Journal of Cranio-Maxillo-Facial Surgery 52 (2024) 157–164

Contents lists available at ScienceDirect

Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com

Effect of arthroscopic discopexy on condylar growth in adolescents with temporomandibular joint disc displacement without reduction: A retrospective self-controlled case series study

Dahe Zhang [a], Ahmed Abdelrehem [b], Yi Luo [a], Pei Shen [a, **], Chi Yang [a, *]

[a] Department of Oral Surgery, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, College of Stomatology, Shanghai Jiao Tong University, National Center for Stomatology, National Clinical Research Center for Oral Diseases, No. 639, Zhi Zao Ju Road, Shanghai, 200011, Shanghai, China

[b] Department of Craniomaxillofacial and Plastic Surgery, Alexandria University, Alexandria, 21563, Egypt

ARTICLE INFO

Article history:
Paper received 30 June 2022
Received in revised form
6 May 2023
Accepted 25 June 2023
Available online 8 July 2023

Handling editor: Prof. Emeka Nkenke

Keywords:
Arthroscopy
Dentofacial deformities
Mandibular condyle
Temporomandibular joint
Temporomandibular joint disorders

ABSTRACT

This study was a retrospective self-controlled study that aimed to evaluate the effect of arthroscopic discopexy on condylar height and mandibular position in adolescents with temporomandibular joint (TMJ) anterior disc displacement without reduction (ADDwoR).

Patients between 10 and 20 years of age and diagnosed with bilateral TMJ ADDwoR by magnetic resonance image (MRI) were included in this study. All patients underwent a period of natural course before arthroscopic surgery and then a follow-up period postoperatively. Changes in condylar height and mandibular position were measured by MRI and X-ray radiographs. Data were analyzed by paired *t*-test, Pearson correlation analysis, and generalized estimating equations.

This study comprised a total of 40 patients with a mean age of 14.80 years. Pearson correlation analysis showed correlations between condylar height and mandibular position changes. The condylar height change during the post-operative period was significantly higher than that during natural course period (3.57 mm, $p < 0.001$). The changes in mandibular position (including ANB angle, SNB angle, and Pog-Np) were significant different (all $p < 0.05$) between the two periods.

This study found that arthroscopic discopexy can promote condylar growth and correct dentofacial deformity in adolescents with bilateral TMJ ADDwoR.

1. Introduction

Temporomandibular joint (TMJ) anterior disc displacement (ADD) is one of the most common TMJ diseases, occurring in nearly 36% of the general population (Naeije et al., 2013). ADD is often characterized by clicking, pain, restricted jaw movement and malocclusion. Apart from the routinely recognized clinical symptoms, ADD can also initiate or predispose to a cascade of events leading to osteoarthritis and condylar resorption (Chantaracherd et al., 2015; Dias et al., 2016; Poluha et al., 2019).

Recent studies have found that ADD is prevalent not only in adults but also in adolescents, especially in teenagers with dentofacial deformities (Huddleston Slater et al., 2007; Ikeda et al., 2014). According to the study from Schellhas et al., 112 of 128 children had ADD in the pre-orthodontic population under 14 years old. Especially of the 60 mandibular retrusion patients, 56 were found to have TMJ ADD (Schellhas et al., 1993). With the aid of magnetic resonance imaging (MRI), ADD was confirmed in the pre-orthodontic adolescents with a prevalence of nearly 50% in a study by Nebbe et al. (Nebbe et al., 2000). Generally, the severity of mandibular retrusion or asymmetry is in line with the advanced stage of ADD. These phenomena have been confirmed by Ooi et al. whose results demonstrated that ADD had a higher prevalence in a class II population than in class III cases (Ooi et al., 2018). In addition, they reported that ADD was also much common in mandibular asymmetry population. Altogether, these studies suggest that ADD

* Corresponding author.
** Corresponding author.
E-mail addresses: shenpei1215@163.com (P. Shen), yangchi1963@hotmail.com (C. Yang).

https://doi.org/10.1016/j.jcms.2023.06.009
1010-5182/

is more prevalent in adolescents with mandibular retrusion and/or asymmetry.

Despite the association between ADD and dentofacial deformity, it is widely believed that ADD is a self-limited disease. Thus, the initial treatment protocol for ADD consists of noninvasive therapies, such as behavioral education, medicine, heat, and muscle relaxants (Schmitter et al., 2005; Wänman et al., 2020). Nevertheless, these treatment alternatives only focus on relieving symptoms rather than considering maintenance of the normal growth of condyle, especially in adolescents who are at the peak of bone growth. An arthroscopic disc repositioning surgery is a minimally invasive procedure that recaptures the disc back to the normal position (Yang et al., 2012; Abdelrehem et al., 2021; Martínez-Gimeno et al., 2021; González et al., 2022). In the previous studies, new bone formation has been commonly found in patients following arthroscopic disc repositioning surgery (Liu et al., 2019; Dong et al., 2021).

