Functional orthodontics after arthroscopic disk repositioning in adolescent anterior disk displacement with mandibular retrusion

Zhiyang Liu, DDS, MS,[a] Qianyang Xie, DDS, MS,[a] Chi Yang, DDS, MD,[a] Minjie Chen, DDS, MD,[a] Guo Bai, DDS, MS,[a] Pei Shen, DDS, PhD,[a] and Zhigui Ma, DDS, PhD[a]

Objective. Condylar remodeling is crucial in retrognathic adolescents with anterior disk displacement without reduction (ADDwoR). This study aimed to evaluate the efficacy of functional orthodontics after arthroscopic disk repositioning surgery in improving condylar remodeling.

Study Design. A retrospective cohort study was performed to evaluate the condylar remodeling in patients with retrognathic unilateral ADDwoR who received arthroscopic disk repositioning surgery from March 2013 to December 2017. The primary predictor variable was functional orthodontics, based on which patients were divided into group A and group B. The outcome variables were condylar remodeling on both the affected side and the unaffected side measured by using the 3-circle method. The independent-sample *t* test was performed to test the difference between the 2 groups. A *P* value less than 0.05 was considered significant.

Results. In total, 117 patients (28 males and 109 females) were included in our study, with 75 cases in group A (follow-up: 7.48 months) and 62 cases in group B (follow-up: 7.95 months). Group A showed better condylar remodeling on the affected side compared with group B, but there was no significant difference on the unaffected side.

Conclusions. Functional orthodontics after arthroscopic disk positioning leads to improved condylar remodeling in patients under 17 years of age with ADDwoR and mandibular retrusion. (Oral Surg Oral Med Oral Pathol Oral Radiol 2020;130:357−362)

Anterior disk displacement without reduction (ADDwoR) is a common form of temporomandibular disorder, in which the disk is in an anterior position in relation to the mandibular condyle in both open- and closed-mouth positions.[1] Patients with ADDwoR often complain of joint pain and limited mandibular movement, which are the most common reasons for seeking treatment.[2]

In recent years, there is a growing interest in the relationship between ADDwoR and condylar resorption and dentomaxillofacial deformities.[3-6] It is reported that the incidence of condylar resorption in patients with ADDwoR is approximately 4 times that of the general population.[7] Xie et al. reported that the average condylar resorption is 1.10 mm on the ipsilateral side in adolescent patients with unilateral disk displacement, leading to a significant decrease in condylar height compared with the normal side.[8-] Therefore, ADDwoR is considered an important risk factor for condylar resorption. More importantly, growth restriction may take place before condylar resorption or juvenile osteoarthritis in adolescent patients with ADDwoR; this may cause mandibular retrusion, mandibular deviation, or other secondary dentomaxillofacial deformities. As a consequence, ADDwoR occurring in adolescence would have a more severe impact on patients' facial appearance, oral function, and mental health compared with that in adulthood.[9]

Adolescent patients with ADDwoR may have similar clinical manifestations, such as mandibular retrusion and Class II malocclusion, which can be very difficult to treat. Our previous retrospective study showed that patients who received no surgery presented with a shorter disk, an increase in disk displacement, and a decrease in condyle height.[9,10] Arthroscopic disk repositioning surgery not only relieves pain and restriction of mouth opening, but it can also prevent resorption and degeneration of the condyle and disk.[11] More than 70% of patients even have new bone formation after surgery.[12] Condylar remodeling is regarded as an important index to evaluate the therapeutic effect of ADDwoR.[13] Although mandibular retrusion can be improved, to some extent, after arthroscopic surgery, some patients still need orthognathic surgery in adulthood for correction of residual dentomaxillofacial deformities. Currently, mandibular functional treatment is one of the most effective methods for treating mandibular retrusion in adolescents.[14,15] Nevertheless, functional orthodontics

Statement of Clinical Relevance

Functional orthodontics after arthroscopic disk repositioning surgery can significantly improve condylar remodeling in adolescent patients with anterior disk displacement without reduction and mandibular retrusion.

[a]Department of Oral Surgery, Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, Key Laboratory of Stomatology, Shanghai, 200011, China.

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is believed to be useful only during puberty, and serious doubts remain about its efficacy in the disk-condyle relationship.[16]

In this study, we evaluated the efficacy of functional orthodontics after arthroscopic disk repositioning surgery in improving condylar remodeling for retrognathic adolescents with ADDwoR.

