Int. J. Oral Maxillofac. Surg. 2024; 53: 413–421
https://doi.org/10.1016/j.ijom.2023.10.005, available online at https://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Clinical Paper
TMJ Disorders

Influence of local factors on the condylar growth after arthroscopic discopexy in adolescents with temporomandibular joint anterior disc displacement without reduction: a retrospective longitudinal study

D. Zhang[a,b,c,d,e,f,g,1], **P. Shen**[a,b,c,d,e,f,g,1], **Y. Zhang**[a,b,c,d,e,f,g], **S. Xia**[a,b,c,d,e,f,g], **Y. Luo**[a,b,c,d,e,f,g], **C. Yang**[a,b,c,d,e,f,g]

[a]Department of Oral Surgery, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, China; [b]College of Stomatology, Shanghai Jiao Tong University, China; [c]National Center for Stomatology, China; [d]National Clinical Research Center for Oral Diseases, China; [e]Shanghai Key Laboratory of Stomatology, China; [f]Shanghai Research Institute of Stomatology, China; [g]Research Unit of Oral and Maxillofacial Regenerative Medicine, Chinese Academy of Medical Sciences, Shanghai, China

D. Zhang, P. Shen, Y. Zhang, S. Xia, Y. Luo, C. Yang: Influence of local factors on the condylar growth after arthroscopic discopexy in adolescents with temporomandibular joint anterior disc displacement without reduction: a retrospective longitudinal study. Int. J. Oral Maxillofac. Surg. 2024; 53: 413–421.

Abstract. The aim of this retrospective longitudinal study was to investigate the condylar growth after arthroscopic discopexy in adolescents with temporomandibular joint (TMJ) anterior disc displacement without reduction (ADDwoR), and to determine whether local or systemic factors influence this growth. A total of 145 patients aged 10–20 years who were diagnosed with ADDwoR by magnetic resonance imaging were included. Patients who underwent arthroscopic discopexy were assigned to the arthroscopy group

Keywords: Arthroscopy; Adolescent; Mandibular condyle; Temporomandibular joint; Temporomandibular joint disorders.

Accepted for publication 10 October 2023
Available online 28 October 2023

[1] Dahe Zhang and Pei Shen are co-first authors.

($n = 108$) and others to the control group ($n = 37$). Demographic information, clinical assessments, body indicators, and bone density information were collected. Condylar height, disc length, and disc position were measured. The mean condylar height change in the arthroscopy group was 2.12 mm more than that in the control group ($P < 0.001$). Condylar growth after surgery was negatively correlated with age ($P = 0.017$) and disc length ($P = 0.015$), and positively correlated with follow-up duration ($P = 0.002$) and disc position ($P < 0.001$). Moreover, arthroscopic discopexy patients had better outcomes regarding improvements in pain ($P = 0.024$), maximum inter-incisal opening ($P < 0.001$), and quality of life ($P < 0.001$) than control patients. In conclusion, arthroscopic discopexy can restore condylar growth and relieve symptoms in ADDwoR patients, and the condylar growth is closely related to the local factors.

Temporomandibular disorders (TMDs) refers to a group of disorders involving the temporomandibular joint (TMJ), masticatory muscles, and associated structures[1]. Anterior disc displacement (ADD) is one of the most common TMDs[2], and is reported to occur in 18–35% of the general population[3]. TMJ noises, pain, and abnormal jaw movements are the most common symptoms of ADD[1–4]. In addition to these symptoms, many studies have reported condylar changes during the natural course of ADD[5–7], with some studies reporting that ADD can lead to mandibular retrusion and/or asymmetry[8–10]. Some studies have indicated that ADD may be one of the causes or a risk factor for TMJ osteoarthritis and condylar resorption[2,11–13]. Hence, close attention should be paid to ADD.

Adolescence is an important period of human development, and the rapid growth during adolescence has attracted much attention[14,15]. ADD is prevalent in not only adults but also adolescents, especially in those with dentofacial deformities[16]. It has been reported that ADD is related to a decreased condylar height in adolescents[17,18], which may lead to various problems, including abnormal mandibular growth, maxillofacial deformity, functional defects, airway narrowing, and even sleep apnoea[19,20]. Moreover, ADD has a close relationship with the relapse of orthodontic or orthognathic treatments[21–23]. Thus, it is important to restore a normal disc–condyle relationship, especially in adolescents with orthodontic needs.

The therapeutic strategy for ADD remains controversial. It is widely believed that ADD is self-limiting, and conservative approaches including education, physical treatment, and exercises are considered the preferred treatment[2,24]. Nevertheless, these treatment strategies mainly focus on symptomatic relief and do not consider condylar growth, especially in adolescents at peak bone growth[1,2,24].

Arthroscopic disc repositioning surgery is an invasive intervention. Annandale[25] first proposed surgical disc repositioning in the TMJ in 1887. Since then, various modified TMJ disc repositioning techniques with different success rates have been advocated. Mehra and Wolford[26] used a Mitek anchor and fixed the disc with a special suture, showing good results. Different from open surgery techniques, McCain et al.[27] introduced the arthroscopic technique for TMJ disc repositioning in 1992. Yang et al.[28] later proposed a new arthroscopic technique for disc repositioning and suturing in the TMJ, showing a high success rate of 95.42%. Yang's techniques have been applied for a long time in clinical practice[29]. The efficacy of arthroscopic discopexy in ADD has been evaluated in numerous studies[28,30,31]. Previous studies have reported obvious condylar remodelling in most patients with ADD after disc repositioning[29,32]. Although arthroscopic discopexy has shown good efficacy overall, factors influencing its efficacy, as well as the mechanisms underlying condylar growth after the surgery, have rarely been reported[2,5,18,24,29].

Thus, the aim of this study was to evaluate the effect of arthroscopic discopexy in adolescent patients with anterior disc displacement without reduction (ADDwoR), and to explore the local and systemic factors that could influence the condylar growth after this operation. This could help determine how arthroscopic discopexy works. The main hypothesis of the study was that the condylar height increase after arthroscopic discopexy depends on age and local factors.

