Vol. 131 No. 4 April 2021

The effect of TMJ disk repositioning by suturing through open incision on adolescent mandibular asymmetry with and without a functional orthodontic appliance

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Objective. The objective of this study was to evaluate the effect of combined temporomandibular joint (TMJ) disk repositioning by suturing through open incision and orthodontic functional appliance (OFA) treatment for adolescents with mandibular asymmetry.

Study Design. Adolescent patients (12-20 years old) with mandibular asymmetry combined with unilateral TMJ disk displacement without reduction were treated with disk repositioning by suturing through open incision with and without postoperative OFA. Magnetic resonance imaging and posteroanterior cephalometric radiographs (PA) were used to measure and compare the changes in condylar height, joint space, and menton deviation pre- and postoperatively.

Results. Twenty-six patients were included in the study. Joint space was significantly increased postoperatively and new bone mostly formed at the superior or posterior superior part of the condyle after 6 to 18 months in all surgically treated joints. Fourteen patients with OFA had a significant increase in condylar height and menton deviation compared to 12 patients without OFA (2.29 ± 0.91 mm vs 1.22 ± 0.69 mm, $P = .003$; 4.56 ± 1.48 mm vs 2.01 ± 0.74 mm, $P = .000$).

Conclusions. Combined treatment with TMJ disk repositioning by suturing through open incision and OFA can promote condylar growth and correct mandibular deviation in adolescent patients. Postoperative OFA can maintain the increased joint space created by disk repositioning and promote new bone formation at the superior and posterior parts of the condyle. (Oral Surg Oral Med Oral Pathol Oral Radiol 2021;131:405−414)

Mandibular asymmetry is a complex malformation with an abnormal relationship between the upper and lower jaws, and the main feature includes malocclusion of teeth in the midline and menton deviation. Studies have shown that mandibular deviation is closely related to asymmetric development of the condyle.[1-5] Anterior disk displacement (ADD) that occurs during adolescence may lead to mandibular developmental disorders such as retrognathia, which occurs when ADD occurs on both sides, or mandibular deviation, which occurs when ADD occurs on one side.[4,6] The overall incidence of mandibular deviation is about 40% and can be as high as 72% in patients with ADD.[1]

ADD is one of the most common temporomandibular joint (TMJ) internal derangements. Clinical manifestations usually include joint clicking, pain, restricted mouth opening, limited chewing, and phonetic disturbances, but some patients may be asymptomatic. Untreated TMJ ADD may cause condylar degeneration or even progressive resorption, which may affect mandibular growth when it occurs in childhood.[7] Research has shown that the severity of the jaw deformity is highly correlated with the magnitude of the disk displacement, disk deformity, and degree of condylar resorption.[8] For severe cases, orthognathic surgery is the only treatment after growth is complete. In the treatment of ADD, Yang[9] and Zhu et al.[10] found that disk repositioning by either arthroscopy or a mini-anchor screw can increase the posterior-superior joint space and stimulate new bone formation, especially in growing patients. Our previous study[10] found that

Statement of Clinical Relevance

We investigated the changes in condylar height and joint space after disk reduction surgery by suturing with/without functional appliances in adolescents, demonstrating that combined treatment can better reduce facial-oral deformity in adolescent patients with articular disk displacement and jaw deformity.

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Received for publication Nov 20, 2019; returned for revision Oct 21, 2020; accepted for publication Nov 25, 2020.

2212-4403/$-see front matter
https://doi.org/10.1016/j.oooo.2020.11.014

articular disk repositioning by mini-screw anchor combined with an orthodontic appliance can effectively promote the growth of the condyle in adolescents with skeletal class II malocclusions. To reduce the difficulty associated with arthroscopy for disk repositioning and the impact on condylar blood supply with open mini-screw implant, He et al.[11] proposed a suturing technique samilar to Yang's arthroscopy method[12] but through a small open incision.

The aim of this study was to evaluate the effect of an open surgery for disk repositioning by suture for adolescent unilateral ADD with mandibular asymmetry. Furthermore, the effect of a postoperative orthodontic functional appliance (OFA) on bone regeneration and mandibular asymmetry correction and its relationship with joint space was analyzed by magnetic resonance imaging (MRI) and posteroanterior cephalometric radiographic measurements.

Fig. 1. Schematic diagram of surgical procedure of temporomandibular joint disk repositioning by suturing through open incision.

PATIENTS AND METHODS

Study design

This is a preliminary study that was approved by the local ethics board of the hospital (Shanghai 9th People's Hospital in China). Declaration of Helsinki guidelines were followed in this study. Adolescent patients with ADD and secondary mandibular asymmetry who underwent unilateral TMJ disk repositioning surgery from July 2013 to August 2018 were included. Inclusion criteria were as follows: (1) age between 12 and 20 years at initial diagnosis; (2) unilateral ADD without reduction (Wilkes stage III to V) and combined mandibular asymmetry; (3) disk repositioning by suturing through a small incision by 1 surgeon (DH)[11]; and (4) MRI examination and posteroanterior cephalometric radiographs (PA) before and after surgery and at follow-ups. Exclusion criteria included (1) less than 6 months' follow-up; (2) other therapy on joints or other types of orthodontic treatment; (3) a history of trauma; and (4) a history of rheumatoid arthritis.