MATERIALS AND METHODS

This was a retrospective cohort study in adolescents with unilateral ADDwoR and mandibular retrusion treated with arthroscopic disk repositioning surgery from March 2013 to December 2017. Informed consent was obtained from all patients before the study, and this study was approved by the Ethics Committee of our hospital and strictly adhered to the tenets of the Helsinki Declaration.

Patients

Patients were included in the study if they (1) were adolescents aged between 10 and 20 years defined by the World Health Organization[17]; (2) were diagnosed with unilateral ADDwoR by using magnetic resonance imaging (MRI) at the first visit; (3) had mandibular retrusion and Class II malocclusion (overjet $\geq$ 5 mm); and (4) received arthroscopic disk repositioning surgery in our hospital from March 2013 to December 2017. Patients were excluded if they had (1) had obvious medial or lateral rotational disk displacement,[18] which could not be observed on MRI scans with the largest sectional area of condyle; (2) received orthognathic surgery before and during postoperative observation; (3) a history of joint infection, jaw fracture or any congenital and systemic diseases that could affect jaw development; and/or (4) poor image quality and declined re-examination.

Study variables and grouping

The primary predictor variable was functional orthodontics. All patients were informed of the postoperative functional treatment. Those who agreed to the treatment were included in group A, whereas the other patients served as controls (group B) Table I.[1] Minor predictor variables included (1) age at the initial visit and (2) follow-up period. Group A and group B were further divided into 3 subgroups according to the Tanner classification of adolescence[19]: A1/B1 subgroup (age $\geq$ 10 years; $<$ 14 years); A2/B2 subgroup (age $\geq$ 14 years; $<$ 16 years); and A3/B3 subgroup (age $\geq$ 17 years; $\leq$ 20 years).

The primary outcome variable was condylar remodeling on the affected side. The secondary outcome variable was condylar remodeling on the normal side. MRI was performed before surgery and 6 to 12 months after surgery. A period of 6 months was considered to be the shortest time necessary to evaluate condylar bony regeneration.[20] Proton density-weighted MRI of the largest sectional area of condyle was selected. Condylar height was measured on the selected MRI image by using the 3-circle method.[21] A circle, o_1, was tangent to the outline of the anterior, posterior, and superior surfaces of the condylar head. Then, another circle, o_2, was confined to the most curved area between the condylar head and the neck, and a third circle, o_3, was placed at the narrowest area of the condylar neck. The long axis of the condyle neck (Y) was determined by o_2 o_3. The line perpendicular to (Y) and tangent to the mandibular notch profile was determined as the horizontal axis (X), and the line parallel to (X) and tangent to the condyle was denoted as (X') (Figure 1). Condylar height (h) was determined as the vertical distance between (X) and (X'), and condylar remodeling was determined as the difference between the postoperative and preoperative condylar heights (see Figure 1).

Table I. Grouping and treatment in each group

	Affected side	*Normal side*
Group A	Disk repositioning surgery + Functional orthodontics	Functional orthodontics
Group B	Disk repositioning surgery	None

Techniques

All arthroscopic disk repositioning surgeries were performed by one of the authors (C.Y.), as described in our previous reports (Figure 2)[22,23]. Postoperative disk position was re-examined by using MRI. Functional orthodontics was best performed 2 to 4 weeks after surgery, by which time the pain in the operated area should have reduced and the anterior movement should

Table II. Demographic descriptions of the 2 groups

Group	*Patients*	*Males*	*Females*	*Mean age (years)*	*Duration of follow-up(months)*
A	75	17	58	15.53 ± 2.65	7.48 ± 1.91
B	62	11	51	15.73 ± 2.63	7.95 ± 2.14
P value				.672 NA	.176 NA
A1	20	5	15	12.35 ± 0.99	8.20 ± 2.29
B1	17	2	15	12.59 ± 0.62	7.29 ± 1.72
P value				.396 NA	.189 NA
A2	27	6	21	14.89 ± 0.89	6.78 ± 1.42
B2	20	4	16	14.90 ± 0.79	7.60 ± 2.16
P value				.965 NA	.123 NA
A3	28	6	22	18.42 ± 1.07	7.64 ± 1.87
B3	25	5	20	18.52 ± 1.08	8.68 ± 2.23
P value				.759 NA	.072 NA

NA = The difference was not significant ($P > .05$).

