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Three-Dimensional Cephalometric Analysis: The Changes in Condylar Position Pre- and Post-Orthognathic Surgery With Skeletal Class III Malocclusion

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Abstract: The study includes 21 adult patients with skeletal class III malocclusion who underwent orthognathic surgery and had computed tomography images records presurgery (T0) up to 6 months after the surgery (T1). The computed tomography images were analyzed three-dimensionally using the Proplan CMF 3.0 software. Different skeletal and dental parameters were used in analyzing the cephalometric analysis of the patients. The change in the condylar axis angle was evaluated on 3 planes: axial, coronal, and sagittal. The anteroposterior position of the condyle in relation to the glenoid fossa was evaluated in the sagittal plane. ∠SNB, ∠ANB, ∠Left *Y*-axis, ∠Right *Y*-axis were statistically significant ($P < 0.01$). Significant differences on the condylar axis angle were found between the groups on the sagittal plane ($P < 0.05$) whereas no significant differences were noted on the axial and the coronal plane. In the anteroposterior condylar position related to the glenoid fossa, the condyle exhibited different displacement on different condyles. The right condyle exhibited more of the posterior displacement whereas the left condyle exhibited more of anterior displacement of the condyle in relation to the glenoid fossa. Numerous studies have done regarding the changes after postsurgery using the two-dimensional cephalometric analysis. Using the 3D techniques helps us to identify the cephalometric point more accurately which thus enhances the accuracy in the cephalometric analysis. However, care should be taken not to change the axis of rotation of the condyle to prevent from the treatment relapse and to avoid temporo-mandibular disorders.

Key Words: 3D Cephalometry, condyle, orthognathic surgery, skeletal class III malocclusion

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The assessment of the cranio-facial structures forms a major part of the orthognathic diagnosis. Cephalometrics has established itself as one of the pillars of comprehensive orthodontic-orthognathic diagnosis and it also aids in treatment planning and follow up of the patients undergoing orthodontic-orthognathic treatment. Cephalometrics helps in the study of skeletal, dental, and soft tissue structures of the craniofacial region, helps in the classification of the skeletal and dental anomalies and establishes the facial type and also in predicting the growth-related changes and changes associated with the surgical treatment.[1,2]

Traditionally skeletal and soft tissue changes following the orthognathic surgery have been assessed in 2 dimensions by superimposing the pre and the postoperative cephalographs on the stable structures of the face such as the anterior cranial base or by comparing the linear and the angular cephalometric measurement.[3] Quantifying the surgical changes using three dimensional images follows the same method as traditional 2 dimensional analysis with the addition of the third dimension (the depth) which augments the amount of information obtained from the facial image. Recent advancement in imaging technology and computerized 3D computed tomography (CT) images has simplified the process of 3D planning by incorporating a computer assisted surgical procedure which has improved in the precision of the orthognathic surgery.[4,5]

Skeletal class III malocclusion is considered as one of the easiest to identify but most difficult to treat, that is the reason it is also called as complex and intractable orthodontic disorders.[6] It exhibits as the maxillary retrusion, mandibular protrusion or a combination of both with a concave facial profile. Facial asymmetry has been detected in 40% of patients with skeletal class III malocclusion.[7] Asymmetrical surgical movement of the jaw can change the postoperative position of the mandibular condyle.[8]

The prevalence of skeletal class III malocclusion is relatively high in the Chinese population than other ethnic group. Prevalence of class III malocclusion in Caucasians ranges from 0.8% to 4.0% and rises up to 12% to 13% in Chinese and Japanese populations.[9,10] It not only affects the oral function such as chewing and deglutition but also affects the overall facial esthetics and tends to get worse as the age increases. Several distinct cephalometric features have been reported in class III patients, such as a short anterior cranial base length, acute cranial base angle, a short and retrusive maxilla,

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proclined maxillary incisors, retroclined mandibular incisors, an excessive lower anterior face height and obtuse gonial angle.[11,12]

These complex cases require careful treatment planning, an integrated approach and patient cooperation. A poor facial appearance is often the patient's chief complaint, but it may be accompanied by functional problems, temporomandibular disorders, or psychosocial handicaps.[13–15] Maxillary advancement, mandibular setback and bimaxillary osteotomy are the 3 basic options to correct the deformity. Patient undergoing orthognathic surgery shows a considerable amount of changes both in the hard tissues and soft tissues. The maxilla and mandible are reoriented during the orthognathic surgery. The soft tissues are also changed with respect to the hard tissue 3 dimensionally. Generally the facial esthetics are improved after the surgery but these changes are judged mainly by the changes in the soft tissues as well.[5]

