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The Analysis of Articular Eminence Changes in Edentulous Patients Using Cone-Beam Computed Tomography

Dişsiz Hastalarda Eklem Çıkıntısı Değişikliklerinin Konik Işınlı Bilgisayarlı Tomografi Kullanılarak Analizi

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ABSTRACT

Objective: The aim of this study was to compare articular eminence (AE) between dentated and edentulous patients by examining internal bone structure of AE with fractal analysis (FA), AE inclination (AEI), and morphology on cone beam computed tomography (CBCT) records.

Methods: A total of 200 AEs were examined. The region of interest for FA was chosen as a square placed at the geometrical center of the AE on sagittal slices. The AEI measurement was performed on the central sagittal slice. All three plane sections were assessed for morphologic evaluation.

Results: There was no significant difference between the groups for FA and distribution of AE morphology (P=.428 and P=.082). The AEI values in the study group were significantly lower compared to control group (P<.001).

Conclusion: Edentulous patients exhibited lower AEI values, but edentulism does not affect the trabecular bone structure of the AE despite these lower values.

Keywords: Temporomandibular joint, mouth, edentulous, computed tomography, cone beam, fractals

ÖZ

Amaç: Bu çalışmanın amacı, dişli ve dişsiz hastalar arasında artiküler eminens (AE) iç yapısını ve morfolojisini fraktal analiz (FA) ve AE inklinasyonu (AEİ) metotları ile konik ışınlı bilgisayarlı tomografi (KIBT) kayıtları üzerinden inceleyerek karşılaştırmaktır.

Yöntemler: Toplamda 200 AE incelendi. FA için ilgilenilen bölge, AE'nin geometrik merkezine yerleştirilen bir kare olarak sagittal kesitlerde seçildi. AEİ ölçümü, merkezi sagittal kesitte gerçekleştirildi. Morfolojik değerlendirme için her üç düzlemde de kesitler incelendi.

Bulgular: Gruplar arasında FA ve AE morfolojisi dağılımı açısından anlamlı bir fark bulunmadı (P=,428 ve P=,082). Çalışma grubundaki AEİ değerleri, kontrol grubuna kıyasla anlamlı derecede daha düşük bulundu (P<,001).

Sonuç: Dişsiz hastalar, daha düşük AEİ değerleri sergilemiştir, ancak dişsizlik durumu bu düşük değerlere rağmen AE'nin trabeküler kemik yapısını etkilememektedir.

Anahtar Kelimeler: Temporomandibular eklem, ağız, dişsiz, konik ışınlı bilgisayarlı tomografi, benzer elemanların oluşturduğu şekiller

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INTRODUCTION

The prevalence of edentulism among elderly individuals remains a critical issue globally.[1] With the increasing number of elderly patients, clinicians should also be aware of the impacts of increased age and edentulousness on oral, dental, and temporomandibular joint (TMJ) health and should shape their treatment plan in light of this awareness.[2]

Articular eminence (AE) is entirely flat at birth; its development begins in childhood and continues until the second decade. Mechanical forces like the eruption of teeth, occlusion formation, and jaws' growth affect and stimulate TMJ development.[3] AE is constantly exposed to mechanical loadings even after its development.[4] Joint loads are originated from the interaction of teeth and muscles.[5] Edentulism, on the other hand, causes a lack of these interactions and dramatically changes masticatory biomechanics. AE alterations can be seen as a result of the adaptation to changing mechanical forces in edentulous patients.[4,6,7]

In the literature, the focus of the studies investigating tooth loss and edentulism are limited to AEI measurements.[4,6,8] Ichikawa et al.[9] explored the internal bone structure of AE during the transition from deciduous to the early mixed dentition. The internal structure of AE in patients with tooth loss has only been investigated by Kawashima et al. [10] using X-ray. Therefore, the literature has not adequately clarified the possible changes in AE internal structure related to tooth loss and its relation to AEI.

Fractal analysis (FA) is a configuration analysis method that makes it possible to assess irregular or complex structures; the fractal dimension (FD) can be calculated as a quantitative result. The FA method has recently gained popularity for examining internal bone structures on dental radiographs. Studies have shown that FD values vary significantly in osteoporotic or pathological conditions.[11-14] The AE inclination (AEI), the determining factor of the condylar path, is defined as the angle between the AE and the Frankfurt horizontal plane.[15] Studies in the literature have shown that AEI shows significant changes as a response to pathological or biomechanical conditions such as the number of teeth.[4,6,8,15] The morphological classification of AE was also introduced in the literature as a visual assessment.[16]

The presented study aimed to comprehensively compare AE between dentated and edentulous patients by examining the internal bone structure of AE with FA, AEI and classifying the AE morphology on cone beam computed tomography (CBCT) records.

