Original Article

Effects of orthodontic camouflage treatment vs orthodontic-orthognathic surgical treatment on condylar stability in Class II hyperdivergent patients with severe temporomandibular joint osteoarthrosis: a retrospective observational study

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ABSTRACT

Objectives: To investigate the differences in profile changes and stability of the condyles between orthodontic camouflage treatment assisted by vertical control and that accomplished via orthognathic surgery in Class II hyperdivergent patients with TMJ osteoarthrosis (TMJOA).

Materials and Methods: This study included 27 Class II hyperdivergent TMJOA patients (54 condyles) who received orthodontic camouflage treatment (13 patients) or orthognathic surgery (14 patients) Cone-beam computerized tomography (CBCT) scans were taken before treatment (T1) and 1 year after treatment (T2). Cephalometric and TMJ measurement analyses were conducted to evaluate the change in profile and condyles from T1 to T2 using independent samples *t*-test and paired *t*-test. Three-dimensional (3D) deviation analysis was also performed to evaluate the stability of condyles from T1 to T2.

Results: Both groups showed significant profile improvement from T1 to T2. The changes in Z angle and ANB angle were larger in the surgical group than in the orthodontic group. Condylar width, length, and height remained stable after treatment in the orthodontic group ($P > .05$), while they reduced by 0.67 $\pm$ 0.85 mm, 1.14 $\pm$ 1.10 mm, and 1.07 $\pm$ 1.34 mm, respectively, in the surgical group ($P < .05$). Superior, posterior, medial, and lateral joint spaces were significantly reduced in the orthodontic group ($P < .05$). 3D deviations intuitively showed that condylar bone in the orthodontic group was more stable than that in the surgical group.

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Conclusions: For Class II hyperdivergent patients with severe TMJOA, orthodontic camouflage treatment with vertical control can effectively maintain the stability of condyles while significantly improving the profile. Surgical treatment yields a better profile but may increase the risk of condyle resorption. (*Angle Orthod.* 2023;93:458–466.)

KEY WORDS: Temporomandibular joint osteoarthrosis; Class II hyperdivergent patients; Vertical control; Orthodontic camouflage treatment; Orthognathic surgery

INTRODUCTION

Temporomandibular joint osteoarthrosis (TMJOA) is a type of chronic degenerative joint disease characterized by destructive changes of the temporomandibular joint (TMJ) structures, leading to pain and disability.[1,2] The prevalence of TMJOA varied among different studies and could reach to 12.1% in Chinese adolescent orthodontic patients and 40.7% in adolescent patients with temporomandibular disorders by cone-beam computed tomographic (CBCT) analysis.[3] The progressive destruction and severe abrasion of the condyle cause the ramus to shorten, leading to retraction of the mandible and even to anterior open bite, which may cause or worsen the Class II hyperdivergent skeletal deformity. For patients with severe TMJOA-associated Class II hyperdivergent malocclusion, orthognathic surgery is considered to be the most effective method to improve facial esthetics.[4] However, the stability of the TMJ condyle should be ensured to prevent the potentially progression of TMJOA, which may lead to deterioration of the profile and decline in quality of life. Several studies[5,6] revealed that following orthognathic surgery, the condyles of TMJOA patients underwent significant resorption, with 1-year rates of up to 54.84%, which may be related to mandibular advancement and rotation.

For patients who refuse surgical treatment, orthodontic camouflage treatment can be an alternative treatment option. Vertical control is widely used in camouflage treatment to improve occlusion and profile, which induces molar intrusion, counterclockwise rotation of the mandible, and facial height reduction. Many studies[7,8] have reported successful molar intrusion of approximately 1–3 mm and counterclockwise rotation of the mandible by 1–4°. There are no published data revealing the effects of vertical control on the TMJ after orthodontic treatment or comparing the changes in condyles between Class II hyperdivergent patients with severe TMJOA undergoing orthodontic treatment with or without orthognathic surgery.

The null hypothesis of this study was that in terms of maintaining condylar stability in TMJOA patients there would be no difference between those receiving orthodontic camouflage treatment with vertical control and those receiving orthodontic-orthognathic surgical treatment. This study aimed to evaluate and compare the effects of orthodontic camouflage with vertical control vs orthodontic-orthognathic surgical treatment relative to the stability of the condyles in Class II hyperdivergent patients with TMJOA. The purpose was to provide a basis for clinical decision-making for orthodontists and to provide more treatment options for patients with TMJOA.

MATERIALS AND METHODS

Sample Selection

This retrospective study was approved by the Institutional Review Board of Peking University School and Hospital of Stomatology (201630096). The sample consisted of 27 female patients (54 condyles), including 13 patients (26 condyles) who underwent orthodontic camouflage treatment and 14 patients (28 condyles) who underwent orthognathic surgery at Peking University School and Hospital of Stomatology between 2014 and 2020.