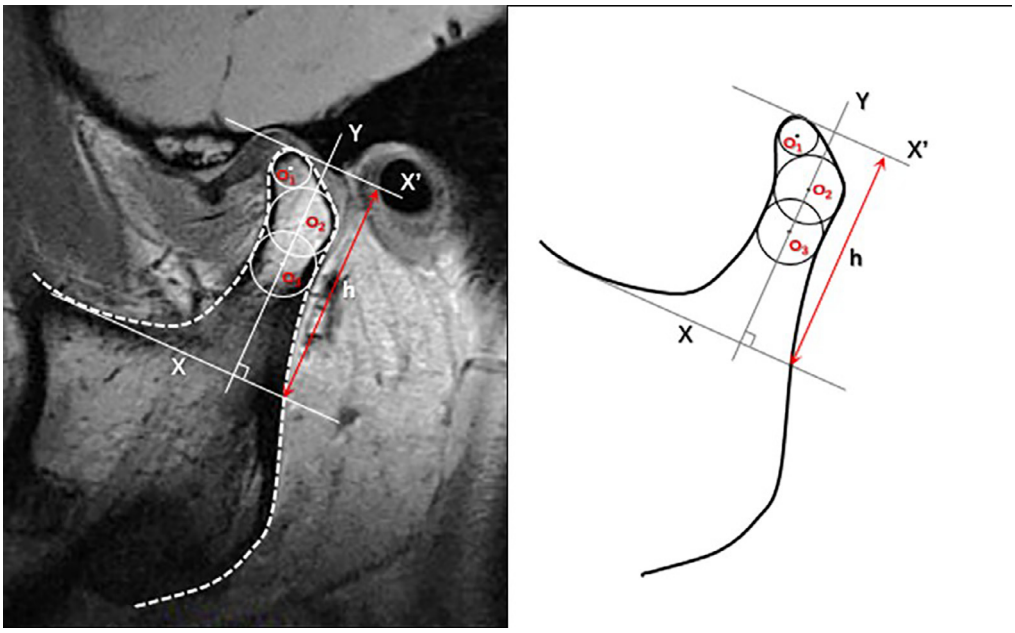

Fig. 1. Measurement of condylar height on magnetic resonance imaging (MRI).

have been partially restored. Anterior repositioning splint (a full splint combined with modified activator; air rotor stripping [ARS]), twin block, and Herbst were used (Figure 3). All patients were asked to position the mandible forward in the edge-to-edge position while taking bite registration, or through a 2-step advancing procedure if the excursion of mandible exceeded 10 mm.

Data analysis

In this study, we compared the total amount of condylar remodeling on both the affected and unaffected sides among different groups by using SPSS software version 23 (SPSS Inc., Chicago, IL). The homogeneity test of variance was performed, and the independent sample *t* test was performed to test the difference between the 2 groups. A *P* value less than 0.05 was considered significant.

RESULTS

In total, 117 adolescent patients with ADDwoR (28 males and 109 females; mean age 15.62 years) were included in this study Table II.[2] The average follow-up time was 7.69 months. There were 75 patients in group A (17 males and 58 females; mean age 15.53 years), with a mean follow-up time of 7.48 months, and 62 patients in group B (11 males and 51 females; mean age 15.73 years) with a mean follow-up time of 7.95 months. There was no significant difference in mean age and follow-up time between the 2 groups ($P > .05$). No recurrence of disk displacement occurred during the follow-up period in both groups (Figure 4).

Primary outcome

The amount of condylar remodeling on the affected side was significantly greater in group A than in group B ($P = .001$) Table III.[3] There was also a significant