Materials and methods

Study design and patients

This retrospective longitudinal clinical study was designed in accordance with the Declaration of Helsinki and approved by the Human Research Ethics Committee of Shanghai Ninth People's Hospital (SH9H-2020-T7–1). Consecutive adolescent patients visiting the TMJ clinic between October 2015 and October 2020 were included in this study. The inclusion criteria were (1) ADDwoR confirmed by magnetic resonance imaging (MRI) according to the reported methods[33]; (2) Wilkes stage II, III, or IV; (3) age between 10 and 20 years at the first visit; (4) a follow-up duration of more than 6 months; (5) no orthodontic treatment during this follow-up; (6) complete clinical information at the first visit. The exclusion criteria included (1) septic arthritis or synovial chondromatosis; (2) disc perforation; (3) history of orthodontic treatment or surgery involving the TMJ before the first visit; (4) history of rheumatic disease, craniofacial growth disturbance, or congenital defect; (5) lack of MRI scans at follow-up.

Given the close relationship between ADD, condylar height, dentofacial deformity[11–13], and relapse of orthodontic treatment[21–23], it was recommended that adolescents with ADDwoR who had orthodontic needs undergo arthroscopic discopexy in the study department, to ensure a stable TMJ. The patients were fully informed about the benefits and drawbacks of the procedure, and they had the right to make an informed decision to either proceed with or decline the surgery. Patients who received arthroscopic discopexy were assigned to the arthroscopy group and were required to have MRI examinations at the following two time points: within a week before arthroscopic surgery (T0) and at follow-up ≥6 months

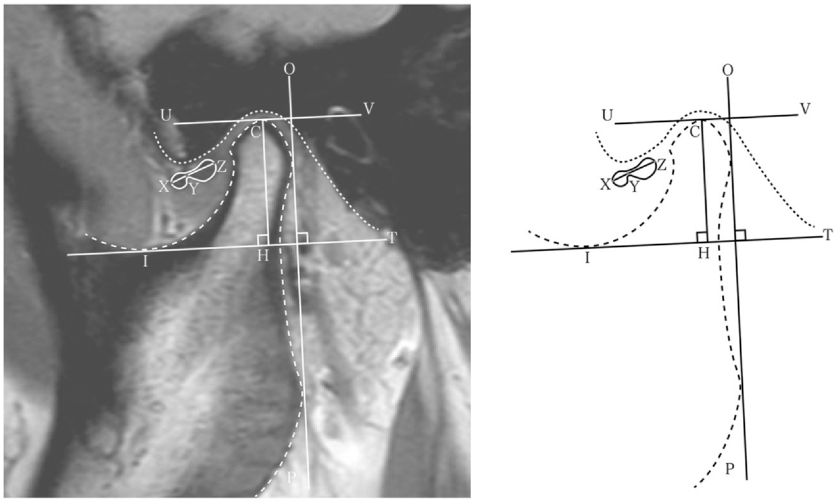

Fig. 1. Measurement of condylar height, disc length, and disc position based on MRI. The condylar height was identified as the length of CH. The disc length was the sum of XY and YZ. The disc position relative to the condyle was defined as the distance between point Y and point C. OP, the posterior border of the ramus; UV, a line perpendicular to OP through the most cranial point of the condyle; IT, a line perpendicular to OP through the deepest point of the sigmoid notch; CH, the distance between UV and IT; X, the most anterior point of the disc; Y, the midpoint of the intermediate zone of the disc; Z, the most posterior point of the disc.

after surgery (T1). Patients who did not receive arthroscopic discopexy but instead underwent health education were assigned to the control group. These patients were required to have MRI examinations at the first visit (T0) and at ≥6 months after T0 (T1).

Treatment protocol for the arthroscopy group

All patients in the arthroscopy group underwent the arthroscopic disc repositioning surgery. All surgeries were performed by one surgeon (C.Y.). The surgery was performed under local anaesthesia as described in a previous study[29]. A 0° arthroscope with a diameter of 2.7 mm was introduced into the upper cavity of the TMJ, and a coblation probe was then inserted to release the anterior disc attached to the capsule. A suture needle was inserted at the interface between the bilaminar zone and the posterior band. The suture was then passed through the needle and gripped by a pair of self-designed suture grippers. Finally, the disc was pulled backwards and tied underneath the cartilage of the external auditory canal using the suture. In order to maintain the new occlusion and unload the joint, the patient was required to wear a splint for 6 months after the surgery: for the first 3 months, the patient was requested to wear the splint 24 h a day except while eating or brushing their teeth; for the next 3 months, they only needed to wear it during the night.

Clinical assessments, physical indicators, and bone mineral density (BMD) examination

Clinical assessments were performed for all study participants. Their history of TMD-related symptoms, including joint sounds, pre-auricular pain, opening restriction, facial asymmetry, and mandibular retrusion, was collected. The assessment of pain was performed by patient-reported questionnaire using a visual analogue scale (VAS) of 0–10, with ‘0’ representing no pain and ‘10’ representing the most severe pain. Maximum inter-incisal opening (MIO) was evaluated by one doctor (C.Y.) using a conventional ruler. Quality of life (QoL) was evaluated using a four-point VAS, with ‘1’ representing the need to rest in bed and ‘4’ representing the ability to perform normal daily activities.

In adolescents, systemic factors including height, weight, and BMI can reflect their physical condition, and bone density can reflect the bone development condition[14]. Each patient’s height and weight were measured while wearing light clothes and no shoes, and their body mass index (BMI) was then calculated. The same BMD scanner was used to measure the BMD at the left femoral neck and left hip joint in all patients (Discovery DXA System; Hologic, Inc., Marlborough, MA, USA). The Z-score (standard deviation of the mean BMD in healthy individuals matched for age and sex)[34] was calculated to evaluate the BMD value. All measurements were performed by the same physician.

MRI evaluation

All patients underwent MRI examinations performed using the same 3 T MRI scanner (Signa; GE HealthCare, Milwaukee, WI, USA), and the image was evaluated as shown in Fig. 1. The posterior border of the ramus (OP) was defined, and two horizontal lines perpendicular to OP were drawn: UV through the most cranial point of the condyle (C) and IT through the deepest point of the sigmoid notch (I). The condylar height was measured as the distance between UV and IT (CH). The midpoint of the intermediate zone of the disc (Y) could always be clearly located. X and Z were the most anterior and posterior points, respectively, according to point C. The disc length was the sum of XY and YZ. The disc position relative to the condyle was defined as the distance between point Y and point C.