The inclusion criteria were age $>$ 18 years; severe skeletal Class II hyperdivergent malocclusion (ANB angle $> 5°$, MP-SN angle $> 37.7°$) in patients for whom orthognathic surgery or orthodontic camouflage treatment had been suggested in the medical record (patients voluntarily chose surgery or nonsurgery depending on their wishes); TMJOA history that had been stable for at least 1 year, without positive CBCT appearance, including subchondral cyst(s), erosion(s), aggravated sclerosis, or newly formed osteophyte(s) and without clinical symptoms, including limitation of mouth opening and pain; and for whom CBCT images before (T1) and 1 year after treatment (T2) were available. The exclusion criteria were uncontrolled TMJOA; severe facial asymmetry; severe sleep apnea; and deformity secondary to trauma, ankylosis, or systemic disease.

For the orthodontic camouflage group, after extraction of four premolars all patients underwent treatment with a classical straight arch wire technique with preadjusted edgewise appliances (Z2 brackets, 3B Ortho, Hangzhou, China). Four miniscrews (diameter: 1.5 mm; length: 8 mm; Zhongbang Medical Treatment Appliance, Xi'an, China) were implanted bilaterally on the buccal and lingual sides of the alveolar bone between the roots of the upper first and second molars to intrude the molars and minimize the use of interarch elastics. The treatment goal was to establish a Class I canine and/or molar relationship, and the treatment time was approximately 3 years.

Patients in the surgical group underwent presurgical orthodontic treatment with the same appliances as were used in the orthodontic group, with mandibular first premolar extractions and no vertical control appliance. The orthognathic treatment included Lefort I osteotomy, bilateral sagittal split ramus osteotomy (BSSRO), and genioplasty with rigid fixation, with upper premolar extractions during surgery, followed by a period of orthodontic refinement.

CBCT scans (NewTom VG scanner, Aperio Services, Verona, Italy) were taken at T1 and T2 with the same protocol (110 kVp; 1 to 3 mA; 0.3-mm voxel size). Patients were instructed to maintain an intercuspated position and to avoid movements during scanning.

Cephalometric and TMJ Measurement Analysis

To evaluate the baseline and changes for mandibular position, dental structures and soft tissue profile as well as bone resorption and position of the condyles from T1 to T2, landmarks and measurements based on CBCT using Dolphin Imaging software (version 11; Dolphin Imaging & Management Solutions, Chatsworth, Calif) was used (Table 1; Figure 1). All measurements were made by one operator two times with a time interval of 1 weeks.

TMJ Three-Dimensional Deviation Analysis

To further assess changes in condylar bone and position, three-dimensional (3D) surface models of the condyles were built and calculated. The CBCT data were imported into Mimics software (Mimics 17.0, Materialise NV, Leuven, Belgium) to generate a skull model including the maxilla, condyle, and mandibular ramus obtained from a semiautomatic segmentation methodology assisted with manual segmentation (Figure 2a). The output data were then imported into Geomagic Studio 12.0 (Geomagic, Littleton, Colo) for surface reconstruction and 3D deviation analysis. As shown in Figure 2b, to evaluate the bone changes on the condyle surface, the posterior edge of the mandibular ramus was selected for surface registration on the isolated mandibular ramus to avoid the influence of surgery on the shape of the mandible. Cheekbones were selected for surface registration to evaluate the changes in position of the condyles before and after treatment (Figure 2c).

Statistical Analysis

To analyze the condylar bone change, the calculated sample size for paired samples estimated that 13 samples were required to achieve at least 80% power with a type II error rate, β, of 0.2 while maintaining an α of 5%. An independent samples *t*-test was used to compare the difference in measurements before and after treatment in each group. A paired *t*-test was used to compare the difference in therapeutic outcome between the two groups. SPSS Statistical Package (version 16.0; SPSS Inc, Chicago, Ill) was used for data analysis, and $P < .05$ indicated a statistical difference.

RESULTS

The patients in the study were all female. No significant difference was found in age between the two groups (24.46 $\pm$ 4.09 years for the orthodontic group and 27.93 $\pm$ 5.51 years for the surgical group; $P > .05$).

Cephalometric Analysis

Both groups achieved good treatment outcomes (Table 2). The Z angle significantly increased by 10 $\pm$ 1.35° in the orthodontic group ($P < .05$) and by 16 $\pm$ 7.24° in the surgical group ($P < .05$). A greater decrease in the ANB angle was observed in the surgical group (3.79 $\pm$ 0.72°; $P < .05$), compared to only 0.97 $\pm$ 0.32° in the orthodontic group ($P < .05$). There were significant differences in the change in the Z angle and the ANB angle between the two groups ($P < .05$). Significant mandibular counterclockwise rotation of 1.41 $\pm$ 0.30° ($P < .05$) was observed in the orthodontic group and rotation of 1.62 $\pm$ 0.54° ($P < .05$) was observed in the surgical group, with no significant difference between the groups ($P > .05$). The measurement reliability was analyzed by calculating the intraclass coefficient of the results, which was $\geq$0.90.

