Clinical and Experimental Health Sciences

Evaluation of Bone Microstructure Parameters by Using Tomographic Methods and Compressive Strength Estimation

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ABSTRACT

Objective: The aim of this study was to evaluate the microstructure of the mandible by micro computed tomography (µCT), cone beam computed tomography (CBCT) and computed tomography (CT) and to estimate the compressive strength of the bone based on the values obtained by these methods.

Methods: Thirty specimens obtained from ex-vivo sheep mandible were scanned by µCT cone beam computed tomography and computed tomography. These specimens were also subjected to compression testing and compression strength values were calculated. Morphometric parameters were evaluated using ImageJ software Bland-Altman lower upper bound agreement and ICC coefficient were used to evaluate the agreement between the tomography methods used and the gold standard. Linear and multivariate stepwise regression analysis was performed to calculate the compression strength value based on the radiomorphometric parameters. Statistical significance level was accepted as .05.

Results: Bone Surface/Total Volume, Bone Volume/Total Volume and Degree of Anistoropy parameters evaluated by CBCT and Fractal Dimension parameter evaluated by CT showed a statistically significant agreement with the gold standard method µCT. Bone Volume/Total Volume and Degree of Anistoropy parameters obtained with µCT (R^2:0.75), Bone Volume/Total Volume, Degree of Anistoropy , Connectivity Density parameters (R^2:0.62), and the Structure Model Index parameter (R2:0.13) obtained by CT can be used to predict the compression strength value.

Conclusion: Bone compression strength can be estimated by CBCT and µCT methods in a desired level. Bone Volume/Total Volume and Degree of Anistoropy parameters are significant determinants of bone mechanical property in not only µCT but also CBCT method.

Keywords: computed tomography, cone beam computed tomography, micro computed tomography, compression strength.

1. INTRODUCTION

In dental practice, predicting the quality and quantity of the alveolar bone increases the success of treatments. The ability to make these predictions can greatly increase the success of periodontal, orthodontic, and surgical treatments, particularly implant applications (1). In the past years, bone structure analyses have mainly been based on bone mineral density measurements (2). However, studies have shown that measuring only bone mineral density is insufficient for these analyses and that trabecular bone microstructure analysis should also be performed (3). The bone structure histologically consists of trabecular and cortical structures. The trabecular structure is more active in the metabolic metabolic procedure and more effective in bone remodeling than the cortical bone because it has a larger surface area (4). This causes the trabecular bone to be more affected during the bone resorption mechanism. However, the standard morphologic parameters used in bone microstructure evaluations are as follows: the ratio of the bone volume (BV) to the total bone volume (TV) i.e., bone volume to total volume the relative volume of calcified tissue in the selected volume of interest (BV/TV), trabecular thickness; mean thickness of trabeculae, assessed using direct 3D method (Tb/Th), bone surface (BS), trabecular separation; mean distance between trabeculae, assessed using direct 3D methods (Tb/Sp), trabecular number; number of trabecules that crosses a particular one pe runit of length across the VOI; (Tb/N), cortical thickness; mean thickness of cortical bone assessed using direct 3D method (Ct/Th), connectivity density; examination of thinning and thickening of trabecular bone in each volume set (Con. Dens), degree of anisotropy; which is the presence or absence of aligned trabecules in a particulardirection (1 is considered isotropic,>1 is considered anisotropic (DA), fractal dimension; which indicates the complexity ofthe specimen surface (FD), and structural model index; which gives information aboutpreponderance of trabecular morphology (0 is an ideal plate, whereas 3 is an ideal cylinder) (SMI) (5). The gold standard for the two-dimensional evaluation of bone microstructures is histologic

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or histomorphometric evaluation, and the gold standard for three-dimensional (3D) evaluation is microcomputed tomography (µCT) (6,7).