Statistical analysis

R version 4.1.0 (www.r-project.org)[35] was used for all analyses. Data are presented as frequencies (percentages) for categorical variables and as the mean ± standard deviation or median (interquartile range) for continuous variables. The *t*-test, Mann–Whitney *U*-test, χ^2 test, and Fisher’s exact test were used to compare the baseline data between the two groups and determine the significance of the difference. Considering the correlation between the right and left condylar heights in the same person, linear mixed-effect models were used for all subsequent analyses. The Pearson correlation coefficient was used to assess the relationships between the variables. In the multivariable analysis, a linear mixed-effects model was established that included the variables showing an association with condylar change in the Pearson correlation analysis. Conclusions were based on the multivariable model. Moreover, the changes in pain, MIO, and QoL in the two groups were also evaluated using the linear mixed-effects models. The estimates and 95% confidence intervals (95% CI) are presented. *P*-values were calculated, and $P < 0.05$ was considered statistically significant.

Results

Participant characteristics

A total of 145 patients met the inclusion criteria, of whom 108 underwent arthroscopic discopexy and were assigned to the arthroscopy group; the remaining 37 patients who did not undergo surgery were assigned to the control group. The majority of the patients in both groups were female: 87.0% in the arthroscopy group, 75.7% in the control group (overall 84.1% female, 15.9% male). The median age of the patients was 16 years in both groups. The follow-up duration did not differ significantly between the groups.

Moreover, 40.7% of the patients in the arthroscopy group and 32.4% in the control group were diagnosed with unilateral ADDwoR. The patients with unilateral and bilateral ADDwoR were analysed separately in further analyses.

No significant differences were observed between the two groups in terms of clinical assessments, height, weight, BMI, and BMD indicators (Table 1). The MRI evaluation revealed no significant difference between the two groups in disc length, disc position, or condylar height at T0 (within a week before arthroscopic surgery) (Table 2). Fig. 2 shows a representative case from each of the two groups, with MRI images obtained before and after follow-up. The case from the control group shows moderate disc deformation and condylar resorption at T0 (Fig. 2A), while after follow-up, more severe condylar resorption and disc deformation can be seen at T1 (Fig. 2B). In the case from the arthroscopy group, the anteriorly displaced disc is seen to be deformed at T0 (Fig. 2C), while after disc repositioning surgery, a normal disc–condyle relationship and new bone formation can be observed (blue arrow, Fig. 2D).

Table 1. Participant characteristics.

	Arthroscopy group ($n = 108$)	Control group ($n = 37$)	*P*-value[a]
Sex, *n* (%)			0.102
Female	94 (87.0)	28 (75.7)	
Male	14 (13.0)	9 (24.3)	
Age (years)	16 (14, 18)	16 (14, 19)	0.609
Duration between T0 and T1 (months)	11 (9, 15)	10 (8, 15)	0.348
Site, *n* (%)			0.370
Unilateral	44 (40.7)	12 (32.4)	
Bilateral	64 (59.3)	25 (67.6)	
Clinical assessment			
Joint sounds, *n* (%)			0.554
Yes	98 (94.2)	31 (96.9)	
No	6 (5.8)	1 (3.1)	
Pre-auricular pain, *n* (%)			0.540
Yes	69 (65.1)	22 (59.5)	
No	37 (34.9)	15 (40.5)	
Opening restriction, *n* (%)			0.982
Yes	65 (61.3)	22 (61.1)	
No	41 (38.7)	14 (38.9)	
Facial asymmetry, *n* (%)			0.827
Yes	28 (25.9)	10 (27.8)	
No	80 (74.1)	26 (72.2)	
Mandibular retrusion, *n* (%)			0.088
Yes	25 (23.4)	14 (37.8)	
No	82 (76.6)	23 (62.2)	
VAS score for pain	2 (0, 3)	1.5 (0, 2)	0.289
MIO (mm)	28 (26, 35)	30 (28, 34)	0.070
VAS score for quality of life	3 (2, 3)	3 (2, 3)	0.075
Height (cm)	162 (159.75, 167.25)	163 (160, 171)	0.275
Weight (kg)	51 (45, 55.25)	50 (45, 58)	0.798
BMI (kg/m^2)	19.07 ± 2.57	18.68 ± 2.59	0.434
Bone density evaluation			
Bone mineral density (g/cm^2)	0.86 ± 0.12	0.87 ± 0.12	0.667
Bone mineral content (g)	47.90 ± 9.77	50.64 ± 12.13	0.169
Z-score	−0.71 ± 0.88	−0.72 ± 0.91	0.946

BMI, body mass index; MIO, maximum inter-incisal opening; VAS, visual analogue scale. Continuous variables are shown as the mean ± standard deviation or median (interquartile range).

[a] *P*-values are based on the Mann–Whitney test, *t*-test, χ^2 test, or Fisher's exact test.

Arthroscopic discopexy restored condylar growth on the affected sides in patients with ADDwoR

The changes in condylar height from T0 to T1 are shown in Fig. 3 and reported in Supplementary Material Table S1. The overall analyses showed that the condylar height decreased in the control group and increased in the arthroscopy group.

All subgroup analyses showed that condylar height increased from T0 to T1 in the arthroscopy group. Notably, in patients with unilateral ADDwoR in the arthroscopy group, the condyle on the affected side grew more than that on the unaffected side after arthroscopic discopexy (mean difference = 1.15 mm, 95% CI 0.25–2.05 mm, $P = 0.013$). In the control group, condylar height decreased on the affected side of patients with unilateral ADDwoR and in those with bilateral ADDwoR. No change in condylar height was observed on the unaffected side in the patients with unilateral ADDwoR in this group. The mean condylar height change in the arthroscopy group was 2.12 mm more than that in the control group ($P < 0.001$). This difference was 2.55 mm in patients with bilateral ADDwoR ($P < 0.001$) and 2.41 mm on the affected side in patients with unilateral ADDwoR ($P < 0.001$). No significant difference in the condylar height change on the unaffected side of patients with unilateral ADDwoR was observed between the two groups.

Correlations between the indicators and the condylar height changes in the arthroscopy group

The Pearson correlation analysis to determine the correlation between the variables and condylar growth in the

Table 2. MRI evaluation of the patients based on the TMJ MRI performed within a week before arthroscopic surgery.