METHODS

This study was retrospective and utilized the medical history and radiographic records of individuals who sought initial dental examination at the Oral and Maxillofacial Radiology Department of the Erciyes University Faculty of Dentistry. The local ethics committee granted ethical approval for the study (Date: September 14, 2022 Decision no: 2022/604). At the time of image acquisition, all patients provided written informed consent permitting the use of their anonymized radiographic data for scientific research. Therefore, no additional informed consent was obtained for the present study.

A power analysis (for 95% power, d = 1.67 and alpha = 0.05 level of error) was performed with G*Power software. It was determined that there should be at least 15 patients in each group. However, to improve the reliability of the results obtained in the presented study, a total of 100 individuals were included.

Patient Selection

Patient files were evaluated retrospectively, and patients who were completely edentulous, had been using removable total dentures for at least two years, and had CBCT records were chosen as candidates to constitute the study group. Records containing information on medication use and medical history noted during patients' routine dental examination were reviewed for this purpose.

The study excluded patients who met any of the following criteria: systemic disease or medication use that could impact bone metabolism, history of TMJ trauma or surgery, symptoms of TMJ disorders which were detected during routine examination, pathologies in the TMJ area, or pneumatized AEs. After the exclusion process, a study group of 50 individuals, consisting of 20 female and 30 male patients, with a mean age of 62.9±4.94 (ranging between 41-75), was formed. Patients with preserved occlusion (defined as the presence of at least 20 teeth in the mouth) and CBCT records were identified to form the control group candidates. The exclusion criteria set for the study group were applied to the control group candidates. After the exclusion process, a control group of 50 individuals, consisting of 20 female and 30 male patients, with a mean age of 62.12±4.71 (ranging between 44-70) was formed.

Imaging Features

CBCT scans of the included individuals were evaluated. The CBCT images were acquired using the New-Tom 5G CBCT device (QR, Verona, Italy) with settings of 110 kV and 3-5 mA settings, 0.16-mm voxel size, 18x16 field of view, and an average exposure time of 5.4 s. Each patient's right and left TMJ regions were evaluated separately; a total of 200 AEs were evaluated (100 for the patient group and 100 for the control group). The CBCT slices of AE were arranged using the NNT software. The images were saved as TIFF files with a resolution of 20 pixels/mm and had a slice thickness of 0.25 mm.

Quantitative measurements were made by two observers (a maxillofacial radiology specialist with 7 years of experience (AÇ) and a maxillofacial radiology research assistant with 4 years of experience (FD)) blindly and independently of each other in a darkroom. The observers completed all measurements by analyzing 12 AEs per weekday and 20 AEs per weekend day, finalizing the entire set of measurements within 14 days.

The mean of the values measured by the observers was utilized for statistical analysis. For the morphological assessment, in cases where there was inconsistency between the two observers, a consensus was reached with discussion. To evaluate intra-observer reliability, each observer reviewed the randomly selected 20% of the data two weeks after the initial measurements.

Fractal Analysis

For the fractal analysis (FA), the section with the widest condylar prominences mediolaterally in the axial plane was determined and used for the secondary reconstruction of the sagittal slice (Figure 1). The secondary reconstructed sagittal slice, along with its prior and latter sagittal slices, were selected and saved in TIFF format. FA was performed on all three selected images, and the mean value of the three measurements was recorded. The purpose of this step is to gather more comprehensive information, as a single section may not provide sufficient details.

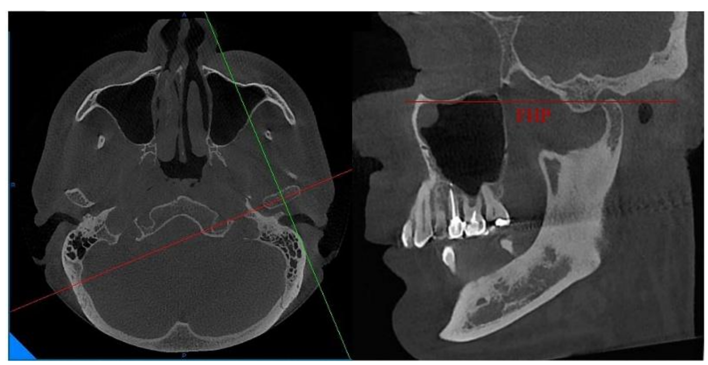

Figure 1. Selection and preparation of the sagittal slice.
FHP: Frankfurt horizontal plane.

