Three Dimensional Evaluation of Changes in Mandibular Condyle Position After Orthognathic Surgery

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Research Article

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Abstract

Background: This study aims to examine the changes in both mandibular condyle positions before and after surgery to evaluate manual temporomandibular joint (TMJ) positioning procedure after bilateral sagittal split ramus osteotomy in adult patients diagnosed with mandibular prognathism and compare them with the studies in the literature.

Methods: Patients diagnosed with mandibular prognathism, including bilateral sagittal split ramus osteotomy (BSSRO) procedures, in addition to their orthodontic treatment, were examined. The study including the examination of 88 right and left mandibular condyles of 44 patients, 24 male and 20 female. This study focused on comparing retrospectively obtained cone-beam computed tomography data of patients for 1-2 weeks before surgery (T0) and a mean of six months postoperatively (T1). DICOM formats of cone-beam computed tomography data were analyzed in the 3D Slicer software program, considering the references of Choi et al.. The examination was made separately in the axial, sagittal and coronal planes. IBM® SPSS® Statistics was used for statistical analysis. After testing the homogeneity of variance and normality, the dependent sample t-test was applied at a 95% significance level.

Results: The left mandibular condyle head rotated inward in the axial plane, but the change in the right condyle head was not statistically significant. In the sagittal plane, there was no significant change of both mandibular condyle heads. In the coronal plane, the right mandibular condyle head showed outward rotation, but the change in the left condyle head was not statistically significant. In addition, there was no statistically significant difference in the distance between the most medial points of the mandibular condyle heads in the coronal plane.

Conclusions: The sagittal plane's changes of the condyles can be maintained as before the surgery with manual positioning in bilateral sagittal split ramus osteotomy procedures. Inward and outward rotations seen in the axial and coronal planes are also consistent with the literature review. Stress occurring between the segments in the fixation process, operator positions during the operation, the direction and amount of the force applied for fixation, and contacts or gaps between the proximal and distal segments may be caused.

Introduction

Orthognathic anomalies are skeletal deformities that occur due to congenital or acquired factors, affecting the teeth, jaws, facial bones and surrounding soft tissues (2). Mandibular prognathism, one of the most common orthognathic anomalies, can be defined as the abnormal positioning of the mandible in front of the maxilla on the sagittal plane. The treatment approach for mandibular prognathism is mainly determined according to the patient's age. While growth modification treatment can be used in growing patients, orthognathic surgical methods should be used in adults (3).

Many surgical methods have been described for the treatment of orthognathic anomalies. Among these techniques, Le Fort 1 osteotomy for the maxilla and BSSRO for the mandible is the most preferred surgical procedures. Although these methods are performed isolated in some cases, treatment of mandibular prognathism requires using these two techniques in combination (3). Using these methods, the maxilla and mandible are divided into separate segments and mobilized. Then, an ideal interocclusal relationship is provided between the maxilla and mandible with the help of preplanned occlusal splints, and rigid osteosynthesis methods are used for final fixation (4).

BSSRO applied to change the three-dimensional (3D) position of the mandible is based on the principle of separating the mandibular ramus from the corpus on both sides and dividing the mandible into three mobile segments. In this way, the relations of the mandibular corpus to the maxilla and skull base are corrected (5). During these procedures, repositioning the mandibular condyle in the ideal position is one of the most important points of the operation. Although many methods have been described in the literature to position the mandibular condyle during BSSRO correctly, it generally depends on the operator’s experience (6).

Treatment planning is done by virtually correcting the relations of the mandibular corpus to the maxilla and skull based on the radiological data (7). Thanks to preoperative model surgery and 3D design technologies, it is possible to provide ideal occlusal and inter-maxillary relations. However, the ideal positioning of the mandibular condyle in the glenoid fossa after BSSRO is still challenging for clinicians (8). Following osteotomies, the fully released ramus may be subjected to undesirable position changes due to muscle deactivation and operator manipulations. Even very small changes in the condyle head position may also cause severe malocclusion and temporomandibular joint disorders (9).

Correct repositioning the condyle in the glenoid fossa is one of the most critical factors in ensuring the ideal occlusal relations following the orthognathic surgery, achieving successful osteogenesis, and preventing relapse. Positioning the proximal segment, the condyle head, is an important step in BSSRO procedures. The centric relation is based on the position of the condyle. The centric relation is the position of the condyles in the fossa independent of tooth contact. This position can be achieved in the clinic by directing the mandible condyle head upwards and forwards (10,11). Positioning is directly related to the operator's experience. TMJ elasticity and muscle relaxation caused by general anesthesia are the 2 main factors that complicate this surgical maneuver. (12) The methods applied for the correct positioning of the condyle in BSSRO; manual positioning, positioning with rigid fixation appliances, positioning via navigation and positioning via sonographic imaging. (13)

Accordingly, in this study, we aimed to evaluate the position of the mandibular condyle before and after the BSSO operation applied for the treatment of patients with mandibular prognathism.

Methods

Patient Selection

This study was designed retrospectively and was created from the archive of patients who underwent surgical treatment in the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Istanbul

University. The surgeries included in this study consisted of only one operator's surgeries. Patients were selected from patients who underwent BSSRO, one of the orthognathic surgical procedures, due to the diagnosis of mandibular prognathism. Radiographic data of the patients included in the present study were obtained by the CBCT device taken 1-2 weeks before the operation (T0) and six months after the operation (T1) by the Department of Oral, Dental and Maxillofacial Radiology of Istanbul University.

Inclusion criteria in this study:

• Individuals diagnosed with mandibular prognathism, whose mandible was located anterior to the maxilla and skull base.

• Individuals whose CBCT data were suitable for the study at 1-2 weeks preoperatively (T0) and at the mean six months postoperatively (T1).

• Individuals over the age of 18.

• Individuals with asymptomatic temporomandibular joint functions.

• Individuals who did not have a history of orthognathic surgery before the operation.

• Individuals without any syndrome diagnosis.

• Individuals without any systemic disease.

Exclusion criteria of this study:

• Individuals without a diagnosis of mandibular prognathism, even if they had a developmental anomaly of the jaws.

• Individuals whose CBCT data were not in radiographic values eligible for the present study.

• Individuals under the age of 18 who had not completed their growth and development.

• Individuals with symptomatic temporomandibular joint during the function.

• Individuals with a diagnosis of any syndrome.

• Individuals with any systemic disease.

• Individuals with trauma or pathological history in the maxillofacial region.

The study started with the CBCT examination of 50 patients but continued with 44 patients since six did not meet the inclusion criteria. In this study, 24 patients were male, and 20 patients were female. The examinations were calculated and compared separately for both right and left mandibular condyles. Therefore, this study included 88 condyle examinations in total.

