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Bimaxillary surgery and temporomandibular joint hard tissue remodeling: a CBCT study on skeletal Class II and Class III patients

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ABSTRACT

This study aimed to evaluate changes in horizontal condylar angulation (HCA), joint space distances (JS), condylar volume (CV), and degenerative alterations of the temporomandibular joint (TMJ) using preoperative and postoperative cone-beam computed tomography (CBCT) images of Class II and Class III malocclusion patients undergoing orthognathic surgery.

This retrospective study included 148 CBCT images obtained from 74 patients who underwent bimaxillary surgery involving Le Fort I osteotomy and bilateral sagittal split ramus osteotomy. Patients were classified into Class II and Class III groups according to ANB angles. The patients' JS, HCA, and CV were measured, and degenerative changes observed in the condyle were recorded. Statistical analyses were performed using TURCOSA statistical cloud software.

CV in Class II patients was significantly lower and HCA of Class II patients was higher in both periods (CV: $p < 0.001/p < 0.001$; HCA: $p < 0.001/p < 0.05$). HCA of Class III patients increased in the postoperative period ($p < 0.001$). In preoperative period, superior and posterior JS distances were significantly higher in Class II patients ($p < 0.05/p < 0.05$). All patients had a negative and significant correlation between HCA and CV ($p < 0.05$). In the postoperative period, sclerosis, osteophyte formation, and condylar resorption were observed significantly more frequently in Class II patients ($p < 0.05/p < 0.001/p = 0.021$).

Different adaptive responses occur in the TMJ of Class II and Class III patients following orthognathic surgery. In Class II patients, postoperative reductions in SJS, PJS, and CV values, together with a higher incidence of degenerative changes, such as sclerosis, osteophyte formation, and condylar resorption, indicate an increased risk for TMJ health in this group. In contrast, the postoperative increase in HCA observed in Class III patients may be considered an adaptive alteration. Therefore, careful monitoring of TMJ health and the implementation of long-term follow-up strategies are clinically essential, particularly in Class II patients.

1. Introduction

Orthognathic surgery (OS) is an interventional procedure to restore the appropriate anatomical and functional relationship in patients with skeletal and dentomaxillofacial deformities (Kaur et al., 2021). OS can alleviate the aesthetic and psychological problems caused by skeletal dentomaxillofacial deformities, as well as functional problems with speech and chewing, and possible temporomandibular joint (TMJ) disorders (Posnick, 2001). The occurrence of TMJ disorders in the postoperative period has been associated with the presence of TMJ dysfunction before surgery or surgical interventions, such as mandibular advancement, that affect the condyle position. The literature has also reported that resorption of the condylar head after OS may cause TMJ disorders (Wolford et al., 2003).

Various structural changes in the condyle after OS have been previously reported in the literature (Borstlap et al., 2004). It has been shown that the condylar position changes in mandibular osteotomy surgeries, which leads to changes in the load balance in the TMJ, leading

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to an adaptation process in the joint. In addition, the changes that occur in bone remodeling and condylar shape after surgery have been associated with this adaptation mechanism in the TMJ (Vandeput et al., 2019).

Cone-beam computed tomography (CBCT) is a tomographic imaging technique based on the cone-beam algorithm. With this imaging method, two-dimensional and three-dimensional reconstructions of the TMJ, maxillofacial region, and skull base can be successfully visualized (Whyte et al., 2021). CBCT is now frequently preferred for the examination of the entire face and skull base hard tissues after trauma, for the examination of maxillofacial structures before orthodontic treatment, for the determination of the surgical procedure before OS, and for the postoperative observation and follow-up of healing in the hard tissues (Miracle and Mukherji, 2009).

Our study aimed to evaluate the changes in the horizontal condylar angulation and joint space distances of the mandibular condyle by examining the preoperative (T1) and postoperative (T2) CBCT images of patients with Class II and Class III malocclusion who underwent OS, as well as to evaluate the changes in condylar volume and degenerative changes observed in the hard tissues of the TMJ.