FA was conducted using ImageJ software (IBM SPSS Corp., Armonk, NY, USA). Region of interest (ROI) was chosen as a square of 64 × 64 pixels, containing only the trabecular bone, and placed at the geometrical center of the AE. The image processing process suggested by White and Rudolph was applied to the images,[17] and subsequently, FD values were determined by the box-counting method. Process steps were as follows: (Figure 2)

- The chosen ROI was duplicated.
- The Gaussian filter (35 sigma) was applied to the duplicated image; this step eliminated large-scale brightness changes and retained only large-scale density differences.
- The subtraction step was performed, by subtracting the duplicate image, which has been blurred, from the initial ROI image.
- Afterward, on the resultant image, each pixel location had 128 gray pixel values added to it. This process changes the feature of the

image, so different brightness levels are represented. This process also sets the threshold value as 128.

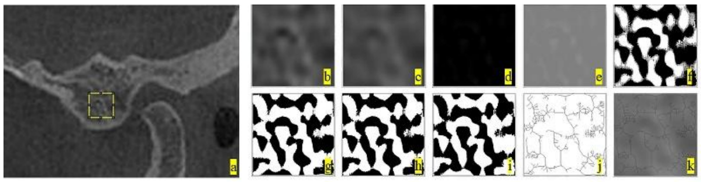

Figure 2. Fractal analysis.

a. Selection of ROI. b. Cropped and duplicated ROI. c.Gaussian filter application. d.Subtraction. e.Addition of 128 pixels. f.Binarisation. g.Erosion. h.Dilatation. i.Invert. j.Skeletonization. k.Overlay of figures 2b and 2j. Please note that the skeletonized image corresponds to original trabeculae.

- The image was then binarized using a brightness threshold value of 128, resulting in an image composed solely of black and white regions. Thus, parts representing the bone marrow and trabeculae became visually distinguishable.
- The emergent image has been eroded to reduce the noise.
- The image has been enlarged with dilation to make the structures more prominent.
- With the 'invert' option of the program, white surfaces were changed into black and black surfaces were changed into white. Consequently, the trabecular bone was represented with black, while the white surfaces represented the bone marrow.
- With the 'skeletonize' option of the program, the structures were etched until only a single pixel line was present.
- The program's fractal box-counting option was used to calculate the FD for each image; the resultant image was parted into squares (2, 3, 4, 6, 8, 12, 16, 32, and 64 pixels). For each square of different sizes, the program calculated the number of squares that contained black areas (representing trabeculae) and the total number of squares. The logarithmic scale graph of the obtained values was drawn. The FD value was obtained by calculating the slope of the line aligned to the points appearing on the graph. Three sections were assessed for each AE, and the mean value of the measurements was noted as the final value for each observer.

AEI measurements

All measurements were made using NNT viewer (NNT software, version 3.0; NewTom, Verona, Italy) 3D imaging software.

The same sagittal slice generated by the widest condylar prominences mediolaterally in the axial plane was used. Before the measurements were made, the Frankfurt horizontal plane, which is the horizontal line extending from the upper border of the meatus acusticus externus to the lower border of the orbit, was adjusted parallel to the horizontal plane in the sagittal plane on CBCT. The top-roof line method was used for AEI measurements. For this method, a line was drawn from the highest point of the glenoid fossa roof to the lowest point of the AE floor in the reconstructed sagittal sections, and the angle between this line and the line parallel to the Frankfurt horizontal plane and passing through the floor of the AE was measured (Figure 3).

Morphologic Classification of AE

All the sagittal, axial, and coronal plane sections were assessed for morphology evaluation, and each observer made a decision. The classification was made according to the features determined by Kurita et al. [16], described below (Figure 4).

- Box type: Presence of a deep fossa with steep posterior slope to the AE.
- Sigmoid type: Presence of a fossa with more gentle posterior slope to the AE, compared to the box type.
- Flattened type: Presence of a shallow fossa and flattened AE.
- Deformed type: If the morphology of AE failed to fit one of the three priorly described types, it was accepted as deformed type.

