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Comparison of Coronoid Process Length by Coronoid-Condylar Index and Levandoski Analysis: A Retrospective Study

Koronoid Proses Uzunluğunun Koronoid-Kondiler İndeks ve Levandoski Analizi ile Karşılaştırılması: Retrospektif Çalışma

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ABSTRACT Objective: The mandibular coronoid process is an anatomical structure related to mandibular function and movement. The elongated process may impinge on the zygomatic bones and restrict mouth opening. A significant portion of individuals with prolonged coronoid processes do not complain of pain, which may lead to misdiagnosis or delayed treatment. The objective of this study was to evaluate the concordance between coronoid process measurements obtained from panoramic radiography and cone beam computed tomography (CBCT) images. **Material and Methods:** A retrospective study design was employed, utilizing panoramic radiographs and CBCT images from the Department of Oral and Maxillofacial Radiology archives, excluding patients with prior maxillofacial surgery or certain pathologies. Levandoski analysis was used on panoramic radiographs and coronoid-condylar index (CCI) was used CBCT images to determine the coronoid process length. **Results:** A statistically significant difference was observed between the analysis methods ($p<0.05$). The length of the coronoid process was observed to be less in the Levandoski analysis than in the CCI. Although there was no significant difference in the length of the coronoid process between the genders when measured using CBCT, this measurement was found to be longer in males than in females when assessed using panoramic radiography ($p<0.05$). **Conclusion:** This study underscores the significance of CIBT as a dependable imaging modality for the accurate measurement of mandibular coronoid process length in comparison to panoramic radiography. The findings of this study mandate further research with larger populations to address its limitations and enhance diagnostic accuracy.

Keywords: Cone beam computed tomography; temporomandibular joint disorders; hyperplasia; panoramic radiography; mandible

ÖZET Amaç: Mandibular koronoid proses, mandibular fonksiyon ve hareketle ilişkili anatomik bir yapıdır. Uzamış proses zigomatik kemiklere baskı yapabilir ve ağız açıklığını kısıtlayabilir. Uzamış koronoid prosese sahip bireylerin önemli bir kısmının ağrıdan şikâyet etmemesi yanlış tanıya veya gecikmiş tedaviye yol açabilir. Bu çalışmanın amacı panoramik radyografi ve konik ışınlı bilgisayarlı tomografi (KIBT) görüntülerinden elde edilen koronoid proses ölçümleri arasındaki uyumu değerlendirmektir. **Gereç ve Yöntemler:** Ağız, Diş ve Çene Radyolojisi Anabilim Dalı arşivindeki panoramik radyografiler ve KIBT görüntüleri kullanılarak, geçirilmiş maksillofasiyal cerrahi veya patoloji hikayesi olan hastalar hariç tutularak, retrospektif bir çalışma tasarımı kullanılmıştır. Koronoid proses uzunluğunu belirlemek için panoramik radyografilerde Levandoski analizi, KIBT görüntülerinde ise koronoid-kondiler indeks (KKİ) kullanılmıştır. **Bulgular:** Analiz yöntemleri arasında istatistiksel olarak anlamlı bir fark gözlendi ($p<0.05$). Koronoid proses uzunluğunun Levandoski analizinde KKİ'ye göre daha az olduğu görülmüştür. Koronoid çıkıntı uzunluğu KIBT ile ölçüldüğünde cinsiyetler arasında anlamlı bir fark olmamasına rağmen, panoramik radyografi ile değerlendirildiğinde bu ölçüm erkeklerde kadınlara göre daha uzun bulundu ($p<0,05$). **Sonuç:** Bu çalışma, panoramik radyografiye kıyasla mandibular koronoid proses uzunluğunun doğru bir şekilde ölçülmesinde güvenilir bir görüntüleme yöntemi olarak KIBT'nin önemini vurgulamaktadır. Bulgular, çalışma kısıtlamalarını ele almak ve tanısal doğruluğu artırmak için daha büyük popülasyonlarla daha fazla araştırma yapılmasını gerektirmektedir.