2. Materials and methods

2.1. Individual selection and determination of the study group

For this study, ethical approval was obtained from the Erciyes University Clinical Research Ethics Committee (no. 2023/680/), and the study was conducted according to the principles defined in the Declaration of Helsinki. This retrospective study included 148 CBCT images — preoperative (T1) and at least 6 months postoperative (T2) — of 74 patients examined in the Department of Oral and Maxillofacial Radiology between February 2015 and November 2023, who underwent OS at the Erciyes University Faculty of Dentistry.

The inclusion criteria were as follows:

1.) Patients with skeletal Class II (ANB $\geq$4) and skeletal Class III (ANB $\leq$0) jaw relationship according to cephalometric measurements.
2) Patients with CBCT images of sufficient diagnostic quality before and at least 6 months after OS.

The exclusion criteria were as follows:

1) Patients for whom blurring and loss of resolution in images, due to patient movement during CBCT acquisition, are thought to have negatively affected diagnostic quality.
2) Patients with craniofacial syndromes that may have caused changes in maxillofacial structures.
3) Patients with systemic diseases (osteoporosis, rheumatoid arthritis, etc.) that may have caused deterioration in bone quality and joint health.
4) Patients with a history of maxillofacial trauma, and who had undergone surgery for this reason.

Seventy-four patients who met the inclusion criteria were included in this study. 49 of the patients in the study group were female and 25 were male. Of these patients, 53 had Class III malocclusion and 21 had Class II malocclusion, and all underwent bimaxillary surgery with Le Fort I and bilateral sagittal split ramus osteotomy (BSSO).

2.2. CBCT image acquisition protocol

All CBCT images were obtained with a NewTom 5G device (Quantitative Radiology, Verona, Italy) using an 18 $\times$ 16 cm^2 FOV, 110 kV, 3–5 mA, and a voxel size of 0.16 mm. The exposure time was 3.6 s and the slice thickness was 0.25 mm. All images were examined in a dimly lit environment, using NNT software (version 3.0; NewTom, Verona, Italy), and on a 32-inch Dell LCD screen (E2420H; Dell, Round Rock, TX, USA) with a resolution of 1280 $\times$ 1024 pixels.

2.3. Linear measurements and anatomical assessments performed on CBCT images

Skeletal malocclusion classification:

Patients included in the study were classified skeletally by measuring ANB angles according to the method described by Riedel (1952). The ANB angle was measured in the sagittal plane.

Classification of degenerative changes observed in the condyle:

Degenerative changes (DC) in the condyle were classified as flattening, sclerosis, erosion, osteophytes, articular loose bodies, subcortical cyst, and condylar resorption (Dygas et al., 2022) (Fig. 1).

Each condyle was evaluated in terms of the DC defined above and recorded as 'Presence/Absence'.

Measurement of the horizontal condylar angle (HCA):

The maximum mediolateral length of the mandibular condyle in the axial plane was defined as the long axis of the condyle. HCA was defined as the angle between the condyle long axis and the coronal plane in the axial plane (Fig. 2).

Measurement of joint space (JS) distances:

The widest section of the JS and the most precise observation of the condyle were determined in the axial and coronal planes, and measurements were made in the sagittal plane (Mohamed et al., 2023). The points to be used for measurement were determined as follows (Wang et al., 2022) (Fig. 2):

Point A — the condyle's highest point.

Point A′ — the glenoid fossa's highest point.

Point B — denoted by where the tangent A′–B line meets the condyle's anterior surface.

Point B′ — located on the glenoid fossa's anterior inclination.

Point C — denoted by the tangent to the condyle's posterior surface.

Point C′ — located on the glenoid fossa's posterior inclination.

Lines B–B′ and C–C′ are perpendicular to the A′–B and A′–C lines. The distance between points B and B′ is the anterior joint space (AJS) distance; the distance between points A and A′ is the superior joint space (SJS) distance; and the distance between points C and C′ is the posterior joint space (PJS) distance.