This study adhered to the principles of the Declaration of Helsinki and was approved by the ethical committee of the university hospital (Protocol number: 2021/2). Informed consent was obtained from patients. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

The Applied BSSRO Technique

BSSrO was started on the medial surface of the mandibular ramus horizontally just above the mandibular foramen and reached the posterior border of the ascending ramus from the anterior. Following the horizontal cut, a vertical osteotomy on the lateral surface of the mandibular corpus at the region of molar teeth, including the inferior border of the mandible, was performed. Finally, the horizontal and the vertical osteotomies were joined by each other by a diagonal osteotomy between the anterior part of the horizontal osteotomy and the superior part of the vertical osteotomy (14).

After the induction of nasotracheal general anesthesia and local infiltrative anesthesia for both sides of the mandible, an incision was made starting on the medial surface of the ramus horizontally just above the mental foramen and reached the posterior margin of the ascending ramus from the anterior side. Then, a full-thickness mucoperiosteal flap was elevated and the medial and lateral surfaces of the ramus and the lateral surface of the corpus were exposed. The inferior alveolar nerve was identified and protected. After the flap elevation, a horizontal osteotomy was made on the inner surface of the ramus, extending from the posterior to anterior, a diagonal osteotomy on the angulus and a horizontal osteotomy on the outer surface of the corpus were performed using a micro saw and Lindeman bur. Following the osteotomies, the mandible was split with an osteotome and hammer. Then, intermaxillary fixation was performed using the guidance of a previously prepared splint. The ramus was manipulated manually from the most anterior lowest point of the proximal segment to the back and up from the angulus, allowing the condyle to come into an ideal centric relationship. At this point, the condyle head was kept in the centric position in the glenoid fossa, while rigid fixation was achieved with a four-hole miniplate and four screws. Finally, the splint was removed, and the soft tissues were sutured using conventional techniques. All of these steps were performed for both sides (5, 14).

All surgical procedures were performed by the same operator to standardize the surgical technique. All patients were hospitalized on the first postoperative day. The patients were treated with interdental elastics for three days, starting from one day after the operation, and antibiotics (amoxicillin/clavulanic acid, Augmentin-BID 1000mg tablet), analgesics (diclofenac potassium, Cataflam 50mg tablet) and mouthwash (chlorhexidine gluconate, Kloroben Gargara) which were administered as a standard medical treatment for a week from the first day after the surgery.

Data Collection and Analysis

The patients' data were used with CBCT devices at two different times, 1-2 weeks before the operation and six months after the operation. Radiographic images were obtained as standard in the Department of

Oral and Maxillofacial Radiology, Istanbul University. During tomography, the patient's head position was positioned so that the Frankfort Horizontal Plane was parallel to the floor.

CBCT data were obtained using a CBCT device (SCANORA® 3Dx Dental CT system, SOREDEX Nahkelantie, Tuusula, Finland) with a FOV area of 140 x 165 mm, including TMJ regions, tube voltage of 90 kVp, tube current of 13 mA, and a scan time of 26 seconds. The cross-sectional thickness of the images was 0.3 mm, and images of equivalent parts were taken at each session.

Right and left condyle positions in the coronal, axial and sagittal planes were studied using open-source and non-commercial software (3D Slicer, Slicer Wiki). Landmarks were defined by considering the methodology proposed by Choi et al.. The distances, ratios, and angles between these landmarks were measured on CBCT slices to objectively compare the pre- and postoperative positions of the condyle heads in the axial, sagittal and coronal planes. (1)

Reference Planes, Points, Lines, Angles, Distances and Ratios Used in this Study

Reference Planes Used in this Study

Axial plane; plane passing through the points right, left porion and right orbitale; coronal plane; plane passing through the right and left porion points and perpendicular to the axial plane; sagittal plane; it is the plane passing through the nasion and basion points and perpendicular to the axial plane.

Reference Points Used in this Study according to Reference Planes

Reference points for the axial plane (Fig. 1); A1R (lateral pole of right condyle head), A1L (lateral pole of left condyle head), A2R (medial pole of right condyle head), A2L (medial pole of left condyle head), BR (backmost point of right carotid canal), BL (backmost point of left carotid head)

Reference points for the sagittal plane (Fig. 2); D1 (lowest point of articular eminence), D2 (lowest point of temporal squamotympanic fissure), C1 (top point of glenoid fossa), C2 (top of condyle head), D3 (corresponding point in perpendicular descending from point C1 to Line 3), D4 (corresponding point on the perpendicular from point C2 to Line 3).

Reference points for the coronal plane (Fig. 3); ER (top point of the right glenoid fossa), EL (Top point of the left glenoid fossa), F1R (lateral pole of the right condyle head), F1L (lateral pole of the left condyle head), F2R (medial pole of the right condyle head), F2L (medial pole of the left condyle head).

Reference Lines Used in this Study according to Reference Planes

Reference lines for the axial plane (Fig. 1); Line 1R (Line passing between the medial (A2R) and lateral (A1R) poles of the right condyle head), Line 1L (Line passing between the medial (A2L) and lateral (A1L) poles of the left condyle head), Line 2 (line passing between the most posterior points of right (BR) and left (BL) the carotid canals).

Reference line for the sagittal plane (Fig. 2); Line 3 (Line passing from the lowest point of the articular eminence (D1) to the lowest point of the temporal squamotympanic fissure (D2)).

Reference lines for the coronal plane (Fig. 3); Line 4 (Line passing between the top point of the right glenoid fossa (ER) and the top point of the left glenoid fossa (EL)), Line 5R (Line passing between the medial pole of the right condyle head (F2R) and the lateral pole of the right condyle head (F1R)), Line 5L (Line passing between the medial pole (F2L) of the left condyle head and the lateral pole (F1L) of the left condyle head).

Reference angles used according to reference planes in this study

Reference angles for the axial plane (Fig. 1); Angle αR (The angle measured between the line passing between the medial (A2R) and lateral (A1R) poles of the right condyle head (Line 1R) and the line passing between the most posterior points of the right (BR) and left (BL) carotid canals (Line 2)), angle αL (The angle measured between the line passing between the medial (A2L) and lateral (A1L) poles of the left condyle head (Line 1L) and the line passing between the most posterior points of the right (BR) and left (BL) carotid canals (Line 2)).