Anahtar Kelimeler: Konik ışınlı bilgisayarlı tomografi; temporomandibular eklem hastalıkları; hiperplazi; panoramik radyografi; mandibula

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The mandibular coronoid process is an anatomical structure that plays a role in mandibular function and movement. This process mainly serves as the attachment point for the temporalis muscle, while its lateral surface partly forms the attachment site for the masseter muscle.[1] An increase in bone formation at the anterior, superior, and posterior aspects of the coronoid process may result from the activity of the anterior and posterior temporal muscle.[2] A number of factors have been identified as playing a role in the ethiology of this condition, involving trauma, hormonal stimulation, hyperfunction of masticatory muscles, pathological changes in muscle tissue and genetic predisposition. In a systematic review by Parmentier et al, the authors discuss various factors associated with elongated coronoid process, including temporalis muscle activity. They note that while increased activity of the temporal muscles has been suggested as a contributing factor, the exact pathogenesis of elongated coronoid process remains unclear.[2-4] The relationship between the mandibular condyle and coronoid process may be affected by several factors, including growth hormone receptor gene variants that affect mandibular morphology.[5] It has also been suggested that transforming growth factor-beta (TGF-β)3 mutations increase bone growth and cause coronoid process hyperplasia (CPH) formation by affecting the TGF-β signalling pathway.[6]

The abnormal growth of the mandibular coronoid process containing histologically normal bone is known as CPH.[7] This abnormality can develop either unilaterally or bilaterally. Elongated coronoid processes can be impingement on the medial surfaces of the zygomatic arches and on the posterior surfaces of the bodies of the zygomatic bones.[8] The American Academy of Orofacial Pain defines CPH as a congenital or developmental temporomandibular joint (TMJ) disorder.[9] CPH develops gradually, resulting in a reduction of the infratemporal space required for mandibular rotation and translation. This may lead to a limitation in mouth opening.[10] Therefore, CPH is a condition that should be evaluated in patients presenting with unexplained trismus. Radiographic examinations should be performed accordingly. The possibility of hyperplasia of the coronoid process should not be excluded in patients with TMJ-related symptoms.

To determine the size of the mandibular coronoid process radiographically, various imaging techniques can be employed. Panoramic radiographs, 15° occipito-mental views, and submentovertex views have been utilized to evaluate the dimensions and shape of the coronoid process, as well as the space between the coronoid processes.[11] The diagnosis of CPH frequently depends on sophisticated imaging techniques, such as computed tomography (CT). 3-dimensional (3D) imaging can assist in differentiating CPH from other conditions that may present similarly, including ankylosis and neoplasms of the coronoid process. The only coronoid measurement technique defined using panoramic radiography is the Levandoski method.[12] Levandoski analysis is effective in the diagnosis of CPH and other morphological abnormalities of the mandible. The accuracy of this method can be affected by the quality of the panoramic radiographs, magnification and the skill of the specialist in interpreting the images. In addition, in some cases, overlapping anatomical structures may block the visibility of the coronoid and condylar processes, which may lead to misdiagnosis.

The Coronoid-Condylar Index (CCI) developed by Tavassol et al. and Stopa et al. can be applied in various imaging modalities such as Cone Beam Computed Tomography (CBCT) or CT. It is useful in identifying functional or pathological abnormalities.[8,13] CCI is an important metric for assessing the relationship between the coronoid and condylar processes of the mandible. The objective of this study was to measure the length of the mandibular coronoid process in CBCT images using Stopa et al. CCI and to compare the 2 approaches using Levandoski analysis on the same subjects' panoramic radiographs.

MATERIAL AND METHODS

The research has been approved by by the Giresun University Clinical Research Ethics Committee (date: December 4, 2023, no: KAEK-264). All procedures performed in the study were in accordance with the tenets of the Declaration of Helsinki. Prior to the acquisition of radiological images, written informed consent is obtained from patients, stipulating the potential utilisation of these images in scientific studies. Consent forms are maintained in the department archive.

The study was designed with a retrospective methodology. Power analysis was performed to determine the sample size. A total of 92 panoramic radiographs and CBCT images of the same patients taken from the archive of Giresun University Department of Oral and Maxillofacial Radiology were used. The study excluded patients who had previously undergone surgery or trauma in the maxillofacial region, metabolic bone disease, any pathology in the condyle and coronoid processes, head and neck radiotherapy history and musculoskeletal anomalies.

