NEU PRESS

Diş Hekimliği DERGİSİ

Vol: 7 No: 1 Year: 2025 | Research Article | e-ISSN: 2687-5535

https://doi.org/10.51122/neudentj.2025.144

Changes in the Condyle After Orthognathic Surgery in Class II and Class III Patients: A Retrospective Three-Dimensional Study

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Article Info

Article History

Received: 26.06.2024
Accepted: 24.11.2024
Published: 28.04.2025

Keywords:
Orthognatic surgery, Temporomandibular joint, Cone-beam computed tomograpy

ABSTRACT

Aim: Orthognathic surgery (OGS) may cause or exacerbate temporomandibular joint (TMJ) disorders and affect mandibular stability. The aim of this retrospective study is to evaluate the changes in the mandibular condyle and ramal angles as a result of mandibular and/or maxiller advancement/set back surgeries in patients with Class ll and Class lll malocclusions after OGS.
Material and Methods: Cone Beam Computed Tomography (CBCT) records which obtained 25 skeletal Class ll (6 males and 19 females mean ages=26.28 ± 5.89 y) and 25 skeletal Class lll (10 males and 15 females mean ages=23.32 ± 3.89 y) who had undergone OGS was selected. CBCT images were evaluated before surgery (T0) and 6 months after surgery (T1) using ITK Snap software to evaluate the measurement of the ramus. Changes of the condylar head were measured in axial, sagittal, and coronal sections.
Results: After OGS the axial ramal angle decreased significantly in both Class ll (4.24°±4.68) and Class III (1.52°±3.1) groups (p<.05). Condylar length in the sagittal dimension decreased significantly (p<.05) also in both groups (Cl II= 0.68 mm, Cl III= 0.13 mm). As a result of our study, it was found that resorption occurred in the condylar length and mandibular the proximal segment rotated laterally after OGS.
Conclusion: It would be appropriate to evaluate Class II and Class III patients who are planned to undergo OGS in terms of TMJ dysfunction before and after surgery.

Sınıf II ve Sınıf III Hastalarda Ortognatik Cerrahi Sonrası Kondil Değişiklikleri: Retrospektif Üç Boyutlu Çalışma

Makale Bilgisi

Makale Geçmişi

Geliş Tarihi: 26.06.2024
Kabul Tarihi: 24.11.2024
Yayın Tarihi: 28.04.2025

Anahtar Kelimeler:
Ortognatik cerrahi, Temporomandibular eklem, Cone-beam bilgisayarlı tomografi

ÖZET

Amaç: Ortognatik cerrahi (OGC) temporomandibular eklem (TME) bozukluklarına neden olabilir veya şiddetlendirebilir ve mandibular stabiliteyi etkileyebilir. Bu retrospektif çalışmanın amacı, Sınıf II ve Sınıf III maloklüzyonlu hastalarda OGC sonrası mandibular ve/veya maksiller ilerletme/geri alma ameliyatları sonucu mandibular kondil ve ramal açılarda meydana gelen değişiklikleri değerlendirmektir.
Gereç ve Yöntemler: OGC geçirmiş olan 25 iskeletsel Sınıf II (6 erkek ve 19 kadın ortalama yaş=26,28 ± 5,89 y) ve 25 iskeletsel Sınıf III (10 erkek ve 15 kadın ortalama yaş=23,32 ± 3,89 y) hastaya ait Konik Işınlı Bilgisayarlı Tomografi (KIBT) kayıtları seçildi. Ramus yüksekliği, uzunluğu, genişliği ve açısını ölçmek için KIBT görüntüleri ameliyattan önce (T0) ve ameliyattan 6 ay sonra (T1) ITK Snap yazılımı kullanılarak değerlendirildi. Kondil başındaki değişiklikler aksiyal, sagittal ve koronal kesitlerde ölçüldü. Gruplar arasındaki verilerin karşılaştırılmasında bağımsız t testi, grup içi korelasyonun değerlendirilmesinde Pearson korelasyon testi kullanıldı.
Bulgular: OGC sonrası aksiyel ramal açı hem Sınıf II (4,24°±4,68) hem de Sınıf III (1,52°±3,1) gruplarında anlamlı derecede azaldı (p<,05). Sagital düzlemdeki kondiler uzunluk her iki grupta da anlamlı derecede azaldı (p<,05) (Cl II= 0,68 mm, Cl III= 0,13 mm). Bu çalışma sonucunda OGC sonrasında kondil uzunluğunda rezorpsiyon meydana geldiği ve mandibular proksimal segmentin laterale rotasyon yaptığı tespit edildi.
Sonuçlar: OGC yapılması planlanan Sınıf II ve Sınıf III hastaların cerrahi öncesi ve sonrasında TME disfonksiyon açısından değerlendirilmesi uygun olacaktır.