Disk repositioning was performed on the affected joint that the mandible deviated to using a small incision as described in our previous study.[11] After fully releasing the anterior attachment of the disk, the displaced disk had a horizontal mattress suture placed through the posterior edge with a 2-0 nonabsorbable suture. The suture through the disk was subsequently brought out through the external auditory canal and secured through the cartilage (Figure 1). According to the preoperative imaging, which showed displaced articular disk and pathologic condyle bone changes such as hypoplastic and corticated or resorption and degeneration without cortication (Figures 2, 5), the status of the disk was checked during operation and confirmed to be displaced anteriorly. Some disks were accompanied with perforation, and the sutures were put in front of the perforation. The disk should be overcorrected to the 1- to 2-o'clock position to prevent relapse.[13] Moreover, in order to avoid disturbing the blood supply of the condyle, which is essential for the new bone regeneration, this surgical technique dose not strip the tissues surrounding the condyle or open the subarticular cavity. After disk repositioning, the joint space was increased and the condyle moved downward, which resulted in an open bite on the surgically treated side. An interocclusal wax registration was made to record this open bite and sent to the orthodontist (ZY) to make the OFA. Patients wore OFA for at least 6 months after disk repositioning surgery to maintain the open bite so that the space created by the surgery would be maintained to promote the growth of the condyle and help to correct the jaw deviation (Figure 3). When the condylar newly formed bone was mature and stable, the orthodontist began to close the open bite and the orthodontist began orthodontic treatment (Figure 4).

Patients who were unable to comply with wearing the OFA and further orthodontic treatment after disk repositioning surgery they were included in the control group for follow-up observation. The condylar height and jaw deviation were compared between the 2 groups with and without OFA during follow-up. Patient age and follow-up period were similar in the 2 groups.

Variables and measurements

Condylar height. A 1.5-T imager (SIGNA; General Electric, Milwaukee, WI) with bilateral 3-in. dual surface coils was used to perform the MRI. Images that contained the largest sections of the condyle were selected, and condylar height was determined based on the 3-circle method.[1,2] Condylar heights measured