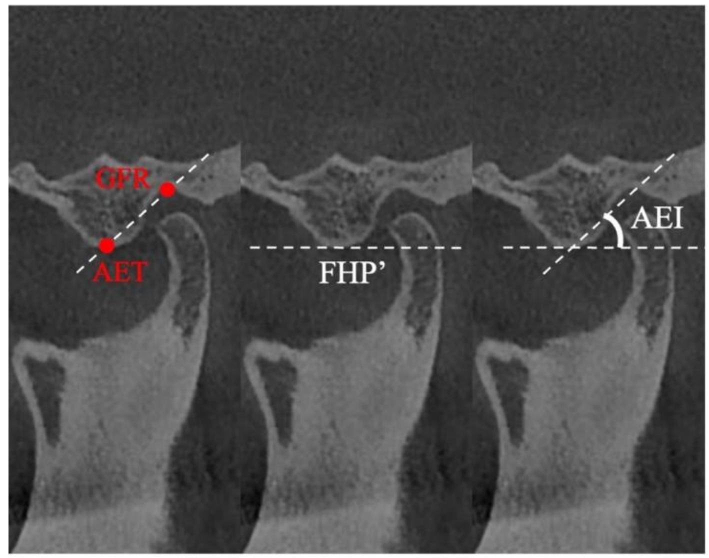

Figure 3. AEI measurement.
GFR: Glenoid fossa roof. AET: Articular eminence tip. FHP: Frankfurt horizontal plane.

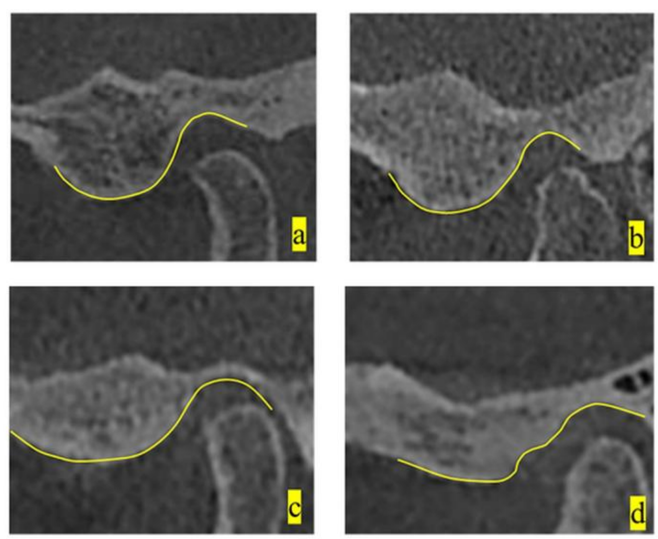

Figure 4. AE types.
a. Box-type. b.Sigmoid type. c.Flattened type. d.Deformed type.

Statistical Analysis

Data analysis was performed through SPSS 24.0 software (IBM SPSS Corp., Armonk, NY, USA). The suitability of the data for normal distribution was examined with the Kolmogorov-Smirnov test. The homogeneity of the variances was examined by Levene's Test. Mean ±SD values were given for normally distributed data, and median (min-max) values were given for non-normally distributed data. The Mann-Whitney U test was used to assess the difference in the non-normally distributed age variable between the dentition and gender groups, according to the Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test showed that the FD and AEI values were normally distributed in both the research and gender groups. The main effects and interactions of gender and dentition factors on normally distributed FD and AEI were examined by two-way analysis of variance. Bonferroni test was used to compare main effects. The Spearman correlation coefficient was used to evaluate the relationship between age, AEI, and FD quantitative data. Chi-square test was used to evaluate differences in categorical variables (gender and articular eminence morphologies) according to groups, and Bonferroni correction was used to determine the significance of differences between groups in multiple pairwise comparisons. In-class correlation coefficient was used to evaluate the intra-observer and inter-observer agreement of quantitative values. In order to evaluate the reliability of the assessment of the articular eminence morphologies, the Cohen κ test was used, based on the original analysis of each observer before reaching consensus in case of disagreement and repeated analyses for each observer. Significance level was taken as *P*<.05.