TMJ Measurement Analysis

The stability of the condyles of the two groups was significantly different (Table 2). Condylar bone measurements, including condyle width, length, and height, showed no significant change in the orthodontic group from T1 to T2 ($P > .05$), but significant reductions of 0.67 $\pm$ 0.85 mm, 1.14 $\pm$ 1.10 mm, and 1.07 $\pm$ 1.34 mm were found in the surgical group ($P < .05$); this was significantly different between the two groups ($P < .05$). The joint spaces, which indicated changes in the position of condyles, showed no significant difference ($P > .05$) in the surgical group between T1 and T2. However, all joint spaces except the anterior joint space were reduced significantly ($P < .05$) in the orthodontic group, suggesting different condylar movements between the two groups.

Table 1. Landmarks and Measurements Used in This Study to Evaluate Changes in Mandibular Position, Dental Structures, and Soft Tissue Profile as Well as the Bone Resorption and Position of the Condyles

Landmarks	Definition
N	Nasion: the anterior point of the intersection between the nasal and frontal bones
S	Sella: the center of the hypophyseal fossa, determined by inspection
SN plane	The line connecting the point S to N
Me	Constructed gonion: bisecting the angle formed by the tangents to the lower and the posterior borders of the mandible
Go	Menton: the most inferior point on the symphysis of the mandible
MP plane	The line connecting the point Go to Me
A	Subspinale: the most posterior point on the exterior ventral curve of the maxilla between the anterior nasal spine and Supradentale
B	Supraemental: the most posterior point on the bony curvature of the mandible between Infradentale and Pogonion
U1	Maxillary central incisor
L1	Mandibular central incisor
FH plane	Plane that passes through the inferior margin of the left orbit and the upper margin of each ear canal
Lateral condylar point, LCo	Most lateral point of the condyle
Medial condylar point, MCo	Most medial point of the condyle
Anterior condylar point, ACo	Most anterior point of the condyle
Superior condylar point, SCo	Most superior point of the condyle
Posterior condylar point, PCo	Most posterior point of the condyle PCo
Ramus tangent line	Tangent to the posterior border of the R-tan ramus
Ramus tangent line perpendicular, R-tan-P	Line perpendicular to R-tan tanging the deepest point of the mandibular incisura
Mandibular positions	
SN-MP angle, °	Angle between MP plane and SN plane
ANB angle, °	Angle between points A and B at N
Dental structures	
U1-SN angle, °	Angle between the long axis of U1 and SN plane
L1-Mp angle, °	Angle between the long axis of L1 and MP plane
Soft tissue profile	
Z angle, °	Angle between FH plane and a line connecting soft tissue pogonion and the most protrusive lip point
Condylar bone	
Mandibular condyle length	Distance from ACo to PCo
Mandibular condyle width	Distance from LCO to MCo
Mandibular condyle height	Distance from SCo perpendicular to R-tan-P
Condylar position	
Anterior joint space	The shortest distance from ACo to the articular fossa
Posterior joint space	The shortest distance from PCo to the articular fossa
Lateral joint space	The shortest distance from the intersection of the vertical line at the outer 1/6 point, of the line connecting LCo and MCo with the surface of the condyle to the articular fossa
Superior joint space	The shortest distance from the intersection of the vertical line at the midpoint of the line connecting LCo and MCo with the surface of the condyle to the articular fossa
Medial joint space	The shortest distance from the intersection of the vertical line at the inner 1/6 point of the line connecting LCo and MCo with the surface of the condyle to the articular fossa

3D Deviation Analysis

3D deviation analysis was carried out to comprehensively display the position and degree of condylar bone resorption. Figure 3 shows possible condylar bone change patterns in the two groups. Red represents protrusion, blue represents retraction, green indicates steady, and the gray area represents severe bone resorption of more than 3 mm that could not be measured by the 3D deviation method with the iterative closest point algorithm. As shown in Figure 3a, the condyle in the orthodontic group was approximately stable, with bone destruction of no more than 0.67 mm. Figure 3b indicates a condyle with postoperative resorption in the surgical group, with maximum resorption of more than 3 mm. Position analysis (Figure 4) showed a counterclockwise rotation of the condyle in the orthodontic group and an inward movement of the condyle in the surgical group.

The complete results are summarized in Supplemental Figures S1 and S2. Almost all of the condyles in the orthodontic group were stable, with bone resorption of not more than 1 mm; however, the condyles in the surgical group showed severe resorption, with eight condyles showed a gray bone destruction region in which bone resorption was more than 3 mm. Supplemental Figure S2 showed that 53.85% (14 of 26) of the condyles in the orthodontic group rotated counter-