Reference angles for the coronal plane (Fig. 3); βR Angle (The angle measured between the Line 5R that passing between the medial pole of the right condyle head (F2R) and the lateral pole of the right condyle head (F1R) and the Line 4 that passing between the top point of the right glenoid fossa (ER) and the top point of the left glenoid fossa (EL)), Angle βL (The angle measured between the Line 5L that passing between the medial pole of the left condyle head (F2L) and the lateral pole of the left condyle head (F1L) and the Line 4 that passing between the top point of the right glenoid fossa (ER) and the top point of the left glenoid fossa (EL))

Reference distances for the sagittal plane (Fig. 2); n (Distance measured between the highest point of the condyle head (C2) and the corresponding point (D4) on the perpendicular descending from point C2 to Line 3), N (Distance measured between the highest point of the glenoid fossa (C1) and the corresponding point (D3) on the perpendicular descending from point C1 to Line 3), m (Distance measured between the lowest point of the articular eminence (D1) and the corresponding point (D4) on the perpendicular descending from point C2 to Line 3), M (Distance measured between the lowest point of the articular eminence (D1) and the lowest point of the temporal squamotympanic fissure (D2))

Reference distances for the coronal plane (Fig. 3); C (Distance measured between the medial pole of the right condyle head (F2R) and the medial pole of the left condyle head (F2L))

Ratios Used according to Reference Planes in this Study

The ratios used for the sagittal plane (Fig. 2); n/N gives the vertical evaluation ratio of the mandibular condyle in the direction of the glenoid fossa, indicating the vertical movement of the condyle head in the glenoid fossa. The m/M ratio gives the horizontal evaluation ratio of the mandibular condyle in the direction of the glenoid fossa, which indicates the horizontal movement of the condyle head in the glenoid fossa.

Data Analysis

A power analysis was conducted to determine the minimum number of patients to be analyzed in this study. While performing power analysis, average and standard deviation values of the difference between n/N, m/M, α and β angles, and C distance before and after surgery in the literature were taken as the basis [4]. To calculate the effect size to be used in the power analysis, the average and standard deviation values received in pre- and postoperative 6-month periods were used. The results were 0.02 ± 0.03 (mean ± standard deviation) and 0.08 ± 0.06 for n/N and m/M ratios, respectively, 2.20 ± 3.36 degrees for angle α, 1.02 ± 3.11 degrees for angle β and 1.73 ± 1.44 mm for C distance. According to all these results, the effect size was calculated at 0.77. In the calculation, Type I error was determined as 0.05, and Type II error as 0.20. One-way t-test analysis was performed. The findings obtained in this study suggested that tomography images of at least 11 patients before and after surgery were required for this study.

In the statistical analysis, mean and standard deviations of n/N and m/M ratios, α and β angles, and distance C were determined and related pairs were compared for pre- and postoperative periods. IBM® SPSS® Statistics was used for statistical analysis. After testing the homogeneity of variance and normality, the dependent sample t-test was applied with a significance level of 95%.

Results

Results in the Axial Plane

The α (αR and αL) angles formed between Line 1 (the line passing between the medial and lateral poles of the condyle head in the axial plane) and Line 2 (the line passing between the backmost points of the right and left carotid canals in the axial plane) in the axial plane were investigated.

An increase in the α angle in the postoperative period indicates inward rotation of the condyle head in the axial plane, while a decrease in the α angle indicates outward rotation of the condyle head in the axial plane.

While the left condyle head (αL) was 20.3 ± 9.6 degrees at T0 time, it was 23.4 ± 7.7 degrees at T1 time, and this increase was significant. This significant increase means that the left condyle head is inward rotated in the axial plane in an average of six months postoperative period than the preoperative period of the patients. The right condyle head (αR) was 21.7 ± 11.5 degrees at T0 time and 21.9 ± 9.1 degrees at T1 time. There was no significant change in the right condyle head, in the axial plane, in the postoperative period than in the preoperative period (Fig. 4).

Results in the Sagittal Plane

To examine the vertical and horizontal position changes of the condyle head in the sagittal plane, the n/N and m/M ratios were examined, respectively. An increase in the n/N ratio indicates that the condyle head moves vertically upwards, while a decrease indicates that the condyle head moves vertically downwards. An increase in the m/M ratio indicates a horizontally backward movement of the condyle head, while a decrease indicates a horizontally forward movement of the condyle head.

The findings obtained in this study showed that the n/N ratio for the right condyle head was 0.64 ± 0.18 at T0 time and 0.59 ± 0.19 at T1 time. For the left condyle head, it was 0.63 ± 0.16 at T0 and 0.58 ± 0.19 at T1. There was no significant change in the sagittal plane for both the right and left condyle head vertically before the operation and in the mean postoperative period of six months (Fig. 5).

The m/M ratio for the right condyle head was 0.58 ± 0.11 at T0 time and 0.57 ± 0.10 at T1 time. For the left condyle head, it was 0.58 ± 0.11 at T0 and 0.59 ± 0.11 at T1. There was no significant change in the sagittal plane and horizontally for both the right and left condyle heads before the operation and in the mean postoperative period of six months (Fig. 6).

There was no change in the sagittal plane, both vertically and horizontally, with the surgery.

Results in the Coronal Plane

In the coronal plane, the β (βR and βL) angles formed between Line 4 (the line passing between the top point of the right glenoid fossa and the highest point of the left glenoid fossa) and Line 5 (the line passing between the medial pole of the condyle head and the lateral pole of the right condyle head) and the C distance between the medial poles of both condyle heads was examined.

An increase in the β angle in the postoperative period indicates inward rotation of the condyle head in the coronal plane, while a decrease in the β angle indicates outward rotation of the condyle head in the coronal plane.

An increase or decrease in the C distance expresses the position change in the coronal plane as an increase or decrease in the distance between the condyle heads in the postoperative period.

While the right condyle head (βR) was 17.6 ± 10.4 degrees at T0 time, it was 14.1 ± 9.6 degrees at T1 time, and this decrease was significant. This significant decrease means that the right condyle head is outward rotated in the coronal plane in the postoperative period of six months on average compared to the preoperative period of the patients. In addition, the left condyle head (βL) was 16.5 ± 9.7 degrees at T0 time and 18.5 ± 9.7 degrees at T1 time. There was no significant change in the left condyle head, in the coronal plane, in the postoperative period than in the preoperative period (Fig. 7).

While the C distance was 83.9 ± 7.4 mm at T0 time, it was 83.9 ± 7.2 mm at T1 time. According to this result, the difference in the distance between the right and left condyle heads in the coronal plane was not significant. Thus, there was no position change in the coronal plane due to the distance between the right and left condyle heads (Fig. 8).

Discussion

BSSRO provides preservation of neurovascular tissues during the osteotomy, extended motion ability on the segmented parts of the mandible, and easy management of condylar displacement. In addition, this technique is relatively easy to implement and allows stable, rigid fixation (15). Due to these factors, BSSO is considered the ideal osteotomy method applied for mandibular prognathism treatment.

Although BSSRO is a useful method to treat mandibular prognathism, long-term success depends on some basic principles. After orthognathic surgery, relapse may develop due to many reasons, such as tongue pressure, improper fixation of osteotomized segments and occlusal instability. Among them, occlusal stability can be considered the most important factor for preserving an ideal interocclusal relationship obtained by the surgical approach.