2.4. Three-dimensional reconstruction and measurement of condylar volume (CV)

Images were recorded in DICOM format using the computer software NNT (NewTom 5G, Imola, Italy), and these data were reconstructed using Simplant Pro 16 software (Materialise NV, Leuven, Belgium). To measure the CV using this software, the condylar neck was cut from the C-plane, and the bone value was thresholded to reveal the volume value of the condyle; for this stage the drawing/erasing mask and the segmentation wizard technique were used (Caughey et al., 2005) (Fig. 2). This process was repeated for the patients' T1–T2 CBCT images and for both condyles.

2.5. Statistical analysis

Data analysis was performed using TURCOSA statistical cloud software (Turcosa Statistical Solutions Ltd. Sti, www.turcosa.com.tr). Normality assumptions for the data were tested using the Shapiro Wilk test and histogram q-q plots. The Levene test was used for data homogeneity assumptions. A paired *t*-test was used to compare the means of dependent quantitative variables, while the Wilcoxon test was used to compare the medians of dependent quantitative variables. An independent two-sample *t*-test was used to compare the means of quantitative variables in two groups. The Mann-Whitney *U* test was used to compare the medians of quantitative variables in two groups. Chi-square

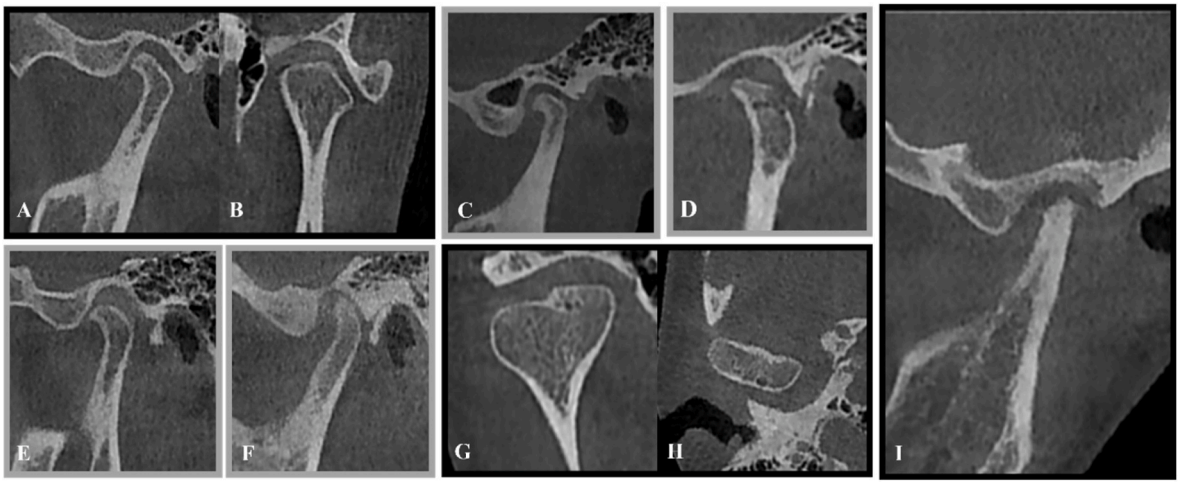


Fig. 1. Degenerative changes observed in the condyle: (A) flattening sagittal view, (B) flattening coronal view, (C) sclerosis, (D) erosion, (E) osteophyte, (F) articular loose bodies, (G) subcortical cyst coronal view, (H) subcortical cyst axial view, (I) condylar resorption.