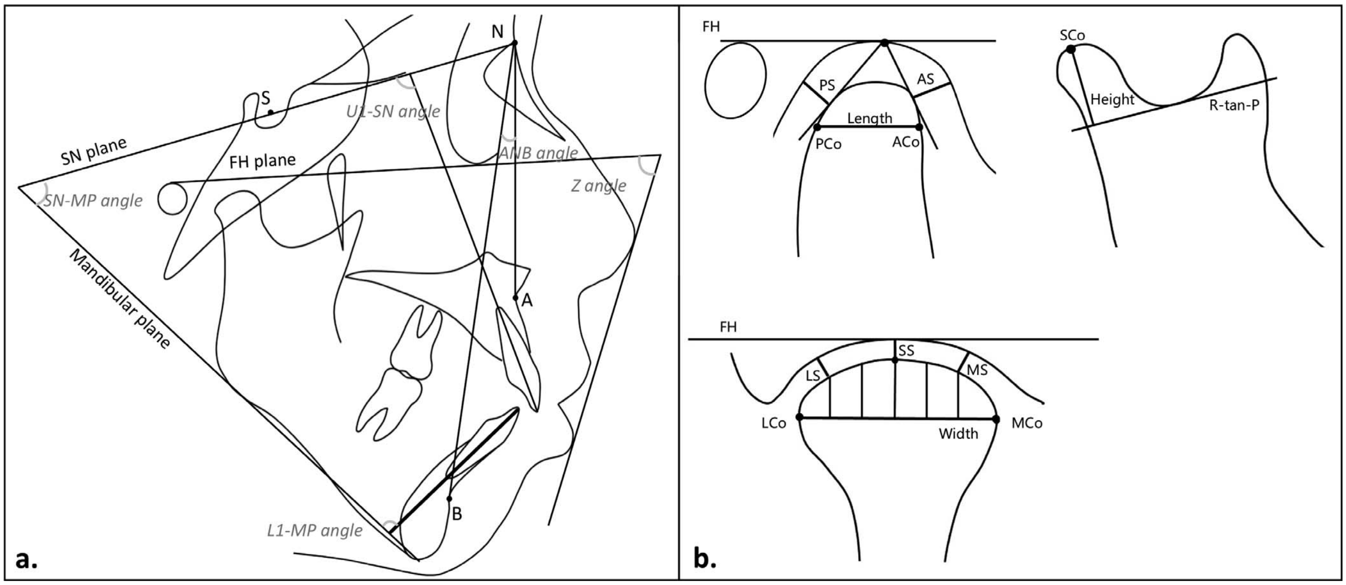

Figure 1. (a) Cephalometric landmarks and measurements identified to evaluate changes in mandibular position, dental structure, and soft tissue profile. SN-MP angle indicates the angle between the mandibular plane (MP) and the SN plane; ANB angle, angle between point A and point B at N; U1-SN angle, angle between the long axis of maxillary central incisor (U1) and SN plane; L1-Mp angle, angle between the long axis of mandibular central incisor (L1) and MP plane; and Z angle, angle between the FH plane and a line connecting the soft tissue pogonion and the most protrusive lip point. (b) Cone-beam computed tomographic (CBCT) landmarks and measurements identified to evaluate changes in condylar bone and position. Condyle length indicates distance from the anterior condylar point (ACo) to the posterior condylar point (PCo); condyle width, distance from the lateral condylar point (LCo) to the medial condylar point (MCo); condyle height, distance from the superior condylar point (SCo) perpendicular to ramus tangent line perpendicular (R-tan-P); anterior joint space (AS), the shortest distance from ACo to the articular fossa; posterior joint space (PS), the shortest distance from PCo to the articular fossa; and lateral joint space (LS), superior joint space (SS), and medial joint space (MS), the shortest distance from the intersection of the vertical line at the outer 1/6 point, the midpoint, and the inner 1/6 point of the line connecting LCo and MCo (LCo-MCo) with the surface of the condyle to the articular fossa, respectively. For secondary outcome variables definitions, refer to Table 1.

clockwise, while movement of the condyles in the surgical group was more variable and complex.

DISCUSSION

This study aimed to evaluate the different effects between orthodontic camouflage treatment with vertical control assistance vs treatment with orthognathic surgery on the condylar bony stability of Class II hyperdivergent patients with severe TMJOA. Though both groups showed ideal treatment outcomes from T1 to T2, the profile improvement of patients in the surgical group was greater. CBCT measurements of condylar width, length, and height showed condylar stability in the orthodontic group and significant bone destruction in the surgical group. 3D deviation analysis showed the bone changes intuitively and suggested complex condylar movement after surgical treatment. The data supported rejection of the null hypothesis: orthodontic camouflage treatment with vertical control was better at maintaining condylar stability for TMJOA patients than was orthodontic-orthognathic surgical treatment.

Orthognathic surgery and orthodontic camouflage treatment are two main strategies to improve occlusion and profile for Class II hyperdivergent patients (Figure 5). Commonly used measurements were selected, including ANB angle and Z angle, to evaluate the soft and hard tissue and to illustrate the improvement in profile after different treatments. Temporary anchorage devices (TADs) are widely used in camouflage treatment to achieve molar intrusion, counterclockwise rotation of the mandible, and facial height reduction (Figure 5a). Additionally, the stability of the TMJ is also important for patients with TMJOA. Several studies have reported TMJ condylar resorption after orthognathic surgery, especially in patients with severe TMJOA, and the rate of progression of TMJOA was up to 54.84%, according to Qin et al.[6] and Crawford et al.[9] Sun et al.[10] reported stable articular bony structure in the majority of TMJOA patients during orthodontic treatment. In the current study, since the condyles were stable before treatment for at least 1 year, the condylar reshaping after treatment suggested recurrence of TMJOA, especially the irregular and abnormal reshaping. Significant condylar resorption was observed in the surgical group, while condylar bone in the orthodontic group remained stable, suggesting that vertical control-assisted orthodontic camouflage treat-