	Arthroscopy group ($n = 108$)	Control group ($n = 37$)	P-value[a]
Disc length (mm)			
Overall	8.35 ± 2.06	7.68 ± 1.87	0.085
Bilateral ADDwoR			
Right side	7.68 ± 1.99	7.59 ± 2.18	0.851
Left side	6.80 (5.47, 9.25)	6.00 (4.90, 7.50)	0.101
Unilateral ADDwoR			
Affected side	9 (7.18, 11.33)	8.25 (7.2, 9.42)	0.353
Unaffected side	9.93 ± 2.26	9.79 ± 1.74	0.848
Disc position based on condyle (mm)			
Overall	10.04 ± 2.23	10.78 ± 2.50	0.093
Bilateral ADDwoR			
Right side	11.70 (10.10, 12.30)	12.10 (10.60, 13.10)	0.287
Left side	11.21 ± 1.99	11.99 ± 2.12	0.106
Unilateral ADDwoR			
Affected side	9.25 (6.10, 11.10)	10.30 (5.85, 11.38)	0.905
Unaffected side	7.25 (5.27, 10.70)	8.75 (5.35, 10.17)	0.944
Condylar height (mm)			
Overall	20.16 ± 3.02	19.54 ± 3.03	0.285
Bilateral ADDwoR			
Right side	21.05 (18.40, 22.12)	19.60 (16.70, 23.10)	0.665
Left side	20.85 (19.27, 22.80)	21.20 (17.90, 23.30)	0.967
Unilateral ADDwoR			
Affected side	19.81 ± 3.30	20.30 ± 3.30	0.652
Unaffected side	23.46 ± 2.50	21.28 ± 3.18	0.014 *

ADDwoR, anterior disc displacement without reduction; MRI, magnetic resonance imaging; TMJ, temporomandibular joint. Continuous variables are shown as the mean ± standard deviation or median (interquartile range).
[a]P-values are based on the Mann–Whitney test or t-test. * $P < 0.05$, significant.

arthroscopy group is presented in Fig. 4. Age was found to be negatively correlated with condylar growth (Fig. 4A, $P < 0.05$), whereas the duration of follow-up was positively correlated with condylar changes (Fig. 4B, $P < 0.05$). Regarding the systemic indicators, height, weight, BMI, BMD, and Z-score showed no significant correlation with condylar growth after arthroscopic discopexy (Fig. 4C–G, $P > 0.05$). For the local factors, disc length showed a negative correlation with condylar growth (Fig. 4H, $P < 0.05$), whereas disc displacement distance showed a positive correlation with condylar height changes (Fig. 4I, $P < 0.01$).

Condylar growth was found to be correlated with age, follow-up duration, disc length, and disc position in the arthroscopy group

Multivariable mixed-effects models were used to further confirm whether the condylar growth after arthroscopic discopexy was related to the indicators. In accordance with the Pearson correlation analysis, the multivariable model was established to include age, duration of follow-up, disc length, and disc position. The results showed that condylar growth after arthroscopic discopexy was negatively correlated with age ($P = 0.017$) and disc length ($P = 0.015$), and positively correlated with follow-up duration ($P = 0.002$) and disc position ($P < 0.001$; Table 3).

Arthroscopic discopexy improved pain, MIO, and QoL

Clinical assessment information was collected during follow-up for 105 participants in the arthroscopy group and 36 participants in the control group. The results in the arthroscopy group demonstrated significant improvements in pain ($P < 0.001$), MIO ($P < 0.001$), and QoL ($P < 0.001$). On the other hand, the control group showed some improvement in pain during follow-up ($P = 0.028$), but no significant change in MIO ($P = 0.074$) or QoL ($P = 0.197$) was observed. Compared with the patients in the control group, significantly better improvements were observed in the arthroscopy group for pain ($P = 0.024$), MIO ($P < 0.001$), and QoL ($P < 0.001$) (Supplementary Material Table S2).

Discussion

TMJ ADD, especially ADDwoR, has received increasing attention in recent years owing to its association with dentofacial deformities and functional defects[5–10]. Although conservative treatment has been recommended for TMJ ADD, the necessity and efficacy of disc repositioning have been reported in numerous studies[28,30,31]. However, the mechanism of condylar growth after surgery has rarely been reported. In the present study, adolescent patients with ADD showed condylar growth after disc repositioning, and the condylar growth was correlated with age and local factors, proving the main study hypothesis.

Apart from the other joints, the TMJ condylar cartilage is fibrocartilage, which has a high bone turnover rate and is highly reactive to mechanical changes[36]. It has been reported that during endochondral bone formation, a majority of chondrocytes in the condyle directly transform into bone cells, proving the vital role of the condyle in the mandibular growth process[37,38]. Moderate biological stress in the TMJ is beneficial to the condylar cartilage metabolism and condylar growth, while excessive stress can cause condylar resorption[12,39]. Disc displacement can lead to increased condylar stress, and it has been reported that anterior displacement of the TMJ disc can increase the intra-articular pressure on the condyle by 9.5–69%[40,41]. These may be the reasons why ADD has been considered a risk factor for condylar resorption and osteoarthrosis in many studies[11–13]. Disc repositioning can provide a physiological anatomy structure, which is of great significance for maintaining the homeostasis of the joint environment, ensuring normal stress and restoring condylar growth[36–38]. Of note, disc repositioning is also necessary because ADD has a close relationship with relapse following orthodontic or orthognathic treatments[17,21–23]. Previous studies have reported that patients with ADD or condylar resorption are prone to relapse after orthodontic and/or orthognathic treatments[22,23]. Thus, for patients with orthodontic needs, it is recommended that they undergo disc repositioning surgery prior to the orthodontic procedures.

In this study, condylar height, which is affected by ADDwoR, decreased without treatment in the control group. Subgroup analysis of the unaffected