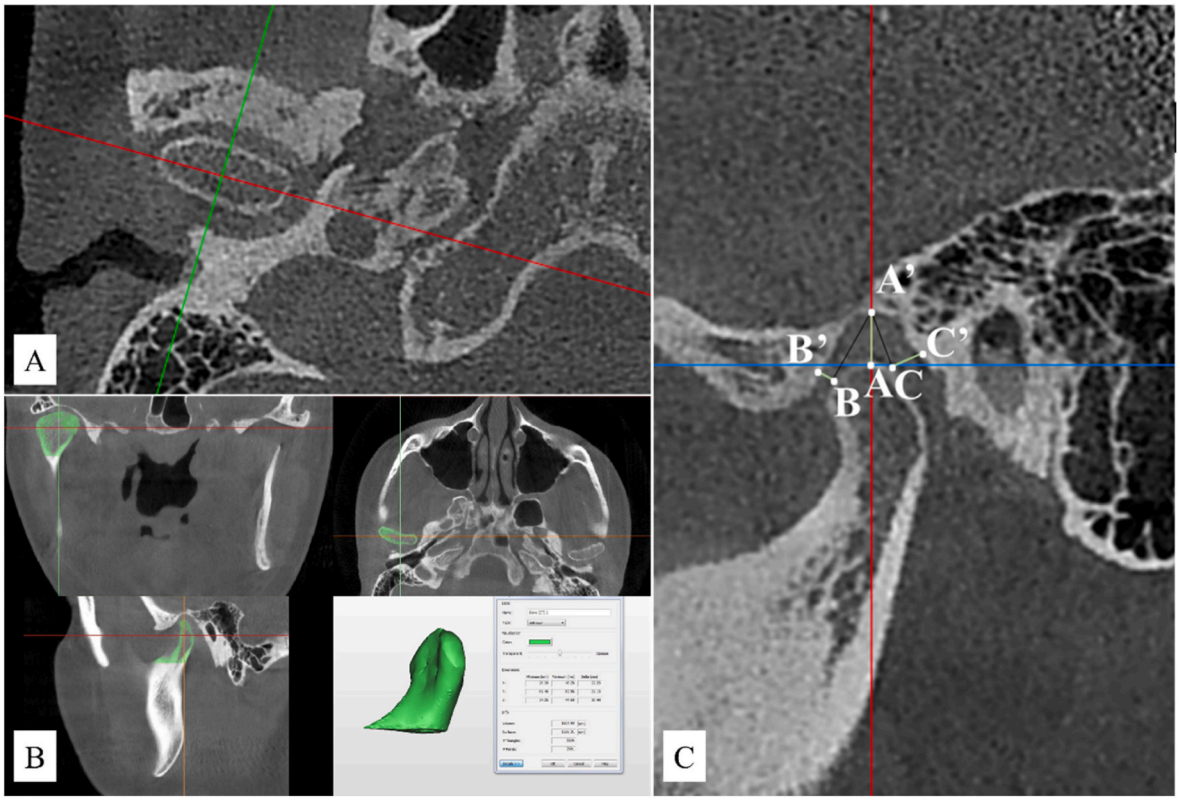


Fig. 2. (A) Measurements of horizontal condylar angle. (B) Volumetric measurement of the condyle. (C) Measurements of joint space distances: B′–B, anterior joint space distance; A′–A, superior joint space distance; C′–C, posterior joint space distance.

tests were used to compare the relationships between qualitative independent variables. McNemar's chi-square test was used to compare the relationships between qualitative dependent variables. Pearson and Spearman tests were used to evaluate the relationships between variables. The significance level was accepted as $p < 0.05$.

For this study, power analysis based on a paired *t*-test was performed, with a significance level of $\alpha = 0.05$, power value = 0.90, and effect size of 0.4, to give a suggested sample size of 68 people. In order to obtain more reliable results, 74 people were taken into consideration, due to the possibility of inaccuracy and data loss.

3. Results

The ages of the patients included in the study ranged from 18 to 50, with a mean age of 22.53 ± 6.21 years. The time difference between the T1 and T2 images ranged from 6 to 86 months, with a mean time difference of 25 ± 20.78 months.

In Class II patients, T2 right/left SJS, PJS, and left CV values were found to be significantly lower than T1 values ($p < 0.05$). In Class III patients, T2 mean values for the right and left HCA were found to be statistically significantly higher than the T1 mean values ($p < 0.001$) (Table 1).

Table 1
Comparison of T1 and T2 HCA, CV, AJS, SJS, and PJS values in Class II and Class III patients.