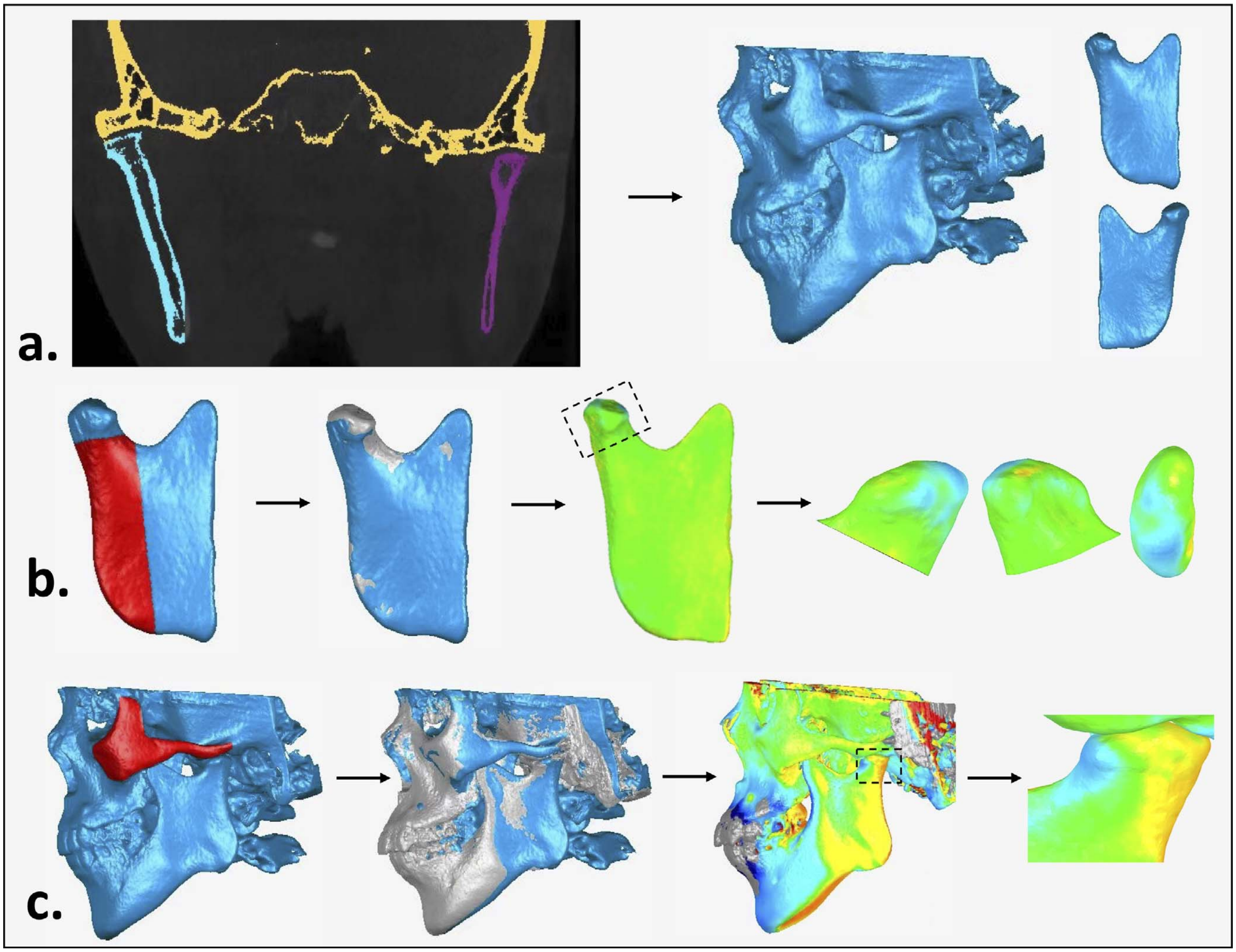

Figure 2. (a) The cone-beam computed tomographic (CBCT) data were imported into Mimics software (Mimics 17.0, Materialise, NV) to create the three-dimensional (3D) model. (b) The posterior edge of the mandibular ramus was selected for surface registration to evaluate the bone changes on the condyle surface. (c) Cheekbones were selected for surface registration to evaluate the position change in condyles before and after treatment.

ment could maintain condylar stability while improving the profile.

The severity of condylar bone destruction may be related to condylar movement. Since the mandible was divided into three pieces by BSSRO, condylar displacement had previously been reported[11,12] to be varied and complex. Buckley et al.[13] also reported that SSRO with rigid fixation could create great condylar position changes, leading to a high incidence of TMJ dysfunction. The 3D deviations found in this study showed complex condylar movement in the surgical group, likely resulting from a combination of operation method, postoperative recurrence, postoperative condyle resorption, and other factors. However, condyles of the orthodontic group rotated slightly or remained in position, which may have contributed to their bony stability.