However, it is still unclear whether repositioning the displaced disc can promote condylar growth and correct dentofacial deformities. In the present study, a retrospective self-controlled before-and-after study was designed and implemented to compare the condylar height and the degree of dentofacial deformities in adolescent patients with ADD without reduction (ADDwoR) before and after the arthroscopic disc repositioning surgery. The hypothesis of the present study is that re-establishing a normal articular disc–condyle relationship by arthroscopic disc repositioning surgery can promote condylar growth, which aids correction of mandibular retrusion in adolescent patients.

2. Materials and methods

2.1. Study design

This was a retrospective self-controlled clinical study based on the TMJ ADD database at Shanghai Ninth People's Hospital between October 2018 and October 2021. The study was designed in accordance with the Declaration of Helsinki for research. Ethics approval was obtained from the Human Research Ethics Committee of Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine (approval no. SH9H-2020-T7-1). Written informed consent was obtained from all participants. This study followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guideline.

2.2. Study participants and data collection

Between October 2018 and October 2021, consecutive adolescent patients whose medical records had information from two periods, separated by a bilateral arthroscopic disc repositioning surgery, were recruited. The first period was the natural course follow-up without any treatment (pre-arthroscopic period), while the second period was the follow-up after arthroscopic surgery (post-arthroscopic period). The inclusion criteria were as follows: (1) age between 10 and 20 years at the first visit/initial diagnosis; (2) patients diagnosed with bilateral ADDwoR in Wilkes stage II, III, or IV based on MRI; (3) patients with failed conservative treatment, including health education and physical therapy; (4) presence of symptoms such as clicking, pain, or restricted jaw movement; (5) both the pre-arthroscopic and post-arthroscopic periods were more than 6 months; (6) patients had at least 3 sets of magnetic resonance images and lateral and posteroanterior cephalometric radiographs, as follows: images at the beginning of the natural course (T0), images within 1 week before arthroscopic surgery (T1), and the latest images at the last follow-up after arthroscopic surgery (T2). The interval between T1 and T0 was deemed as the pre-arthroscopic period, while the duration between T1 and T2 was defined as post-arthroscopic period; both of the two periods were required to be more than 6 months. Exclusion criteria were as follows: (1) previous TMJ surgery or occlusal treatment; (2) a history of trauma or rheumatoid arthritis; and (3) magnetic resonance images and/or lateral and posteroanterior cephalometric radiographs of both the pre- and post-arthroscopic periods taken in other hospitals.

2.3. Treatment protocol

All of the patients included in the study underwent MRI examination and lateral and posteroanterior cephalometric radiographs at their visits. When taking the lateral and posteroanterior cephalometric radiographs, all of the patients were guided by a trained radiologist to reach the centric relation according to the Dawson bilateral manipulation technique (Dawson, 1973). After a period of follow-up with only health education, patients underwent the bilateral arthroscopic disc repositioning surgery. Briefly, the surgery was performed under local anesthesia with a 2.7-mm, 0° arthroscope being introduced into the upper joint cavity. A coblation probe was then used to release the anterior disc from the capsule attachment. Afterwards, a suturing needle was inserted at the interface between the bilaminar zone and the posterior band, and the thread was then gripped by a pair of self-designed suture grippers (lasso and hook types). Finally, the disc was pulled backward by the suture, which was then tied underneath the cartilage of the external auditory canal (Liu et al., 2019). All of the arthroscopic surgeries were conducted by one surgeon (C·Y). In order to maintain the new occlusion and to unload the joint, patients were required to wear a splint after surgery. The splint was worn for 6 months. At the first 3 months, patients were required to wear it 24 h per day except when eating or brushing the teeth. From months 4–6, they were required only to wear it during the night.

2.4. Study variables

The predictor variable was the arthroscopic disc repositioning and suturing technique (pre-vs post-arthroscopic). The primary outcome variables were the changes in condylar height, and the secondary outcome variables were skeletal position (dentofacial deformity) during the pre-arthroscopic and post-arthroscopic periods, respectively.

2.5. Outcome measurements

The condylar height was measured as the vertical distance between two perpendicular lines to the ramal plane that runs through the apex of the condylar head and the lowest point of mandibular notch, respectively, based on MRI findings (Supplementary Fig. S1) (Liu et al., 2020). The skeletal position was evaluated from the lateral and posteroanterior cephalometric radiographs. Skeletal position variables included ANB angle, SNB angle, and Pog-Np (horizontal distance from pogonion [Pog] to the vertical line of the Frankfort horizontal plane through nasion) (Supplementary Fig. S2). Changes in ANB angle, SNB angle, and Pog-Np were determined in terms of mandibular retrusion.

2.6. Statistical analysis

All data were analyzed by R version 4.1.0 (www.r-project.org) (Team, 2021). The baseline data were presented as mean (SD) or median (interquartile range [IQR]) for continuous variables, or as frequencies (percentages) for categorical variables. A paired *t*-test was used to compare the variables within each period, and a

generalized estimating equation (GEE) (Liang et al., 1986) was used to compare the change in the variables between the two periods. Subgroup analysis was performed by GEE. Pearson correlation analysis was calculated to define the relationship between the condylar height and skeletal positions. The 95% confidence intervals (CI) and p values were calculated. All statistical tests were two-sided, and the statistical significance was set at a level of $p < 0.05$.