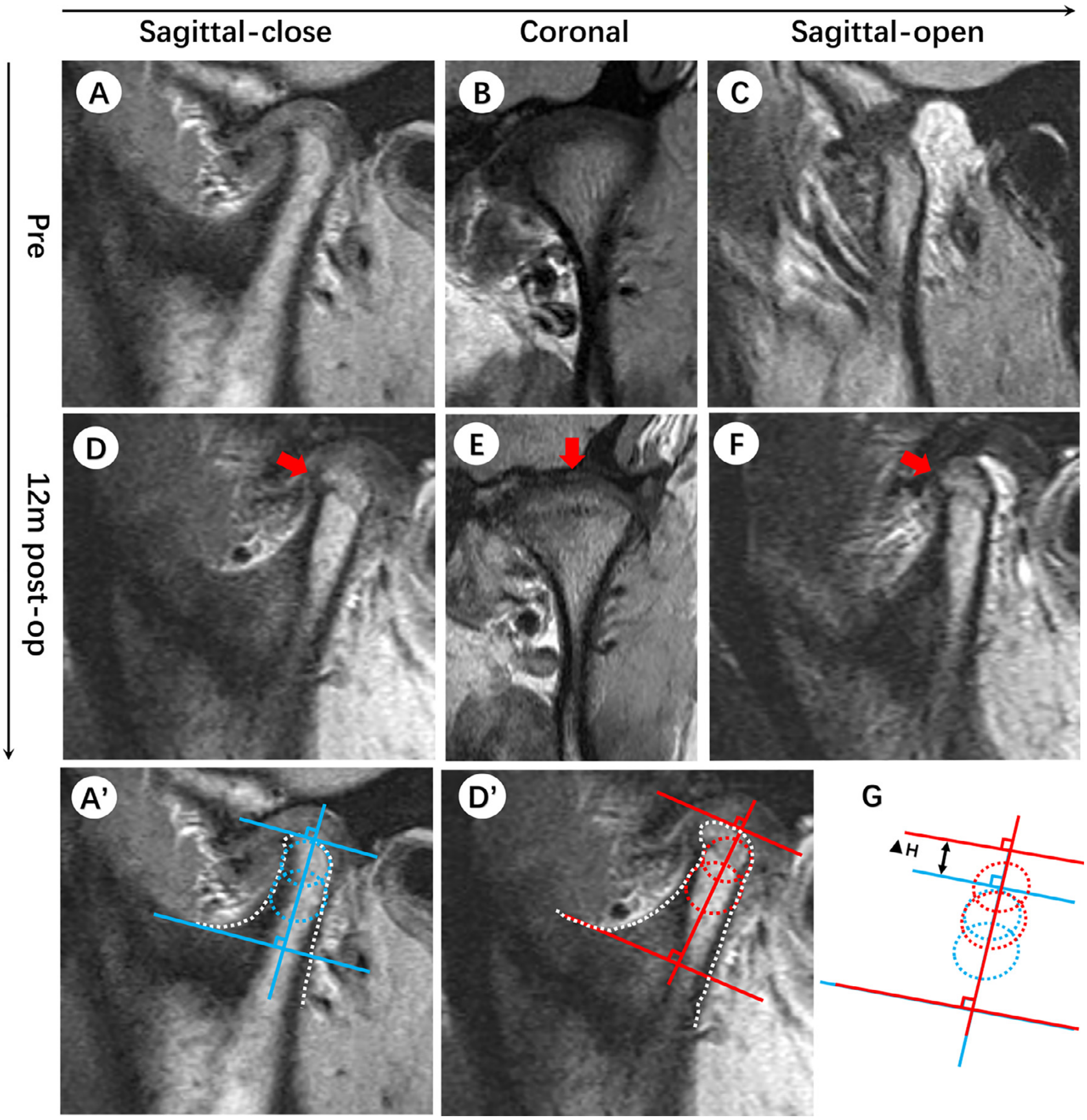

Fig. 2. Magnetic resonance images (MRI) of a 15-year-old boy with anterior disk displacement. **(A)-(C)** Anterior disk displacement without reduction on the left side postoperatively. **(D)-(F)** Images taken 12 months postoperatively showed plenty of new bone formation (red arrows). **(G)** Superimposition of the condylar height in A′ and D′ to measure the difference. *A′*, measurement of preoperative condylar height in MRI image; *D′*, measurement of postoperative condyle height in MRI image.

preoperatively and at the last follow-up were recorded and the difference between them was calculated. The position of any regenerated bone was assessed in follow-up MRI tracings as previously described (Figure 2).[10]

Mandibular deviation. Using posteroanterior cephalometric radiographs, the facial midline was defined as the line perpendicular to the line connecting the left and right intersections of the zygomaticofrontal suture and lateral orbital margin through the crista galli. The horizontal distance from menton to midline was the value of the mandibular asymmetry (Figure 5).[1,2] The degree of mandibular asymmetry before the operation and during follow-up was compared.

Joint space. Based on the method described in the literature,[14] a line (Y) drawn between the summits of the postglenoid tubercle (P′) and the articular eminence (A′) was used as the reference plane. The line Y′ was parallel to Y and tangent to the roof of the glenoid fossa (S′). The distance from the most superior point of the condyle (S) to line Y′ was defined as the superior joint space. To measure the anterior joint space and posterior joint space, lines tangent to the most prominent anterior and posterior aspects of the condyle were