The results revealed that for Class II hyperdivergent patients with TMJOA history, vertical control-assisted orthodontic camouflage treatment was an effective way to improve the facial profile while maintaining condylar stability, but this does not mean that surgical treatment will necessarily do harm to condyles with TMJOA history. For patients with high esthetic requirements, orthognathic surgical treatment is still the first choice, but the TMJ status requires much more attention, especially for those with previous TMJOA history.

The main limitation of the present study was the sample size, which was small as a result of the difficulty of data collection. More valid scientific results can be obtained by increasing the number of patients in future studies. The prevalence of severe TMJOA was reported[14] to be more common in female patients, and women usually have greater requirements for

Table 2. Statistical Analysis of Mandibular Position, Dental Structures, and Soft Tissue Profile as Well as Condyle Width, Length, Height, and Joint Space Measurements at T1 and Changes from T1 to T2[a]

	T1			T2-T1				
	Orthodontic	Surgical		Orthodontic		Surgical		
Measurement	Mean ± SD	Mean ± SD	*P*	Mean ± SD	*P*	Mean ± SD	*P*	*P*
Mandibular positions								
ANB angle, °	7.84 ± 1.93	8.40 ± 2.18	.49	−0.97 ± 0.32	.01*	−3.79 ± 0.72	.00*	.00*
SN-MP angle, °	37.59 ± 7.55	38.87 ± 5.15	.73	−1.41 ± 0.30	.00*	−1.62 ± 0.54	.01*	.7
Dental structures								
U1-SN angle, °	99.48 ± 7.91	101.27 ± 6.86	.53	−7.43 ± 1.30	.00*	−1.03 ± 1.57	.52	.00*
IMPA, °	97.82 ± 7.13	94.33 ± 4.70	.14	−4.16 ± 1.89	.05*	−1.56 ± 1.84	.41	.2
Soft tissue profile								
Z angle, °	52.38 ± 8.64	52.14 ± 7.04	.81	10.00 ± 1.35	.00*	16.00 ± 7.24	.00*	.00*
Condylar bone								
Mandibular condyle length, mm	14.26 ± 2.93	13.74 ± 2.78	.50	0.05 ± 0.91	.77	−1.14 ± 1.10	.01*	.03*
Mandibular condyle width, mm	6.91 ± 1.55	6.74 ± 1.61	.69	−0.22 ± 0.65	.09	−0.67 ± 0.85	.00*	.01*
Mandibular condyle height, mm	7.81 ± 1.43	7.28 ± 2.79	.37	−0.11 ± 0.38	.16	−1.07 ± 1.34	.00*	.00*
Condylar position								
Anterior joint space, mm	2.09 ± 0.69	2.25 ± 1.02	.49	−0.16 ± 0.75	.26	0.62 ± 2.45	.23	.11
Superior joint space, mm	2.08 ± 0.52	2.55 ± 1.03	.04*	−0.43 ± 0.66	.00*	0.61 ± 2.82	.30	.09
Posterior joint space, mm	2.47 ± 0.91	2.38 ± 0.93	.72	−0.93 ± 1.25	.00*	0.51 ± 2.39	.31	.01*
Medial joint space, mm	2.52 ± 0.85	3.24 ± 3.18	.27	−0.66 ± 0.83	.00*	−0.85 ± 3.53	.25	.78
Lateral joint space, mm	2.08 ± 0.60	2.88 ± 2.96	.19	−0.26 ± 0.57	.02*	−0.79 ± 3.22	.24	.39

[a] T1 indicates before treatment; T2, after treatment. * *P* values<.05 are considered significant.

appearance. Few male patients were identified during sample selection and, to avoid the possible effects of gender on the results, this study finally focused on female patients; however, this also resulted in a potential limitation in terms of representation of the population. Though patients involved all suffered severe TMJOA based on the methodology used by Alexiou et al.,[15] the extent of condylar destruction and malocclusion before treatment was still different among the patients, which may have affected the patient