The occlusal stability can be provided by proper dental occlusion maintained by orthodontic rehabilitation. However, if the postoperative condyle position is improper, occlusal stability is inevitable (16). Even if postoperative interocclusal relations are ideal, malocclusion and relapse are highly eventual in a short period after BSSO (17). In other words, the ideal condyle position is the key to maintaining occlusal stability after BSSO. On the other hand, incorrect positioning of the condyle causes malocclusion and relapse and long-term morphological changes, such as temporomandibular disorders (dysfunction, hypomobility, and hypermobility), condylar resorption and condylar atrophy (8, 18).

While the new position of the mandibular corpus is provided by intermaxillary fixation of the pre-prepared occlusal splint, many methods have been described for repositioning the mandibular condyle during the surgical procedure. Although some experimental methods, such as computer-aided orthognathic positioning systems, sonographic condyle positioning methods, or fixation of the ramus to the maxilla before the BSSO by a positioning screw or a miniplate before segmentation, seem useful, the conventional method which is a manual repositioning the condyle during the fixation procedure may be the most common technique preferred by surgeons (19). We should note that although it is still controversial, fixation provided by manual positioning is superior to other methods regarding both time management and postoperative results as long as it is performed by an experienced surgeon. However, minimized muscle contraction occurred due to general anesthesia and neuromuscular blockers complicate the repositioning maneuvers. For the repositioning, the proximal segment is pushed back from the lower point to make the condyle head positioned anteriorly, while the condyle is directed extraorally upward from the mandibular angulus to take it to the preoperative position (5).

Various repositioning methods have been developed and their common objectives are postoperative painless patient management and stable condyle position. Gerressen et al. compared repositioning systems with the manual positioning technique and concluded that using a repositioning device did not lead to an improvement in long-term skeletal stability (20). Bethge et al. concluded that sonographic condyle repositioning devices used intraoperatively were not more effective than manual repositioning, although they are fast, comfortable, and cost-effective (19). Sander et al. stated that the changes after manual condyle repositioning were minimal. Thus, intraoperative fixation of the condyles was time-consuming, unnecessary and caused extra costs (21).

Hollender et al. showed an especially anterior and inferior movement of the mandibular condyle head after the BSSRO procedure (22). Hu et al. reported that the mandibular condyle head moved backward and rotated anteriorly in patients who performed mandibular set-back with BSSRO (23). Kim et al. noted that although positional changes were observed in the mandibular condyle head after BSSRO procedures, there were no significant changes that would affect the patients clinically (24). Ruo-han Ma et al. superimposed the three-dimensional models they made and examined them at preoperative 1 week, postoperative 1 to 2 weeks, 3 months, 6 months and 12 months. They reported an initial change in the mandibular condyle position, but this change stabilized at three months postoperatively. In addition, they also reported that the condyles of most of the patients did not fully return to their preoperative position within a year after the operation (25). Jevgenija Podcernina et al. investigated condylar positional, structural and volumetric changes after bimaxillary or only maxillary orthognathic surgeries in skeletal Class III patients using CBCT. They found that the position of the mandibular condyles changed immediately after surgery in the only maxillary orthognathic surgery group. However, the mandibular condyles returned to their preoperative position at a one-year follow-up. They reported no significant difference in mandibular condylar position between preoperative and one-year follow-up in any of the study groups. They reported condylar rotation in the axial and coronal planes in the bi-maxillary surgery group. In their study, it was determined no radiological sign of condylar bone degeneration one year after the operation (26).

For changes in the axial plane, Choi et al. stated that an increase in the α angle, which is one of the references in our study, was observed in the initial examinations so that the mandibular condyle head rotated inward. However, it returned to the preoperative state in their subsequent examinations (1). Ueki et al. reported that inward or outward rotation of the condyle head could occur when tight fixation is made, but the inward rotation of the condyle head is more frequent (27). Lee et al. reported a rotation of the condyle head and that the proximal segment turned inward postoperatively (16). Kim et al. reported that the angle of the mandibular condyle head increased by 2.23° on the right and 2.18° on the left, as a result of which the mandibular condyles made the inward rotation (28). Nishimura et al. stated that in patients with mandibular prognathism, the lateral part of the mandibular condyle head rotates anteromedially due to internal fixation of the proximal segment, and there is less change in non-rigid fixation compared to rigid fixation (29). Kim et al. reported that the condyles were inclined to turn outward, but this turn did not reach a significant value (30).

This inward rotation of the head of the mandibular condyle, which occurs in the axial plane, is thought to occur while the screw is being inserted in the rigid fixation procedures during surgery. In this study, while the αL on the left condyle head was 20.3 ± 9.6 degrees at T0 time, it increased to 23.4 ± 7.7 degrees at T1 time, which means that the left condyle head rotates inward in the 6-month postoperative period. However, the increase for αR, valid for the right condyle, is not significant. These different results in the right and left mandibular condyle heads may be obtained because the operator is always in the same operating position on the patient's right during the surgery, and as a result, the direction and amount of force applied during the fixation phase are different. (1, 27)

For changes in the sagittal plane, in the study conducted by Choi et al., no significant change occurred in the pre- and postoperative period in the m/M ratio, which represents the horizontal movement of the mandibular condyle head. However, they reported a significant decrease in the initial time after surgery in the n/N ratio, which represents the vertical movement of the mandibular condyle head, so there was a vertical orientation to the superior. However, in their further postoperative examinations, they reported that the n/N value returned to the initial values, and they observed a return to the preoperative state of the mandibular condyle head (1). Ueki et al. reported no significant change in the anteroposterior direction after orthognathic surgery with BSSRO (27). Lee et al. reported that the condyle head moved down and forward, albeit in average small amounts, regarding the superoinferior and anteroposterior changes (16). Kim et al. concluded that the superior directional movement of both the right and left mandibular condyle head and the anterior directional movement of the right condyle were significant (30).

As a result of the comparison of the preoperative and postoperative CBCT data in the n/N and m/M ratios of this study, which will show the changes in the sagittal plane, there was no significant change in either the anteroposterior or the superoinferior direction. The results are in agreement with the literature. In addition, these results show that the manual positioning maneuver applied for positioning the mandibular condyle position during BSSRO procedures (directing the proximal part backward from the lower level of the vertical corpus osteotomy line and extraorally upward from the mandibular angulus) is sufficient to provide the initial anteroposterior and superoinferior relation of the mandibular condyle. It shows that the operation of any additional devices or processes during the operation is not necessary regarding cost, time and benefit to be obtained during the operation.