To cite this article: Bozkurt S., Karamehmetoğlu Yılancı H., Kurt Demirsoy K. & Bozkurt Ö. Changes in the Condyle After Orthognathic Surgery in Class II and Class III Patients: A Retrospective Three-Dimensional Study. NEU Dent J. 2025;7:87-96. https://doi.org/10.51122/neudentj.2025.144

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INTRODUCTION

Over /Under-developed jaw growth may cause dentofacial deformities. It is necessary to undergo combined surgical and orthodontic treatment when the disagreement is beyond the range of orthodontic camouflage due to patient's requests for aesthetics and achieving an ideal occlusion with superordinate treatment outcomes and stability. [1] Orthognathic surgery (OGS) is a method of maxillomandibular deformity correction related to dental occlusion by osteotomy or replacing of the mandible and maxilla, in order to achieve optimal dental occlusion and facial aesthetic. These surgical procedures have an impact on the condylar region, which includes the temporomandibular joints (TMJ) and mandibular condyles. Evaluating craniofacial structures is a crucial part of orthognathic diagnosis. OGS is commonly used to treat individuals with Class II (Cl II) or Class III (Cl III) malocclusion and skeletal abnormalities.[2]

3D images have progressively utilized in clinical settings for the demonstration of hard and soft tissues.[3] Measuring 3D models of pre-operative and post-operative in Cone beam computed tomography (CBCT) has been used for 30 years to evaluate post-operative stability and morphological changes of TMJ.[1] Particularly, CBCT monitors both soft and hard tissues; for this reason, it is becoming more frequently used in the evaluation of operative consequences and the facial aesthetic changes generated by OGS.[4,5] By controlling the condyle position, the surgical procedure can be planned more accurately with Computer-aided design and computer-aided manufacturing (CAD/CAM) technologies.[6] In additional, various 3D imaging programs facilitate clinical experts in predicting post-surgical skeletal, dental and condylar outcomes. 3D based volumetric methods have been latterly used to measure post-operative outcomes to cope with the limitations of linear evaluation.[3]

Changed jaw position can cause or aggravate TMJ disorders and mandibular stability can affected have been found by many scientist.[7-9] The condylar repositioning during fixation is one of the challenges of OGS.[1] The post-surgical changes in the condyle morphologically and also stability of operation are thought to result from the post-operative condylar position.[1] Despite the fact that the reason for post-operative resorption of condyle remains unknown, most effective way for reducing post-operative TMJ symptoms is retaining the condylar head position physiologically and minimizing intra-operative movement of condyle.[10,11] One of the effective factors to relapse is the used fixation method for bone fragments, and the positioning of the proximal segment, including the mandibular condyle, is the most substantial factor affecting skeletal stability and relapse after OGS.[12] However, dissimilar recording algorithms and segmentation methods have been adopted by previous studies; therefore, a consensus on this matter is hard to achieve regarding post-operative changes in position of TMJ and morphology of condyle.[8,13-16] Furthermore, the nature of the tendency to resorption of condyle after OGS can be varied between skeletal Cl II and Cl III patients markedly, and these differences have been mentioned by very few studies.[10,11,13]

The aim of this retrospective study is assessment of the changes in the mandibular condyle region as a result of mandibular movement differences in patients with different malocclusions after OGS.

MATERIALS AND METHODS

This retrospective study was conducted and received approval from the Research Ethics Committee of Nevşehir Hacı Bektaş Veli Üniversitesi University with decision number 2023.07.05. Written informed consent documents were obtained from the all patients.

G Power 3.1.9.2 (Heinrich-Heine-Universidad Düsseldorf, Düsseldorf, Germany) with an alpha significance level of 95% to detect a minimum between-group difference of 0.94 mm with a standard deviation of 1.40 was used to figure out the effective sample size was determined through a power analysis conducted for linear regression and sample size. The analysis showed that minimum 50 samples would be necessary for an α of 0.05 and a power of 0.95. However, in order to ensure that the results of the study are more reliable, it is planned to include data from at 50 patients in total.

