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ORIGINAL ARTICLE

# Three-dimensional evaluation of the temporomandibular joints after unilateral surgically assisted rapid maxillary expansion in adults: A preliminary retrospective study

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## Abstract

**Background:** Unilateral surgically assisted rapid maxillary expansion (U-SARME) is a successful method for correction of true unilateral posterior crossbite (TUPC).

**Objectives:** This retrospective preliminary study aimed to evaluate the position and morphology of condyles in TUPC cases and the effects of U-SARME on condyle with the help of cone beam computed tomography (CBCT).

**Methods:** Fifteen patients (mean age: 18.69 ± 1.59 years) who were diagnosed as TUPC and undergone U-SARME were selected. Preoperative (T0) and after 6-month retention (T1) DICOM data of CBCT images were evaluated with MIMICs version 19.0 software. Condylar morphology (medio-lateral and antero-posterior dimensions) and position (anterior, posterior, medial and lateral joint spaces, frontal/axial axis angles, the ratio of posterior to anterior joint space and the percentage of posterior to anterior joint space) were evaluated. Student's *t*-test was used for intergroup (crossbite, normal) comparisons. Paired-samples *t*-test was used for intra-group comparisons ($p = .05$).

**Results:** There were no positional or dimensional asymmetry of the condyles between crossbite and normal sides initially and after expansion. Regarding T0-T1 changes, while significant increase was determined in medial (0.3 ± 0.29 mm; $p = .001$) and superior (0.39 ± 0.7 mm; $p = .045$) joint spaces on crossbite side, posterior (0.79 ± 0.99 mm; $p = .008$), superior (0.5 ± 0.79 mm; $p = .029$) and lateral joint spaces (0.31 ± 0.54 mm; $p = .042$) presented significant increases on normal side. However, no significant changes were found between crossbite and normal sides at T0 and T1.

**Conclusions:** Condyles were symmetrical in true unilateral posterior crossbite cases and the symmetry were not disrupted following U-SARME.

KEYWORDS
surgically assisted asymmetrical expansion, temporomandibular joint

## 1 | BACKGROUND

Posterior crossbite (PC) is reported globally with a frequency of 9.4%–11.7% in mixed and permanent dentition.[1] PC can be subdivided into skeletal, dental and functional, or unilateral and bilateral.[2] Unilateral PCs are divided into two groups: functional PC (FPC) and true unilateral PC (TUPC).[3] FPC constitutes 67%–79% of unilateral PCs. The diagnosis and treatment modalities of these two conditions differ

  

from each other. In FPC, bilateral maxillary constriction is present, and a mandibular shift is observed during the opening and closing of the mouth. During intercuspation, upper and lower midlines do not coincide, whereas upper and lower midline coincidence is observed with the open-mouth position.[4–7] Furthermore, TUPC presents a more constricted or collapsed maxillary arch on one side and no change in midline coincidence during opening and closing of the mouth.[8–11]

Therefore, the treatment approaches for these two distinct conditions are also different. While FPC is treated with bilateral maxillary expansion, TUPC treatment requires unilateral expansion (asymmetrical expansion) to avoid non-occlusion on the normal side.[12] The transverse relationship between the maxillary and mandibular posterior dentition can thus only be corrected on the constricted side. Many different appliances and methods for unilateral expansion have been reported in this regard.[3,8,11–17] However, these methods alone are insufficient to treat TUPC in adults because of the resistance created by circummaxillary and midpalatal sutures. Clinicians can overcome these side effects and limitations in adults with the assistance of unilateral surgically assisted rapid maxillary expansion (U-SARME) on the constricted side.[12] However, another successful technique was mentioned in a case report[17] describing unilateral mini-implant-assisted rapid palatal expansion (U-MARPE) in an adult patient without surgical assistance.