For changes in the coronal plane, in their study, Choi et al. reported that the condyle head angle (β angle) in the coronal plane decreased in the early period examinations after BSSRO (1). Choi et al., in another study, reported that as a result of the examination, it decreased by 0.65 on the right and 0.5 on the left (31). Kim et al. in their study reported that the condyle head angle decreased by the same mean of 0.92° on both sides (30).

In this study, the findings showed that while the right condyle head (βR) was 17.6 ± 10.4 degrees at T0 time, it was 14.1 ± 9.6 degrees at T1 time, and this decrease was significant. In addition, while the left condyle head (βL) was 16.5 ± 9.7 degrees at T0 time, it increased to 18.5 ± 9.7 degrees at T1 time. However, it has been shown statistically that increase is not a significant change in the postoperative period compared to the preoperative period. The decrease in the β angle of the right condyle head showed that the right condyle head was outward rotated. This result is compatible with the literature. In addition, we think that both the effects of the fixed position of the operator during the operation, which also affect the axial plane and the direction and amount of the force during the fixation processes are effective on this outward rotation.

For the change in the distance between the most medial points of the condyle heads examined in the coronal plane, Choi et al. reported that the distance between the condyle heads between the groups with high and low asymmetry due to menton deviation showed a minimal increase in the early postoperative examinations. Statistically, there was an increase only in the group with less asymmetry. However, they reported that it tended to return to the initial distance range in further investigations (1). Choi et al., in another study, reported no significant difference although the distance between the condyles tended to increase (31). Lee et al. reported that the distance between the preoperative and postoperative condyle heads after BSSRO in the non-severe and severe asymmetry groups was clearer in severe asymmetry cases than in non-severe cases, but there was a significant difference in the direction of increase (32).

In the change of intercondylar distance (distance C), which includes another examination of this study in the coronal plane, while it was 83.9 ± 7.4 mm at T0 time, it was 83.9 ± 7.2 mm at T1 time. The percentage change in the distances seen in this study was an indication that there was no significant change, which showed that the distance between the right and left mandibular condyle heads did not change in the pre- and postoperative periods when compared. Given the literature review, this finding is consistent with the results that the distance between the mandibular condyle heads tends to return to the initial distance in post-operative examinations.

Conclusion

In our study, the position change of the mandibular condyle head before and after the operation in orthognathic surgery patients with BSSRO applied in addition to the orthodontic treatment of patients with mandibular prognathism was investigated. The following results within the limits of the present study are:

1. With the manual positioning method we apply during BSSRO procedures. It can be positioned at the same point as the preoperative position of the mandibular condyle without any displacement in the anteroposterior and superoinferior directions in the sagittal plane.
2. The inward rotation of the left mandibular condyle head in the axial plane and the outward rotation of the right condyle head in the coronal plane, which we obtained in the results of our study, are compatible with the literature. These:

• To stress occurring between segments in fixation processes

• No bending in fixation materials

• Failure to provide passive compatibility of fixation materials

• Direction and amount of force applied for fixation

• To contacts or interferences between proximal and distal segments

• To operator working always in the same position relative to the patient during the operation considered to be connected.

The limitation of this study is that we cannot have information about the positions of the mandibular condyles in the early and late stages after the operation since CBCT data in this study have been obtained from the patients according to the ALADA principles, before the operation and six months after the operation as long as no complications develop. However, the present results are compatible with the studies in the literature.

Declarations

Ethics approval and consent to participate: Approval was obtained from the ethics committee of Istanbul University Faculty of Dentistry with the file reference number 2021/02. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Consent for Publication: The publication consent form was obtained from all participants to be published in the study.

Availability of data and materials: The patient list was obtained from the patient archive of the Department of Oral and Maxillofacial Surgery of Istanbul University. The radiographic records of the patients included in the study were obtained from the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Istanbul University. DICOM data of preoperative and 6-month postoperative CBCT radiographs of the patients were retrospectively used in the study. In the study, the data were measured using 3D Slicer, Slicer Wiki software application.

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Authors’ Contributions:

Erol Cansız: Conceptualization, Methodology, Supervision, Resources, Writing - Review & Editing.

Osman Küçükçakır: Conceptualization, Methodology, Software, Validation, Investigation, Data Curation, Writing - Original Draft, Visualization.

Sabahat Zeynep Yey: Writing - Review & Editing.

Merve Öztürk: Writing - Review & Editing.

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Figures

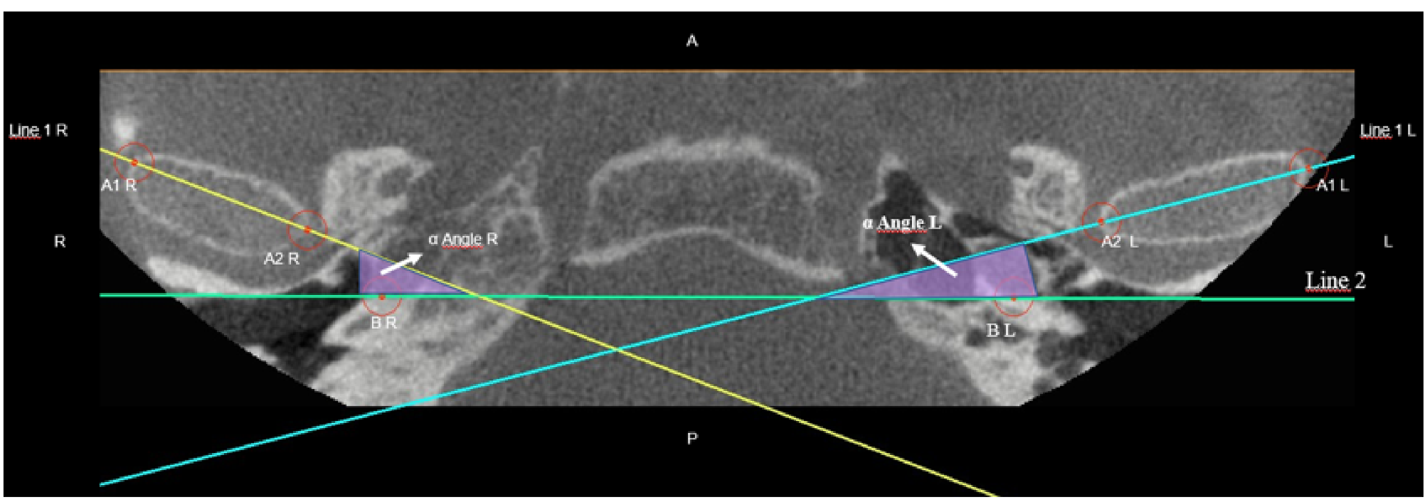

Figure 1

Landmarks specified on the computed tomography images to quantify the positions of the condylar heads for the axial plane. A1R: Lateral pole of the right condyle head. A1L: Lateral pole of the left condyle head. A2R: Medial pole of the right condyle head. A2L: Medial pole of the left condyle head. BR: The most posterior point of the right carotid canal. BL: The most posterior point of the left carotid canal. Line 1R: The line which is passing through points A1R and A2R. Line 1L: The line which is passing through points A1L and A2L. Line 2: The line which is passing through points BL and BR. *α* angle R: The angle formed between Line1R and Line 2. *α* angle L: The angle formed between Line1L and Line2.

