated that the study's findings would give a general overview of mandibular bone density assessment in people with diabetes using CBCT, demonstrating how variations in bone density lead to a decrease in bone mineralization. Therefore, when developing a treatment strategy for the mandibular bone, the practitioner must exercise caution. Future studies based on sectioning are anticipated to use more sophisticated technology and look at gender differences in people with various kinds of systemic diseases.

This study does, however, have certain biases and limitations. For instance, there was no gender discrimination in the study, the area of focus was narrow, and the length of diabetes was not considered. Moreover, the study sample included people whose ages ranged widely from 25 to 60. This may result in bias because aging and menopause can promote bone loss even in the absence of diabetes, which could be a complicating factor. Osteoporosis is a chronic and long-term bone illness that is more common in men over 65 and in women over 55, approximately, since as bone loss grows with age, so does its frequency.[17] This phase is characterized by accelerated bone remodeling brought on by estrogen deficiency, which results in bone density loss.[18]

Involutional osteoporosis affects both men and women and is more strongly associated with aging.[19] Type I osteoporosis, also known as postmenopausal osteoporosis, is a subtype of involutional osteoporosis that primarily affects women between the ages of 51 and 75 and is characterized by fast bone loss. Osteoporosis develops due to a variety of reasons. Certain elements, such as those related to the environment and certain hormones, can be changed. The following are examples of environmental factors: nutritional factors, which raise the risk of heart disease and stroke; low calcium intake; vitamin D deficiency due to nourishing problems; poor absorption or low exposure to sunlight; excessive protein intake in an unbalanced diet; and excessive phosphate or salt intake. The following factors are known to directly increase the risk of osteoporosis: (a) calcium loss through urine[20]; (b) sedentary lifestyle, anaerobic exercise, and excessive mechanical load; (c) chronic pharmacological treatment, such as anticonvulsants, glucocorticoids, tranquilizers, or chemotherapy; (d) consumption of coffee, alcohol, or smoking; and (e) body weight, which accounts for 15% to 30% of the variation in bone mineral density (BMD) at any age and in any bone region measured.[21]

Among the endocrine factors are: (a) conditions related to low bone mass, such as delayed menarche or menstrual cycle changes; (b) menopause, either surgically or naturally, before the age of 45; (c) hormone-infertile women; and (d) premenopausal estrogen deficiency caused by anovulation because of anorexia nervosa, excessive exercise, mental stress, etc. As far as Western nations are concerned, they are the most significant risk factors for osteoporosis.[22] Given that they can be changed to lower the risk of osteoporosis, it is crucial to examine these modifiable risk factors.

Conclusion

Compared to non-DM patients, T2DM patients had reduced mandibular bone density. The condyle experienced the greatest projected percentage loss in bone density, with the angulus and symphysis closely behind.

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Conflict of Interest

The authors declared no conflict of interest

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CONFLICT OF INTEREST

Authors declared no conflicts of Interest.

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DATA SHARING STATMENT

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