The effect of PC on the morphology and position of the condyles varies from none to major.[7,18–26] Studies[7,18–22,26] report the uncertainty of this association, with the presence of other contradictory studies.[23–25]

In general, many studies have examined the impact of PC and maxillary expansion on the joints.[7,18–31] Kecik et al.[21] concluded that the condyles in unilateral PC cases were mispositioned in the glenoid fossa on the crossbite side. Lam et al.[22] and Hesse et al.[7] mentioned that PC may cause asymmetrical positioning of the condyle within the glenoid fossa. Muraglie et al.[26] suggested that glenoid fossa and articular eminence asymmetry exist between the crossbite and normal sides in unilateral PC cases. However, Leonardi et al.[24] found symmetrical condylar positioning between the crossbite and normal sides. Pittman et al.[25] reported no positional differences in the condyles, and they attributed this to condylar remodelling.

Because none of these studies categorised unilateral PCs as FPC and TUPC, they do not provide information about TUPC. U-SARME is a promising treatment option for TUPC. However, it is unclear whether the asymmetrical treatment modality creates asymmetry in condylar positions. Clarification will ensure that this method can be used safely. The present study collects innovative knowledge about the condylar effect of TUPC and U-SARME. Therefore, this study aimed to evaluate, via a 3D approach, the morphological and positional condylar features in adults with TUPC and the effects of U-SARME. The null hypothesis of the present study is that, unlike FPC, there is no difference in condylar symmetry before or after treatment in TUPC.

## 2 | MATERIALS AND METHODS

### 2.1 | Sample selection

This single-centre, single-blinded, retrospective, preliminary study was approved by the Ethical Committee of the Faculty of Dentistry, Marmara University (approval date and number: 13.05.2020, 2020/15) and was conducted in accordance with the World Medical Association Declaration of Helsinki (World Medical Association, 2013).[32] The inclusion criteria were age over 17 years (indication for surgical assistance), presence of TUPC, unilateral PC in which one side of the maxilla is determined to be more constricted (distances between the posterior teeth and the midpalatal suture were measured for both sides on plaster models), no change in midline coincidence during opening or closing of the mouth, which indicates the absence of a shift in the mandible (this was determined from mouth opening and closing videos acquired from each patient routinely in the clinic), treatment with U-SARME (unilateral [asymmetrical] rapid maxillary expansion with unilateral surgical assistance [osteotomies were performed only on the constricted side: midpalatal suture, anterior apertura piriformis osteotomy, lateral zygomatic process osteotomy, posterior pterygoid osteotomy]),[12] and complete cone-beam computed tomography (CBCT) records, including initial (T0) and 6 months after expansion (T1).

The exclusion criteria were temporomandibular joint (TMJ) disorders, genetic or congenital craniofacial anomaly, missing pre- or post-expansion records, systemic or mental disorders, mandibular shift (i.e. FPC), history of facial trauma, mouth opening limitation (<40 mm) and history of headaches. Twenty-two patients who were treated with U-SARME between 2011 and 2021 were included in the study. After the exclusion of patients with TMJ symptoms, missing records and mandibular shift, 15 patients (seven males, eight females; mean age: $18.69 \pm 1.59$ years) were analysed.

### 2.2 | Treatment protocol and data collection

Expansion was performed using an asymmetrically designed Hyrax appliance (Hyrax®, Dentaurum, Ispringen, Germany) following unilateral surgical assistance (Figure 1). Anterior, lateral, posterior and midpalatal suture osteotomies were performed on the constricted (C) side. The expansion was performed twice daily (0.25 mm × 2/day) and continued as needed according to each patient's crossbite, including 30% overcorrection as a routine protocol. The appliances were kept in the mouth for 6 months for retention purposes. CBCT images acquired initially (T0) and 6 months post-expansion (T1) were collected from the archive for evaluation. Hyrax appliances were not in the mouth when the CBCT images were taken at T0 and T1. The images were acquired using an Iluma Imtec Imaging Machine (3M, Ardmore, Oklahoma) with a setting of 120 kV, 1–4 mA, 0.0936 mm voxel size and 14.2 × 21.1 cm field of view. During image acquisition, the patients sat in an upright position with their Frankfort horizontal plane (FHP) adjusted parallel to the floor.