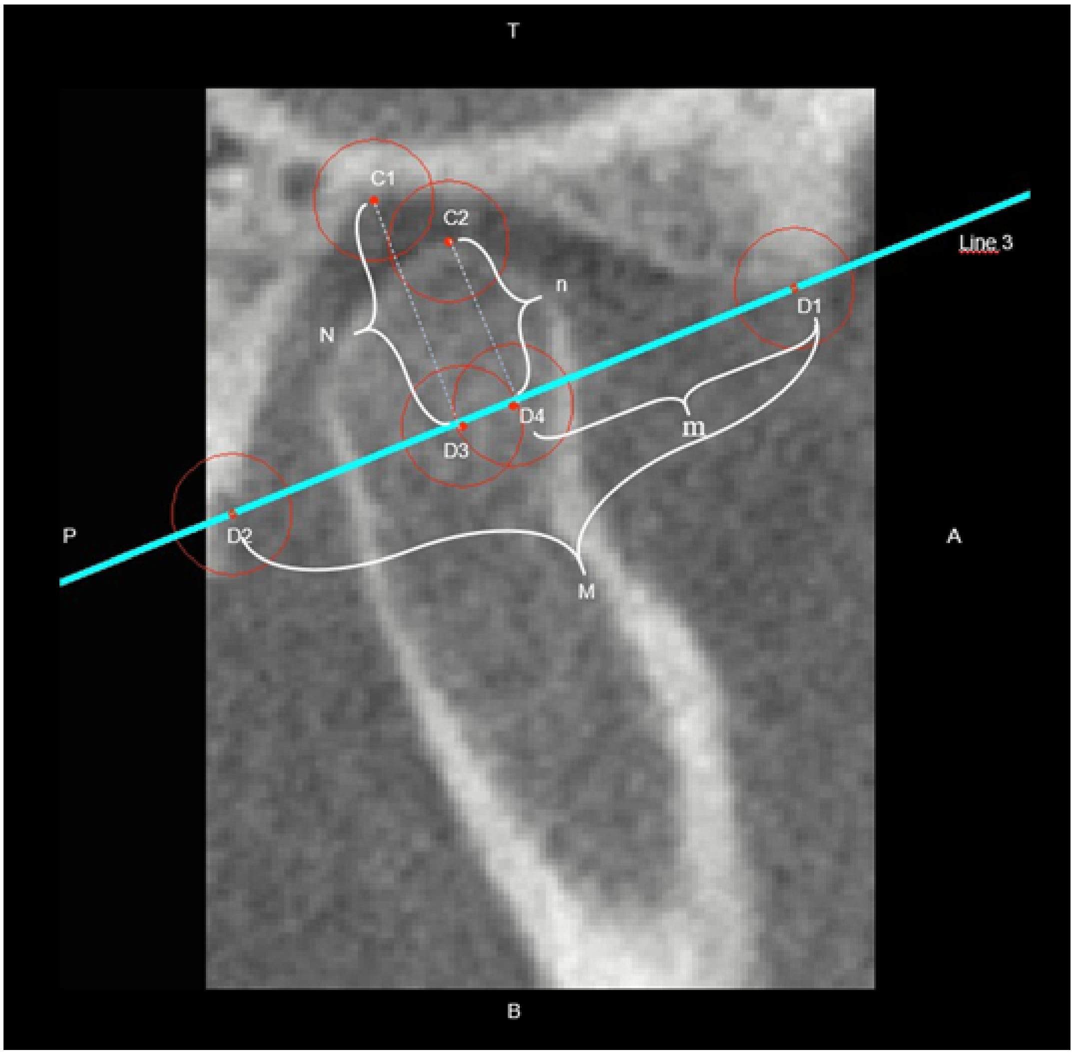

Figure 2

Landmarks specified on the computed tomography images to quantify the positions of the condylar heads for the sagittal plane. C1: The highest point of the glenoid fossa. C2: The highest point of the condyle head. D1: The lowest point of the articular eminence. D2: The lowest point of the temporal squamotympanic fissure. D3: The point of the line drawn perpendicular to Line 3 from point C1. D4: The point of the line drawn perpendicular to Line 3 from C2. *M* is the distance between D1 and D2, *m* is the distance between D1 and D4, *N* is the distance between C1 and D3, and *n* is the distance between C2 and D4.

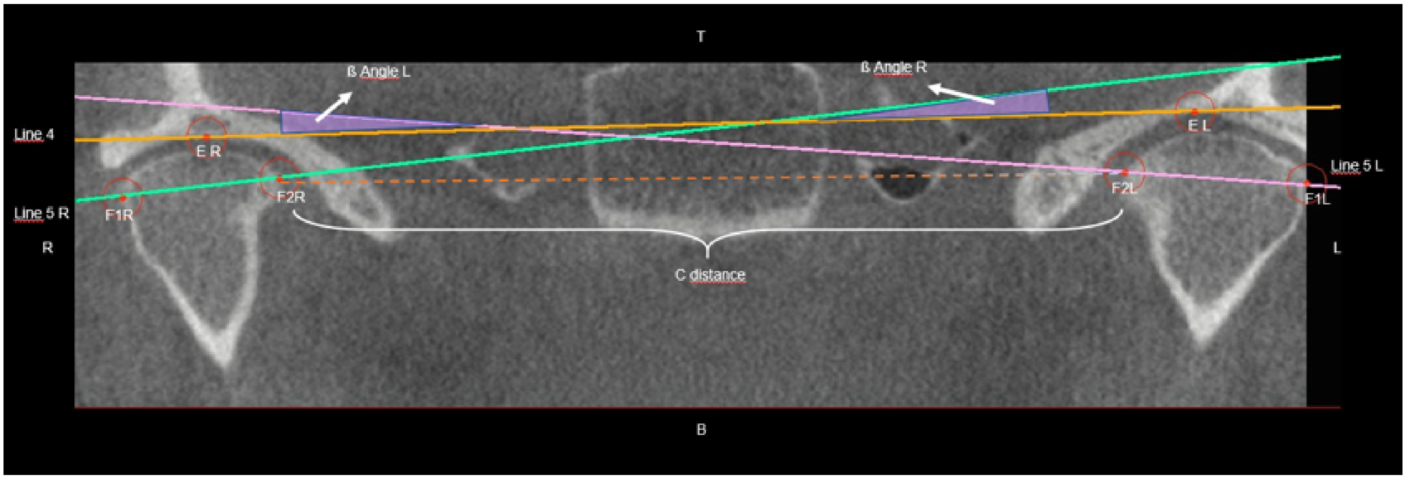

Figure 3

Landmarks specified on the computed tomography images to quantify the positions of the condylar heads for the coronal plane. ER: The highest point of the right glenoid fossa. EL: The highest point of the left glenoid fossa. F1R: The lateral pole of the right condyle head. F1L: The lateral pole of the left condyle head. F2R: The medial pole of the right condyle head. F2L: The medial pole of the left condyle head. Line 4 passes through ER and EL, Line 5 R passes through F1R and F2L points, and Line 5 L passes through F1R and F1L points. β Angle R is the angle between Line 4 and Line 5 R, β Angle L is the angle between Line 4 and Line 5L, and C is the distance between F2R and F1L points.