3. Results

Throughout the study period, a total of 869 patients underwent arthroscopic disc repositioning surgery. Initially, 502 patients were between 10 to 20 years of age. For the final analysis, 40 patients (5 male and 35 female) had the complete information from the pre-arthroscopic and post-arthroscopic periods (Fig. 1). The average age at the pre-arthroscopic period was 14.80 years, and the mean follow-up duration was 11.25 months (IQR, 7.63–17.00 months), while the mean follow-up duration was 8.75 months (IQR, 7.00–12.50 months) at the post-arthroscopic period. The baseline characteristics and demographic data of included patients are presented in Table 1. A representative case is shown in Fig. 2.

3.1. Condylar height and skeletal position changes between groups

Changes in the condylar height between the pre-arthroscopic and post-arthroscopic periods are presented in Fig. 3 and Table 2. The overall condylar height decreased in the pre-arthroscopic period ($p < 0.001$), while it increased in the post-arthroscopic period ($p < 0.001$). In both periods, changes in the condylar height on the left and right sides were significant ($p < 0.001$) and similar to the change in overall condylar height. The increase in overall condylar height in the post-arthroscopic period was 3.57 mm more than that in the pre-arthroscopic period ($p < 0.001$). Condylar height on the left and right sides increased more in the post-arthroscopic period than in the pre-arthroscopic period (left: 3.40 mm, $p < 0.001$; right: 3.74 mm, $p < 0.001$). Skeletal position changes in the pre-arthroscopic and post-arthroscopic period are presented in Table 2. The difference between the two groups was significant in ANB, SNB, and Pog-Np (ANB angle: −2.68°, $p < 0.001$; SNB angle: 3.04°, $p < 0.001$; Pog-Np, −4.59 mm, $p < 0.01$).

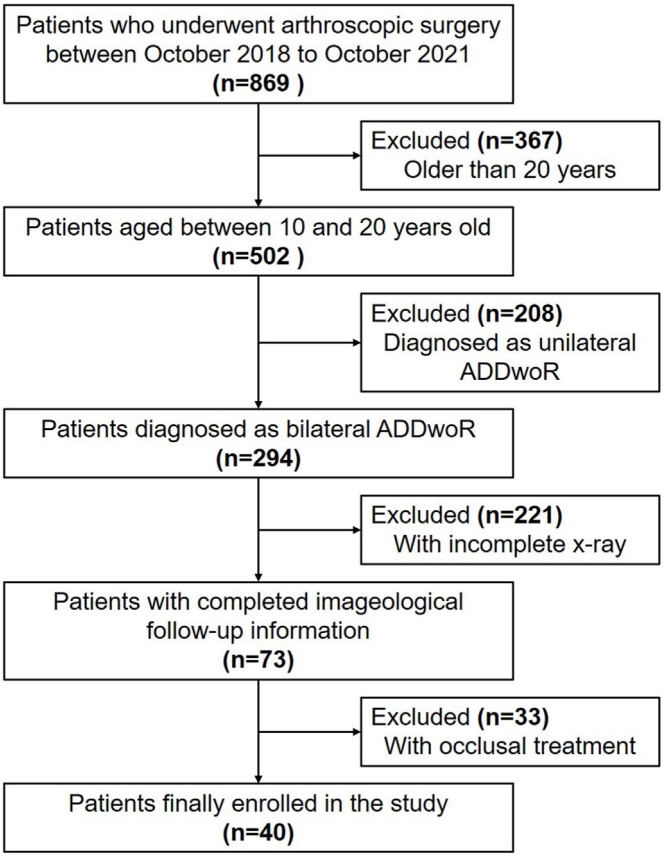

Fig. 1. Flow diagram of the study.

3.2. Subgroup analysis

To further investigate the impact of arthroscopic surgery on condylar growth and mandibular position, both condylar height and skeletal position were investigated in the subgroups of patients of different ages and sex, and follow-up duration. The post-arthroscopic period showed a marked increase in condylar height (Fig. 4) and an obvious improvement in skeletal position (Fig. 5).

3.3. Correlations between condylar height and skeletal position

Pearson correlation analysis between condylar height and skeletal position are presented in Fig. 6. The changes in overall condyle height were positively correlated with SNB angle changes ($r = 0.621$, $p < 0.001$) and were negatively correlated with the changes in ANB angle and Pog-Np (both $|r| > 0.3$, $p < 0.01$).

4. Discussion

Literature reports have confirmed that TMJ ADD, especially ADDwoR, can result in condylar resorption and a decrease in condylar height (Hu et al., 2016). However, the influence of disc repositioning surgery on condylar height is still unclear. In addition, the correlation between ADD and dentofacial deformity has not been well investigated in previous literature. In this retrospective self-controlled before-and-after study, the results showed that condylar height decreased 1.00 mm accompanied by an aggravation of mandibular retrusion during its natural course. Conversely, following arthroscopic disc repositioning surgery, an obvious condylar growth was found with the correction of dentofacial deformity. Subgroup analysis confirmed that both the condylar height and skeletal position changes had statistical differences between the two periods. Pearson correlation analysis showed that the changes in condylar height had a correlation with mandibular

Table 1
Basic characteristics of adolescents with TMJ ADD.