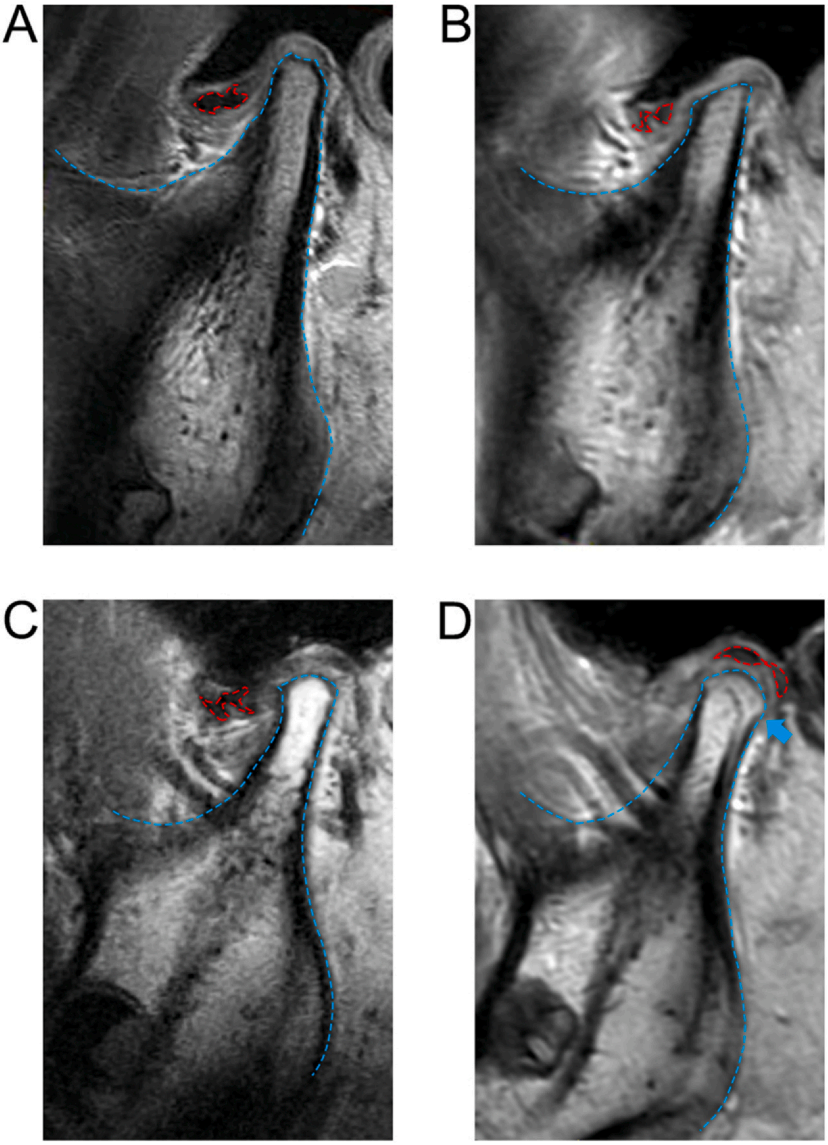

Fig. 2. MRI images of two representative cases. Control group: (A) T0, (B) T1. Arthroscopy group: (C) T0, (D) T1. The red lines show the disc and the blue lines indicate the contour of the condyle. The blue arrow shows the new bone formation after surgery.

side in patients with unilateral ADDwoR indicated that the condyle without ADDwoR was stable during the normal course. Studies in animal models have observed that unilateral condylar lesions affect the contralateral condyle[42,43]. Finite element models of human unilateral ADDwoR have shown a strong stress-related change on the healthy side[44]. Thus, the contralateral condyle may show abnormal growth in unilateral ADDwoR. These results indicate that without disc repositioning, TMJ ADDwoR can lead to condylar resorption in adolescents. In the arthroscopy group, condylar height increased by more than 1.5 mm in the condyles affected by ADDwoR. Condylar growth after disc repositioning was significantly better than that without disc repositioning in the condyles with ADDwoR, while no significant difference was observed in the condyles without the disease. In addition, condylar growth on the affected side was greater than that on the unaffected side in patients with unilateral ADDwoR after arthroscopic discopexy. This may be attributed to the reduced biological stress on the affected condyle[39]. However, more studies and evidence are warranted to confirm the mechanism of the increased growth of the condyle after disc repositioning. In summary, these findings confirm that arthroscopic discopexy can restore the condylar growth in adolescents with ADDwoR.

Adolescence is characterized by increases in height and weight, along with a rapid increase in bone mass[45]. It is debatable whether the condylar growth after disc repositioning is related to the bone remodelling ability in adolescents with ADDwoR[32]. Thus, Pearson correlation analysis and further multivariable analysis were performed to gain an insight into the mechanism. It was found that systemic indicators including height, weight, BMI, and BMD levels were not correlated with condylar growth. Notably, the condyle grew more in younger patients, indicating that disc repositioning at a younger age is beneficial to condylar growth. The positive association between the follow-up duration and condylar growth indicates a good outcome of the surgery. Furthermore, condylar height increased more in patients with a shorter disc and longer disc displacement distance. These results may be explained by the fact that a long disc with a short displacement distance tends to indicate milder condylar resorption, resulting in less significant condylar remodelling after disc repositioning. On the other hand, a short disc and a long displacement distance are usually related to a more severe condylar resorption, and thus more condylar growth can be observed after disc repositioning. These findings suggest that condylar growth is closely related to the environment surrounding the condyle, particularly the condition of the disc, rather than the body or bone condition. In summary, condylar growth after disc repositioning is related to age and local factors, but not systemic indicators.

The pain level, MIO, and QoL were also evaluated in both groups. Patients in the arthroscopy group showed better improvements in pain, MIO, and QoL when compared to those in the control group. Consistent with this study, previous studies have also reported improvements in pain, MIO, and QoL in patients after disc repositioning[31,46,47]. Pain is one of the most common and important symptoms in TMDs[1–4], and it may be due to the impingement of the highly innervated retrodiscal tissue in TMJ ADDwoR patients[31]. This could explain why restoring the normal structure of the TMJ through disc repositioning can relieve the pain. The improvement in jaw movement (MIO) can be attributed to the improved mobility of the disc and joint after disc repositioning[46,47]. The improvements in pain and MIO contribute to the improvement in QoL. Hence, this study provides evidence for the good efficacy

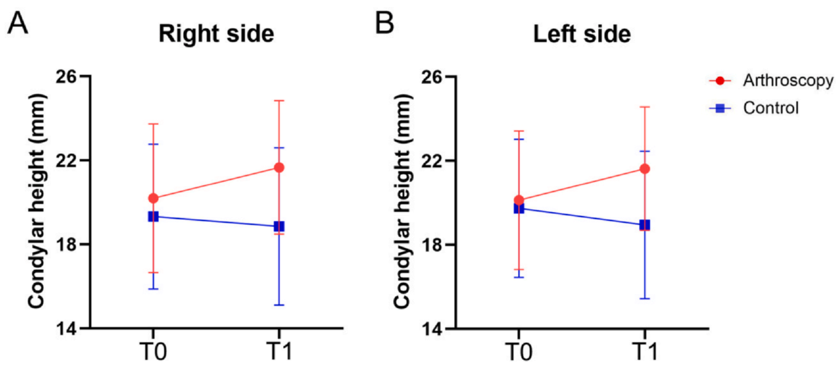

Fig. 3. Condylar height changes in the two groups from T0 to T1: (A) right condylar height changes and (B) left condylar height changes. The circles and squares show the mean values and the error bars show the standard deviation.

of disc repositioning with regard to improvements in pain, MIO, and QoL.