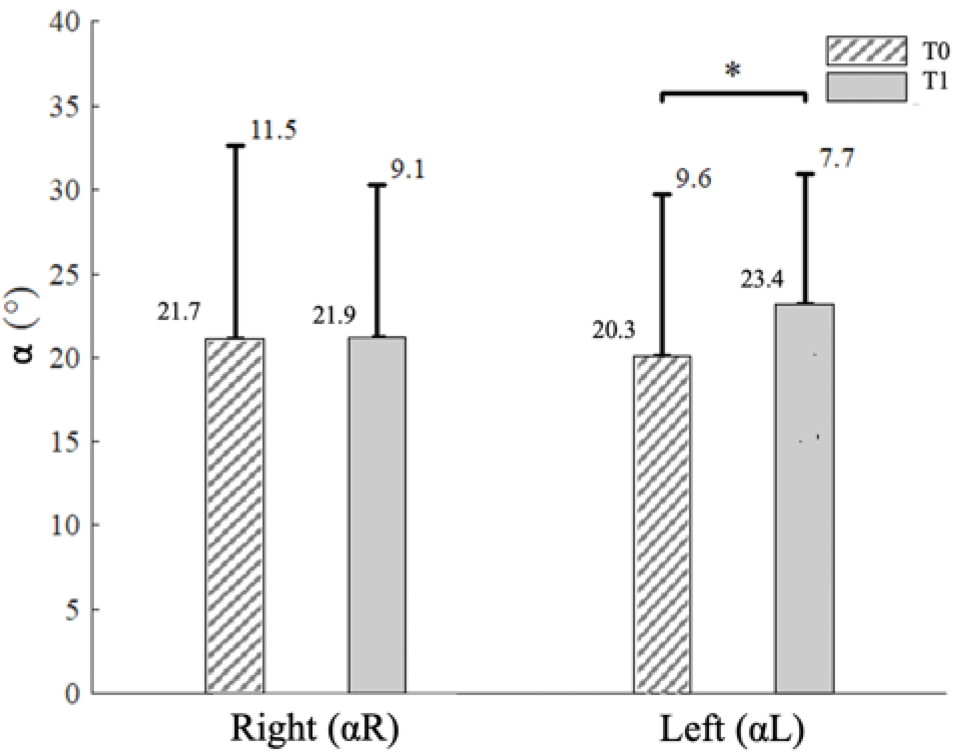

Figure 4

Comparison of the pre- and postoperative angle α. It is the angle between Line1 (passing through the lateral and medial pole points of the condyle head) and Line 2 (passing through the rearmost points of the right and left carotid canal) in the axial plane. * indicates statistical significance between the related pairs.

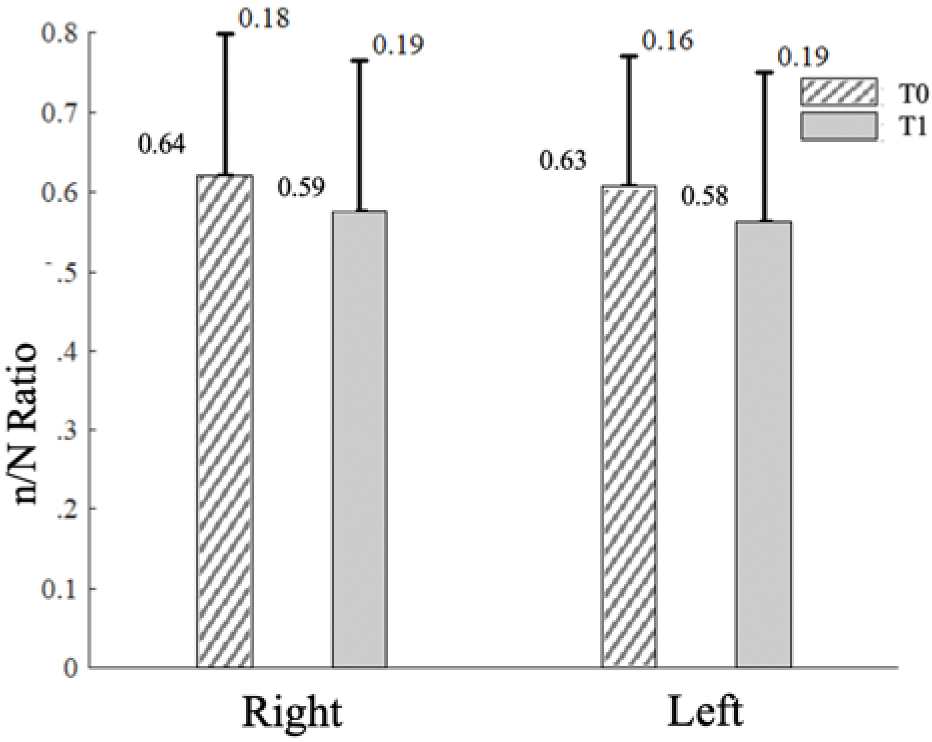

Figure 5

Comparison of the pre- and postoperative n/N ratio. *n/N*: vertical evaluation rate of the mandibular condyle in the direction of the glenoid fossa.