Variables	Value
Follow-up duration, mon, median (IQR)	
Pre-arthroscopic period	11.25 (7.63, 17.00)
Post-arthroscopic period	8.75 (7.00, 12.50)
Age at T0, year, mean (SD)	14.80 (2.38)
Sex, n (%)	
Male	5 (12.5)
Female	35 (87.5)
Skeletal characteristics at T0	
ANB, °, mean (SD)	5.13 (2.65)
SNA, °, mean (SD)	80.84 (3.39)
SNB, °, mean (SD)	75.71 (4.45)
Pog-Np, mm, mean (SD)	14.03 (8.17)
Condylar height at T0	
Left side, mm, mean (SD)	23.40 (4.07)
Right side, mm, mean (SD)	22.72 (4.27)

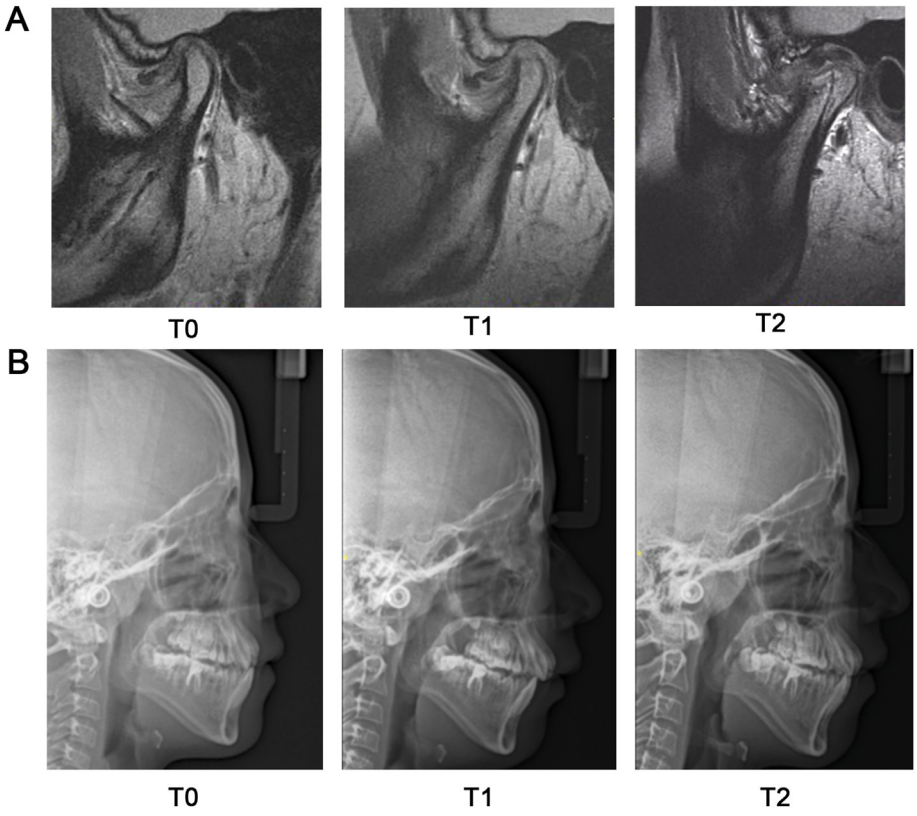

Fig. 2. (A) Magnetic resonance images of lateral and posteroanterior cephalometric radiographs of a representative case from T0 to T2. (B) Lateral and posteroanterior cephalometric radiographs. T0, the beginning of the natural course; T1, within 1 week before arthroscopic surgery; T2, the last follow-up after arthroscopic surgery.

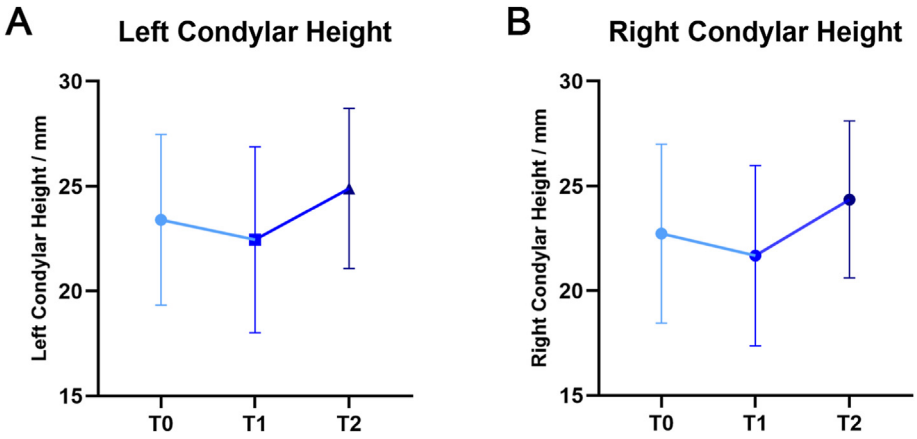

Fig. 3. Condylar height changes on the two sides from T0 to T2. (A) Left condylar height. (B) Right condylar height.