The optimum position of the condyle in dentistry has always been a controversial issue. There are various studies which define the optimum position of the mandibular condyle for prosthetic rehabilitation.[16,17] In a radiographic study, Ricketts reported that most of the patients with temporomandibular joint (TMJ) disorders was concentric.[18] Ikeda et al in limited cone beam computed tomography assessed symptoms free subjects who had no disk displacements as verified by magnetic resonance imaging, and showed that the ratio of the position of the condyle to the glenoid fossa (anterior space to superior space to posterior space) was 1.0 to 1.9 to 1.6.[19]

During the orthognathic surgery, proper condylar positioning is one of the most important factors in postoperative stability. Changes mostly occur in the position of the mandibular condyle, the articular disc and the paradiscal tissues. If there is an inappropriate condylar placement of the TMJ, it can result in many postoperative complications which may further result in idiopathic condylar resorption, different functional disorders and in a long time may result in post-operative relapse.[20–22] Knowing the condylar movement after the orthognathic surgery can help prevent postoperative instabilities. There are different factors contributing to the change in condylar position during orthognathic surgery. These factors mainly include the posture of the patient during surgery, the orientation of the muscles of mastication, the use of muscle relaxants, improper rigid fixation, faulty fixation methods, intracapsular bleeding of the TMJ, and edema formation of the TMJ, internal derangement or a combination of all these factors.[23]

AIM OF THE STUDY

The purpose of this study is to evaluate the pre and postsurgical cephalometric findings, investigate the condylar axis angle on different planes and the changes in the anteroposterior position of the mandibular condyle of severe skeletal class III malocclusion by three-dimensional approach.

MATERIAL AND METHODS

Inclusion Criteria

1. Skeletal class III malocclusion (ANB angle$<$-3°).
2. Age of the patient $>$18 years old.
3. Complete case history with pre and post treatment CT data, photographs, lateral and frontal cephalogram, orthopantomogram.
4. Informed consent signed by the patient and the family members to take part in the clinical research.

Exclusion Criteria

1. Patient with congenital abnormalities such as cleft lip and palate and any other associated syndromes.
2. Patient suffering from systemic diseases (Diabetes, Hypertension, Pulmonary Disorders, Bronchial Asthma, Allergies).
3. No any history of trauma to the jaw.
4. No any history of temporomandibular disorders.

Clinical Data

A retrospective study was performed in adult patients aged 18 to 35 years (Mean: 24 years) with skeletal class III malocclusion (Mean∠ANB:-4.05°) who had undergone orthognathic surgery from the study period from March of 2014 to April of 2017.

Computed Tomography Assessment

For all the subjects, we obtained CT to assess the craniofacial structures, the cephalometrics, the position of the mandibular condyle, skeletal and occlusal changes before surgery (T0) and 6 months after surgery (T1) (Figs. 1–4). These CT images were taken on Phillips 256-slice helical CT system (Phillips company, Netherlands) from 923 hospital (formerly called 303 Hospital of Nanning). Patients were trained to bite in a centric relation before obtaining the CT images and the clinician confirmed the mandibular position before acquiring the CT images. DICOM images of the coronal, axial, and sagittal views were generated and analyzed in the Proplan CMF 3.0 software. The axes of the coordinates in a 3D image (0, 0, 0) represented the Nasion. Four landmark points (PoL, PoR, OrR, OrL) based on the FH plane were indicated to set the natural head position (Supplementary Digital Content, Table 1, http://links.lww.com/SCS/B674).

Cephalometry Wizard

The Cephalometry wizard were used to indicate the anatomical landmarks to perform a Cephalometric analysis. The analyses used were Condyle Points, Downs, Frankfurt, Steiner and Tweeds.

Measurement of Skeletal Changes

In this study, reference planes and points were determined (Supplementary Digital Content, Table 2, http://links.lww.com/SCS/B675). Three different planes constructed are FH plane, mid sagittal reference plane and coronal plane.