The computed tomography (CT), method, particularly multislice computed tomography (MSCT), has a larger radiation dose than other bone quality assessment methods (8,9). Kulah et al. compared the images they obtained using two different cone-beam computed tomography devices with voxel sizes in the range of 0.075 to 0.2 mm and field of view (FOV) of 40×40 to 80×80 with the images obtained by the micro computed tomography device, which is considered the gold standard among tomography methods, for bone microstructure parameters. As a result of their research, they demonstrated that the bone microstructure parameters, specifically BV/TV and DA, obtained from the images acquired with the low voxel size cone-beam computed tomography device exhibited the highest compatibility with micro computed tomography and could be used as an alternative (10). Ibrahim et al. evaluated bone structure in human cadavers using a cone-beam computed tomography device with a voxel size of 0.08 mm. They investigated which parameter exhibited better compatibility with the gold standard. It was observed that trabecular number showed the best agreement with micro computed tomography results, followed by trabecular thickness and trabecular separation parameters (11).

2. METHODS

All procedures performed in studies involving animal researches local ethic committee rules. The study was approved by Van Yüzüncü Yıl University Animal Researches Local Ethic Committee (06.02.2020-approval number: 2020/01).

2.1. Sample Preparation

Thirty samples were obtained ex vivo from sheep mandibles. The samples were obtained by inserting a 10*3 mm trepan burr parallel to the axial plane. To prevent moisture loss, the samples were wrapped in cotton wool impregnated with saline solution and stored at – 20 °C (Figure 1).

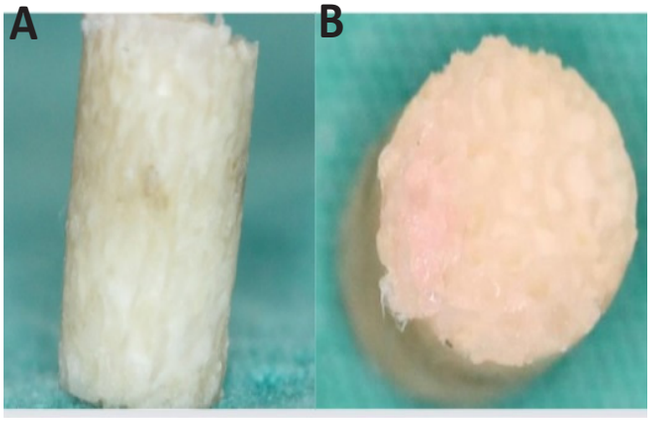

Figure 1. *Image of samples.*

2.2. Acquisition of µCT Images

Each sample were placed perpendicular to the ground plane and scanned (SkyScan, Kontich, Belgium) at 80 kVp, 125 µA, a scan time of 50 ms, and a section thickness of 10.00 µm.

2.3. Acquisition of CBCT Images

Each sample was placed perpendicular to the ground plane and scanned using a KaVo 3D eXam cone beam tomography device (KaVo Dental, Biberach, Germany) at 120 kVp, 5 mAs, a scan time of 7 s, a voxel size of 0.125 mm, and 16*4 cm FOV (Field of View).

2.4. Acquisition of CT Images

The samples were placed parallel to the ground plane in accordance with the scanning axis and scanned at a voxel size of 0.625 mm using a 2011 GE brand Brightspeed Model 16-section CT scanner (Healthcare, Milwaukee, WI) with a 12226 Exam X-ray tube at 120 kVp, 69 mA, and a scan time of 0.6 s.

2.5. Radiologic Analysis

To equalize the different slice thicknesses of the devices, all the CT and CBCT images were analyzed using five slice intervals, while the µCT images were analyzed using sixty-two slice intervals. All the consecutive slice images were analyzed and aligned using the study protocol of Panmekiate et al.. The bone microstructure parameters were evaluated using ImageJ-Bone J software (National Institutes of Health, USA) (Figure 2) (12). All transferred images were converted into a single file containing consecutive images (Image-Stacks-Images to Stack). The images were manually drawn to include the area of bone (ROI) to be analyzed (Rectangle Selection). The file containing the areas to be analyzed was converted to black and white image format (Process-Binary-Make Binary). The prepared images were subjected to plugins-bonej-analyse skeleton, anisotrophy, connectivity, fractal dimension, isosurface, structure model index, thickness, volume fraction processes in the ImageJ program. In the evaluation of Connectivity Density parameter in radiological images, in addition to the algorithms applied to other parameters, a purification process has also been conducted as part of the procedure. All procedures were repeated for images of thirty specimens obtained with three different tomography imaging methods.