RESULTS

The median (min-max) values for the age variable were 64 (41 - 75) years for the study group and 63 (44 - 70) years for the control group. There were 60 (60%) males and 40 (40%) females in the study group and 60 (60%) males and 40 (40%) females in the control group. There was no significant difference between the study and control groups regarding age and gender distribution. (For age: *P*=.229; for gender distribution: *P*=1) (Table 1).

Table 1. Distribution of age and gender variables.

	Dentition		Test St.	*P*
	Edentulous	Dentate		
Age median (min-max)	64 (41 - 75)	63 (44 - 70)	4510.000*	.229
Gender				
Male n(%)	60 (60%)	60 (60%)	χ^2 =0.000**	1
Female n(%)	40 (40%)	40 (40%)		

** Mann Whitney U Test, ** Chi-square test statistic*

The mean ± SD values of FD measurements were found to be 1.19 ± 0.07 in the study group and 1.20 ± 0.07 in the control group. There was no significant difference between the study and control groups for FD values (*P*=.428).

The mean ± SD values for AEI measurements were 36.18 ± 7.14 in the study group and 43.58 ± 5.38 in the control group. The AEI values in the study group were significantly lower than those in the control group (*P*<.001) (Table 2 and Table 3). No significant correlation was found between AEI and FD in the study and control groups (*P*=.282 and *P*=.137, respectively).

The distribution of articular eminence morphologies in the study group was 27 (27%) box-shaped, 46 (46%) sigmoid, 22 (22%) flattened, and 5 (5%) deformed type. In the control group, the distribution of articular eminence morphologies was 32 (32%) box-shaped, 52 (52%) sigmoid, and 16 (16%) flattened type. The distribution of AE morphology did not differ significantly between the study and control groups (*P*=.082), (Table 4).

Table 2. Results of bidirectional analysis of variance evaluating FD and AEI variables in terms of gender and dentition

		F	*P*	Partial Eta Square
FD	Gender	11.670	**.001**	0.056
	Dentition	0.630	.428	0.003
	Gender*Dentition	2.864	.092	0.014
AEI	Gender	35.748	**<.001**	0.154
	Dentition	82.109	**<.001**	0.295
	Gender*Dentition	1.618	.205	0.008

Two-way ANOVA

Table 3. Descriptive statistics and multiple comparison results for FD and AEI variables

FD		Gender		Total
		Female	Male	
Dentition	Dentate	1.17 ± 0.08	1.21 ± 0.05	1.20 ± 0.07
	Edentolous	1.18 ± 0.07	1.19 ± 0.07	1.19 ± 0.07
	Total	**1.17 ± 0.07[a]**	**1.20 ± 0.06[b]**	
AEI		Gender		Total
		Female	Male	
Dentition	Dentate	41.21 ± 4.79	45.16 ± 5.20	**43.58 ± 5.38[a]**
	Edentolous	32.52 ± 7.30	38.62 ± 5.92	**36.18 ± 7.14[b]**
	Total	**36.86 ± 7.53[a]**	**41.89 ± 6.45[b]**	

a,b: Different superscript letters indicate a statistically significant difference.

Table 4. Articular eminence morphologies distribution in dentition and gender

		Dentition		Test St.	*P*
		Edentolous	Dentate		
Articular Eminence Morphologies	Box-shaped	27 (27%)	32 (32%)	χ^2 =6.602	.082
	Sigmoid	46 (46%)	52 (52%)		
	Flattened	22 (22%)	16 (16%)		
	Deformed	5 (5%)	0 (0%)		
		Gender		**Test St.**	***P***
		Male	**Female**		
Articular Eminence Morphologies	Box-shaped	**47 (39.17%)[a]**	**12 (15%)[b]**	χ^2 =23.881	**<.001**
	Sigmoid	59 (49.17%)[a]	39 (48.75%)[a]		
	Flattened	**11 (9.17%)[a]**	**26 (32.5%)[b]**		
	Deformed	3 (2.5%)[a]	3 (3.75%)[a]		

χ^2 = Chi-square test statistic, a,b: Different superscript letters indicate a statistically significant difference in articular eminence morphology for each row.

No statistically significant correlation was observed between the FD values and age in the study and control groups (*P*=.794 and *P*=.870, respectively). There was no significant correlation between AEI and age in the study and control groups (*P*=.664 and *P*=.509, respectively).