	Variables		T1 ($n = 21$) $\bar{x} \pm$ SD	T2 ($n = 21$) $\bar{x} \pm$ SD	*p*-value
Class II	Right	HCA	29.00 ± 10.04	27.94 ± 11.36	0.448
		CV	957.36 ± 289.38	915.01 ± 333.51	0.298
		AJS	1.88 ± 0.61	2.09 ± 0.78	0.269
		SJS	2.6 ± 0.84	1.82 ± 0.61	**0.001***
		PJS	2.80 ± 1.23	1.89 ± 1.04	**0.015***
	Left	HCA	28.65 ± 10.49	28.60 ± 9.81	0.969
		CV	962.23 ± 287.91	854.62 ± 312.38	**0.012***
		AJS	2.17 ± 0.68	2.09 ± 0.78	0.645
		SJS	3.02 ± 1.60	1.91 ± 0.96	**0.014***
		PJS	2.96 ± 1.45	1.89 ± 1.10	**0.008***
Class III	Right	HCA	18.24 ± 7.13	21.57 ± 7.28	**<0.001***
		CV	1364.71 ± 346.55	1351.28 ± 377.11	0.673
		AJS	2.07 ± 0.84	2.12 ± 0.89	0.515
		SJS	2.17 ± 0.79	2.27 ± 0.83	0.134
		PJS	1.98 ± 0.61	1.93 ± 0.52	0.588
	Left	HCA	17.78 ± 6.25	22.14 ± 5.96	**<0.001***
		CV	1306.74 ± 402.37	1319.82 ± 344.79	0.743
		AJS	2.22 ± 0.84	2.12 ± 0.89	0.315
		SJS	2.25 ± 0.78	2.29 ± 0.83	0.522
		PJS	1.89 ± 0.56	1.96 ± 0.62	0.419

T1: preoperative, T2: postoperative, HCA: horizontal condylar angle, CV: condylar volume, AJS: anterior joint space, SJS: superior joint space, PJS: posterior joint space.
$\bar{x}$= aritmetic mean, SD = standard deviation, *$p < 0.05$.

Class II median values for T1 ANB ($p < 0.001$), right SJS and PJS ($p = 0.041/p = 0.003$) and left PJS ($p < 0.001$), T1 right–left HCA ($p < 0.001/p < 0.001$) and T2 ANB ($p < 0.001$), and T2 right/left HCA ($p = 0.019/p < 0.001$) were found to be statistically significantly higher than Class III median values. Class III median values for T1 right and left CV ($p < 0.001/p < 0.001$), T2 right SJS ($p = 0.030$), and T2 right and left CV ($p < 0.001/p < 0.001$) were found to be statistically significantly higher than Class II median values (Table 2).

A negative and statistically significant correlation was found between T1 and T2 for both sides of HCA and CV for all patients ($r = -0.4677/p < 0.001$, $r = -0.3623/p = 0.002$, $r = -0.3995/p < 0.001$, $r = -0.2855/p = 0.014$) (Table 3).

In the T1 period, sclerosis and osteophyte formation were observed more frequently in Class II than in Class III patients at a statistically significant level ($p < 0.05$). In the T2 period, sclerosis, osteophyte formation, and left-side condylar resorption were observed more frequently in the right and left condyle in Class II than in Class III patients at a statistically significant level ($p < 0.05$) (Table 4).

4. Discussion

In the literature, many factors have been reported that cause changes in the hard tissues of the TMJ and may subsequently cause TMJ disorders. Therefore, the cause of TMJ diseases is considered multifactorial (Huang et al., 2002). These factors include trauma history, occlusal factors, osteoarthritis, third molar surgery, OS, and female gender (Brand et al., 1995; Bósio et al., 1998; Alrizqi and Aleissa, 2023). There are different results in the literature regarding the effects of OS on TMJ.

Table 3
Evaluation of the relationship between HCA and JS values and CV value.