Patient selection criteria

This study was based on CBCT records of 50 adult patients (34 females, 16 males) with skeletal Cl II (6 males and 19 females; mean age during the surgery: 26.28 ± 5.89 years) and Cl III (10 males and 15 females; mean age during the surgery: 23.32 ± 3.89 years) malocclusions selected from the archives of İstanbul Medipol Univercity, Faculty of Dentistry and who had undergone OGS from 2018 to 2023. The patient age ranged from 17-44 years, with a mean age of 24.8 ± 5.16 years at the time of operation.

The inclusion criteria were as follows:

- Group 1: Adult Skeletal Cl III patients (SNB > 80°, Wits < -1 mm),
- Group 2: Adult Skeletal Cl II patients (SNA>84°, Wits > 2 mm),
- Normal vertical growth pattern (total angle: 396 ± 3°(gonial, saddle, and articular angle)),
- For group 1, bilateral sagittal split ramus osteotomy mandibular setback and/or Le Fort I maxillary advancement surgery,
- For group 2, bilateral sagittal split ramus osteotomy mandibular advancement and/or Le Fort I maxillary impaction setback surgery,
- The availability of pre (T0: just before surgery) and post (T1: approximately 6 months after surgery) operative CBCT images.

The exclusion criteria were; pregnancy, severe mandibular asymmetry, congenital anomalies or genetic syndrome, severe maxillofacial trauma history and TMJ dysfunction.

The surgical plans encompassed both single jaw and bimaxillary surgeries. Within both the Cl III and Cl II groups, 23 patients underwent bimaxillary surgery, while 2 patients in each group underwent mandibular sagittal split osteotomy exclusively (Table 1).

Table 1 Age, sex, type of malocclusion, and surgical method for all included patients.

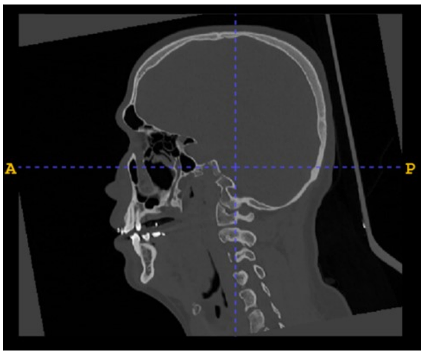
	Cl II (C2) group, n=25	Cl III (C3) group, n=25
Average age	26.28 ± 5.89 y	23.32 ± 3.89 y
Male	6	10
Female	19	15
One-jaw approach	2	2
Two-jaw approach	23	23
Surgery with genioplasty	14	9

Image Acquisition and Measurements

All CBCT images were assessed at two time points: before surgery (T0) and 6 months after surgery (T1). The CBCT images were acquired using the MSCT, Philips Brilliance ICT 256 (Philips Medical Systems, Eindhoven, the Netherlands), with scan settings of 120 kV and 150 mAs. Subsequently, the images were transferred to ITK-SNAP software (version 4.0.1; open-source software available at http://www.itksnap.org/pmwiki/pmwiki.php) for analysis.

To ensure consistency in image orientation, the Frankfort horizontal plane was positioned parallel to the floor on sagittal images, while the midline was arranged to pass between the anterior nasal spine and posterior nasal spine on axial images (Figure 1). Initially, a head mask with a threshold value for bone structures (minimum 226, maximum 3071 Hounsfield units) was generated. Subsequently, the mandibular condylar region was delineated from the cranial base in three sections (axial, sagittal, and coronal) using a manual editing tool.

Fig 1: Head position orientation during measurements of CBCT images



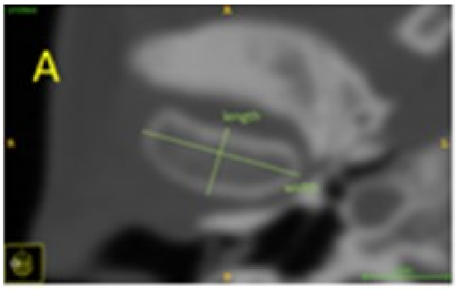
The 3D reconstruction of the condyle was assessed as the area between the line (C plane) passing parallel to the Frankfort horizontal plane from the sigmoid line and the perpendicular passing through the lowest endpoint of the tuberculum articulare. To minimize the influence of potential position changes post-operative, linear measurements were conducted by measuring direct distances.