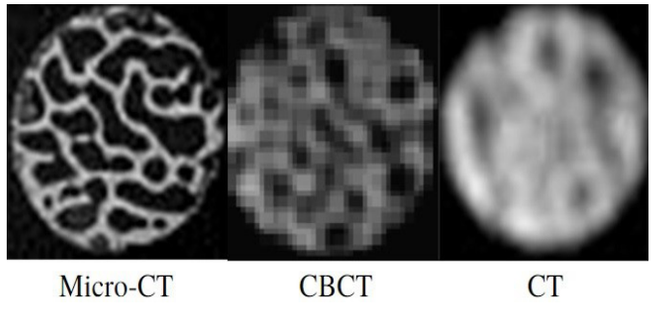

Figure 2. *Images of bone samples taken with three different tomography methods. (Micro-CT: micro computed tomography, CBCT: cone beam computed tomography, CT: computed tomography.)*

2.6. Compression Test Experiment

In order to keep the effect of temperature on the sample's constant, each sample was kept in separate boxes in a – 20 degree freezer. Each sample was placed on the lower jig table of the device with its long axis perpendicular to the ground plane. All compression tests were performed using a universal testing machine (Shimadzu Corporation, Kyoto, Japan). Each sample has been placed on the lower jig table of the device with its long axis perpendicular to the horizontal plane to prevent its movement against the forces and to secure the sample in place, using pink base plate wax of the same thickness as the table at the pre-determined exact center. The device has been calibrated after each setup to ensure it is in the appropriate position for testing. After the device is turned on, a compression test template is created in the software program on the computer by entering the properties of the samples to be tested. In the compression strength test, force is applied in the direction parallel to the long axis of the sample. Before starting the test, the upper jig, which will apply the force, is brought to the allowed shortest distance from the sample without making contact, using the manual movement button. Once the test begins, the applied force has shown a rhythmic and consistent increase. The force increase rapidly decreases and resets to zero after reaching the maximum force at which the samples deform. The compression strength of the sample is recorded, considering the highest force applied by the device before the samples deform.

2.7. Statistical Analysis

The Bland–Altman test was used to evaluate whether the CBCT and CT methods could be alternatives to the µCT method, which is considered the gold standard. Linear regression and multiple stepwise regression analyses were performed to predict compressive strength based on the microstructure parameters. All the analyses were performed using SPSS software (IBM SPSS Statistics 20.0; IBM Co., Armonk, NY, US

3.RESULTS

3.1. Comparison of CBCT and µCT Tecniques

There was a statistically significant moderate agreement between the DA and BV values obtained using the CBCT and µCT methods (ICC = .484 and p < .001; ICC = .537 and p < .05). This parameter was statistically significant between CBCT and µCT but not statistically significant between the CT and µCT values.

There was a statistically significant poor agreement between the BS/TV and BS (Bone Surface) values obtained using the CBCT and µCT methods (ICC = .319 and p < .05; ICC = .294 and p< .05). No statistically significant agreement was observed between the CT and µCT values of this parameter.

There was a statistically significant good agreement between the BV/TV and TV values obtained using the CBCT and µCT methods (ICC = .703 and p < .001; ICC = .673 and p < .001). No statistically significant agreement was observed between the CT and µCT values of this parameter.

3.2. Comparison of CT and µCT Tecniques

There was a statistically significant moderate agreement between the FD values obtained using the CT and µCT methods (ICC = .474 and p < .05). No statistically significant agreement was observed between the CBCT and µCT values of this parameter (Table 1).