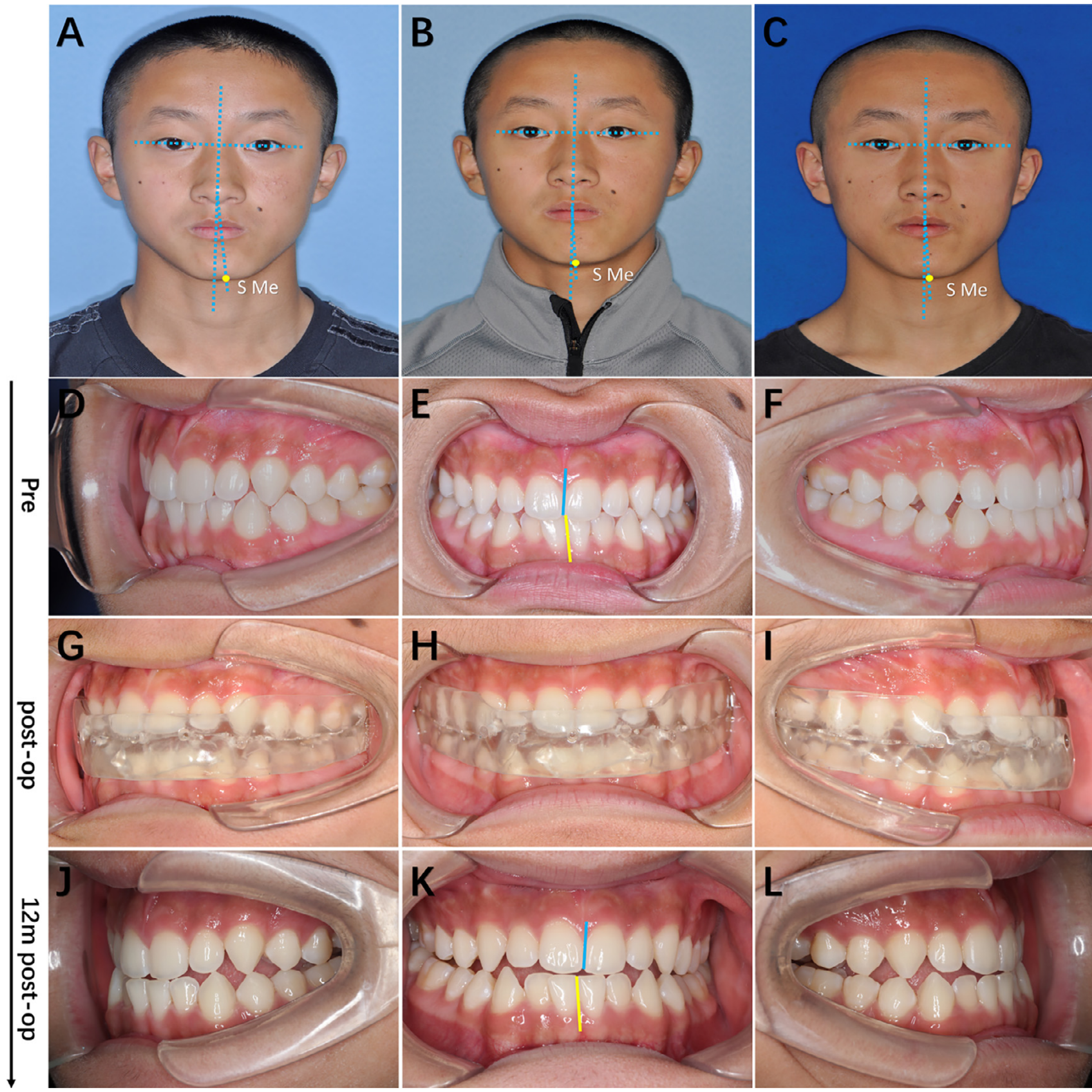

Fig. 3. Patient in Figure 2 before and after combined left side disk repositioning and orthodontic functional appliance (OFA). **(A)** Preoperative facial profile showed chin deviation to the left; **(B)** chin deviation corrected immediately after operation; **(C)** chin correction 12 months postoperatively; **(D)-(F)** preoperative occlusal images; **(G)-(I)** OFA applied immediately postoperative; **(J)-(L)** occlusal images 12 months postoperatively. *S Me*, soft tissue menton point.

made from S′ (anterior and posterior tangent points were A and P). Lines perpendicular to the S′/A and S′/P lines were drawn through point A and point P. The anterior and posterior joint spaces were expressed by the distances from points A and P to the corresponding glenoid fossa (Figure 5). Joint space was compared before and after the operation and during follow-up.

Statistical analysis

All data were analyzed by IBM SPSS Statistics version 18.0 (IBM Corp., Armonk, NY). Differences between the 2 groups including patient age, MRI and x-ray follow-up time, joint space, and condylar height were analyzed separately through independent sample *t*-tests or paired *t*-tests. Pearson correlation coefficients were calculated for the relationship between the height of the new bone and the joint space of the ipsilateral condyle. $P < .05$ or was considered statistically significant.

RESULTS

Twenty-six patients were included in the study. There were 8 males and 18 females with an average age of 16.08 years and a mean follow-up period of 8.88 months (6-18 months). Twelve patients were in the disk repositioning without OFA group. Their average age was 16.67 years with a mean follow-up period of 7.92 months (6-15 months). Fourteen patients were in the disk repositioning with OFA group. Their average age was 15.07 years with a mean follow-up period of