The mean ± SD values of FD measurements were found to be 1.17 ± 0.07 in females and 1.20 ± 0.06 in males. The mean ± SD values of AEI measurements were found to be 36.86 ± 7.53 in females and 41.89 ± 6.45 in males. There were significant differences for FD and AEI in terms of gender. FD and AEI values of female individuals were significantly lower compared to the male individuals (*P*=.001 and *P*<.001, respectively). FD mean ± SD values were 1.18 ± 0.07 for the study group and female gender, 1.19 ± 0.07 for the study group and male gender, 1.17 ± 0.08 for the control group and female gender, and 1.21 ± 0.05 for the control group and male gender. For FD, the interaction between gender and dentition was not found to be statistically significant (*P*=.092). The partial eta squared values indicated that the main effect for gender was 0.056, while the main effect for dentition was 0.003. This suggests that the effect of gender was more substantial than the effect of dentition in the study. AEI mean ± SD values were 32.52 ± 7.30 for the study group and female gender, 38.62 ± 5.92 for the study group and male gender, 41.21 ± 4.79 for the control group and female gender, and

45.16 ± 5.20 for the control group and male gender. For AEI, the interaction between gender and dentition was not found to be statistically significant (P=.205). The partial eta squared values indicated that the main effect for the gender variable was 0.154, while the main effect for dentition was 0.295. Notably, the effect of dentition was found to be higher than that of gender in this study (Table 2 and Table 3). The distribution of articular eminence morphologies in males was 47 (39.17%) box-shaped, 59 (49.17%) sigmoid, 11 (9.17%) flattened and 3 (2.5%) deformed type. The distribution of articular eminence morphologies in females was 12 (15%) box-shaped, 39 (48.75%) sigmoid, 26 (32.5%) flattened and 3 (3.75%) deformed type. There was also a significant difference for the gender in AE morphology (P<.001). Box-type AEs were found to be significantly more common in males than females. The flattened AE type is significantly less common in males than females (Table 4).

In the AEI and FD measurements, the intra-class correlation coefficients for intra-observer agreement are 0.968 and 0.965, respectively, and the intra-class correlation coefficients for inter-observer agreement are 0.954 and 0.969, respectively, and all coefficients represent excellent reliability. Regarding the evaluation of the AE morphologies, the κ value for the intra-observer agreement is 0.989, and the κ value for the inter-observer agreement is 0.965. All calculated κ values represent excellent fit.

DISCUSSION

In the literature, no other study has investigated the internal structure of AE in edentulous patients using advanced imaging techniques like CBCT to the authors' knowledge. Although edentulous patients exhibited significantly lower AEI values, the trabecular bone structure of AE remains unaffected by edentulism.

Remodeling of bone occurs in areas subjected to high loads. For TMJ, these areas were identified as AE and condylar head. Degenerative changes in the condylar head are widely recognized, but it is equally important to examine any degenerative modifications in the temporal region. This comprehensive evaluation of the TMJ is necessary to develop an accurate treatment plan, as the temporal region is exposed to external chewing forces and can adapt its morphological shape accordingly.[18] Ichikawa et al.[9] stated that wide trabeculae in the anterior-posterior direction were present in the AE during the early mixed dentition due to increases in the contact area of the occlusion and the force exerted on the posterior surface of the mandibular condyle during biting and chewing, resulting from the development of the muscles around the jaw. It has been concluded that trabeculae in the AE exhibit changes related to functional pressure.[9] Žabarović et al.[8] suggested that changes in the biomechanical conditions due to aging and tooth loss may influence the remodeling and reshaping of the AE.

The TMJ region is an area that is quite difficult to view effectively with two-dimensional radiologic techniques due to superimpositions over the temporal bone. CBCT provides a detailed three-dimensional examination of cranial hard tissue structures, and compared to computed tomography, it offers higher spatial resolution and lower radiation doses.[19] Using panoramic radiography for AE examination has disadvantages due to magnification and image distortion; furthermore, the internal structure of AE cannot be evaluated clearly due to superimpositions.[4] The present study utilized CBCT as the preferred imaging method due to the reasons mentioned above.