Table 2
Condylar height and skeletal position changes in pre- and post-arthroscopic periods.

Item	Pre-arthroscopic period		Post-arthroscopic period		Post- vs. Pre- arthroscopic periods	
	Mean changes (95% CI)	*p*-value [a]	Mean changes (95% CI)	*p*-value [a]	Mean changes (95% CI)	*p*-value [b]
Overall	−1.00 (−1.39 to −0.61)	<0.001	2.57 (2.15–2.98)	<0.001	3.57 (2.92–4.21)	<0.001
Left side, mm	−0.95 (−1.49 to −0.41)	<0.001	2.45 (1.85–3.05)	<0.001	3.40 (2.39–4.40)	<0.001
Right side, mm	−1.05 (−1.52 to −0.58)	<0.001	2.69 (2.15–3.22)	<0.001	3.74 (3.00–4.48)	<0.001
ANB, °	1.09 (0.69–1.48)	<0.001	−1.60 (−1.92 to −1.28)	<0.001	−2.68 (−3.22 to −2.15)	<0.001
SNA, °	0.05 (−0.23 to 0.33)	0.713	0.40 (0.03–0.77)	0.033	0.35 (−0.15 to 0.85)	0.169
SNB, °	−1.04 (−1.49 to −0.58)	<0.001	2.01 (1.56–2.45)	<0.001	3.04 (2.34–3.74)	<0.001
Pog-Np, mm	2.70 (1.19–4.20)	0.001	−1.89 (−4.02 to 0.23)	0.080	−4.59 (−7.50 to −1.68)	0.002

[a] Mean change differences within groups were calculated by Paired *t*-test.
[b] Mean change differences between groups were calculated by GEE.

Subgroup	Pre-arthroscopic period (n=40)	Post-arthroscopic period (n=40)	Mean changes (95% CI)	P-value
Left condylar height				
All	40	40	3.40 (2.39 to 4.40)	<0.001
Age				
<15years	20	20	2.83 (1.68 to 3.97)	<0.001
≥15years	20	20	3.97 (2.36 to 5.58)	<0.001
Gender				
Male	5	5	4.35 (2.46 to 6.25)	<0.001
Female	35	35	3.26 (2.15 to 4.37)	<0.001
Duration				
<=12months	23	23	3.29 (1.87 to 4.72)	<0.001
>12months	17	17	3.54 (2.18 to 4.90)	<0.001
Right condylar height				
All	40	40	3.74 (3.00 to 4.48)	<0.001
Age				
<15years	20	20	3.57 (2.72 to 4.41)	<0.001
≥15years	20	20	3.91 (2.69 to 5.12)	<0.001
Gender				
Male	5	5	3.93 (1.88 to 5.98)	<0.001
Female	35	35	3.71 (2.92 to 4.51)	<0.001
Duration				
<=12months	23	23	3.18 (2.47 to 3.88)	<0.001
>12months	17	17	4.50 (3.12 to 5.88)	<0.001

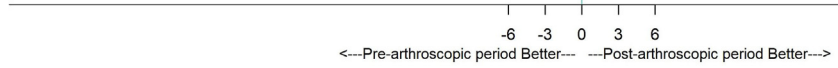

Fig. 4. Subgroup analysis of condylar height changes in the pre- and post-arthroscopic periods.

position changes. These results suggested that arthroscopic surgery can promote condylar growth and correct dentofacial deformity.

Since adolescents are growing individuals, any potential negative effects on the dentofacial growth should be seriously taken into consideration. Basic research has demonstrated that a majority of chondrocytes in the fibrocartilaginous condylar cartilage directly transform into bone cells during endochondral bone formation (Zhou et al., 2014; Jing et al., 2015; Stocum et al., 2018). Quantitative data showed that hypertrophic chondrocytes in condylar cartilage contributed to almost 80% of bone cells in subchondral bone during mandibular ramus development (Jing et al., 2015). These data indicate that condylar health plays an important role in mandibular growth. However, once the TMJ disc is displaced forward, an intra-articular pressure, especially on the top of condyle, could increase by 9.5%–69% (Iwasaki et al., 2009, 2017). Studies have confirmed that excessive pressure on the condylar surface can lead to chondrocyte apoptosis or an impediment to an endochondral bone formation (Li et al., 2017). This might be the reason why many studies have implied that TMJ ADD is an important risk factor for osteoarthrosis or condylar resorption (Dias et al., 2016; Ângelo et al., 2018b; Takaoka et al., 2021). If condylar resorption or mandibular growth inhibition caused by TMJ ADD occurs in an adolescent patient whose body is in the growth spurts period, dentofacial deformity would result or even deterioration. These results were confirmed by a previous study (Xie et al., 2016).