Measurements, including height, length, width (Figure 2), ramal angular changes (Figure 3), and volume of the condylar head (Figure 4), were obtained in axial, sagittal, and coronal sections. Individual evaluations were performed separately for the right and left condyle in the images captured at T0 and T1 for each patient. Subsequently, the average of these measurements was calculated. The discrepancies between the obtained values at T0 and T1 were then compared for analysis. Additionally, the maxillary advancement, mandibular setback/advancement amounts were evaluated as the horizontal displacement of point A and B relative to the true vertical line passing through the Sella point.

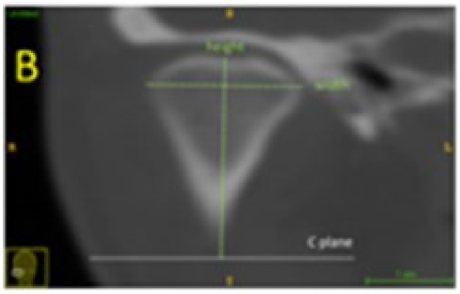
Statistical Analysis

The average rates of movement for soft and hard tissues were measured across the 10 facial regions of each patient. For reliability testing, all measurements were repeated twice with an interval of 15 days for 10 randomly selected patients. An investigation was conducted to explore the relationship between changes in soft tissue and movements in the underlying hard tissue using Scatter plots. For each corresponding pair, the Pearson correlation parameter was calculated.

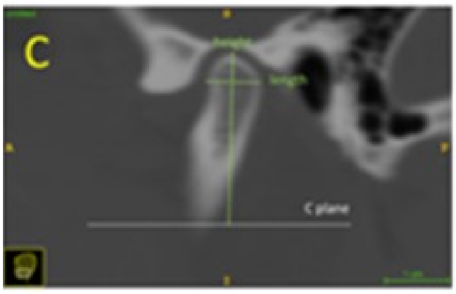
Fig 2: Measurement of condylar linear changes



A, width and length on the axial section; The width between the medial pole and the lateral pole at the axial section at the level of its greatest geometric dimension, the length between the anterior pole and the posterior pole at the axial section at the level of its greatest geometric dimension.



B, width and height on the coronal section; The width between the medial pole and the lateral pole at the coronal section at the level of its greatest geometric dimension, the distance between the highest point of the condylar head to the C plane at the coronal section at the level of its greatest geometric dimension.

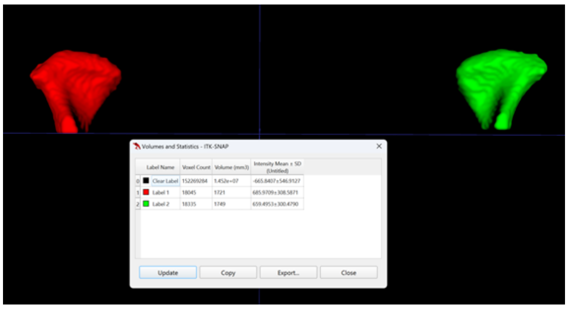


C, length and height on the sagittal section; The length between the most forward and backward points of the condylar head at the sagittal section at the level of its greatest geometric dimension, the distance from the highest point of the condylar head to the C plane at the sagittal section at the level of its greatest geometric dimension.

Fig 3: Measurements of angular changes from CBCT.

A, axial ramal angle; Angular changes from the ascending ramus to the midsagittal plane at the axial section at the level of its greatest M-D dimension
B, sagittal condylar angle; Angular changes from the condylar axis (the line connecting the center of the condylar head and the center of the condylar neck) to the Frankfort horizontal plane at the sagittal section at the level of its greatest length
C, coronal ramal angle; Angular changes from the ascending ramus to the Frankfort horizontal plane at the coronal section at the level of its greatest vertical ramus height.

Fig 4: Volumetric evaluation of the condylar head



The data were analyzed using IBM SPSS V23. The Shapiro-Wilk Test was used to evaluate the normality of distribution. Independent Sample t-test was used to compare normally distributed parameters between groups, whereas the Mann-Whitney U Test was utilized for those not conforming to normal distribution. The relationship between parameters that showed normal distribution was examined using Pearson's Correlation Coefficient, while Spearman's rho Correlation Coefficient was used for parameters that did not distribute normally. The significance level was determined as $p<0.05$.

RESULTS

Angular and volumetric changes in Cl II and Cl III groups are shown in Table 2. While the axial ramal angle decreased in both groups, the coronal ramal and sagittal condylar angles increased. The amount of axial ramal angle decrease and coronal ramal increase were found to be statistically significant in the Cl III group (p: 0.020, p: 0.020 sequentially). The changes in both groups for axial width and coronal width increased, while decreases were observed in other morphological measurements. Coronal width increase amount was significant in the Cl II group (p: 0.034). In both groups, condylar volume decreased after OGS, however, the difference between the groups was not found significantly.