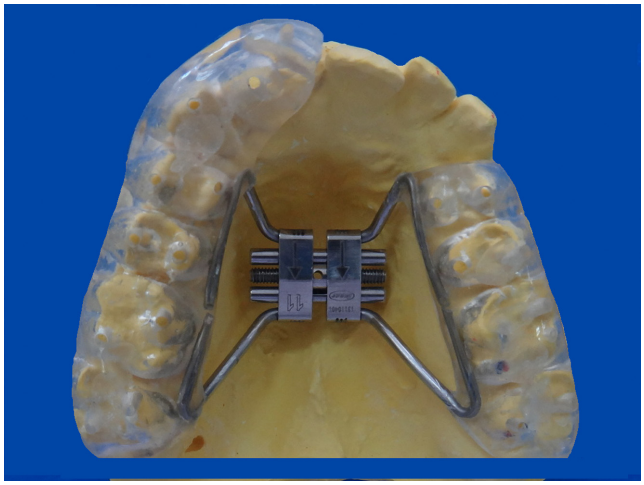

FIGURE 1 Asymmetrical designed hyrax expander.

## 2.3 | Cone-beam computed tomography analysis

DICOM data were uploaded to MIMICs version 19.0 software. All images were reoriented according to the FHP and midsagittal plane (MSP). The definitions of the lines, planes and measurements used in the present study are presented in Table 1. Linear and angular measurements were performed on the sagittal, axial and frontal sections to assess the symmetry between the condyles in the anteroposterior and mediolateral aspects. The sagittal sections were evaluated where the mediolateral diameter of the right or left condyle was the greatest on the axial and coronal sections. To determine the condylar position, the anterior, posterior and superior joint spaces were measured on the sagittal section (Figure 2). The medial and lateral joint spaces were evaluated on the frontal section (Figure 3). In addition, angular measurements were performed to determine rotational asymmetries (Figure 4), and the anteroposterior

TABLE 1 Definitions of the lines, planes and measurement used in the present study.

| | Symbol | Explanation |
|---|---|---|
| Lines | | |
| | Horizontal line parallel to FH | Passes through the most superior point of glenoid fossa, parallel to Frankfurt horizontal plane |
| | Line 1 | In the sagittal slice, drawn through the most superior point of glenoid fossa tangent to the most anterior point of condyle |
| | Line 2 | In the sagittal slice, drawn through the most superior point of glenoid fossa tangent to the most posterior point of condyle |
| | Line 3 | In the coronal slice, drawn through the most superior point of glenoid fossa tangent to the most medial point of the condyle |
| | Line 4 | In the coronal slice, drawn through the most superior point of glenoid fossa tangent to the most distal point of the condyle |
| Planes | | |
| | FHP | Frankfort Horizontal Plane passes between right orbitale, right and left potions |
| | MSP | Mid-sagittal plane passes between Nasion-Basion and perpendicular to FHP |
| | Frontal long axis plane | Plane between the most anterior point of condyle, posterior point of condyle and gonion |
| | Axial head long axis plane | Plane between the most medial point of condyle, distal point of condyle and gonion |
| Measurements | | |
| | Anterior joint space | The distance from the most anterior point of condyle to best fit to anterior slope of glenoid fossa |
| | Posterior joint space | The distance from the most posterior point of condyle to best fit to posterior slope of glenoid fossa |
| | Superior joint space | The distance from the most superior point of condyle to best fit to superior point of glenoid fossa |
| | Medial joint space | The distance from the most medial point of condyle to best fit to medial slope of the glenoid fossa |
| | Lateral joint space | The distance from the most distal point of condyle to best fit to distal slope of the glenoid fossa |
| | P/A ratio | Posterior/anterior joint space |
| | Percentage of posterior to anterior joint space | [(Posterior–Anterior)/(Posterior + Anterior)] × 100 |
| | Frontal long axis angle | Angle between frontal long axis plane and MSP |
| | Axial head long axis angle | Angle between axial head long axis plane and MSP |