The mandible is one of the most actively remodeling bones in human body. It can grow under tension, as well as undergo resorption under stress. In the present study, once the displaced disc returned to its normal position, the pressure on the condyle decreased, which can promote an increase in condylar height. This result was in accordance with previous studies showing that condylar remodeling was usually found after disc repositioning surgery (Dong et al., 2021).

However, in spite of the association between TMJ ADD and dentofacial deformity, up to now, treatments for adolescent patients with TMJ ADD have given priority to reversible and conservative management methods (Al-Baghdadi et al., 2014). These methods might have certain effects on relieving patients' symptoms, such as pain, clicking or mouth opening limitations, but have little influence on correction of the relationship between the disc and condyle. Interventional methods including arthroscopy and open surgeries are recommended for patients who have intractable chronic pain or dysfunction and have failed to respond to conservative treatments (Dimitroulis et al., 1995; Sembronio et al., 2008; Diraçoğlu et al., 2009; Millón-Cruz et al., 2020). Several studies have demonstrated that disc repositioning can improve joint noise, pain, maximum interincisal opening, mandibular functions, and quality of life in patients with TMJ ADD (Adame et al., 2012; Martín-Granizo et al., 2016; Ângelo et al., 2018a; Loureiro Sato et al., 2020; Elshamaa et al., 2022). The present study highlighted the issue that timely surgical treatments to re-establish the normal relationship between the disc and condyle are necessary for adolescent patients in order to promote condylar growth and to avoid dentofacial deformity.

The current study has the following strengths: (1) the study design was a retrospective, self-controlled study that investigated the outcomes of the arthroscopic disc repositioning technique by comparing the pre-arthroscopic natural course with the post-arthroscopic period in the same group of individuals (longitudinal study), thereby avoiding the inevitable bias from individual