Measurement of Condylar Axis Changes

To evaluate changes in the condylar axis, the angular measurement on 3 different planes were obtained according to the reference planes (Supplementary Digital Content, Table 3, http://links.lww.com/SCS/B676).

Measurement of the Antero-Posterior Condylar Position in the Glenoid Fossa

The spaces between the mandibular condyle and the glenoid fossa were used on the sagittal multiplanar construction image, which was parallel to the mid sagittal reference plane passing through the center of the condyle. Anterior and the posterior space was measured on the sagittal plane with a value 4 times enlarged multiplanar reconstruction image. The lines tangent to the most prominent anterior and the posterior aspects of the mandibular condyle were drawn from the most superior aspect of the glenoid fossa on the reference plane. Anterior and posterior distances were measured from the most prominent anterior and posterior points of the condyle to the glenoid fossa.

These values were transferred to the Pullinger formula [24]

$$\frac{Posterior\ space - Anterior\ space}{Posterior\ space + Anterior\ space} \times 100$$

This equation determined the percentage of anterior or posterior displacement of the condyle, with concentricity as a reference. A score of −12 approximately to +12 indicated concentricity, with less than −12 indicating a posterior position, and more than +12 indicating an anterior position (Supplementary Digital Content, Table 4, http://links.lww.com/SCS/B677).

Statistical Analysis

Error of method: The reliability of obtaining measurement on CT images was computed using Dahlberg formula[25] for the determination of the standard error was applied for the double determination, and the standard errors were expressed in degrees and millimeters. The formula is:

$$S_e^2 \sum d^2/2n$$

S_e is the standard deviation of the differences of each of the replicates from the mean, n is the number of CT measurements, and d is the difference between the primary and the secondary data. The standard error of the angular measurement was found to be 0.41°.

Comparison of the presurgery and the postsurgery groups were done by comparing the means of these groups. Paired *t*-test were done to analyze the statistical differences among these groups. Data were statistically analyzed using IBM SPSS version 23.0 for windows.

RESULTS

Among the 21 patients, 19 patients underwent bilateral split sagittal ramus osteotomy (BSSRO) 1 patient underwent intraoral vertical ramus osteotomy and 1 patient underwent unilateral sagittal split ramus osteotomy. Out of the 19 patients undergoing BSSRO, 8 patients underwent BSSRO followed by Genioplasty whereas, 11 patients underwent only BSSRO. Out of 21 patients, 16 patients were found to have the deviation of the mandible either to the right or left with asymmetrical facial proportion.

After the surgery no patient had any evidence of wound infection, bone instability, malunion or long-term malocclusion. Significant differences were observed between the pre and the postsurgery groups in different skeletal parameters. There was a remarkable improvement in the skeletal facial profile after orthognathic surgery. Significant changes were observed in both SNB and ANB ($P < 0.01$) suggesting that these values improved significantly close to the normal values (Supplementary Digital Content, Table 5, http://links.lww.com/SCS/B678). Significant differences were observed on the growth axis or the *Y*-axis (both right and the left) ($P < 0.01$) achieving the mean value of the skeletal class I growth axis pattern. However, no significant differences were observed in SNA as no any surgical procedure were performed on the maxilla.

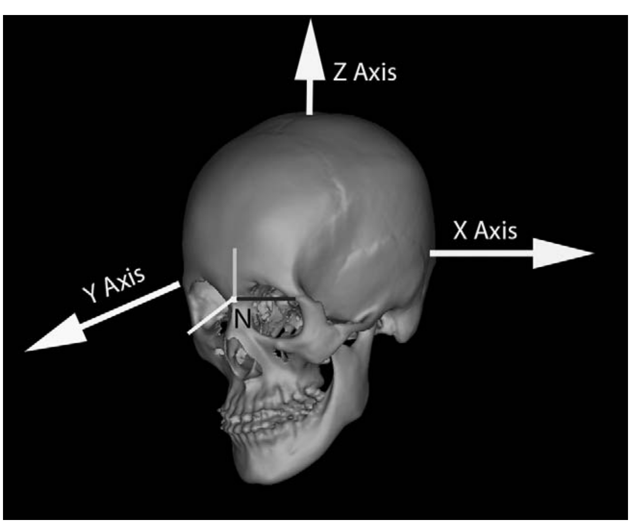

FIGURE 1. Axes of coordinates in a 3D image. The (0, 0, 0) coordinate represents the Nasion, and the negative and positive directions in the *x*, *y*, *z* axes representing the left and right, forward and backward, and up and down, respectively and the Cephalometry wizard on Proplan.