A panoramic X-ray unit (Hyperion X5, Myray, Italy) operating at 60-85 kVp voltage and 4-15 mAs milliampere-second was used to obtain 2-dimensional (2D) radiographic images. The patients were placed upright, heads and necks in a neutral position, and the Frankfort plane parallel to the floor during the scanning procedure. CBCT images were acquired utilizing a dental volumetric imaging system (Newtom Giano HR, Verona, Italy), operating at a voltage of 90 kVp and a current of 6 mA for a duration of 7.2 seconds within a field of view measuring 16×18 cm, characterised by a voxel resolution of 300 µm. Dimensional measurements were performed directly on the Digital Imaging and Communications in Medicine images using the NNT software program (Newtom, Verona, Italy). The measurements were obtained from 3D reconstructed CBCT scans. All measurements and examinations were conducted using a 22-inch colour LCD screen with a resolution of 1920x1080 pixels (MDRC 2222 Option BL, Barco, Belgium). Measurements were performed by an experienced dentomaxillofacial radiologist. The measurements were repeated 2 weeks later by the same observer.

Levandoski analysis was used on panoramic radiographs and CCI was used CBCT images to determine the coronoid process length. Four lines were drawn on the panoramic radiographs (Figure 1). The maxillary vertical midline descending from the nasal septum forms line 1. Lines drawn tangentially from the gonion (Go), the tip of the condyle (Cd) and the tip of the coronoid process (Cor) intersect line 1 perpendicularly. As a result of this intersection, lines 2, 3 and 4 are formed respectively. Two distances between these three points were measured:

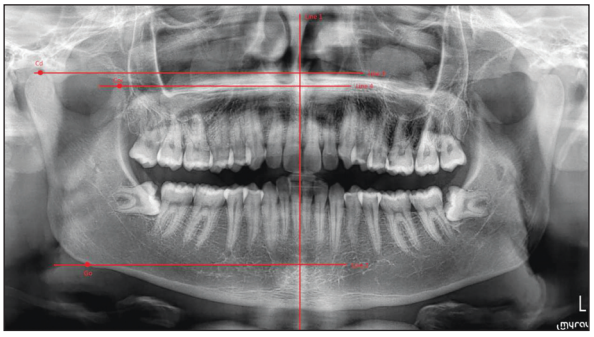

FIGURE 1: Lines drawn for Levandoski analysis on a panoramic radiograph

Cor-Go: Distances between the Cor and Go points.

Cd-Go: Distances between the Cd and Go points.

Cor-Go: Cd-Go: The ratio used to determine the length of the coronoid process.[12]

Measurements of the condylar and coronoid processes in a lateral projection were acquired through CBCT evaluation accompanied by 3D reconstruction. In order to avoid errors that might arise from comparing the absolute lengths of the separately measured sections, it was decided to analyse only their ratios. Three main lines were identified in the lateral projections of the mandible on CBCT (Figure 2):

Line tangent to the apexes of the coronoid process and condyle (A)

Line tangent to the angular region of the mandible and the inferior border of the mandible within the mental area. (B).

The third line should be drawn tangent to the outline of the mandibular angle and the posterior part of the condylar head. (C).[13]

Thus, the following points were determined:

G: The coordinate at which lines B and C converge,

E: The point of tangency between line A and the summit of the condylar head,

D: The point of tangency between line A and the apex of the coronoid process. Following that, measurements were made of the condylar height (GE) and coronoid height (GD). The mathematical formula for calculating the CCI is as follows:

CCI=GD:GE

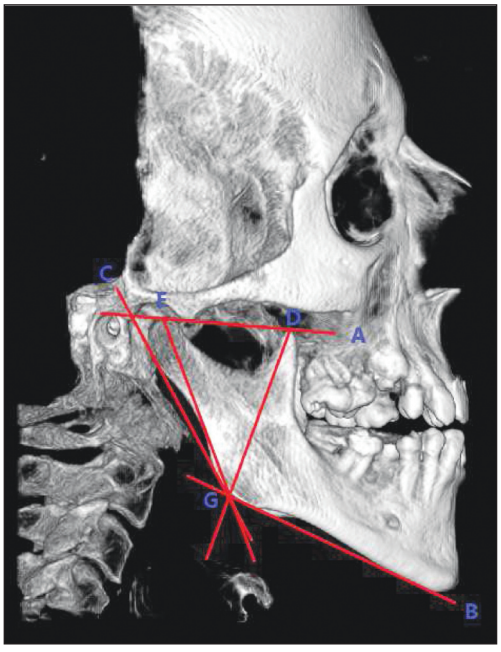

FIGURE 2: Lines drawn for coronoid-condylar index measurements on reconstructed 3D CBCT images
CBCT: Cone beam computed tomography