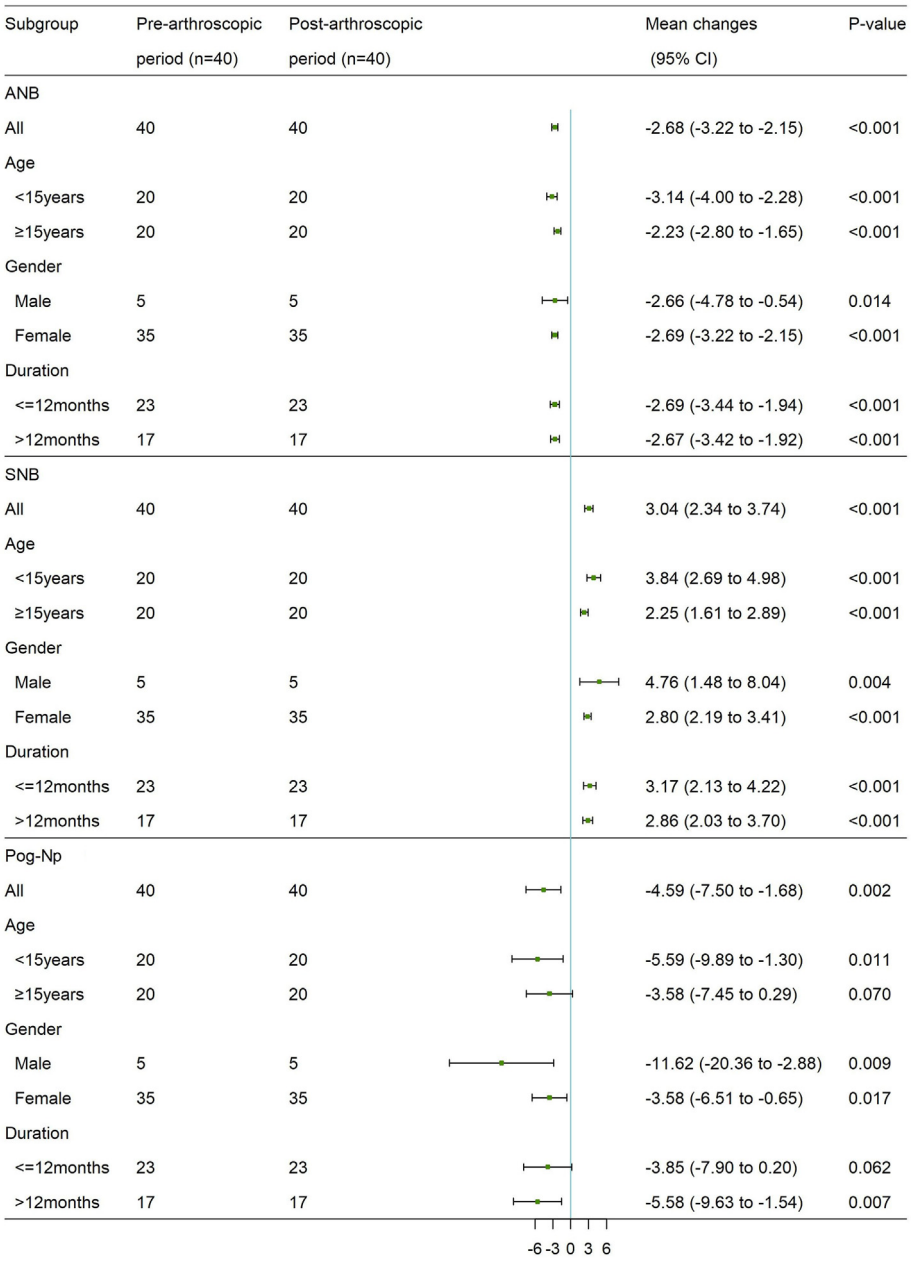

Fig. 5. Subgroup analysis of skeletal position changes in the pre- and post-arthroscopic periods.

variations regarding expression of the subjective parameters; and (2) the study analyzed both condylar height changes on magnetic resonance images together with skeletal position changes using lateral and posteroanterior cephalometric radiographs.

Although the current study results poses distinct advantages, there are still some limitations. First, it is a retrospective study which had its inherent shortcomings, as various confounders could not be controlled. Hence, further prospective studies with a larger sample size and long-term follow up are necessary to assess the efficacy and stability of arthroscopic discopexy, especially in adolescent patients with ADDwoR. Second, the present study focused on adolescent patients due to the superior remodeling characteristics of the body during this growth period. However, data on growing status, such as height, weight, and body mass index, were not collected. Although the changes in condylar height and skeletal position in the same patients can illustrate the necessity and efficacy of arthroscopic surgery, the growing speed of the whole body at puberty might influence the condylar height changes and degree of dentofacial deformity. Hence further studies are required to analyze the relationships between condylar height changes and growth speed of the whole body. Third, the pre-arthroscopic and post-arthroscopic periods in the same subset of patients was of variable durations, and therefore, heterogeneity of follow-up duration would impact the results.

5. Conclusion

In adolescent patients, TMJ ADD can result in a decrease in condylar height and can provoke dentofacial deformity. On the contrary, arthroscopic disc repositioning surgery can promote condylar height increase and correct dentofacial deformity.

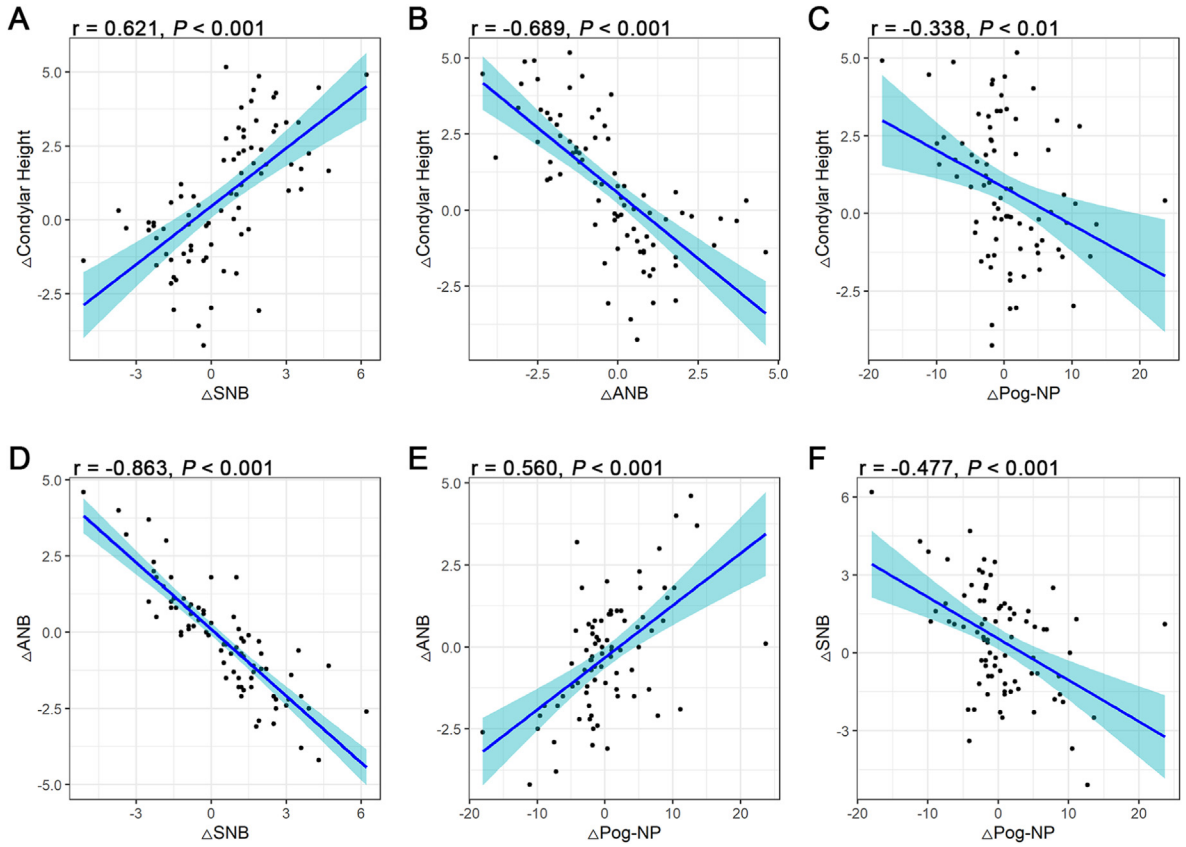

Fig. 6. Correlations between condylar height and skeletal positions. (A–C) Correlations between change in overall condylar height and change in SNB angle, ANB angle, and Pog-Np, respectively. (D–F) Correlations among the change in SNB angle, ANB angle, and Pog-Np.