In the literature, structural analysis of trabecular bone can be effectively performed on CBCT records with 0.1 to 0.5 slice thickness.[20] In the present study, the slice thickness was 0.25, and the trabecular structure was able to be analyzed without prominent superimpositions of adjacent trabecular bone. Previous studies on the TMJ region also effectively used FA on CBCT sections and reported significant differences.[11,12,21]

In the present study, FD values did not differ between the study and control groups. Kawashima et al.[10] reported that the density and complexity of the trabecular bone of the AE decreased in edentulous patients compared to the dentulous specimens. Ichikawa et al.[9] investigated the AE of twenty temporal bones detached from the dried skulls and found an increase in the bone volume fraction and trabecular thickness in the early mixed dentition compared to the deciduous dentition; however, there was no significant difference for FD. An autopsy study compared the AE of three groups (dentate, edentulous, and edentulous with dentures) and found that the mean values of the measured parameters for surfaces, thicknesses, and lengths were consistently lower in the edentulous group compared to the other two groups.[22] The variability in results observed between studies may be attributed to differences in research methodologies. Despite having the advantages of conducting a study with retrospective clinical data, such as the increase in the number of patients, the possibilities for a more detailed examination of the bone are limited in the presented study due to the lack of in vitro specimen evaluation.

An earlier study reported significant differences for the FD values of the mandibular condyles between dentate and edentulous individuals.[11] The structural features of the AE and mandibular condyle are quite different. The internal structure of the AE consists of transversely oriented trabeculae and thick cortices, while the internal structure of the condyle shows vertically oriented thin trabeculation.[23] Therefore, these two structures, which are exposed to the same masticatory forces, may be affected at different levels by these forces.[23] Muir and Goss [24] reported that degenerative bone alterations were more commonly observed in the condyle than in the AE.

In the literature, there are a few studies related to AEI and edentulism.[4,6,25-28] Csadó et al.[6] reported that AEI values were highest in the maintained occlusion group, while the lowest values belonged to the edentulous patients. Studies on panoramic radiography have identified a significant relationship between tooth loss and lower AEI values and AE flattening.[4,25-27] Hamza et al.[28] also reported that AEI values were higher in the dentate group, followed by partially edentulous, and lowest in the edentulous group in their study conducted on CBCT. A recent review noted that many articles had emphasized the significance of tooth loss on AEI.[29] It has also been reported that both edentulous groups using conventional complete and implant-supported dentures displayed significantly lower AEI values than dentate control subjects.[27] The findings of the present study are compatible with the literature. However, there are also a few studies that reported no significant difference for the AEI related to dental status.[8,30]

While AEI values can reveal flattening, it does not give detailed information about deformation.[18] In the presented study, the number of flattened and deformed AEs was higher in the edentulous group than in the control group; however, the difference was insignificant. Muir and Goss[24] evaluated the radiologic features of condyle and AE and stated that all osseous changes were more common in the edentulous group than in the dentate group. Granados[7] stated that the dental condition changed the structure of the TMJ, and the time of being edentulous increased the deformation rate.

In the presented study, FD and AEI values did not significantly correlate with age. Tabor and Rokita[31] investigated the comparison of trabecular bone architecture in young and old bones and noted that lower FD values were present for the old bones; however, FA was inadequate to indicate age-related changes in the trabecular bone. Although the literature extensively documents the loss of bone microarchitecture in the aging skeleton, the adaptation of the TMJ structures to advanced aging remains insufficiently explored.[32,33] In the literature, aging is also considered one of the factors affecting the morphological changes of the TMJ components. Csadó et al.[6] defined a relationship between advanced age and lower AEI values; however, the researchers emphasized dental status as a more decisive factor. Oruba et al.[25] stated that flattening of the AE is associated with the loss of occlusal support rather than aging. Hamza et al.[28] found no statistical difference concerning age for the AEI. Ünal Erzurumlu and Çelenk[4] also found no statistical relationship between age and mean AEI, noting that this insignificance could be related to the age range of their study population, similar to the present study. According to Sümbüllü et al.[34], the highest AEI values were observed in individuals aged between 21 and 30, with a subsequent decrease after 30 years. Muir and Goss[24] highlighted that the frequency of flattening and sclerosis was positively associated with age in the edentulous group, as was sclerosis in the dentate group in their study investigating TMJ structures.