This retrospective longitudinal study included two groups of patients from the same source with a balanced baseline, and multivariable models were used to minimize biases caused by individual differences and confounders. Furthermore, the differences between unilateral and bilateral ADDwoR were considered and analysed separately in subgroup analyses, ensuring more accurate conclusions. However, there are still some limitations that should be considered. First, this was a retrospective study, hence some biases cannot be completely eliminated. Second, as the allocation of patients to the two groups was not randomized, there may be potential selection biases. Third, the variable follow-up duration may increase the bias. Hence, further prospective randomized controlled trials with larger sample sizes and longer follow-up durations are required to validate the study findings.

In conclusion, in adolescent patients, TMJ ADDwoR can lead to a decrease in condylar height in the affected

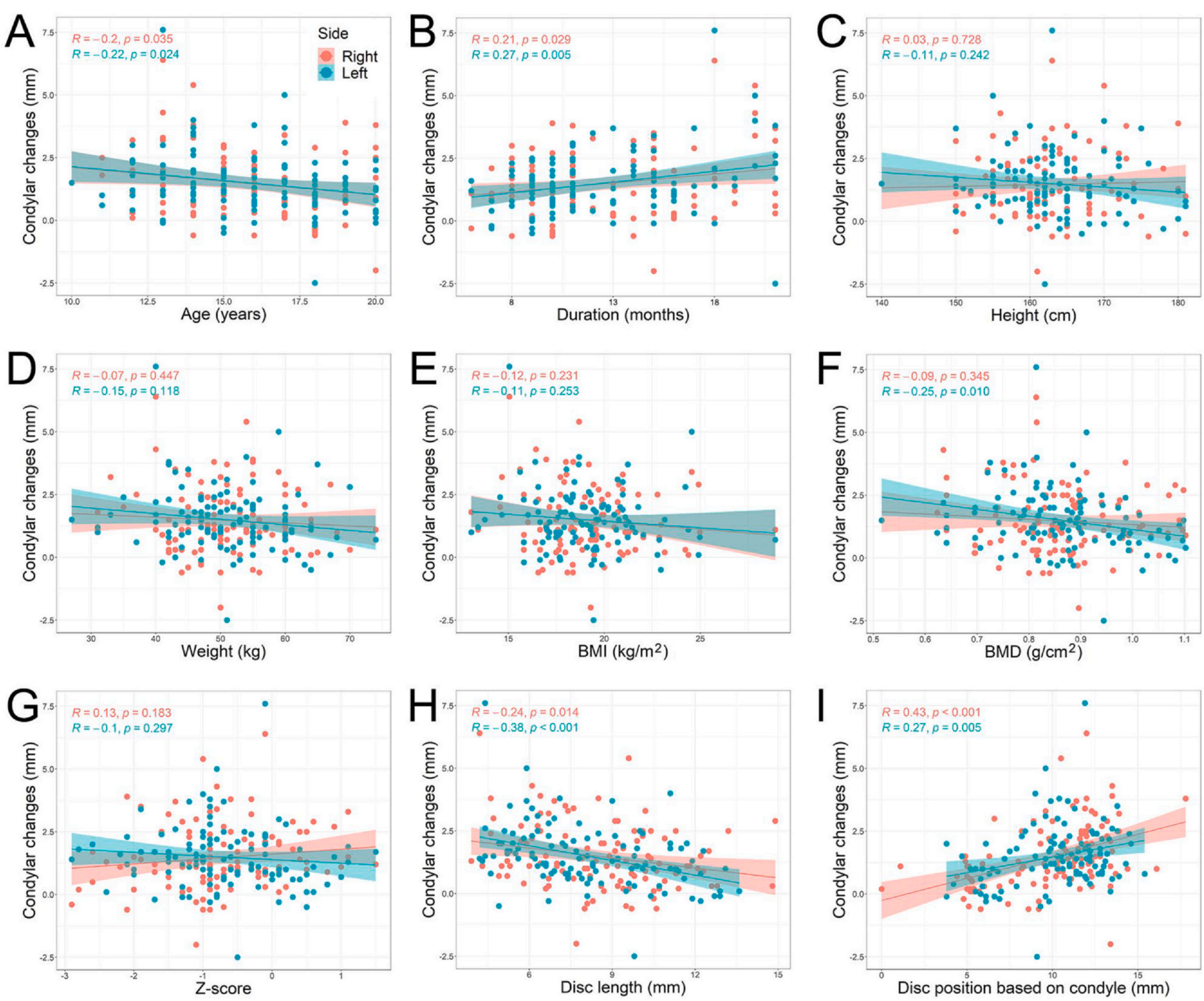

Fig. 4. Correlations between the indicators and condylar height changes after arthroscopic discopexy. The correlation of condylar height change after arthroscopic discopexy with (A) age, (B) follow-up duration, (C) height, (D) weight, (E) BMI, (F) BMD, (G) Z-score, (H) disc length, and (I) disc position relative to the condyle. BMI, body mass index; BMD, bone mineral density.

Table 3. Association of local and systemic factors with condylar growth in the arthroscopy group by multivariable analysis.

Factors	Estimate (95% CI)	*P*-value
Age (years)	−0.09 (−0.16 to −0.02)	0.017*
Duration between T0 and T1 (months)	0.07 (0.03–0.12)	0.002*
Disc length (mm)	−0.09 (−0.16 to −0.02)	0.015*
Disc position based on condyle (mm)	0.14 (0.08–0.19)	< 0.001*

CI, confidence interval. *P < 0.05, significant.

condyle, which can be improved through arthroscopic discopexy. Condylar growth after the surgery was found to be related to age and local factors, such as disc length and disc displacement distance, but not systemic indicators, including height, weight, BMI, and BMD levels. Furthermore, arthroscopic discopexy showed positive outcomes in terms of pain reduction, increased MIO, and improved QoL. In summary, arthroscopic discopexy appears to be an effective treatment option for restoring condylar growth and improving symptoms in adolescents with ADDwoR, and the condylar growth after arthroscopic discopexy is closely related to local factors.

Ethical approval

This study was approved by the Human Research Ethics Committee of Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine (approval No. SH9H-2020-T7-1).

Patient consent

Informed signed consent was obtained from all participants.

Funding

This study was supported by the National Natural Science Foundation of China (81870785, 82071134, 82370980), Natural Science Foundation of Shanghai (22ZR1437600), Shanghai's Top Priority Research Center (2022ZZ01017), and the dominant disease biological sample project of the Ninth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine (YBKA201908).

Declaration of Competing Interest

The authors declare that they have no competing interests.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ijom.2023.10.005.