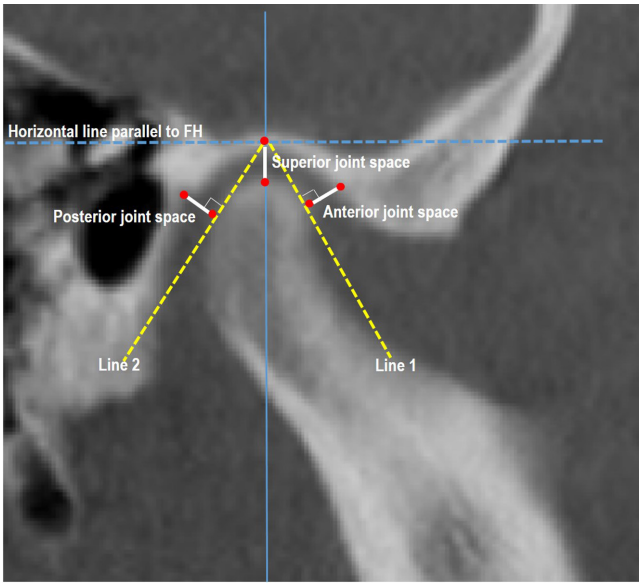


FIGURE 2 Anterior, posterior and superior joint spaces measured on the sagittal section.

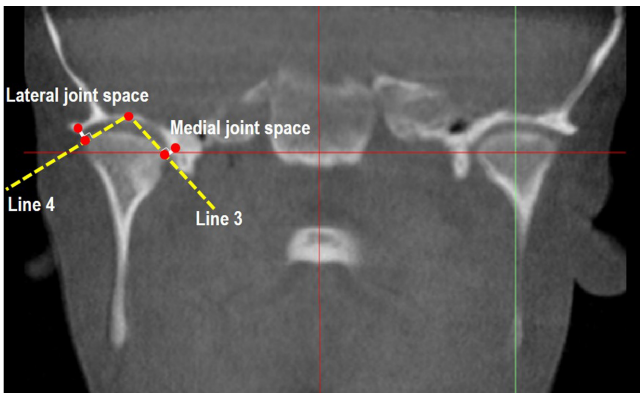


FIGURE 3 Medial and lateral joint spaces measured on the frontal section.

and mediolateral dimensions of the condylar head were evaluated. The posterior-to-anterior joint space ratio[17] and the percentage of posterior-to-anterior joint space[17–20] were calculated. A posterior-to-anterior joint space ratio of 1.00 indicated a perfectly centred condyle.[17] The percentage of condylar displacement from the centric position is expressed as:

([Posterior joint space − anterior joint space]/[Posterior joint space + anterior joint space]) × 100.

The results represent the following:

- 0: absolute centric position of the condyle.
- −12%–12%: centric position of the condyle.
- <−12%: posterior position of the condyle.
- >12%: anterior position of the condyle.[18]

## 2.4 | Statistical analyses

IBM SPSS Statistics 22 software (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp) was used for statistical analysis.

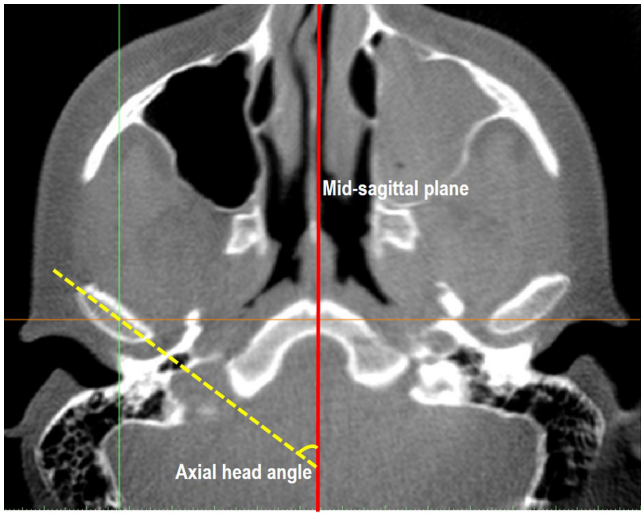


FIGURE 4 Measurement of axial head long axis plane (angular measurement).