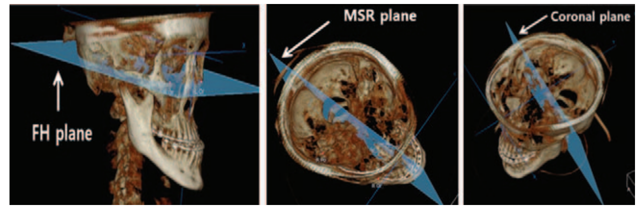

FIGURE 2. Figure showing the different reference plane used in the study.

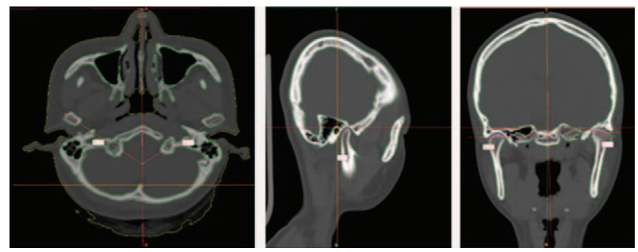

FIGURE 3. Condylar axis angle on multiplanar reconstruction images. Axial condylar axis angle, sagittal condylar axis angle, and coronal condylar axis angle.

The distribution of the different condylar axis angle is shown in Figures 5D and 6A to C. After the careful evaluation of the condylar axis on the 3 planes there was significant differences between the pre and the postsurgical group on the sagittal plane ($P < 0.05$). However, no significant differences were noted on the axial and the coronal plane (Supplementary Digital Content, Table 6, http://links.lww.com/SCS/B679). There was a decrease in the axial and the coronal condylar axis angle suggesting that there was an inward rotation of the condyle. However, the change is found to be statistically not significant. Whereas in the sagittal view the angle is increased suggesting that there was an anterior displacement of the condyle.

Both anteroposterior condylar position related to the glenoid fossa were changed from the presurgery and the postsurgery groups (Supplementary Digital Content, Table 7, http://links.lww.com/SCS/B680). The condyle exhibited different displacement on different condyles (Fig. 6D). The right condyle exhibited more of the posterior displacement whereas the left condyle exhibited more of

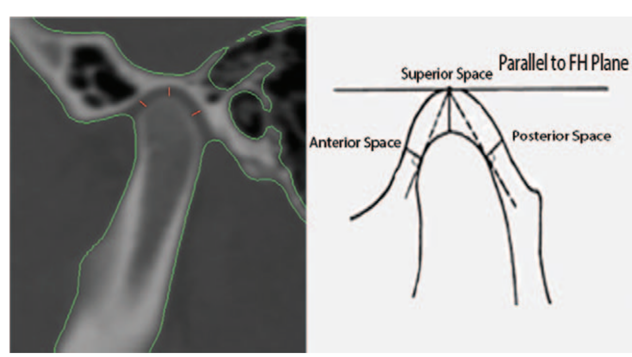

FIGURE 4. Antero-posterior condylar position in the glenoid fossa in multiplanar reconstruction images.

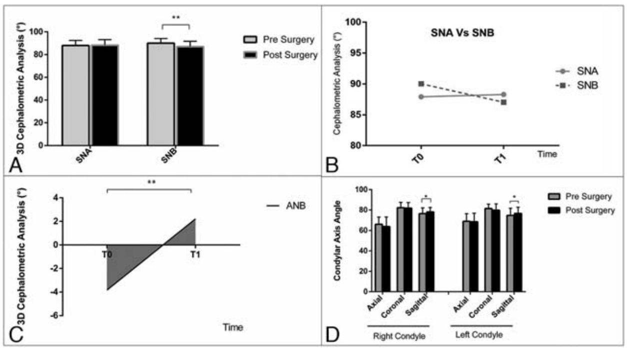

FIGURE 5. A, 3D Cephalometric analysis results in the pre and postsurgery group. **Indicates significance difference ($P < 0.01$). B, 3D Cephalometric analysis showing SNA versus SNB in the pre and postsurgery groups. T0, before surgery; T1, 6 months after surgery. C, Difference is the ANB angle analysis result in pre and postsurgery groups. T0, before surgery; T1, 6 months after surgery. **Indicates significance difference ($P < 0.01$). D, Condylar axis angle analysis results in the pre and postsurgery group. *Indicates significance difference ($P < 0.05$).

an anterior displacement of the condyle in relation to the glenoid fossa.