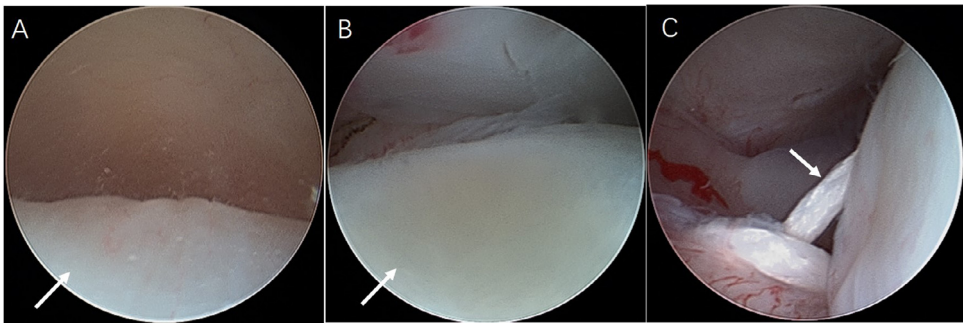

Fig. 2. Photographs of arthroscopic surgery. **(A)** Photograph before repositioning: The arrow points to anterior displacement temporomandibular joint (TMJ) disk. **(B)** Photograph after repositioning: The arrow points to a repositioned TMJ disk. **(C)** Photograph after fixation: The arrow points to a suture for the fixation of TMJ disk.

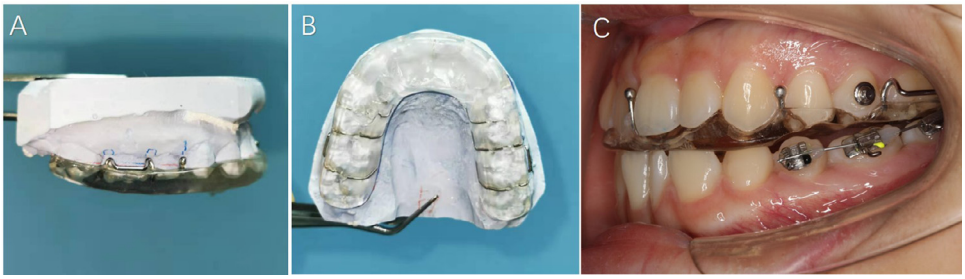

Fig. 3. Magnetic resonance imaging (MRI) of temporomandibular joint (TMJ). **(A)** Preoperative MRI: The arrow points to anterior displacement TMJ disk. **(B)** Postoperative MRI: The arrow points to a well-repositioned TMJ disk.

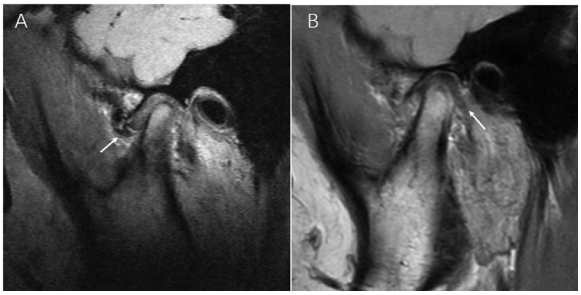

Fig. 4. Photographs of functional appliance. **(A)** A side view of air rotor stripping (ARS). **(B)** An inferior view of ARS. **(C)** An intraoral view of ARS.

difference in condylar remodeling on the affected side between A1 and B1 ($P < .01$) and between A2 and B2 ($P < .05$), but there was no significant difference between A3 and B3 ($P > .05$) Table IV.[4]

Table III. Comparison of condylar remodeling on affected side between the 2 groups

Group	*Condylar remodeling on affected side (mm)*
A	1.86 ± 1.17
B	1.28 ± 0.78
P value	.001*

*The difference was significant ($P < .01$).

Table IV. Comparison of condylar remodeling on the affected side among subgroups

Group	*Condylar remodeling on affected side (mm)*	*P value*
A1	2.70 ± 1.11	.005*
B1	1.70 ± 0.85	
A2	2.09 ± 1.08	.012†
B2	1.32 ± 0.89	
A3	1.05 ± 0.72	.573 NA
B3	0.96 ± 0.46	

*The difference was significant ($P < .05$).
†The difference was significant ($P < .01$).

Table V. Comparison of condylar remodeling on normal side

Group	*Condylar remodeling on normal side (mm)*	*P value*
A	0.58 ± 0.67	.208 NA
B	0.45 ± 0.52	
A1	0.91 ± 0.54	.047*
B1	0.56 ± 0.49	
A2	0.55 ± 0.78	.598 NA
B2	0.43 ± 0.66	
A3	0.38 ± 0.56	.946 NA
B3	0.38 ± 0.43	

*The difference was significant ($P < .05$).

Secondary outcome

There was no significant difference in condylar remodeling on the unaffected side between group A and group B ($P > .05$). There was a significant difference between A1 and B1 ($P < .05$), but there was no significant difference between A2 and B2 ($P > .05$) and between A3 and B3 ($P > .05$) Table V.