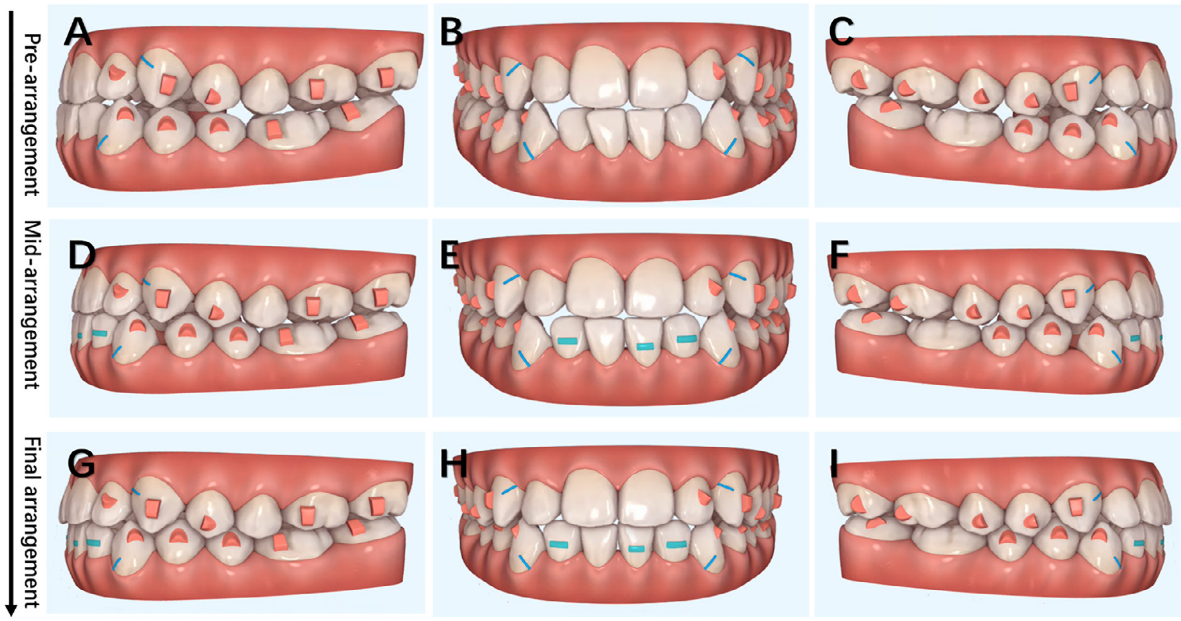

Fig. 4. Images of predicted tooth positions by computer-aided orthodontic tooth arrangement: **(A)**-**(C)** pre-arrangement; **(D)**-**(F)** mid-term arrangement; **(G)**-**(I)** final arrangement.

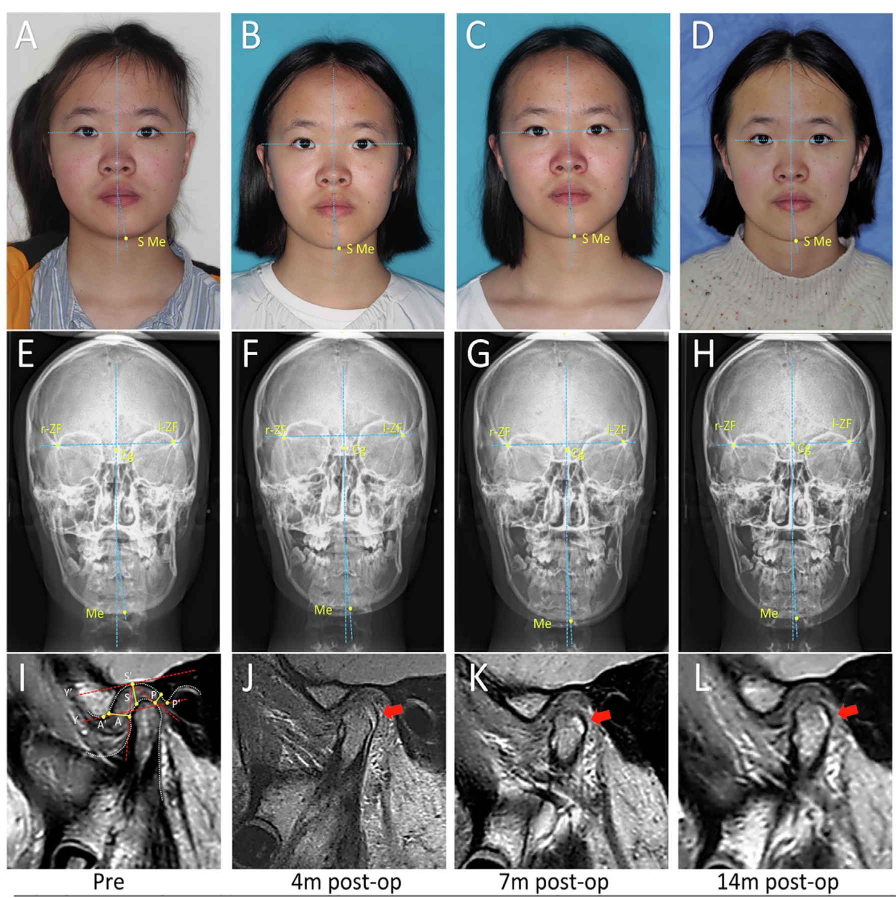

Fig. 5. A 17-year-old girl before and after combined left side disk repositioning and orthodontic functional appliance. **(A), (E)** Preoperative facial profile and posteroanterior cephalometric radiographs showed chin deviated to the left. **(B), (F)** Images taken 4 months after disk repositioning showed chin deviation was corrected. **(C), (G)** Seven months after operation; **(D), (H)** 14 months after operation. **(I)**-**(L)** Joint space measurement after disk repositioning showed that superior and posterior space on the condyle was increased and new bone formation (red arrows) from 4 to 14 months after operation. S Me, soft tissue menton point; Me, menton point.

Table 1. Comparison of basic information of patients in two groups.

	Op		*Op+OFA*		*P value*
	Avg	*SD*	*Avg*	*SD*	
Age	16.67	2.10	15.07	2.02	0.976
MRI FU	7.92	3.12	9.71	3.43	0.862
X-ray FU	9.71	3.07	8.83	4.63	0.157

FU: Follow-up period, Avg: average, SD: standard deviation; Op, operation of disk repositioning by suturing; *Op+OFA*, operation combined with orthodontic functional appliance.