The conformity of the parameters to the normal distribution was assessed using the Shapiro–Wilk test. Student's *t*-test was used for the intergroup (crossbite, normal) comparisons in normally distributed data, the Mann–Whitney *U*-test was used in non-normally distributed data. The paired-samples *t*-test was used for the intra-group comparisons of parameter changes from the T1 values to the T0 values for normally distributed data while Wilcoxon signed-ranked test was used for non-normally distributed data. To assess the intra-examiner reliability, the measurements were repeated by the same operator for 20% of selected patients 1 week after the first measurements.

# 3 | RESULTS

The intraclass correlation coefficient (ICC) ranged between 0.964 and 1.000 and showed a high level of agreement.

## 3.1 | Intragroup comparison

There was a significant increase in the medial (0.3 ± 0.29 mm, $p = .001$) and superior (0.39 ± 0.7 mm, $p = .045$) joint spaces on the crossbite side, while the posterior (0.79 ± 0.99 mm, $p = .008$), superior (0.5 ± 0.79 mm, $p = .029$) and lateral (0.31 ± 0.54 mm, $p = .042$) joint spaces on the normal side increased significantly from T0 to T1. There were no changes on either side in terms of frontal long axis angle, axial head long axis angle, anterior joint space or posterior to anterior joint space ratio (Table 2). There were no significant changes in the anteroposterior or mediolateral dimensions of the condylar head on either side.

## 3.2 | Intergroup comparison

While at T0, the condyle on the crossbite side was in the centric position, the non-crossbite side was in the anterior position according

**TABLE 2** In-group and inter-group evaluations of the changes in the temporomandibular joint.

| | Crossbite side | Normal side | |
|---|---|---|---|
| | Mean ± SD (mm) | Mean ± SD (mm) | *p* |
| Anteroposterior thickness (mm) | | | |
| T0 | 13.16 ± 2.41 | 13.28 ± 3.11 | .903[a] |
| T1 | 13.49 ± 3.03 | 13.34 ± 3.3 | .899[a] |
| Difference | 0.33 ± 1.33 | 0.06 ± 1.28 | .572[a] |
| *p* | .353[b] | .866[b] | |
| Mediolateral thickness (mm) | | | |
| T0 | 19.07 ± 2.32 | 19.36 ± 2.19 | .734[a] |
| T1 | 19.22 ± 2.58 | 19.44 ± 2.07 | .797[a] |
| Difference | 0.15 ± 0.65 | 0.09 ± 0.6 | .793[a] |
| *p* | .394[b] | .589[b] | |
| Frontal long axis angle (°) | | | |
| T0 | 80.11 ± 4.65 | 79.71 ± 5.17 | .825[a] |
| T1 | 80.78 ± 5.25 | 80.1 ± 4.19 | .697[a] |
| Difference | 0.67 ± 2.27 | 0.39 ± 2.07 | .806[c] |
| *p* | 0.274[b] | 0.480[b] | |
| Axial head long axis angle (°) | | | |
| T0 | 74.57 ± 5.58 | 75.83 ± 6.99 | .591[a] |
| T1 | 74.88 ± 5.37 | 74.13 ± 5.25 | .703[a] |
| Difference | 0.31 ± 2.5 | −1.69 ± 4.35 | .081[c] |
| *p* | .642[b] | .154[b] | |
| Anterior joint space (mm) | | | |
| T0 | 2.48 ± 1.54 | 1.8 ± 0.8 | .161[c] |
| T1 | 2.28 ± 1.46 | 1.84 ± 0.73 | .624[c] |
| Difference | −0.2 ± 0.9 | 0.04 ± 0.48 | .362[a] |
| *p* | .233[d] | .753[d] | |
| Posterior joint space (mm) | | | |
| T0 | 2.53 ± 1 | 2.33 ± 0.8 | .554[a] |
| T1 | 3.03 ± 1.42 | 3.12 ± 1.23 | .842[a] |
| Difference | 0.5 ± 1.04 | 0.79 ± 0.99 | .434[a] |
| *p* | .085[b] | .008[b, **] | |
| Superior joint space (mm) | | | |
| T0 | 2.57 ± 0.65 | 2.27 ± 0.6 | .203[a] |
| T1 | 2.96 ± 0.75 | 2.77 ± 0.96 | .554[a] |
| Difference | 0.39 ± 0.7 | 0.5 ± 0.79 | .694[a] |
| *p* | .045[b, *] | .029[b, *] | |
| Medial joint space (mm) | | | |
| T0 | 5.52 ± 1.71 | 6.27 ± 1.19 | .305[c] |
| T1 | 5.83 ± 1.86 | 6.35 ± 1.27 | .371[a] |
| Difference | 0.3 ± 0.29 | 0.09 ± 0.38 | .092[a] |
| *p* | .001[b, **] | .362[d] | |
| Lateral joint space (mm) | | | |
| T0 | 7.14 ± 1.97 | 6.14 ± 1.63 | .142[a] |
| T1 | 7.34 ± 1.98 | 6.45 ± 1.53 | .182[a] |
| Difference | 0.2 ± 0.42 | 0.31 ± 0.54 | .967[c] |
| *p* | .089[b] | .042[b, *] | |
| P/A ratio | | | |
| T0 | 1.55 ± 1.31 | 1.51 ± 0.77 | .624[c] |
| T1 | 1.88 ± 1.27 | 1.98 ± 1.23 | .806[c] |
| Difference | 0.33 ± 1.17 | 0.47 ± 0.97 | .838[c] |
| *p* | .083[d] | .125[d] | |
| Percentage of posterior to anterior joint space | | | |
| T0 | 5.97 ± 37.55 | 13.54 ± 25.16 | .522[a] |
| T1 | 16.36 ± 37.29 | 24.46 ± 24.27 | .486[a] |
| Difference | 10.39 ± 22.58 | 10.93 ± 21.94 | .948[a] |
| *p* | .097[b] | .074[b] | |