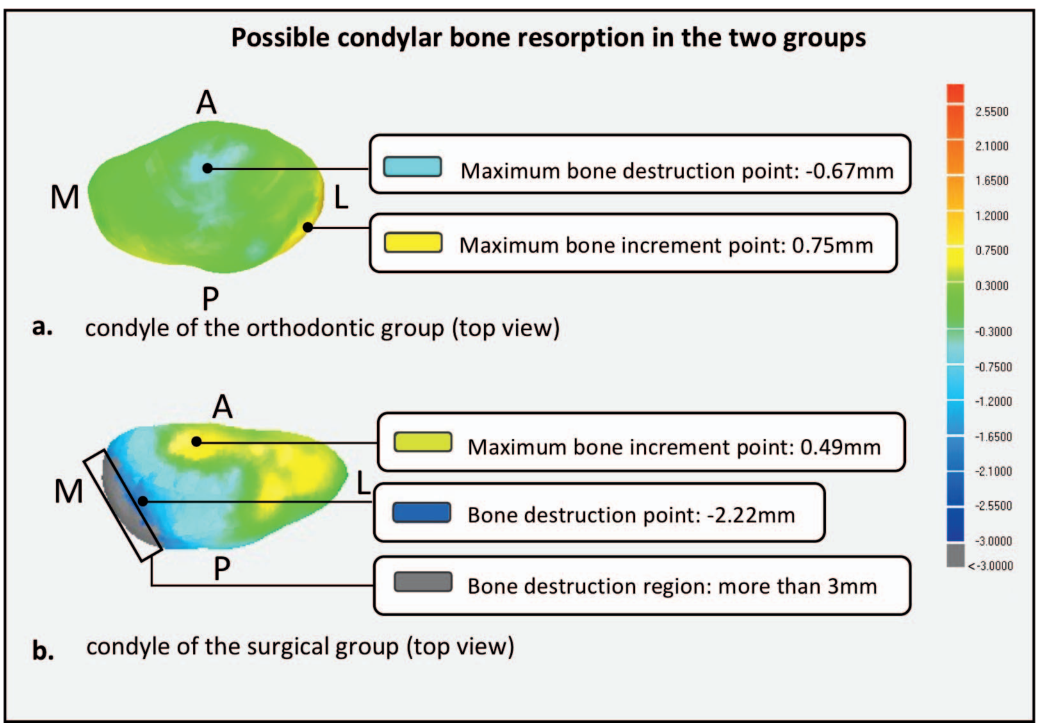

Figure 3. (a) Top view of the possible condylar bone change pattern from T1 to T2 in the orthodontic group. (b) Top view of the possible condylar bone change pattern from T1 to T2 in the surgical group. T1 indicates before treatment; T2, after treatment; A, anterior; P, posterior; M, medial; and L, lateral.

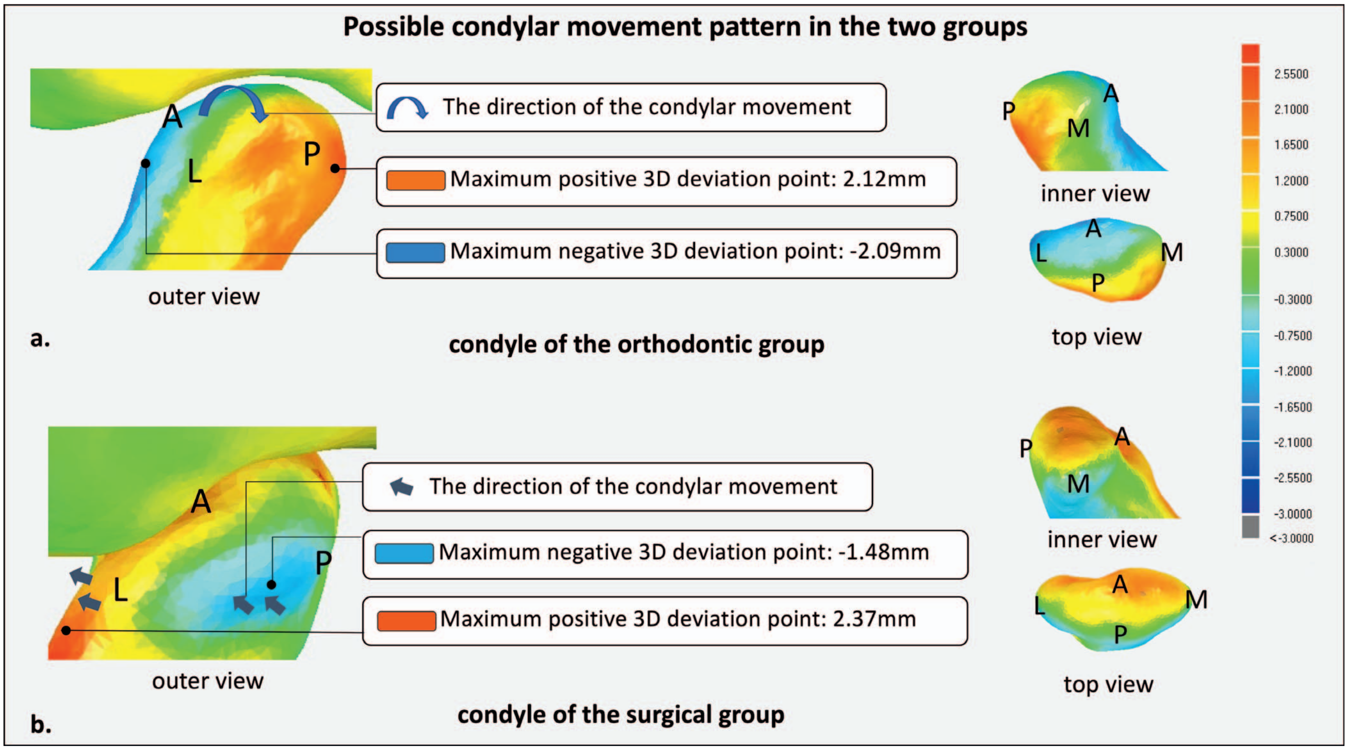

Figure 4. (a) The possible condylar movement pattern from T1 to T2 in the orthodontic group. (b) The possible condylar movement pattern from T1 to T2 in the surgical group. The arrow indicates the direction of condylar movement. T1 indicates before treatment; T2, after treatment; A, anterior; P, posterior; M, medial; and L, lateral.