Table 1. *Bland and Altman limits of agreement of all assessed parameters.*

	MD	SD	Limits of Aggrement (%95 CI)		ICC (%95 CI)	p
			Lower	Upper		
BS/TV						
CBCT – µCT	0.043	0.042	-0.039	0.124	0.319 (-0.206 – 0.648)	**<.05**
CT – µCT	0.119	0.049	0.022	0.216	0.035 (-0.077 – 0.208)	>.05
BV/TV						
CBCT – µCT	0.027	0.064	-0.098	0.153	0.703 (0.376 – 0.859)	**<.001**
CT – µCT	0.222	0.065	0.094	0.350	0.023 (-0.042 – 0.138)	>0.05
BS						
CBCT – µCT	1965.340	1281.169	-545.752	4476.432	0.294 (-0.208 – 0.645)	**<.05**
CT – µCT	2626.991	1468.520	-251.309	5505.292	-0.047 (-0.208 – 0.186)	>.05
BV						
CBCT – µCT	606.133	3690.823	-6627.880	7840.147	0.537 (0.03 – 0.779)	**<.05**
CT – µCT	778.400	4508.492	-8058.245	9615.045	0.08 (-0.938 – 0.563)	>.05
TV						
CBCT – µCT	-2166.667	5675.618	-13290.879	8957.545	0.673 (0.326 – 0.843)	**<.01**
CT – µCT	-18666.667	9907.619	-38085.600	752.267	0.091 (-0.124 – 0.356)	>.05
FD						
CBCT – µCT	-0.143	0.285	-0.702	0.416	-0.123 (-0.962 – 0.408)	>.05
CT – µCT	0.098	0.199	-0.292	0.488	0.474 (-0.03 – 0.741)	**<.05**
DA						
CBCT – µCT	0.208	0.140	-0.066	0.483	0.484 (-0.236 – 0.798)	**<.001**
CT – µCT	0.180	0.308	-0.424	0.784	-0.386 (-1.398 – 0.27)	>.05

MD: Mean Deviation, SD: Standart Deviation, CI: Confidence Interval, ,BS/TV: Bone Surface/Total Volume, BV/TV: Bone Volume/Total Volume, BS: Bone Surface, BV: Bone Volume, TV :Total Volume, FD: Fractal Dimension, DA: Degree of Anisotrophy. p<.05

The statistically significant parameters are shown in the linear regression model, along with the microstructure parameters obtained using the three tomography methods (Table 2).

Table 2. *Linear regression models showing the relationship between microstructure parameters analyzed by µCT, CBCT, CT and compressive strength.*

	BS/TV	BV/TV	FD	Tb/Th	DA	Con. Dens	SMI
µCT							
R^2	0.279	0.612	0.158	0.389	0.303	NS	NS
F	10.812	44.08	5.262	17.862	12.195	NS	NS
CBCT							
R^2	0.356	0.431	NS	NS	0.302	0.165	NS
F	15.649	21.242	NS	NS	12.123	5.534	NS
CT							
R^2	0.134	NS	NS	NS	NS	NS	0.155
F	4.338	NS	NS	NS	NS	NS	5.133

NS: not significant. BS/TV: Bone Surface/Total Volume, BV/TV: Bone Volume/Total Volume, FD: Fractal Dimension, Tb/Th: Trabecular Thickness, DA: Degree of Anisotrophy, Con. Dens: Connectivity Density, SMI: Structure Model Indeks. µCT: Micro Computed Tomography, CBCT:Cone Beam Computed Tomography, CT: Computed Tomography.

3.3. Multiple Stepwise Regression Analyse of Bone Parameters of µCT Scanning

A multiple stepwise regression model was created to predict the compressive strength of the bone specimens based on the BV/TV and DA values obtained using µCT. The calculated regression model was statistically significant (F (2,25) = 42.255; p < .001), with R^2 = .753. The estimated compressive strength of the bone specimens was equal to – 278.442 + 2825.965 *BV/TV – 49.432*DA. Both the BV/TV and DA parameters, which were analyzed using the µCT method, were statistically significant determinants (Table 3).

BV/TV, DA and Con. Dens values, a multiple stepwise regression model was created to predict the compressive strength of bone specimens. The calculated regression model was statistically significant (F (3, 25) – 16,149, p<.05) and R^2=.619. The estimated compressive strength of the bone specimens is equal to 751.328+750.919*BV/TV-711.786*DA-69490.423*Con. Dens. BV/TV DA and Con. Dens parameters are statistically significant determinants (Table 3).