		Variables	*N*	Correlation	Test statistic (*t*)	*p*-value
T1	Right	CV-AJS	74	−0.0878	−0.7475	0.457
		CV-SJS	74	0.0891	0.7587	0.451
		CV-PJS	74	−0.1772	−1.528	0.131
		HCA-CV	74	−0.4677	−4.4903	**<0.001***
	Left	CV-AJS	74	−0.0982	−0.8374	0.405
		CV-SJS	74	−0.105	−0.8963	0.373
		CV-PJS	74	−0.2671	−2.3523	0.021
		HCA-CV	74	−0.3623	−3.2983	**0.002***
T2	Right	CV-AJS	74	−0.1116	−0.9526	0.344
		CV-SJS	74	0.2004	1.7359	0.087
		CV-PJS	74	−0.1215	−1.039	0.302
		HCA-CV	74	−0.3995	−3.6975	**<0.001***
	Left	CV-AJS	74	−0.0919	−0.7831	0.436
		CV-SJS	74	0.084	0.7153	0.477
		CV-PJS	74	−0.1106	−0.9443	0.348
		HCA-CV	74	−0.2855	−2.5278	**0.014***

HCA: horizontal condylar angle, JS: joint space, AJS: anterior joint space, SJS: superior joint space, PJS: posterior joint space, CV: condylar volume, *N*: sample size, T1: preoperative, T2: postoperative.

Table 2
Comparison of HCA, CV, AJS, SJS, and PJS values between Class II and Class III patients.

Time		Variables	Class II ($n = 21$)	Class III ($n = 53$)	*p*-value
T1		Age	20 (18–23)	21(19–24)	0.364
		ANB	7.93 ± 2.07	−3.69 ± 2.33	**<0.001***
	Right	HCA	29.0 ± 10.04	18.24 ± 7.13	**<0.001***
		CV	957.36 ± 289.38	1364.71 ± 346.55	**<0.001***
		AJS	1.9 (1.45–2.15)	1.8 (1.55–2.35)	0.630
		SJS	2.3 (2.15–3.0)	2.0 (1.5–2.5)	**0.041***
		PJS	2.5 (1.9–3.55)	1.8 (1.6–2.25)	**0.003***
	Left	HCA	28.65 ± 10.49	17.78 ± 6.25	**<0.001***
		CV	979.48 (715.06–1146.87)	1254.14 (1042.37–1431.77)	**<0.001***
		AJS	2.0 (1.5–2.6)	2.0 (1.6–2.6)	0.942
		SJS	2.8 (1.9–3.65)	2.0 (1.5–2.8)	0.072
		PJS	2.96 ± 1.45	1.89 ± 0.56	**<0.001***
T2		ANB	5.5 (3.85–6.9)	2.5 (0.9–3.45)	**<0.001***
	Right	HCA	28.8 (19.9–35.85)	22.0 (16.75–26.1)	**0.019***
		CV	915.01 ± 333.51	1351.28 ± 377.11	**<0.001***
		AJS	2 (1.65–2.5)	2 (1.5–2.65)	0.899
		SJS	1.8 (1.4–2.0)	2.3 (1.65–2.8)	**0.030***
		PJS	1.6 (1.3–2.2)	1.8 (1.6–2.2)	0.198
	Left	HCA	28.60 ± 9.81	22.14 ± 5.96	**<0.001***
		CV	847.36 (632.14–1018.05)	1304.74 (1063.97–1530.47)	**<0.001***
		AJS	2.4 (1.6–2.9)	2.2 (1.7–2.75)	0.618
		SJS	2 (1–2.5)	2.3 (1.8–2.8)	0.152
		PJS	1.6 (1.1–2.2)	1.8 (1.55–2.45)	0.137

ANB: A-nasion-b angle, HCA: horizontal condylar angle, CV: condylar volume, AJS: anterior joint space, SJS: superior joint space, PJS: posterior joint space, T1: preoperative, T2: postoperative.
*$p < 0.05$.

Table 4
Comparison of degenerative changes in TMJ between Class II and Class III patients in T1 and T2 periods.