[a]Student's *t*-test.
[b]Paired-samples *t*-test.
[c]Mann–Whitney *U*-test.
[d]Wilcoxon signed-ranked test.
*$p < .05$; **$p < .01$.

to the percentage of posterior-to-anterior joint space parameter (5.97 ± 37.55 and 13.54 ± 25.16, respectively); however, the difference between the sides was not significant ($p = .522$). At T1, both condyles moved anteriorly to similar degrees (constricted side: 10.39 ± 22.58, normal side: 10.93 ± 21.94); however, the differences were not significant for either side ($p = .948$). Furthermore, the T1 values between the crossbite and normal sides were not significantly different ($p = .486$) (Table 2).

## 4 | DISCUSSION

In the studies evaluating the TMJ of unilateral PC cases, there is generally no specification of whether the defined unilateral PC is FPC or TUPC. Most of the studies investigating unilateral PC are about FPC.[20–22,25,27,28] Furthermore, it is important to note the differences in the treatments for FPC and TUPC. In the treatment of FPC, bilateral maxillary expansion is required; for the treatment of TUPC, unilateral maxillary expansion is preferred to prevent non-occlusion on the normal side and subsequent prolongation of treatment duration.[12]

In TMJ assessment, evaluating condylar symmetry is crucial. In the present study, condylar morphology was assessed using measurements of anteroposterior and mediolateral condylar thickness, and the morphology was similar on the normal and crossbite sides following both in-group and inter-group comparisons. Therefore, we confirmed our hypothesis by concluding that there were no differences in the position or morphology of the condyles between the

crossbite side and the normal side initially or after expansion. Similarly, Melgaço et al.[29] reported symmetry between the right and left sides after they compared the right and left condyles before and after bilateral rapid maxillary expansion. In addition, they reported minor intragroup changes in the right and left condyles separately, as in our study.

Almaqrami et al.[27] reported a difference between the normal and crossbite sides regarding the superior and anterior condylar distances in FPC cases. In their study, the anterior joint space was found to be greater on the crossbite side (C: 2.47±0.84, N: 2.16±0.51; $p=.046$) compared with the normal side, while the superior joint space was greater on the normal side than on the crossbite side (C: 2.87±0.74, N: 3.20±0.84; $p=.023$). This indicates the presence of initial mandibular shifting. In contrast, in our study, no such significant differences were found before or after treatment in the side comparison. This is likely due to the lack of mandibular shifting in TUPC cases. Therefore, TUPC cases must be treated by U-SARME to prevent scissor bite on the normal side. The unaltered condylar positions from T0 to T1 highlight the accuracy of clinical diagnosis and the treatment success of U-SARME.