3.4. Multiple Stepwise Regression Analyse of Bone Parameters of CT Scanning

A multiple stepwise regression model was created to predict the compressive strength of bone specimens based on the SMI value, one of the bone microstructure parameters analyzed by CT. The calculated regression model was statistically significant (F (1, 28) = 5.133, p< .05) and R^2=.125. The estimated compressive strength of the bone specimens is equal to 639,677-132,453*SMI. The SMI parameter, which is one of the bone microstructure parameters analyzed in the CT method, is a statistically significant determinant (Table 3).

Table 3. *Multiple stepwise regression models showing the relationship between microstructure parameters analyzed by µCT, CBCT, CT and compressive strength.*

	β^1 (%95 CI)	SE	β^2	t	p
µCT					
Constant	-278.442 (-536.395-20.489)	125.248		-0.223	.035
BV/TV	2825.965 (2016.424+3635.505)	393.069	0.699	7.189	.000
DA	-349.4321 (-517.603-181.261)	81.655	-0.416	-0.279	.000
CBCT					
Constant	751.328 (174.774+1327.881)	279.943		2.684	.013
BV/TV	750.919 (-26.101+1527.938)	377.279	0.323	1.99	.058
DA	-711.786 (-1162.972-260.599)	219.072	-0.448	-3.249	.003
Con. Dens.	-6940.423 (-126176.934.12803.912)	27523.889	0.379	-2.525	.018
CT					
Constant	63.677 (336.372+942.983)	148.069		4.320	.000
SMI	-132.453 (-252.11-12.696)	58.464	-0.394	-2.266	.031

B^1: Unstandardized beta coefficient, SE: Standard error, θ^2: Standardized beta coefficient, CI: Confidence Interval. BV/TV: Bone Volume/Total Volume, FD: Fractal Dimension, Degree of Anisotrophy, Con. Dens: Connectivity Density, SMI: Structure Model Indeks. µCT: Micro Computed Tomography, CBCT:Cone Beam Computed Tomography, CT: Computed Tomography.

4. DISCUSSION

CBCT is commonly utilized to assess bone quality, with a primary emphasis on bone density, as observed in studies such as those conducted by Corpas et al., Ibrahim et al. (3,13). However, to gain a more comprehensive understanding of its impact on the integration of implants with bone tissue, it is imperative to consider bone quality from the microstructural perspective of trabecular bone, as underscored in research by Gonzalez-Garcia et al. (14). Trabecular bone microstructure not only plays a vital role in bone healing and implant stability, as elucidated by Minkin and Marinho, but it also significantly contributes to overall bone strength, as indicated by studies such as Manske et al. (15,16). In this study, we evaluated all the parameters evaluated in the previous studies in three different tomography devices and tried to learn the parameters that best comply with the gold standard and to evaluate the estimation of bone compression strength based on these parameters. We also tried to understand the preferability of the cone beam computed tomography method according to the gold standard.

Limitations of this study can be related with organic components of bone tissue. For example, some authors found an association between bone fracture and bone collagen integrity (17). Optimal ratio of bone organic-inorganic components was reported as a fundamental determinant of bone mechanical quality (18). In some studies, it has

been stated that the ratio of "bound and pore water" is associated with bone fragility (19). Also, deteriorated micro-arrangement between collagen fibrils and apatite crystals was responsible for reduced bone strength (20). As proven by the studies above, organic component is affective on bone strength, However, we did not include a organic bone parameter to this study.

Knowledge about the microstructure and quality of the trabecular bone structure before surgical procedures and in some systemic diseases affecting the bone structure is very important in the success and prognosis of treatment. Radiologic evaluation of bone quality will provide clinicians with very useful information. In recent studies, it is argued that Magnetic Resonance Imaging (MRI) method may be an alternative for trabecular and cortical bone evaluations since it does not contain ionizing radiation (21, 22) and MRI can evaluate organic component and water ratio of bone (19).

With the emergence of new techniques for measuring bone fragility, using not only the mass but also the microstructure of the bone has proven to be very effective in calculating the strength of the bone. Many researchers argue that bone mineral density is still very important in determining the strength of bone. However, many recent studies have shown that microstructure parameters alone, independent of knowledge of mineral density, are sufficient for evaluating bone strength (23).