Table 2 Comparison of angular and volumetric changes between Cl II and Cl II group from T0 to T1

	Cl II Mean (SD)	Cl III Mean (SD)	p
Axial Ramal Angle	4.24 (4.68)	1.52 (3.1)	**0.020***
Coronal Ramal Angle	-0.26 (3.53)	-0.35 (2.98)	**0.020***
Sagittal Condylar Angle	-0.3 (4.83)	-0.29 (4.48)	0.996
Axial Width	-0.18 (0.81)	-0.26 (0.46)	0.654
Axial Length	0.21 (0.63)	0.14 (0.43)	0.628
Coronal Width	-0.53 (1.16)	-0.1 (0.87)	**0.034****
Coronal Height	0.16 (1.52)	0.57 (1.15)	0.116
Sagittal Length	0.68 (1.23)	0.14 (0.41)	0.103
Sagittal Height	0 (1.8)	0.71 (1.44)	0.107
Condylar Volume	90.65 (176.02)	97.92 (176.24)	0.594

SD standard deviation, Statistically significant at $p < 0.05$, *Independent t test, **Mann Whitney U test

Table 3 shows that there was a statistically insignificant correlation between condylar volume and angular changes in Cl II and Cl III groups. There is a moderate positive significant correlation between the change in sagittal condylar angle and the displacement of point A in both Cl II and Cl III groups. There is a strong positive significant correlation between the change in sagittal condylar angle and the displacement of point B in the Cl III group. Additionally, there is a moderate positive significant correlation between sagittal height and the displacement of points A and B in the Cl II group (Table 4).

Table 3 Comparison of angular changes between Cl III and Cl II group from T0 to T1 in Condylar volume

	Condylar Volume			
	Class II		Class III	
	r*	p	r**	p
Axial Ramal Angle	-0.149*	0.476	0.110**	0.601
Coronal Ramal Angle	0.040*	0.851	-0.180**	0.388
Sagittal Condylar Angle	0.092*	0.661	-0.136**	0.517

Statistically significant at $p < 0.05$, *Spearman's rho correlation coefficient; **Pearson correlation coefficient

DISCUSSION

The common effects of OGS on the mandibular condyles are remodeling and displacement. Due to a physiological adaptation period of the TMJ, it can cause significant major results related to occlusion.[8] The resorption process, which causes volumetric change in the condyle, begins with the exceeding of TMJ adaptation capacity.[8,17] OGS may be one of the triggering factors for condylar resorption[8], particularly in Cl II patients, if rigid fixation is applied.[18]

The application of different recording protocols in CBCT studies may affect the observed morphological changes.[1] Registration, segmentation, and analysis were identified as essential steps in the analysis of condyle by a recent literature review.[15] In order to designate volume of condyle in CBCT evaluations, different methods have been suggested antecedently.[8] Bayram et al. used a planimetry method in CBCT examinations to test the accuracy of volume analysis of the mandibular condyle.[19] Dolphin 3D Imaging software (Dolphin Imaging and Management Solutions) was used by Goulart et al.[20] and V-Works 4.0 imaging software (Cybermed Inc., Seoul, Korea) was used by Schlueter et al.[21] using various Hounsfield unit window widths. All these methods have been shown to be dependable for assessing condylar volume[8], and could have been used in this study with some minor revisions. ITK-SNAP software was used to evaluate tomography images. The images were oriented so that the Frankfort horizontal plane was parallel to the ground in sagittal sections. DICOM datasets were investigated in sagittal, coronal, axial slices, and 3D reconstruction. Right and left condyle CBCT images of each patient taken at T0 and T1 measurements were made separately and then the average of these measurements was used for evaluation. The right and left condyle TMJs are structures connected by a single bone that work simultaneously. Nevertheless, there may be differences in a particular bone resorption or remodeling period for each condyle because of the variational amounts of stress. In this bilateral difference, chewing habits may be a key point, because the used side of the condyle is subjected to lower loads than the opposite side condyle.[8,22] Consistent with previous studies, it was determined that 19 of the patients had resorption in one of the condyles and apposition in the other according to volumetric evaluation. No correlation has been found between the right and left sides in terms of volume changes previously. [8,23] Associated with these results, right and left condyle were measured separately but were not evaluated in relation to each other's.