DISCUSSION

Patient undergoing orthognathic surgery shows a considerable amount of changes in the hard and the soft tissues. The facial esthetics are improved significantly in the case of mandibular prognathism. Jung et al reported that after the surgery mandibular prognathism was significantly corrected and 3D evaluation shows a significant differences in the hard tissues as well as the soft tissues.[26] Wang et al in 2009 reported that in their study between pre surgery and postsurgery cephalometric analysis except N-S-Ar, N-S-Ba, N-S-Go, NBa-PtGn and *Y* axis, other discrepancies all had statistical differences ($P < 0.05$).[27] Our study also showed that most of the cephalometric analysis except SNA were found to be statistically significant. Three dimensional cephalometric analyses showed that SNB angle changed from ($90 \pm 4.12°$) to ($87.05 \pm 4.63°$) ($P < 0.01$) indicating that the backward displacement of point B improved significantly close to the normal. Similarly, ANB angle was improved from ($-3.83 \pm 1.85°$) to ($2.21 \pm 1.37°$) indicating that the relationship of the mandible to the maxilla improved significantly ($P < 0.01$) to the skeletal class I facial type. Most of the surgeries were performed on the lower jaw rather than the upper jaw, so least changes were expected in the upper jaw.

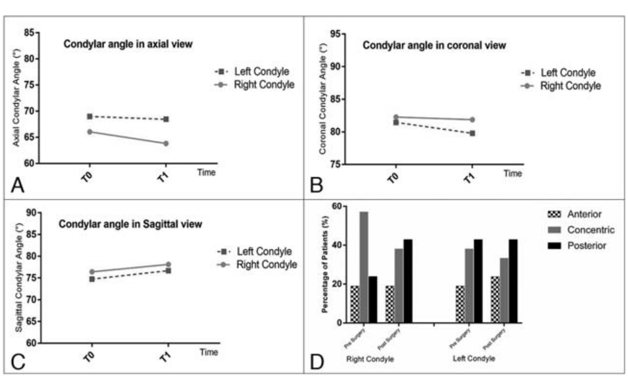

FIGURE 6. A, Axial condylar angle in axial view. T0, before surgery; T1, 6 months after surgery. B, Coronal condylar angle in the coronal view. T0, before surgery; T1, 6 months after surgery. C, Sagittal condylar angle in sagittal view. T0, before surgery; T1, 6 months after surgery. Significant differences *($P < 0.05$) were observed in the Sagittal Condylar Angle. D, Anteroposterior condylar position in presurgery and postsurgery groups in the anterior, concentric, and posterior position.

Orthognathic surgery is likely to cause changes in the postsurgical condylar position and has been reported to have potential for idiopathic condylar resorption, functional disorder, and postsurgical relapse. Although there have been many studies on changes in condylar position after the orthognathic surgery, most have investigated the changes within a 6 month period of time after surgery and investigations were record with the help of 2 dimensional radiography and among them also very few cases have been reported amongst the patient with skeletal class III malocclusion.[28–30]

Wang et al in 2016 reported that fusing of the CBCT and 3D images used as a new method in evaluating the soft and the hard tissue changes after orthognathic surgery was feasible and accurate.[31] The virtual 3D composite craniofacial models permitted concurrent assessment of hard and soft tissues during the diagnosis and treatment planning.

Many studies have reported that condylar axis rotation after surgery, and the effects of sagittal split ramus osteotomy (SSRO) / transoral vertical ramus osteotomy and rigid fixation/non rigid fixation. Ueki et al in 2007 assessed the change in the condylar long axis and the skeletal stability following SSRO and intraoral vertical ramus osteotomy for mandibular prognathia.[29] Frey et al in 2008 suggested that all the symptoms after SSRO tend to decline over time and the amount of advancement and mandibular rotation should not be considered as risk factors for the development of temporomandibular disorders in patients without preexisting conditions.[30]

There are few studies concerning the anteroposterior position of the condyle related to glenoid fossa using 3D computed tomography. Published studies on postoperative changes of the mandibular condyle have mostly been performed using the traditional two-dimensional radiography with limited findings. Recent efforts to overcome such limitations include the use of three-dimensional cone beam volumetric imaging. The cone beam volumetric imaging is found very useful for measuring and assessing the complex anatomical structures such as the TMJ.[32]