Goulet et al. used µCT to examine the microstructure of trabecular bone and mechanical tests to evaluate the relationship between the elastic modulus and the total strength of the bone. The researchers concluded that BV, connectivity parameters, and number of trabeculae are highly effective parameters in determining mechanical properties. They stated that increases in the BV parameter are naturally associated with an increase in the density value (24).

In addition, Ding et al. used µCT to investigate microstructural changes in trabecular bone samples taken from patients with early osteoarthritis. They evaluated the relationship of the data they obtained to the strength and failure energy values of the bone. In the regression model they derived, they showed that none of the microstructure parameters could determine the strength and failure energy values of the bone as well as the SMI parameter (25). In the present study, the relationship between the values obtained as a result of µCT evaluation of the microstructure of the bone and the compressive strength of the bone was evaluated, and it was seen that the SMI (R2: 16%) and BS/TV (R^2: 13%) parameters were statistically effective, although the percentage of model identification was low. An increase in the SMI parameter is associated with an increase in the number of rod-shaped trabeculae, whereas an increase in the BS/TV value is associated with an increase in bone mineral density (14,26). In addition, recent studies using the gold standard µCT have shown that some new parameters are statistically more effective in determining mechanical properties than the SMI parameter (27,28).

Maquer et al. proved that the combined evaluation of BV/TV and DA parameters, which are microstructure parameters evaluated by µCT, are the most effective variables in calculating the young's modulus of trabecular bone (27). But in their µCT study on the stiffness and yield strength of trabecular bone, Musy et al. concluded that BV/TV and DA parameters were the best parameters for predicting the mechanical properties of bone, accounting for more than 98% of the regression model (28). Using the histomorphometric method of two-dimensional imaging, Han et al. evaluated the microstructure of samples taken from the knee bones of patients with osteoarthritis (29). They also calculated the Osteoarthritis Research Society International (OARSI) values of these samples. The OARSI classification system is an atlas-based grading system that evaluates osteophyte formation and lateral compartment narrowing (29, 30) concluded that the higher the BV/TV parameter, the higher the OARSI value for bone and cartilage. In the present study, multiple stepwise regression models created with BV/TV and DA parameters obtained by using µCT (the gold standard of ex vivo evaluation) and CBCT imaging (widely used in dentistry applications) were found to be highly effective in determining the compressive strength of trabecular bone. The DA parameter is related to the direction of the stress to which the bone is exposed; it is a numerical indication of the three-dimensional configuration of the bone structure (30). A high DA value means that the trabeculae in the trabecular bone are more frequently aligned in the same direction (31). When trabeculae are aligned in the same direction, the ability to absorb the applied force declines. Thus, there is a negative correlation between the compressive strength of bone and the DA parameter. This alignment also explains why similar microstructure parameters have a similar effect in determining the mechanical properties of bone.

Kang et al. investigated the extent to which implant stability is affected by the microstructure parameters of bones obtained from pigs (26). They used both µCT imaging and CBCT imaging to analyze the microstructure, and they compared their data with the stability according to peak frequency SPF (Implant Stability Criterion) parameter used to determine the primary stability of implants. The BV/TV, BS/TV (BSD), and SMI parameters, from data obtained by µCT imaging, were the variables in the model with the highest descriptiveness. In the present study, among the data obtained by µCT imaging, the BV/TV parameter alone accounts for approximately 58.9% of the compressive strength regression model. Teo et al. reported that a decrease in con. dens. value will not affect the BV and BV/TV values but will lead to a loss of strength in the bone (32). This suggests that the con. dens. parameter should be included in the multiple stepwise regression model between CBCT microstructure parameters and compressive strength. Again, using the CT method to evaluate the microstructure parameters, we observed a negative correlation between compressive strength and the SMI parameter. Kang et al. also found a negative correlation between the SMI value and SPF. This can be interpreted as signifying an increase in the number of rod-shaped trabeculae, which weakens both

the osseointegration between the implant and bone and the compressive strength of the bone to resist forces (26).