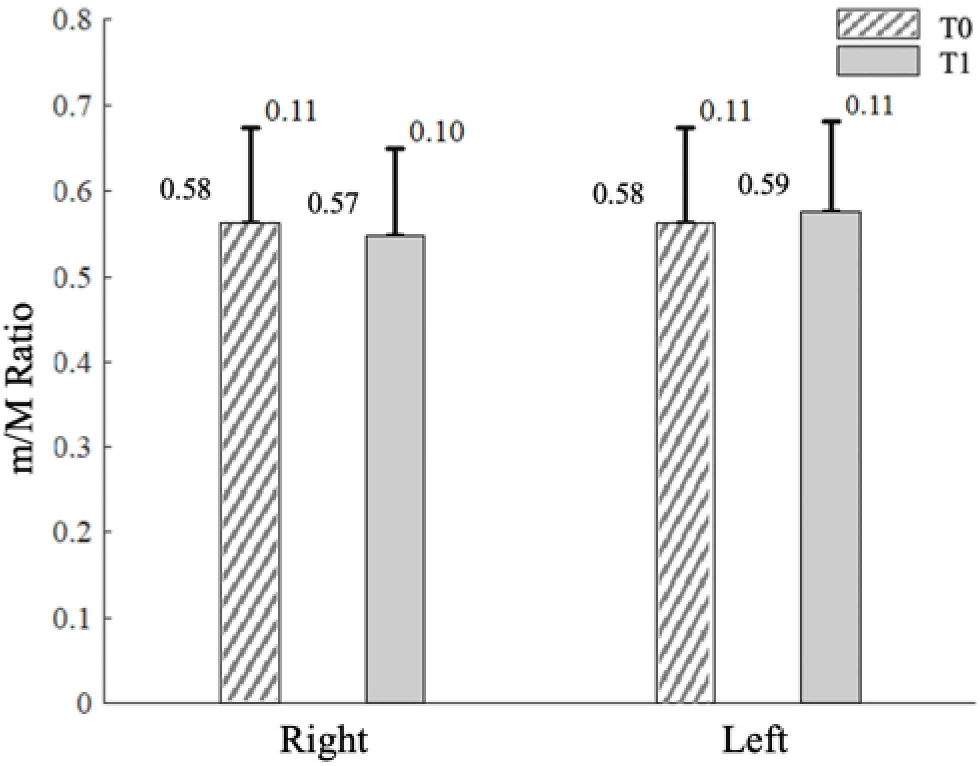

Figure 6

Comparison of the pre- and postoperative m/M ratio. *m/M*: horizontal evaluation rate of the mandibular condyle in the direction of the glenoid fossa.

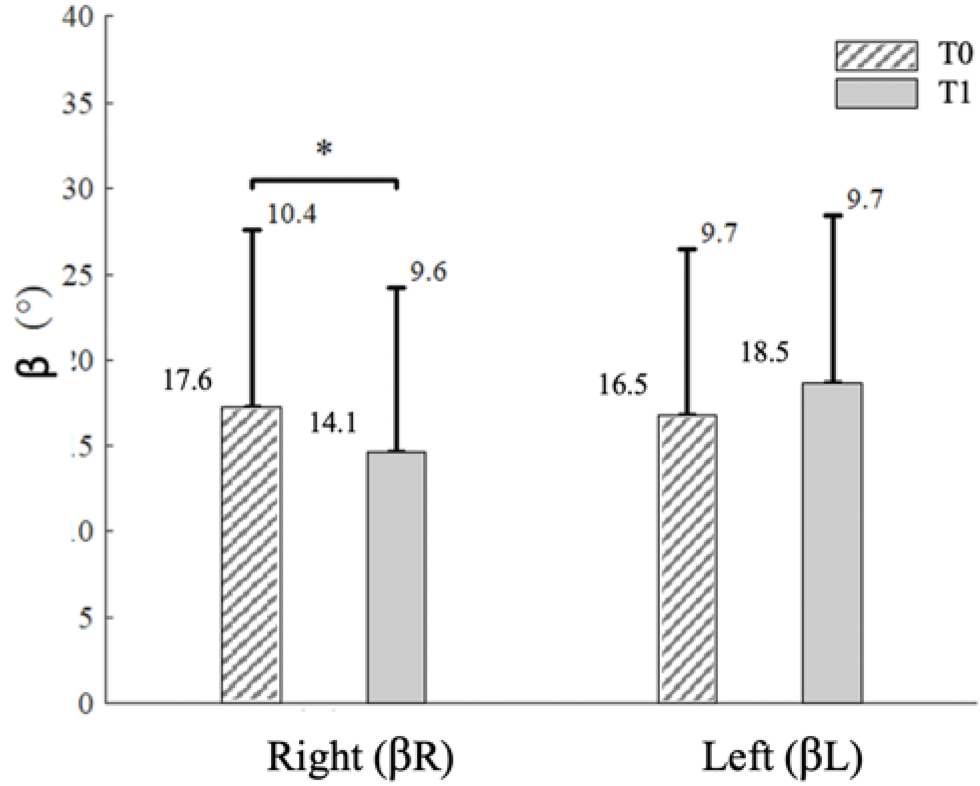

Figure 7

Angle β. It is the angle between the line passing through the lateral and medial pole points of the condyle head and the line passing through the highest points of the right and left glenoid fossa in the coronal plane. * indicates statistical significance between the related pair.

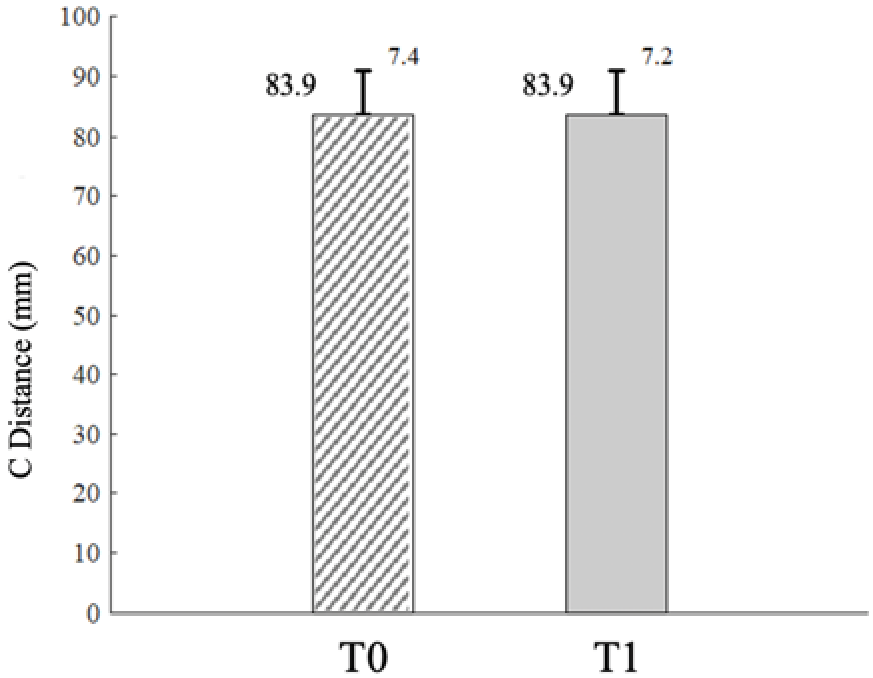

Figure 8

The distance (C) between the right and left lateral pole points of the condyle heads.