DISCUSSION

This study retrospectively reviewed the effects of postoperative functional treatment on condylar remodeling in patients age 10 to 20 years with unilateral ADDwoR and mandibular retrusion. The combination of postoperative functional orthodontics with arthroscopic surgery has been shown to be a promising treatment strategy in such cases, and the average amount of condylar remodeling on the affected side increased to 1.86 mm compared with an average of 1.28 mm in group B. Age was an important factor affecting the efficacy of condylar remodeling on the affected side. The average amount of condyle remodeling on the affected side was 2.70 mm in patients age 10 to 13 years, 2.09 mm in patients age 14 to 16 years, and 1.05 mm in patients age 17 to 20 years. Clearly, the younger the patient, the better was the outcome of the combined therapy. We also found that patients age 10 to 13 years and age 14 to 16 years had significantly higher condylar remodeling on the affected side compared with group B, but there was no significant difference for

patients age 17 to 20 years. Thus, postoperative functional appliance is recommended for patients younger than 17 years of age with ADDwoR and mandibular retrusion.

On the unaffected side, functional treatment was performed in group A, whereas no treatment was performed in group B. Condylar remodeling improved significantly in patients age 10 to 13 years, but no significant difference was observed in patients age 14 to 16 years and 17 to 20 years.

In our previous study, we had concluded that surgery was essential in adolescent patients with ADDwoR.[9] Condylar resorption would stop as a result of repositioned temporomandibular joint (TMJ) disk, and condylar remodeling would take place.[8] Otherwise, dentomaxillofacial deformities may become worse as a result of condylar resorption and growth restriction caused by disk displacement.[24] In this study, the average new bone formation on the affected side in group B was 1.28 mm. Arthroscopic surgery as a minimally invasive surgery has offered a stable. disk-condyle relationship and made further treatment safer. There is also convincing evidence that functional treatment plays an important role in the treatment of patients with mandibular retrusion.[25] Such treatment is apparently useful during a period of rapid growth and development. We found that those age 10−13 years were the most appropriate candidates for functional orthodontics, which could be extended to those age 10 to 16 years with the help of arthroscopic surgery.

There are concerns about unstable disk-condyle relationship in patients receiving functional treatment.[26] However, a good disk-condyle relationship was observed on both the affected and unaffected sides during follow-up in our study; this can alleviate concerns about the side effects of functional treatment.

The success of combined treatment mainly relies on the growth and development potential of adolescents. The joint space and condylar cartilage pressure may influence condylar reconstruction as well. An animal experiment has confirmed that the mechanical load of 150 kPa was the modest pressure for the proliferation and apoptosis balance of chondrocyte.[27] Thus, a normal, well-positioned disk can not only maintain an appropriate joint space but also an appropriate cushion against joint pressure, protecting the condyle from resorption and providing a good environment for development. Another study concluded that functional treatment promoted the differentiation of condylar chondrocytes and the formation of cartilage matrix by promoting the expression of Sox 9 and type II collagen.[28] Runx2 has been proven to provoke condylar cartilage adaptive remodeling as well.[29] However, the exact mechanism remains to be further elucidated.

Although the amount of condylar remodeling brought about by the combined treatment is still limited, this approach is an important breakthrough in the treatment of such a refractory disease. Use of greater condylar remodeling to achieve facial changes and minimize the dentomaxillofacial deformities of adolescent patients with ADDwoR remains a challenge. In this study, selection bias may exist because postoperative functional treatment was chosen by the patients themselves and their family members, and the stability of condylar remodeling requires a longer-term follow-up observation.

CONCLUSIONS

The combined treatment is a safe and effective method for patients age 17 years with ADDwoR and mandibular retrusion. The success of arthroscopic disk repositioning surgery lays a solid foundation for further treatment, and postoperative functional orthodontics helps achieve additional positive effects.

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Reprint requests:

Qianyang Xie,
Department of Oral and Maxillofacial Surgery,
Shanghai Ninth People's Hospital,
Shanghai Jiao Tong University School of Medicine,
639 Zhi Zao Ju Road,
Shanghai 200011,
China.
Xieqianyang86@126.com, Yangchi1234@yeah.net,
Chenminjie00@126.com