Leonardi et al. evaluated the condyles of FPC cases and reported the initial absence of positional asymmetry between the crossbite and normal sides.[24] Anterior, superior and posterior joint space measurements at T0 between the crossbite side and normal side were not significantly different. After rapid maxillary expansion, the superior joint space increased on the crossbite side (0.37 mm) more than on the normal side (0.28 mm). A significant difference in the superior joint space at T1 between the normal and crossbite sides was reported. The posterior space increased only on the crossbite side (0.34 mm); however, the difference between sides at T1 was not statistically significant. In contrast with these findings, in the present study, no differences were found between the crossbite and normal sides in any parameters at T1.

According to Melgaço et al.'s[29] study, significant anterior and inferior displacement of the condyles occurred after rapid maxillary expansion, with average values of 0.52 mm for anterior and 0.49 mm for inferior displacement. In the present study, we observed anterior and inferior movement on both sides; however, the increase in posterior joint space was only significant on the normal side.

Due to the absence of mandibular shift and asymmetry in the condylar positions at T0 and T1 in the present study, the results indicating the symmetry of the condyles on the normal and crossbite sides before and after unilateral expansion were similar to those of bilateral maxillary crossbite before and after bilateral maxillary expansion, not FPC. Therefore, it can be concluded that condylar positions have different characteristics in TUPC and bilateral PC compared with FPC.

However, some studies[18,28] reported no significant difference between normal and crossbite sides in unilateral PC patients, unlike Almaqrami et al.[27] Pinto et al.[18] evaluated condylar positions of FPC cases and numerically reported the presence of asymmetry between crossbite and normal sides; however, the difference was not statistically significant. The results of other FPC studies are in line with the findings of Pinto et al.[28]

Although the increases in superior (0.5 mm) and posterior (0.79 mm) joint spaces on the normal side were significant in the present study, there was no positional asymmetry between the crossbite and normal sides initially or after expansion for these parameters. Furthermore, significant in-group changes were observed in the medial and lateral joint spaces; however, no difference was found following inter-group comparison of the crossbite and normal sides. The different mesiodistal movements of the condyles might be related to differences in the tipping amounts of the maxillary posterior teeth after expansion. In the literature, it was mentioned that the expansion was greater on the crossbite side, and so extrusion of the palatinal cusp of the posterior teeth led to premature contact with lower molars.[12] The study reports immediate changes, so these results may change in the long term. Therefore, adaptation in the condylar head and condylar spaces should be compared between short- and long-term studies.

For future studies, comparing TUPC cases with control groups without PC would be beneficial.

## 5 | CONCLUSION

Treatment with unilateral maxillary expansion assisted by U-SARME did not disrupt the symmetry of condylar positions according to the short-term results. In addition, TUPC had no negative effects on condylar shape or position initially. Condyles were symmetrical both initially and after treatment in patients with TUPC. The uncertainty about what occurs in the surrounding tissues, especially the condyle position, is somewhat clarified by the present findings that the protocol did not cause any changes in condylar position; therefore, U-SARME can be used safely in the clinic. Although the short-term results were promising, further studies with larger sample sizes and long-term results should be evaluated three-dimensionally.

### AUTHOR CONTRIBUTIONS

*Conception and design*: Gülden Karabiber and Hanife Nuray Yılmaz. *Collection of data*: Gülden Karabiber. *Analysis of data*: Hanife Nuray Yılmaz. *Interpretation of the data and writing the manuscript*: Gülden Karabiber and Hanife Nuray Yılmaz.

### CONFLICT OF INTEREST STATEMENT

Gülden Karabiber and H. Nuray Yılmaz declare that they have no conflict of interest.

### DATA AVAILABILITY STATEMENT

Data not available due to ethical restrictions.

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