	Degenerative changes	Right			Left		
		Class II	**Class III**	***p*-value**	**Class II**	**Class III**	***p*-value**
T1	Flattening	12	25	0.607	17	33	0.999
	Sclerosis	10	5	**<0.001***	9	1	**0.002***
	Erosion	0	1	0.999	0	1	0.999
	Osteophytes	10	4	**<0.001***	11	2	**<0.001***
	Articular loose bodies	0	1	0.999	0	1	0.490
	Subcortical cyst	0	1	0.999	2	0	0.078
	Condylar resorption	1	1	0.490	2	0	0.284
T2	Flattening	17	32	0.109	12	37	0.414
	Sclerosis	9	4	**<0.001***	6	2	**0.005***
	Erosion	0	0	–	0	1	0.999
	Osteophytes	11	7	**<0.001***	8	3	**0.001***
	Articular loose bodies	0	0	–	2	2	0.318
	Subcortical cyst	2	2	0.318	1	0	0.284
	Condylar resorption	2	1	0.192	3	0	**0.021***

TMJ: temporomandibular Joint, T1: preoperative, T2: postoperative.
*$p < 0.05$.

While some authors report that TMJ diseases may regress after OS, some authors have reported that OS may be a predisposing factor for TMJ diseases (Bays and Bouloux, 2003; Dujoncquoy et al., 2010).

In their study, Saccucci et al. reported that the highest CV was observed in Class III patients, and the lowest CV in Class II patients (Saccucci et al., 2012). Park et al., in a study that included 16 patients with Class II and Class III malocclusions who underwent surgery with BSSO, reported lower CV in Class II patients in the T1 period (Park et al., 2023). As far as is known, there is no study in the literature reporting the opposite of these findings. The results of our study were also consistent with the literature. Some studies have report different results regarding the changes observed in CV in the T2 period for both malocclusions. Park et al. reported that a significant CV decrease was observed in Class II and Class III patients in the T2 period (Park et al., 2023). On the other hand, Hsu et al. observed a decrease in condyle dimensions only in patients with Class II malocclusion in the T2 period in their study, which included CBCT images of 34 Class III and 17 Class II malocclusion patients (Hsu et al., 2022). In addition, Da Silva et al., in a retrospective study that included CBCT images of 57 Class II malocclusion patients who underwent BSSO and Le Fort I surgery, reported that Class II patients had a decrease in CV after OS (Da Silva et al., 2018). In our study, Class II and Class III patients showed a decrease in T2 CV, but this decrease in volume was statistically significant only on the left side in Class II patients. All these studies report differing results regarding the effect of OS on CV in both malocclusions. These differences may be related to variations in sample size in the studies and the effects of differences in TMJ surgical technique, fixation method, and orthodontic treatment procedures used.

In our study, HCA was significantly higher in Class II patients than in Class III patients in the T1 and T2 periods. Rodrigues et al. reported that condylar angulation differed between the two groups in a study in which they examined the CT images of Class II Division 1 and Class III patients (Rodrigues et al., 2009). Alhammadi et al. reported that there was a difference in the mediolateral angles of the condyle in patients with Class II and Class III malocclusion, but was not statistically significant (Alhammadi et al., 2016). These differences in the literature can be attributed to variations in the times at which CBCT was obtained after OS, and therefore to the fact that the remodeling process in the TMJ was not present in the same period. Also, our study showed no significant change in the HCA of Class II patients in the T2 period, while the HCA of Class III patients increased. Ueki et al. reported a significant increase in HCA values after OS in their study, which included patients who underwent surgery with intraoral vertical ramus osteotomy (Ueki et al., 2008). These data in the literature were consistent with the results of our study.

There are some studies in the literature regarding the effect of OS on JS distances. Krisjane et al., in a study examining TMJ via CT images, found the AJS, SJS, and PJS distance values to be significantly higher in Class II than in Class III patients (Krisjane et al., 2009). Alhammadi et al. found all three JS distances to be higher in Class II compared with Class III patients (Alhammadi et al., 2016). Lobo et al. found SJS and PJS distances to be higher in Class II patients, while AJS distance was higher in Class III patients (Lobo et al., 2019). In our study, SJS and PJS distances were statistically significantly higher in Class II compared with Class III patients in the T1 period, while no difference in AJS distance was observed between classes. All these studies showed that SJS and PJS distances were higher in Class II compared with Class III patients. However, the authors could not reach a consensus on the differences in AJS distances in different skeletal malocclusions.