9.71 months (6-18 months). There were no significant differences in sex distribution by chi-square test (P = .216) and age and follow-up period by independent sample *t*-test between the 2 groups (Table I).

MRI measurements showed that all surgically treated condyles had new bone formation after disk repositioning (Figures 2, 5). In the group without OFA, the condylar height on the surgically treated sides increased by 1.22 ± 0.69 mm (*P* = .000) and increased to 0.17 ± 0.62 mm on the unaffected sides (*P* = .376; Table II). In the group with OFA, the condylar height on the surgically treated sides increased by 2.29 ± 0.91 mm (*P* = .000) and increased 0.23 ± 0.67 mm on the unaffected sides (*P* = .222; Figures 2 and 5, Table II). The posteroanterior cephalometric radiographic measurements showed that the menton deviation improved by 2.01 ± 0.74 mm in the group without OFA (*P* = .000; Figures 2 and 5, Table III) and by 4.56 ± 1.48 mm in the group with OFA (*P* = .000; Figures 3 and 6, Table III). Independent sample *t*-test showed significant differences in the amount of change in condylar height and menton deviation pre- and postoperatively within the 2 groups and between the 2 groups (Tables II, III).

Joint space (including anterior, superior, and posterior) on both sides preoperatively, within 1 week postoperatively, and during follow-up visits was measured by MRI. Superior and posterior joint spaces on the surgically treated sides significantly increased but there were no changes on the unaffected sides 1 week after disk repositioning in both groups ($P < .05$). In the group with OFA, joint space on the surgically treated sides was similar after a mean follow-up of 9.71 months compared to immediately postoperative ($P >$ .05). However, in the group without OFA, joint space was significantly decreased after a mean follow-up of 7.92 months ($P < .05$).

Table 3. Comparison of menton deviation between the 2 groups.

Groups	*MA0*	*MA1*	*Me*
Op	6.06 ± 1.23†	4.05 ± 1.19†	2.01 ± 0.74*
Op+OFA	8.05 ± 1.99§	3.49 ± 1.59§	4.56 ± 1.48*

MA0: Pre-operative mandibular deviation, MA1: Follow-up mandibular deviation, Me: Mandibular deviation change, Op, operation of disk repositioning by suturing; *Op+OFA*, operation combined with orthodontic functional appliance.
†P = 0.000
§P = 0.000
*P = 0.000.

Pearson correlation analysis indicated that chin deviation improvement was statistically correlated with the amount of condylar bone formation (*P* = .041) and change in superior joint space (*P* = .038) on the surgical side (Figure 7, Tables IV and V).

DISCUSSION

Because the condyle is an important growth center of the mandible, articular disk displacement may inhibit normal condylar development and cause jaw deformity when it occurs during the growth period. Clinicians have used OFAs to treat adolescents with early ADD. Cone beam computed tomography examination revealed new bone regeneration in the condyle after such treatment.[14] Although OFAs can correct anterior disk displacement with reduction by pulling the mandible forward, thus restoring the normal disk-condyle relationship, some patients still showed recurrence.[15]

Table 2. Comparison of condylar height in the two groups.

		H0	*H1*	*H*
Op	Affected side	24.66 ± 2.81†	25.88 ± 3.16†	1.22 ± 0.69*
	Healthy side	28.17 ± 2.56§	28.34 ± 2.72§	0.17 ± 0.62¶
Op+OFA	Affected side	23.93 ± 3.11††	26.23 ± 3.09††	2.29 ± 0.91*
	Healthy side	27.44 ± 3.36§§	27.67 ± 3.36§§	0.23 ± 0.67¶

H0: Pre-operative condylar height, H1: Follow-up condyle height, H: New height of condyle, Op, operation of disk repositioning by suturing; *Op +OFA*, operation combined with orthodontic functional appliance.
†P = 0.000
§P = 0.376
††P = 0.000
§§P = 0.222.
*P = 0.003
¶P = 0.817.

Fig. 6. Occlusion changes in the patient in Figure 5 before and after combined disk repositioning and treatment with an orthodontic functional appliance. **(A)**-**(C)** Mandibular incisor midline was deviated to the left in the preoperative occlusion; **(D)**-**(F)** mandibular incisor midline was corrected in the postoperative occlusion and there was an open bite on the bilateral posterior teeth. **(G)**-**(I)** Images taken 14 months postoperatively showed the occlusion was stable. **(J)**-**(L)** Computer-aided final orthodontic tooth arrangement.