IBM SPSS 22.0 (IBM Corporation, USA) was employed for the purpose of data analysis. In this study conducted on 92 patients, researchers first presented descriptive statistics regarding socio-demographic characteristics. A Kolmogorov-Smirnov normality test was conducted to determine the most appropriate test statistic. The dependent sample t-test was employed for two groups of dependent variables with a normal distribution, while the Wilcoxon signed-rank test was utilized for 2 groups of dependent variables that were not normally distributed. All statistical tests used were tested at 95% confidence level. Intraclass Correlation Coefficient (ICC) was used for intraobservation agreement.

RESULTS

The mean age of the participants was 42.15±13.93 years. Of the participants, 41.3% (n=38) were male and 58.7% (n=54) were female. A comparative analysis of the patient measurements was conducted using the 2 distinct measurement techniques, with the findings presented in Table 1. A statistically significant difference was observed between the techniques ($p<0.05$). The lengths of the right and left coronoid processes were compared according to the measurement methods employed, and the results are displayed in Table 2 ($p>0.05$). There was no statistically significant difference between right and left lengths in both methods. The measurements obtained by the 2 methods were compared according to gender and the results are given in Table 3. Although there was no significant difference in the length of the coronoid

TABLE 1: Comparison of ratios according to measurement methods

		n	$\bar{X}$	SD	Minimum	Maximum	p value
Imaging method	Method						
CBCT	CCI	184	1.00	0.09	0.78	1.28	0.000*
Panoramic	Levandoski	184	0.94	0.07	0.74	1.19	

*p<0.05; n: Sample; SD: Standart deviation; CBCT: Cone beam computed tomography; CCI: Coronoid-condylar index

TABLE 2: Comparison of ratios between the left and right sides

Imaging method		n	$\bar{X}$	SD	Minimum	Maximum	p value
CBCT	CCI						
	Right	92	1.00	0.09	0.78	1.28	0.917
	Left	92	1.00	0.08	0.81	1.20	
Panoramic	Levandoski						
	Right	92	0.94	0.07	0.76	1.19	0.493
	Left	92	0.94	0.07	0.74	1.15	

n: Sample; SD: Standart deviation; CBCT: Cone beam computed tomography; CCI: Coronoid-condylar index

TABLE 3: Comparison of ratios measurements according to gender

Imaging method		n	$\bar{X}$	SD	Minimum	Maximum	p value
CBCT	CCI						
	Male	76	1.00	0.08	0.78	1.20	0.594
	Female	108	1.00	0.09	0.81	1.28	
Panoramic	Levandoski						
	Male	76	0.95	0.07	0.74	1.19	0.030*
	Female	108	0.93	0.06	0.76	1.10	

*p<0.05; n: Sample; SD: Standart deviation; CBCT: Cone beam computed tomography; CCI: Coronoid-condylar index

process between the genders when measured using CBCT, this measurement was found to be longer in males than in females when assessed using panoramic radiography (p<0.05). ICC was 0.773 for measurements on panoramic radiographs and 0.91 for measurements on CBCT images.

DISCUSSION

Various imaging and analysis techniques are used to determine the dimensions and hyperplasia of the coronoid process. With the aim of enhancing the identification of CPH, Kubota et al. utilized the Levandoski panographic analysis on conventional panoramic radiography in their investigation.[12] The researchers inferred that in cases where a patient presents with restricted mouth opening and the ratio exceeds 1.1, additional examinations are warranted due to the potential presence of hyperplasia of the coronoid processes in the mandible. In their study of CT images, Stopa et al. identified the presence of coronoid hyperplasia when the ratio of the coronoid process of the mandible and the height of the condyle, which they termed the CCI, exceeded 1.15.[13] Mattei et al. conducted a study using CCI on CT images and Levandoski analysis on panoramic radiographs of 11 patients with CPH. The results of the study show that the mean length ratio measured by panoramic radiography using the Levandoski method (1.09 [0.09]) was lower than that measured by CCI. (1.21 [0.09]; P=0.0001).[14] In this study comparing coronoid process measurements with CCI and Levandoski analyses, it was found that measurements from panoramic radiographs were lower compared to CBCT, as in the study by Mattei et al. Panoramic radiographs and CBCT differ significantly in diagnostic accuracy and clinical application due to their inherent technical and imaging characteristics. Panoramic radiographs are prone to magnification and distortion, especially when patient positioning is incorrect. This can lead to measurement inaccuracies in areas such as cortical and trabecular bone thickness, gonial and antegonial regions or alveolar bone. Linear and angular measurements from panoramic radiographies usually require careful calibration. CBCT provides 3D imaging with minimal distortion, enabling precise assessment of bone morphology and density. Unlike panoramic radiographs, CBCT eliminates magnification and superimposition errors, providing highly accurate volumetric data.[15] The discrepancy in the results of the Levandoski analysis can be attributed to the magnification of the panoramic radiographs and the overlapping of bony structures, which render the measurement process challenging.