In the presented study, the FD values of the males were significantly higher compared to females. The pathways for the loss of trabecular bone microarchitecture may vary between genders. A study utilizing CBCT to evaluate mandibular condyles found gender differences in FD values, with edentulous patients exhibiting more pronounced differences between genders.[11] For AEI, there was also a significant difference for gender, AEI values were found to be higher in male individuals compared to females in the presented study. Consistent with the AEI findings, the incidence of box-type AE was significantly higher in male patients compared to females. In the literature, controversial results are reported for gender differences related to AEI. Zabarović et al.[8] found significantly higher AEI in both dentate and edentulous male specimens, in line with the present study. Ünal Erzurumlu and Çelenk[4] found significantly higher AEI values for males compared to females in edentulous patients; however, could not find a gender difference between male and female dentate patients. On the contrary, a recent study reported no statistical difference for gender in their dentate, partially edentulous, and edentulous patients.[28] Sümbüllü et al.[34] also did not report any significant difference for genders in their study assessing the TMJ dysfunction and healthy controls. A review concluded that while some studies suggest that factors such as biological sex and age may play a role in differences in AE angulations, the most significant factor appears to be edentulism, in line with the presented study.[29]

Csadó et al.[6] emphasized the maintenance of the intercuspal position and the vertical dimension of occlusion and stated that deformation and flattening of AE might occur without a physiological vertical dimension. Csadó et al.[6] also highlighted the importance of early prosthetic rehabilitation. It was determined that the deformation of the TMJ structures increased as the patient's duration of edentulism increased.[7] However, according to a recent study by Şirin Sarıbal et al.[27], dentures did not prevent the decrease in AEI values. The present study included patients who had used complete dentures for at least two years in the study group. However, due to the retrospective nature of the study, there is a lack of information about prosthesis-wearing habits, duration of edentulism, and quality of dentures. Moreover, having a minimum of 20 teeth was considered sufficient to be included in the control group; thus, the control group did not consist entirely of completely dentate patients. In the literature, it has been shown that even a single tooth loss affects AEI; therefore, a comparison of the edentulous patients with patients without any tooth loss might display more dramatic differences regarding to AE.[26] Muir and Goss[24] reported increased remodeling in the TMJ regarding edentulism. Tallents et al.[35] found that missing posterior teeth may cause degenerative joint disease. Degenerative osseous changes of TMJ and internal derangements are known to affect AE by reducing the AEI and displaying the flattening of AE.[16,34,36] Moreover, lower FD values of the mandibular condyles were also reported in degenerative joint diseases.[12,13,21]

Due to the retrospective nature of this study, information regarding prosthesis-wearing habits, duration of edentulism, and denture quality was unavailable. To avoid reducing the sample size, patients who had used dentures for at least two years were included; however, this introduces the risk of remodeling in TMJ structures during this period. Additionally, in the control group, factors such as restorative procedures and attrition, which could affect occlusion and TMJ function, could not be eliminated due to the limited number of patients. The variability of these factors may have influenced the findings. Another limitation results from the exclusion of patients with TMJ symptoms based on routine examination. The lack of standardization in TMJ assessments poses a limitation in consistency. Future prospective studies with larger sample sizes, more detailed data on patients' dentures, and control groups composed entirely of fully dentate patients are needed to address these limitations.

CONCLUSION

Lower AEI values found in patients who have used a prosthesis for two years may affect TMJ function and impair the quality of the masticatory system, but whether this constitutes a direct predisposing factor for TMJ diseases requires further investigation. Although the increase in the proportion of flattened and deformed AEs in edentulous patients did not achieve statistical significance, it should not be overlooked. The TMJ hard tissues of individuals with tooth loss can exhibit substantial changes, and the analysis of these changes should be considered in treatment planning. The presented findings warrant consideration in clinical practice and future research.

Ethics Committee Approval: Erciyes University local ethics committee granted ethical approval for the study (Date: September 14, 2022, Decision no: 2022/604).

Informed Consent: This retrospective study used cone beam computed tomography records obtained during clinical practice. At the time of image acquisition, all patients provided written informed consent permitting the use of their anonymized radiographic data for scientific research. Therefore, no additional informed consent was obtained for the present study.

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Hasta Onamı: Bu retrospektif çalışmada, klinik uygulama sırasında elde edilmiş konik ışınlı bilgisayarlı tomografi kayıtları kullanılmıştır. Görüntülerin elde edilmesi sırasında tüm hastalardan, anonimleştirilmiş radyolojik verilerinin bilimsel araştırmalarda kullanılmasına izin veren yazılı aydınlatılmış onam alınmıştır. Bu nedenle, mevcut çalışma için ek bir aydınlatılmış onam alınmamıştır.
Hakem Değerlendirmesi: Dış bağımsız.
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