For anterior disk displacement without reduction, the use of an OFA has the risk of augmenting the disk displacement and even leading to condylar resorption. In those situations, repositioning surgery can be used to predictably restore the disk-condyle relationship.[12,16]

There are 2 methods for articular disk repositioning: arthroscopic or open surgery.[12,16] The effect of disk repositioning has been reported by Goncalves et al.,[17] who proposed MiTek anchors to reposition the articular disk and performing simultaneous orthognathic surgery on patients with moderate to severe dental and maxillofacial deformities after puberty. Long-term follow-up showed bone regeneration in the condyle, especially in 5 patients younger than 16 years of age, who showed a slight increase in condylar height (average = 0.4 mm; range, 0.1-1.5 mm). Hu et al.[18] and Chen et al.[19] found that arthroscopic disk repositioning and modified articular disk repositioning with an anchor significantly increased the posterior-superior joint space and stimulated the proliferation of the condyle. In another study, double contour images could be seen on MRI.[20] Other authors observed that the condyle appeared to move forward and downward, thereby reducing the degree of jaw retrusion.[19] Additionally, our previous study showed that articular disk repositioning by anchor combined with an OFA could reduce occlusal deformity in adolescent patients with skeletal class II malocclusion.[10] Because arthroscopic disk reduction surgery is technically difficult to perform, He et al.[11] proposed an open method that repositions the disk by suturing it

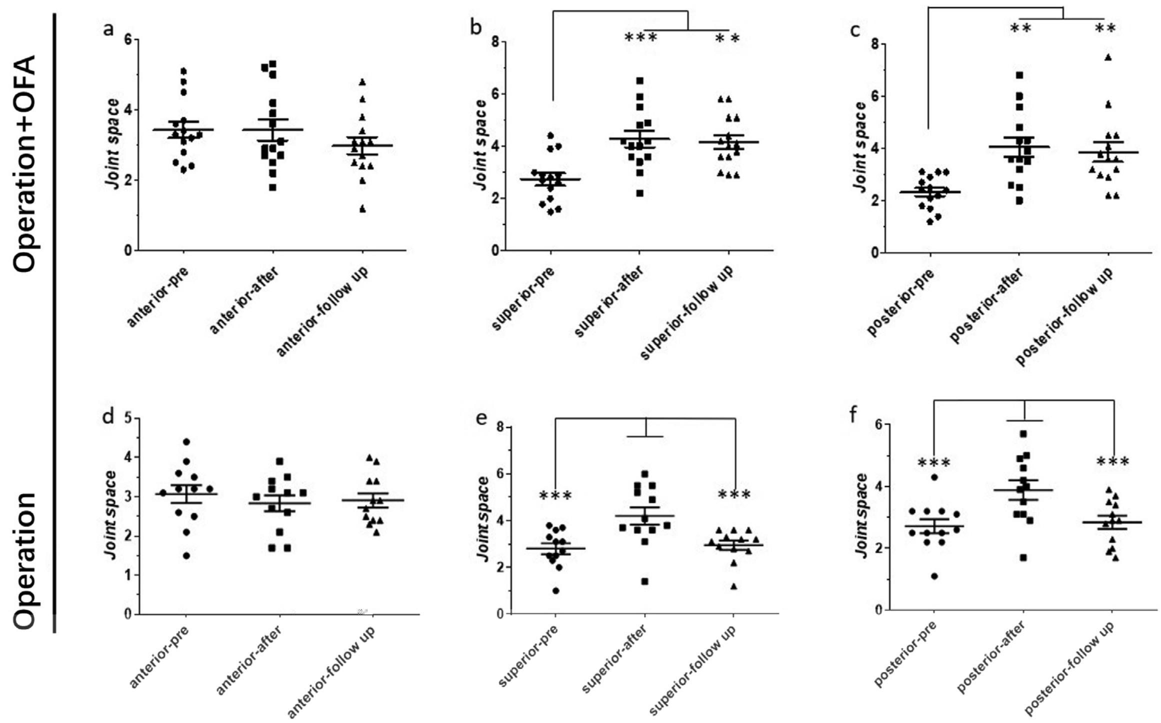

Fig. 7. Paired *t*-test of ipsilateral joint space between the 2 groups at 3 time points. *$P < .05$. **$P < .01$. ***$P < .001$.

through a small incision. This method is essentially the same as arthroscopic disk repositioning surgery, but direct viewing makes the surgery simple and practical. This method is also good for idiopathic condylar resorption−induced small condyles or patients with osteoporosis when a mini-screw anchor is difficult to implant. It also avoids stripping the tissues surrounding the condyle when the anchor is inserted and thereby reduces the reduction in condylar blood supply. According to the results of this study, disk repositioning by suturing through a small incision had a good effect on condylar bone regeneration, and the use of OFA after surgery produced a better effect than using a mini-anchor (2.29 ± 0.91 mm vs 1.74 ± 0.98 mm).[10]

Our previous study showed that after the disk has been repositioned, the joint space (anterior and superior) increased (significantly) by nearly 2 mm and the

Table 4. Comparison of contralateral and ipsilateral joints space at three time points.