In the present study, measurements of the right and left coronoid processes were performed using both CCI and Levandoski analysis. No significant difference was found between the right and left measurements with either method. In a study of panoramic radiographs of 500 individuals in southern India, Manoj et al. observed an asymmetry between the right and left sides of the condyle and coronoid, further emphasising the importance of considering both sides when analysing mandibular structures.[16] Studies conducted by Kubota et al. and Erdem et al. using the Levandoski method revealed that there was no statistically significant difference between the measurements of the right and left coronoid processes.[12,17] In

his review of CPH cases, Goh reported that bilateral hyperplasia of the coronoid process represented 79.1% of reported cases.[1] In their study with CCI, Stopa and colleagues observed no significant difference in the ratio of right to left side in patients with CPH.[13] Keselik et al. conducted a study of 22 dry mandibles, which yielded no statistically significant difference in coronoid lengths between the right and left side.[18] The conclusion that the right and left coronoid process measurements were symmetrical in the study may encourage clinicians to consider both sides equally in the evaluation of mandibular structures.

CPH is most commonly observed in males during the second decade of life.[7] Nevertheless, cases have been documented in females.[1] Gender-related differences have been identified in studies investigating mandibular morphology. In their study, Gomes et al. found that the height and volume of the coronoid process were significantly greater in males than in females. This gender difference was attributed to the higher masticatory force in males and thus greater bone remodelling on the mandibular bone.[19] In the study in which the CCI was developed, Stopa et al reported that 10 of the 13 patients with bilateral CPH were male.[13] In a separate study using the same index, two-thirds of patients with CPH were male.[20] In another study of panoramic radiographs using Levandoski's analysis, we found no difference between the genders.[17] In this study, gender and coronoid process measurements were analysed using both methods. In the CCI analysis no difference was found between the gender, but in the Levandoski analysis the coronoid process was larger in males.

There are not enough studies on the prevalence of CPH, which is rare. A review of the literature found studies that reported a prevalence of CPH of 0.3%, 0.5% and 1.02.[17,21,22] Future studies should include larger and more diverse populations, alongside detailed evaluations of observer agreement and calibration protocols. The present study is subject to some limitations. Due to its cross-sectional, retrospective nature, longitudinal monitoring of factors affecting the coronoid process length is not possible. Limitations such as the retrospective design and exclusion of certain patient groups should also be addressed in subsequent research to provide a more comprehensive understanding of coronoid process morphology. The design of future prospective longitudinal studies on a large sample of participants from different ethnic groups may contribute to an increase in knowledge about the process length and the factors that may alter it.

CONCLUSION

This study highlights the significance of CBCT as a reliable imaging modality for accurately measuring the length of the mandibular coronoid process compared to panoramic radiography. The results demonstrate that measurements obtained via CBCT provide superior consistency due to its higher resolution and reduced geometric distortion. Furthermore, the observed discrepancies between the Levandoski analysis and the CCI emphasize the limitations of 2D radiographic methods in assessing anatomical structures.

No significant difference was observed in the lengths of the coronoid process between the right and left sides, which supports the literature information on mandibular symmetry.

Future studies should include larger and more diverse populations, alongside detailed evaluations of observer agreement and calibration protocols. Limitations such as the retrospective design and exclusion of certain patient groups should also be addressed in subsequent research to provide a more comprehensive understanding of coronoid process morphology.

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

This study is entirely author's own work and no other author contribution.

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