References

1. Leeuw RD. Orofacial pain: guidelines for assessment, diagnosis, and management. *Quintessence* 2008.
2. Poluha RL, Canales GT, Costa YM, Grossmann E, Bonjardim LR, Conti PCR. Temporomandibular joint disc displacement with reduction: a review of mechanisms and clinical presentation. *J Appl Oral Sci* 2019;**27**:e20180433https://doi.org/10.1590/1678-7757-2018-0433
3. Naeije M, Te Veldhuis AH, Te Veldhuis EC, Visscher CM, Lobbezoo F. Disc displacement within the human temporomandibular joint: a systematic review of a 'noisy annoyance'. *J Oral Rehabil* 2013;**40**:139–58. https://doi.org/10.1111/joor.12016
4. Gauer RL, Semidey MJ. Diagnosis and treatment of temporomandibular disorders. *Am Fam Phys* 2015;**91**:378–86.
5. Zhu H, He D, Yang Z, Lu C, Zhao J, Yang C. The effect of condylar regeneration after different disc repositioning surgeries in adolescents with skeletal Class II malocclusion. *J Oral Maxillofac Surg* 2021;**79**:1851–61. https://doi.org/10.1016/j.joms.2021.03.011
6. Zhu H, He D, Yang Z, Song X, Ellis 3rd E. The effect of disc repositioning and post-operative functional splint for the treatment of anterior disc displacement in juvenile patients with Class II malocclusion. *J Craniomaxillofac Surg* 2019;**47**:66–72. https://doi.org/10.1016/j.jcms.2018.09.035
7. Ooi K, Inoue N, Matsushita K, Mikoya T, Minowa K, Kawashiri S, Tei K. Relations between anterior disc displacement and maxillomandibular morphology in skeletal anterior open bite with changes to the mandibular condyle. *Br J Oral Maxillofac Surg* 2020;**58**:1084–90. https://doi.org/10.1016/j.bjoms.2020.05.023
8. Wolford LM, Gonçalves JR. Condylar resorption of the temporomandibular joint: how do we treat it? *Oral Maxillofac Surg Clin North Am* 2015;**27**:47–67. https://doi.org/10.1016/j.coms.2014.09.005
9. Sansare K, Raghav M, Mallya S, Mundada N, Karjodkar F, Randive P, Meshram D, Shirsat P. Aggressive condylar resorption. *J Craniofac Surg* 2013;**24**:e95–6. https://doi.org/10.1097/SCS.0b013e3182798eff
10. Shen P, Xie Q, Ma Z, Abdelrehem A, Zhang S, Yang C. Yang's classification of juvenile TMJ anterior disc displacement contributing to treatment protocols. *Sci Rep* 2019;**9**:5644. https://doi.org/10.1038/s41598-019-42081-5
11. Chantaracherd P, John MT, Hodges JS, Schiffman EL. Temporomandibular joint disorders' impact on pain, function, and disability. *J Dent Res* 2015;**94**(3 Suppl):79s–86s. https://doi.org/10.1177/0022034514565793
12. Dias IM, Cordeiro PC, Devito KL, Tavares ML, Leite IC, Tesch Rde S. Evaluation of temporomandibular joint disc displacement as a risk factor for osteoarthrosis. *Int J Oral Maxillofac Surg* 2016;**45**:313–7. https://doi.org/10.1016/j.ijom.2015.09.016
13. Takaoka R, Yatani H, Senzaki Y, Koishi Y, Moriguchi D, Ishigaki S. Relative risk of positional and dynamic temporomandibular disc abnormality for osteoarthritis—magnetic resonance imaging study. *J Oral Rehabil* 2021;**48**:375–83. https://doi.org/10.1111/joor.13138
14. Chulani VL, Gordon LP. Adolescent growth and development. *Prim Care* 2014;**41**:465–87. https://doi.org/10.1016/j.pop.2014.05.002
15. Wit JM. Should skeletal maturation be manipulated for extra height gain. *Front Endocrinol ((Lausanne))* 2021;**12**:812196https://doi.org/10.3389/fendo.2021.812196
16. Ikeda K, Kawamura A, Ikeda R. Prevalence of disc displacement of various severities among young preorthodontic population: a magnetic resonance imaging study. *J Prosthodont* 2014;**23**:397–401. https://doi.org/10.1111/jopr.12126
17. Zhuo Z, Cai X, Xie Q. Is anterior disc displacement without reduction associated with temporomandibular joint condylar height in juvenile patients younger than 20 years. *J Oral Maxillofac Surg* 2015;**73**:843–9. https://doi.org/10.1016/j.joms.2014.12.013
18. Xie Q, Yang C, He D, Cai X, Ma Z, Shen Y, Abdelrehem A. Will unilateral temporomandibular joint anterior disc displacement in teenagers lead to asymmetry of condyle and mandible? A longitudinal study. *J Craniomaxillofac Surg* 2016;**44**:590–6. https://doi.org/10.1016/j.jcms.2016.01.019