		Op+OFA (Avg+SD)			*Op (Avg+SD)*		
		S0	*S1*	*S2*	*S0*	*S1*	*S2*
Anterior	Affected side	3.43 ± 0.23	3.43 ± 0.30	2.98 ± 0.25	3.07 ± 0.79	2.83 ± 0.70	2.91 ± 0.63
	Healthy side	2.31 ± 0.51	2.34 ± 0.64	2.43 ± 0.67	2.33 ± 0.38	2.62 ± 0.83	2.56 ± 0.45
Superior	Affected side	2.75 ± 0.24[†,§]	4.27 ± 0.31[†]	4.16 ± 0.26§	2.80 ± 0.81[††]	4.20 ± 1.29[††,§§]	2.95 ± 0.69[§§]
	Healthy side	2.66 ± 0.52	2.79 ± 1.00	2.80 ± 0.90	2.37 ± 0.94	2.52 ± 0.73	2.52 ± 1.06
Posterior	Affected side	2.33 ± 0.17[¶,*]	4.05 ± 0.37[¶]	3.86 ± 0.38[*]	2.72 ± 0.78[¶¶]	3.88 ± 1.10[¶¶,**]	2.84 ± 0.73[**]
	Healthy side	2.27 ± 0.69	2.62 ± 1.15	2.48 ± 0.94	2.52 ± 0.71	2.53 ± 0.70	2.58 ± 0.90

Op, operation of disk repositioning by suturing; *Op+OFA*, operation combined with orthodontic functional appliance. S0: preoperative; S1: immediately postoperative; S2: postoperative follow-up.
†P = 0.000
§P = 0.002;
¶P = 0.002
*P = 0.002
¶¶P = 0.002
††P = 0.001
§§P = 0.002
**P = 0.001.

Table V. Pearson correlation analysis of the changes in the height of the new bone and the joint space of the ipsilateral condyle

	ΔH	ΔMe
ΔH	—	0.041*
ΔMe	0.041*	—
AΔS (post-pre)	0.162	0.277
SΔS (post-pre)	0.502	0.171
PΔS (post-pre)	0.772	0.535
AΔS (follow-up-post)	0.553	0.803
SΔS (follow-up-post)	0.108	0.038*
PΔS (follow-up-post)	0.970	0.405
AΔS (follow-up-pre)	0.175	0.282
SΔS (follow-up-pre)	0.330	0.406
PΔS (follow-up-pre)	0.516	0.832

ΔH, new height of condyle; *ΔMe*, amount of mandibular deviation; *A*, anterior; *S*, superior; *P*, posterior; *ΔS*, difference in joint clearance.
*$P < .05$.

condyle moved downward, which resulted in an open bite on the surgically treated side.[8] This is due to repositioning of the articular disk back on top of the condyle, as well as tissue edema and effusion. However, our previous research found that the open bite would gradually disappear an average of 28 days after surgery because of chewing and the reduction in tissue edema and effusion in the joint space.[21] Therefore, the condyle will move upward. In this study, in order to correct jaw deviation and promote new condylar bone formation, we used OFA to maintain the joint space and open bite. The results showed that the OFA group had significantly more new condylar bone formation on the superior and posterior parts than patients without OFA. Therefore, the correction in jaw deviation in patients treated with OFA was also better than that in patients without OFA. Before the combined surgical and OFA treatment, ZY examined the degree of tooth and jaw deformity and predicted the tooth and jaw position and further open bite closure by computer-aided simulation of tooth arrangement.

Although some patients selected in this study stopped growing, we still found new bone formation on the superior and posterior parts of the condyle after disk repositioning, especially in patients treated with OFA. We also observed new bone formation in adults in our previous study,[16] though not as much as in adolescents. Compared to a simple OFA, surgical treatment restored the normal disk-condyle relationship. From this point of view, we may assume that repositioning of the articular disk was one of the reasons that new bone formed on the affected condyle. On the other hand, a postoperative OFA can better maintain the increased joint space created by disk repositioning, which is conducive to condylar bone regeneration. The combination of disk repositioning surgery and use of an OFA seems to normalize the deviated jaw developed by ADD in our adolescent patients and may avoid the need for orthognathic surgery after growth has completed.

Currently, there is no unified understanding of the cause of TMJ ADD. Most scholars believed that micro injury is an important factor. In addition, spasms of the external pterygoid muscle, chronic abnormal pressure, and occlusion disorders may be related to TMJ ADD. Patients selected in this study had a history of joint pop and click and then developed mouth opening limitations. Thus, they developed disk dislocation over a time irrespective of other factors.

CONCLUSIONS

Articular disk repositioning combined with a postoperative OFA increased and maintained the superior and posterior joint space, as well as promoted bone regeneration of the condyle, thus minimizing the degree of jaw deformity. However, more cases, longer follow-up, and prospective research are needed to evaluate the therapeutic effects. The phenomenon of "double contour" new condylar bone remodeling and factors influencing it also need further study.

FUNDING

This study was supported by grants from the Clinical Plus Project of Shanghai 9th People's Hospital (JYLJ201805), the Science and Technology Commission of Shanghai Municipality Science Research Project (20Y11903900).

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