Da Silva et al.[8] employed a combination of Dolphin 3D Imaging and ITK-SNAP to integrate functionalities from two software applications. The segmentation tool in Dolphin 3D heavily relies on the thresholding of bone voxel values and the suppression of surrounding tissues.[20] The ITK-SNAP software segmentation tool was better than Dolphin 3D to enhance the precision of volume measurements.[8] ITK SNAP software made it possible to segment condyles using the "zone competition" approach, which achieves a more precise measurement by demarcating the volume within the condyle and minimizing the effect of the threshold and surrounding tissues.[8] Due to the evaluation and standardization advantages, in this study measurements were completed with The ITK-SNAP software instead of Dolphin 3D.

Previous examinations have shown the reduction of the mandibular condyles in mean volume was statistically significant.[8] Similar volumetric reductions were found in our study, however, this finding was statistically insignificant (p=0.59). Even though it has been found that the resorption period is more remarkable in Cl II group performed bimaxillary surgery previously,[8,24] the amount of resorption is higher in Cl III patients (97.92±176.24mm^3) in the present study. While 25 of the patients had a volume decrease in both condyles, 6 patients had a volume increase in both condyles. Even though the basic expectation in adult subjects is to result in endochondral growth, these findings may indicate that the condyle can form new bone after repositioning through an adaptive biomechanical process.[25] Further investigations with extended follow-up periods following OGS are necessary to substantiate this hypothesis.

The axial and coronal width for both Cl II and Cl III groups increased in our study and was supported by Me´ndez-Manjo´n et al.[26] who showed the supreme changes in the lateral and posterior side of the condyle in the right after OSG. While the coronal width increase was statistically significant, the axial width increase was not statistically significant in this study. Kim et al. [27] also found similar findings that the condyles are directed more posteriorly in the post-surgical period, but in the following periods return to position originally. However, Li-Fang Hsu et al.[1] found axial condylar length and width both reduction were statistically significant, which was similar to our study in axial length evaluation. But also this result was statistically insignificant for each group. Post-operative localized resorption or bone remodeling at the condyle was indicated by previous researchers. In the condylar height Li-Fang Hsu et al.[1] observed similar non-significant reduction. It has been shown that in most cases there may be little or no change, or even an increase in volume.[8] In accordance with previous studies[28], no significant correlation was found between the distance of jaw movement and condylar changes.

Despite the comprehensive analysis conducted in this study, several limitations should be acknowledged. The relatively small sample size in this retrospective study might limit the generalizability of the findings. Further studies with larger cohorts could provide more robust conclusions. The follow-up period of approximately 6 months after surgery might not capture long-term changes in condylar morphology and volume. Longer follow-up durations are essential to assess the stability of surgical outcomes over time. The fact that this study was performed in a single institution may limit the diversity of patient characteristics and surgical techniques. Polycentric studies involving diverse patient populations could enhance the external validity of the results. Although cone beam computed tomography (CBCT) imaging was utilized for analysis, variations in imaging protocols and segmentation techniques could introduce variability in the measurements. Standardization of imaging protocols and analysis methods could mitigate these limitations. The lack of a control group, such as patients undergoing orthodontic treatment without OGS, limits the ability to directly compare the effects of surgery versus non-surgical interventions on condylar morphology.

While various statistical analyses were employed, other advanced techniques, such as finite element analysis or machine learning algorithms, could provide deeper insights into the complex relationships between surgical interventions and condylar changes. This study relied on retrospective analysis of patient data, and ethical considerations regarding patient privacy and consent were addressed. However, retrospective studies inherently carry limitations in data availability and quality compared to prospective studies. Further research that takes these limitations into account will contribute to a more detailed determination of the impact of OGS on condyle morphology and patient outcomes.

CONCLUSION

In conclusion, although in this study an insignificant reduction in mean condyle volume was found after OGS in both Cl II and Cl III groups, the changes in the dimensional measurement of condyle may be different from each other. Further research seems necessary to compare patients with surgery first and after orthodontic treatment surgery to evaluate whether condylar resorption is due to orthodontics or surgery.

Ethical Approval

This study has been approved by the Non-Pharmaceutical and Medical Device Ethics Committee of Nevşehir Hacı Bektaş Veli University with decision number 2023.07.05.

Financial Support

The authors declare that this study received no financial support.

Conflict of Interest

The authors deny any conflicts of interest related to this study.

Author Contributions

Design: KKD, Data collection and processing: HY Analysis and interpretation: ÖB, Literature review: SB, Writing: SB.

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