19. Chouinard AF, Kaban LB, Peacock ZS. Acquired abnormalities of the temporomandibular joint. *Oral Maxillofac Surg Clin North Am* 2018;**30**:83–96. https://doi.org/10.1016/j.coms.2017.08.005
20. Hatcher DC. Progressive condylar resorption: pathologic processes and imaging considerations. *Semin Orthod* 2013;**19**:97–105.
21. Wolford LM. Can orthodontic relapse be blamed on the temporomandibular joint. *J Orthod Sci* 2014;**3**:95–105. https://doi.org/10.4103/2278-0203.143227
22. Mitsimponas K, Mehmet S, Kennedy R, Shakib K. Idiopathic condylar resorption. *Br J Oral Maxillofac Surg* 2018;**56**:249–55. https://doi.org/10.1016/j.bjoms.2018.02.016
23. Gonçalves JR, Cassano DS, Wolford LM, Santos-Pinto A, Márquez IM. Postsurgical stability of counterclockwise maxillomandibular advancement surgery: affect of articular disc repositioning. *J Oral Maxillofac Surg* 2008;**66**:724–38. https://doi.org/10.1016/j.joms.2007.11.007
24. Al-Baghdadi M, Durham J, Araujo-Soares V, Robalino S, Errington L, Steele J. TMJ disc displacement without reduction management: a systematic review. *J Dent Res* 2014;**93**(7 Suppl):37s–51s. https://doi.org/10.1177/0022034514528333
25. Annandale T. On displacement of the inter-articular cartilage of the lower jaw, and its treatment by operation. *Lancet* 1887;**129**:411. https://doi.org/10.1016/S0140-6736(02)28282-3
26. Mehra P, Wolford LM. The Mitek mini anchor for TMJ disc repositioning: surgical technique and results. *Int J Oral Maxillofac Surg* 2001;**30**:497–503. https://doi.org/10.1054/ijom.2001.0163
27. McCain JP, Podrasky AE, Zabiegalski NA. Arthroscopic disc repositioning and suturing: a preliminary report. discussion 579–580 *J Oral Maxillofac Surg* 1992;**50**:568–79. https://doi.org/10.1016/0278-2391(92)90435-3
28. Yang C, Cai XY, Chen MJ, Zhang SY. New arthroscopic disc repositioning and suturing technique for treating an anteriorly displaced disc of the temporomandibular joint: part I—technique introduction. *Int J Oral Maxillofac Surg* 2012;**41**:1058–63. https://doi.org/10.1016/j.ijom.2012.05.025
29. Liu X, Zheng J, Cai X, Abdelrehem A, Yang C. Techniques of Yang's arthroscopic discopexy for temporomandibular joint rotational anterior disc displacement. *Int J Oral Maxillofac Surg* 2019;**48**:769–78. https://doi.org/10.1016/j.ijom.2018.12.003
30. Gonçalves JR, Cassano DS, Rezende L, Wolford LM. Disc repositioning: does it really work? *Oral Maxillofac Surg Clin North Am* 2015;**27**:85–107. https://doi.org/10.1016/j.coms.2014.09.007
31. Abdelrehem A, Hu YK, Yang C, Zheng JS, Shen P, Shen QC. Arthroscopic versus open disc repositioning and suturing techniques for the treatment of temporomandibular joint anterior disc displacement: 3-year follow-up study. *Int J Oral Maxillofac Surg* 2021;**50**:1351–60. https://doi.org/10.1016/j.ijom.2021.02.018
32. Dong M, Jiao Z, Sun Q, Tao X, Yang C, Qiu W. The magnetic resonance imaging evaluation of condylar new bone remodeling after Yang's TMJ arthroscopic surgery. *Sci Rep* 2021;**11**:5219. https://doi.org/10.1038/s41598-021-84591-1
33. Cai XY, Jin JM, Yang C. Changes in disc position, disc length, and condylar height in the temporomandibular joint with anterior disc displacement: a longitudinal retrospective magnetic resonance imaging study. *J Oral Maxillofac Surg* 2011;**69**:e340–6. https://doi.org/10.1016/j.joms.2011.02.038
34. Hong SW, Kang JH. Bone mineral density, bone microstructure, and bone turnover markers in females with temporomandibular joint osteoarthritis. *Clin Oral Investig* 2021;**25**:6435–48. https://doi.org/10.1007/s00784-021-03946-0
35. R Core Team. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing; 2021⟨https://www.R-project.org/⟩.
36. Willems NM, Langenbach GE, Everts V, Zentner A. The microstructural and biomechanical development of the condylar bone: a review. *Eur J Orthod* 2014;**36**:479–85. https://doi.org/10.1093/ejo/cjt093
37. Jing Y, Zhou X, Han X, Jing J, von der Mark K, Wang J, de Crombrugghe B, Hinton RJ, Feng JQ. Chondrocytes directly transform into bone cells in mandibular condyle growth. *J Dent Res* 2015;**94**:1668–75. https://doi.org/10.1177/0022034515598135
38. Stocum DL, Roberts WE. Part I: development and physiology of the temporomandibular joint. *Curr Osteoporos Rep* 2018;**16**:360–8. https://doi.org/10.1007/s11914-018-0447-7
39. Liu Z, Qian Y, Zhang Y, Fan Y. Effects of several temporomandibular disorders on the stress distributions of temporomandibular joint: a finite element analysis. *Comput Methods Biomech Biomed Eng* 2016;**19**:137–43. https://doi.org/10.1080/10255842.2014.996876
40. Iwasaki LR, Gonzalez YM, Liu Y, Liu H, Markova M, Gallo LM, Nickel JC. Mechanobehavioral scores in women with and without TMJ disc displacement. *J Dent Res* 2017;**96**:895–901. https://doi.org/10.1177/0022034517704375
41. Iwasaki LR, Crosby MJ, Gonzalez Y, McCall WD, Marx DB, Ohrbach R, Nickel JC. Temporomandibular joint loads in subjects with and without disc displacement. *Orthop Rev)* 2009;**1**:90–3. https://doi.org/10.4081/or.2009.e29
42. Ghassemi Nejad S, Kobezda T, Tar I, Szekanecz Z. Development of temporomandibular joint arthritis: the use of animal models. *Joint Bone Spine* 2017;**84**:145–51. https://doi.org/10.1016/j.jbspin.2016.05.016
43. Cohen WA, Servais JM, Polur I, Li Y, Xu L. Articular cartilage degeneration in the contralateral non-surgical temporomandibular joint in mice with a unilateral partial discectomy. *J Oral Pathol Med* 2014;**43**:162–5. https://doi.org/10.1111/jop.12113
44. Pérez del Palomar A, Doblaré M. Influence of unilateral disc displacement on the stress response of the temporomandibular joint discs during opening and mastication. *J Anat* 2007;**211**:453–63. https://doi.org/10.1111/j.1469-7580.2007.00796.x
45. Cousminer DL, Mitchell JA, Chesi A, Roy SM, Kalkwarf HJ, Lappe JM, Gilsanz V, Oberfield SE, Shepherd JA, Kelly A, McCormack SE, Voight BF, Zemel BS, Grant SF. Genetically determined later puberty impacts lowered bone mineral density in childhood and adulthood. *J Bone Miner Res* 2018;**33**:430–6. https://doi.org/10.1002/jbmr.3320
46. McCain JP, Hossameldin RH, Srouji S, Maher A. Arthroscopic discopexy is effective in managing temporomandibular joint internal derangement in patients with Wilkes stage II and III. *J Oral Maxillofac Surg* 2015;**73**:391–401. https://doi.org/10.1016/j.joms.2014.09.004
47. Clark GT, Moody DG, Sanders B. Arthroscopic treatment of temporomandibular joint locking resulting from disc derangement: two-year results. *J Oral Maxillofac Surg* 1991;**49**:157–64. https://doi.org/10.1016/0278-2391(91)90104-t

Correspondence to: Shanghai Ninth People's Hospital
Shanghai Jiao Tong University School of Medicine
No. 639
Zhi-zao-ju Road
Shanghai 200011
China.
E-mail: yangchi1963@hotmail.com