Using µCT, Ding et al. analyzed trabecular bone samples obtained from osteoarthritic and osteoporotic human hips and subjected them to compression testing. They concluded that patients with similar BV/TV values did not show similar compressive strength. They argued that the BV/TV parameter is largely effective in determining compressive strength but that factors such as abnormal collagen structure and degree of mineralization may also affect this determination (33). In present study, the parameters affecting the compressive strength were investigated and it was concluded that the parameters such as BV/TV, BS/TV DA Tb/Th and FD evaluated by µCT were statistically effective parameters on compressive strength. In addition, parameters such as BV/TV, BS/TV DA and Con. Dens. In fact, our study supports the study of Ding et al. and clarifies what other parameters are effective on compressive strength.

Müller et al. argued that a resolution thickness higher than 100 micrometers should not be used when analyzing trabecular bone with µCT (34). For this reason, in present study, we performed image acquisition ten times more detailed than the recommended thickness (10 micrometers).

Pauwels et al. investigated how different voxel sizes and kVp values in CBCT imaging have an effect on the microstructural parameters of bones obtained from human mandible. The results showed that the kVp value had no significant effect on most parameters. BV/TV and DA parameters were not affected by voxel size changes. BS/TV, FD and Con. Dens values decreased gradually with increases in voxel size, while Tb/Sp, Tb/Th and SMI values increased (35). In the regression model between bone microstructure parameters and bone compressive strength, BV/TV DA and Con. Dens. parameters were observed. Considering the results of Pauwels et al. study, BV/TV and DA parameters were not affected by changes in voxel size, whereas Con. Dens. parameter changes inversely with voxel size. In the regression model, the Con. Dens parameter and compressive strength in the regression model, it can be interpreted that increases in voxel size will cause an increase in compressive strength.

Diederichs et al. evaluated the microstructure of human calcaneus bone specimens with both MSCT and µCT. They performed MSCT imaging in three different protocols (120 kVp, 200 mAs, 120 kVp, 160 mAs, 80 kVp, 200 mAs). BV/TV and Tb/Th parameter values were statistically significantly correlated with the values obtained with µCT in all three imaging protocols. The Tb/Sp parameter values obtained with only the first imaging protocol (120 kVp, 200 mAs) showed a statistically significant correlation with the values obtained with µCT (36). In present study, only the FD parameters obtained with both methods were found to be statistically significant and moderately concordant (ICC=.474; p< .05). Our imaging protocol was 120 kVp, 69 mAs. As seen in Diederichs et al. study, microstructure parameters are statistically affected by differences between protocols. Therefore, it is thought that the possible difference may be due to changes in mAs level.

Parsa et al. evaluated the microstructure of samples obtained from human cadavers with CBCT, MSCT and µCT. As a result, they showed that there was an excellent correlation between BV value and bone density value evaluated by MSCT and µCT. They also concluded that there is a very strong correlation between the BV/TV parameter, which is considered as the gold standard in bone quality assessments of implant sites, and CBCT gray values (37).

Kulah et al. evaluated cadaveric maxillary bone samples with two CBCT and one µCT devices. As a result of the study; similar to the findings of this study; they showed that the BV/TV and DA parameter values obtained with the CBCT imaging method were compatible with the values obtained with the µCT imaging method (10). In present study, it was observed that the parameters such as BV/TV, BS/TV, BS, BV, TV and DA evaluated with the CBCT imaging method were statistically significantly compatible with the µCT imaging method.

Although µCT imaging method is considered as the gold standard among imaging methods, it has some disadvantages such as not being suitable for clinical use, high radiation content, and not being available in every clinic. At this point, it has been a study that clarifies in which areas the CBCT imaging method, which is now more widely used in our clinics and offers many advantages in terms of radiation amount and procedure time, can be an alternative to the µCT imaging method.

In conclusion, microstructure parameters of CBCT were more compatible with gold standard values comparing with CT parameters. Bone compression strength can be estimated by CBCT and µCT methods in a desired level. BV/TV and DA parameters are significant determinants of bone mechanical property in not only µCT but also CBCT method.

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Research idea:AK
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