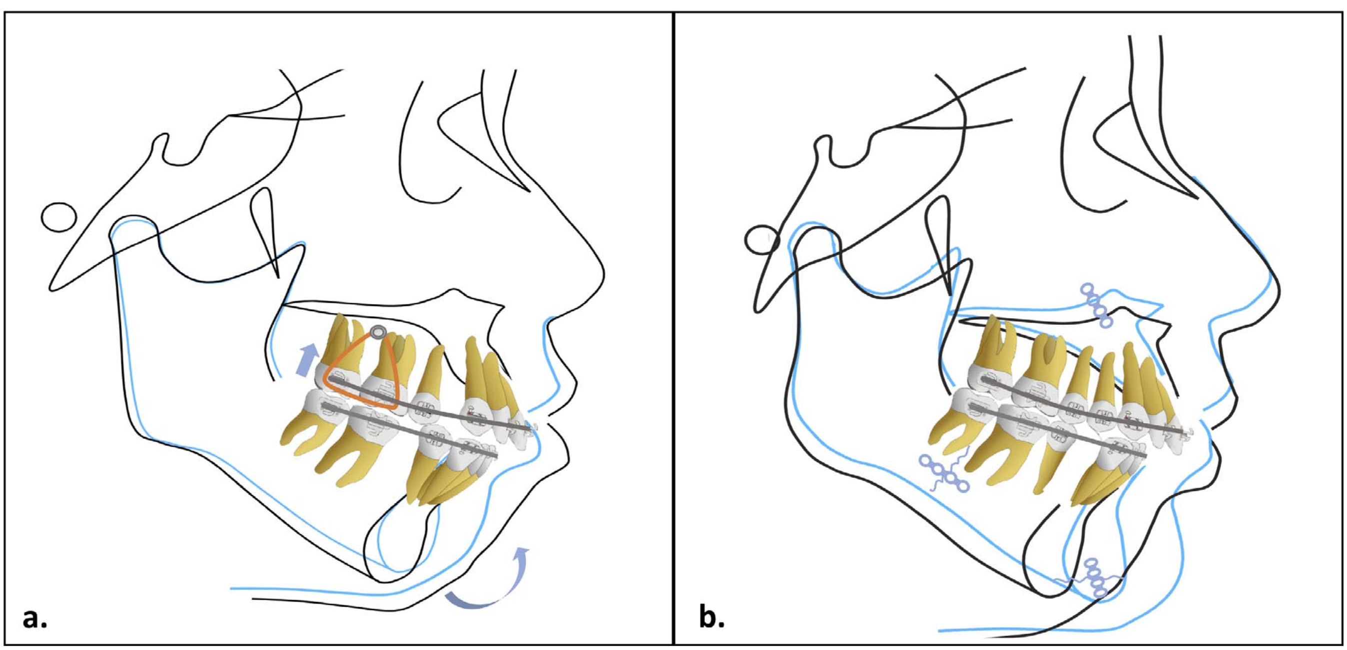

Figure 5. (a) Schematic graph of the TAD-assisted vertical control during orthodontic camouflage treatment for Class II hyperdivergent patients with temporomandibular joint (TMJ) osteoarthrosis. (b) Schematic graph of the orthognathic surgery for Class II hyperdivergent patients with TMJ osteoarthrosis.

progress and outcomes. Since both condyles from the same patients were included in this study, further studies are needed to distinguish this complex confounding factor.

CONCLUSIONS

- For Class II hyperdivergent patients with severe TMJOA, vertical control-assisted orthodontic camouflage treatment can be used to maintain condyle stability effectively while improving the profile to a certain extent.
- Surgical treatment yields a better profile but may increase the risk of condylar resorption.

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SUPPLEMENTAL DATA

Supplemental Figures S1 and S2 are available online.

Supplemental Figure S1. (a) Top view of the condylar bone change based on three-dimensional (3D) deviation analysis in the orthodontic camouflage group from T1 to T2. (b) Top view of the condylar bone change based on 3D deviation analysis in the surgical group from T1 to T2. a–aa refer to different patients: T1 indicates before treatment; T2, after treatment; A, anterior; P, posterior; M, medial; and L, lateral.

Supplemental Figure S2. (a) Outer view of the condylar position change based on three-dimensional (3D) deviation analysis in the orthodontic group from T1 to T2. (b) Outer view of the condylar position change based on 3D deviation analysis in the surgical group from T1 to T2. a–aa refer to different patients: T1 indicates before treatment; T2, after treatment; A, anterior; P, posterior; and L, lateral.