Numerous studies have been conducted to evaluate the result of various different surgical techniques and postsurgical therapies to minimize relapse. Considering the horizontal condylar axis changes after the mandibular orthognathic surgery influences the stability, Ueki et al in 2005 reported that when rigid fixation is used, improper positioning of the proximal segment can cause various different problems including TMJ dysfunction.[22] They reported that immediately after the surgery the SSRO group consistently showed a trend towards an increased angle of the condylar long axis, which showed a tendency to decrease slightly with time.

Kawamata et al in 1998 evaluated the pre surgical and the postsurgical condylar position using a jaw bone based model based on the pre and the postsurgical CT images of patients with mandibular prognathism.[33] They found that the condyle moved backward whereas in our study we found that there is an increase in the sagittal condylar axis suggesting the forward movement of the condyle ($P < 0.05$). Kim et al in 2013 reported that both the axial condylar angles rotated inward after SSRO and tend to turn outward even when its rotation was small, however the amount of outward rotation was not statistically significant.[20] In our case we found out that there was a decrease in the axial and the coronal axis angle suggesting there was an inward rotation of the condyle. In a different study done be Kim et al in 2010, changes of the condylar axis in the coronal and the sagittal views showed statistically significant differences that tend to decrease.[18] Moreover such condylar position changes during the postsurgical maintenance period were shown to be similar to the findings of Ghang et al in 2013.[34]

Freihofer et al in 1975 showed that condyles appeared to be positioned anteriorly in the glenoid fossa.[35] Similarly, Will et al in 1984 found that both condyles were positioned posteriorly in patients who underwent SSRO to advance the mandible.[36] However, Hackney et al in 1989 found no correlation between the amount of mandibular advancement and changes in the condylar position or mandibular shape.[37] Hu et al in 2000, suggested that posterior displacement and forward rotation of the condyle after mandibular setback resulted from the tension of the temporalis and masseter muscle.[38] Lee and Park in 2002 reported that the mandibular condyle was located more anteriorly after the mandibular setback and was related to overcorrection.[39]

Following Pullinger method for the assessment of the anteroposterior condylar position in the glenoid fossa, the condyle was categorized into 3 groups: anterior, concentric, and posterior position.[24] Many studies showed that condylar position was changed after the orthognathic surgery or that there was no change.[40–43] Alhammadi et al in 2016 investigated the 3D changes in the anteroposterior position of the mandibular condyle as well as the joint space parameters following the maxillary first premolar extraction in skeletal class II patients using the Pullinger method and found that there was a statistically significant posterior position of the condyle with relation to the vertical plane.[44] However in ours the right condyle exhibited more of a posterior displacement and left condyle exhibited more of an anterior displacement. This may be due to the reason as the patients included in our study most of them had a lower face deviation either to the right or left and also the surgical procedure performed are also different so different displacement of the condyle was expected. Wang in 2016 conducted a similar study as ours using Proplan CMF 1.2 to analyze the changes in the facial symmetry and TMJ structures at different periods of after intraoral condylectomy combined with orthognathic surgery and concluded that the condylar axis angle on horizontal plane gradually grew and the condyle moved slowly upward on both sides. They also assessed the anteroposterior position of the condyle by using the Pullinger method and the result obtained were as similar to ours.[45]

CONCLUSION

The results of this study suggest that with increasing in the advancement of the imaging technology 3D analysis helps the surgeon in visualizing the hard and the soft tissues way better than the traditional approach. This study shows that after orthognathic surgery there was a remarkable improvement in the facial profile of skeletal class III malocclusion. This study also suggest that the condyle tend to move in a certain direction after surgery and this movement can influence the treatment outcome of the patient on a long run. However, care should be taken not to change the axis of rotation of the mandibular condyle to prevent from the treatment relapse and to avoid different temporo mandibular disorders. Although this study yielded significant results over a period of 6 months after surgery, it was performed in a very limited number of patients. Further research on changes in the condylar position is needed with a longer observation period, considering various factors such as occlusion and the fixation method. For more accurate comparison, the relationship between the mandibular condyle and the articular disk should be recorded by magnetic resonance imaging.

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