This study found no correlation between CV and JS distances in Class II and Class III patients in the T1 and T2 periods. Similarly, Da Silva et al., in their study that included 57 Class II malocclusion patients who underwent BSSO and Le Fort I surgery, reported no correlation between CV and JS distances in the T2 period (Da Silva et al., 2018). Holte and Pinholt, 2023 reported that the changes observed in the condyle were associated with increased PJS distance (Holte and Pinholt, 2023). There is a limited number of studies in the literature evaluating the relationship between JS distance and CV, and therefore more studies in this area are needed.

In our study, a negative and statistically significant correlation was observed between HCA and CV in the T1 and T2 periods. Ikeda et al. reported a negative correlation between transverse condylar angulation and CV in their study, which included patients with mandibular asymmetry (Ikeda et al., 2017). These data are consistent with our study results.

Politis et al., in their study examining the T2 images of 730 patients who underwent OS with BSSO, reported that six patients with bilateral condylar resorption were young women with severe retrognathia, high angles, and small condyles (Politis et al., 2019). Aneja et al., in a study that included postoperative panoramic images of 25 patients, reported that mandibular advancement of more than 6 mm in female patients under the age of 18, who underwent mandibular advancement and recession surgery with BSSO, posed a high risk for progressive condylar resorption (PCR) (Aneja et al., 2017). These results suggest that young women should be included in the high-risk group in terms of PCR when planning OS. In addition, postoperative clinical follow-up of these patients is crucial for the early diagnosis of possible TMJ diseases.

Our study reported the most frequently observed DC in the T1 and T2 periods to be flattening and osteophyte formation, and the least frequently observed DC to be erosion. Sclerosis and osteophyte formation were statistically significantly more frequently observed in Class II than in Class III patients in the T1 and T2 periods. Walewski et al.

reported that the most common DC was flattening, followed by osteophytes, erosions, sclerosis, and subchondral cysts. However, they did not report a difference in DCs among types of malocclusion (Walewski et al., 2019). Yamada et al. reported that the most common DC was osteophyte formation in 258 condyles, with 6.6% flattening, 6.2% erosion, and 12% osteophytes (Yamada et al., 2001). Waleski et al. also reported that osteophyte formation was the most common change among DCs that caused pain symptoms (Walewski et al., 2019). Kim et al. observed that the rate of osteoarthritic changes was 32% in women and 15.5% in men (Kim et al., 2011). These results support the suggestion that female gender may be a predisposing factor for osteoarthritic changes.

This study has certain limitations. The 6th-month, 1st-year, and 2nd-year follow-up CBCT images of all patients included in the study were unavailable. Therefore, we could not observe the direction of the changes observed in the TMJ hard tissues in the early and late periods. Another limitation was that the patients did not have TMJ clinical examination records. Therefore, we could not observe the clinical correlation between the DC in the TMJ hard tissues and the radiographic findings.

5. Conclusions

These results show that OS causes changes in the TMJ in both types of malocclusion, but TMJ hard tissues of Class II patients are more affected than those of Class III patients by OS. The fact that DCs such as sclerosis, osteophyte formation, and condylar resorption are observed more frequently in Class II patients is valuable information for clinicians in terms of being prepared for possible TMJ complaints in these patients in the postoperative period.

Author contributions

Beyza Yalvaç Pınarbaşı: conceptualization, data curation, investigation, methodology, resources, visualization, writing — original draft. Meryem Etöz: conceptualization, methodology, project administration, supervision, writing — review and editing. Orhun Öztürk: formal analysis. Ahmet Emin Demirbaş;: supervision, writing — review and editing. Emrah Soylu: methodology, supervision, writing — review and editing. Ahmet Yağcı: supervision.

Ethical approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Erciyes University (protocol no. 2023/680).

Conflict of interest

None.

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