Declaration of competing interest

The authors declare that they have no competing interests.

Authorship contribution statement

Dahe Zhang: contributed to conceptualization, formal analysis, and interpretation, critically revised the manuscript; **Ahmed Abdelrehem**: contributed to data acquisition, and statistical analysis, critically revised the manuscript; **Yi Luo:** contributed to data curation, and critically revised the manuscript; **Pei Shen**: contributed to conceptualization, formal analysis, investigation, and interpretation, drafted and critically revised the manuscript; **Chi Yang:** contributed to conceptualization, design, analysis, and investigation, drafted and critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work.

Funding

This study was supported by National Natural Science Foundation of China (81870785 & 82071134), dominant disease biological sample project of the Ninth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine (YBKA201908).

Data Availability

All data generated or analyzed during the present study are included in this published article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcms.2023.06.009.

References

Abdelrehem, A., Hu, Y.K., Yang, C., Zheng, J.S., Shen, P., Shen, Q.C., 2021. 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. 50, 1351–1360.

Al-Baghdadi, M., Durham, J., Araujo-Soares, V., Robalino, S., Errington, L., Steele, J., 2014. TMJ disc displacement without reduction management: a systematic review. J. Dent. Res. 93, 37s–51s.

Ângelo, D.F., Gil, F.M., González-García, R., Mónico, L., Sousa, R., Neto, L., Caldeira, I., Moura, C., Francisco, L.C., Sanz, D., Alves, N., Salvado, F., Morouço, P., 2018a. Effects of bilateral discectomy and bilateral discopexy on black Merino sheep rumination kinematics: TEMPOJIMS–phase 1–pilot blinded, randomized preclinical study. J. Cranio-Maxillo-Fac. Surg. 46, 346–355.

Ângelo, D.F., Morouço, P., Monje Gil, F., Mónico, L., González-Gárcia, R., Sousa, R., Neto, L., Caldeira, I., Smith, M., Smith, S., Sanz, D., Abade Dos Santos, F., Pinho, M., Carrapiço, B., Cavaco, S., Moura, C., Alves, N., Salvado, F., Little, C., 2018b. Preclinical randomized controlled trial of bilateral discectomy versus bilateral discopexy in black Merino sheep temporomandibular joint: TEMPOJIMS–phase 1–histologic, imaging and body weight results. J. Cranio-Maxillo-Fac. Surg. 46, 688–696.

Chantaracherd, P., John, M.T., Hodges, J.S., Schiffman, E.L., 2015. Temporomandibular joint disorders' impact on pain, function, and disability. J. Dent. Res. 94, 79s–86s.

Dawson, P.E., 1973. Temporomandibular joint pain-dysfunction problems can be solved. J. Prosthet. Dent 29, 100–112.

Dias, I.M., Cordeiro, P.C., Devito, K.L., Tavares, M.L., Leite, I.C., Tesch Rde, S., 2016. Evaluation of temporomandibular joint disc displacement as a risk factor for osteoarthrosis. Int. J. Oral Maxillofac. Surg. 45, 313–317.

Dimitroulis, G., Dolwick, M.F., Martinez, A., 1995. Temporomandibular joint arthrocentesis and lavage for the treatment of closed lock: a follow-up study. Br. J. Oral Maxillofac. Surg. 33, 23–26 discussion 26-27.

Diraçoğlu, D., Saral, I.B., Keklik, B., Kurt, H., Emekli, U., Ozçakar, L., Karan, A., Aksoy, C., 2009. Arthrocentesis versus nonsurgical methods in the treatment of temporomandibular disc displacement without reduction. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod. 108, 3–8.
Dong, M., Jiao, Z., Sun, Q., Tao, X., Yang, C., Qiu, W., 2021. The magnetic resonance imaging evaluation of condylar new bone remodeling after Yang's TMJ arthroscopic surgery. Sci. Rep. 11, 5219.
Elshamaa, M.M., Elborolosy, S.A., 2022. Functional outcomes after using the glenoid fossa as a fixed anchorage for the temporomandibular joint discopexy in patients with disc displacement without reduction. J. Cranio-Maxillo-Fac. Surg. 50, 26–31.
Goizueta Adame, C.C., Muñoz-Guerra, M.F., 2012. The posterior double pass suture in repositioning of the temporomandibular disc during arthroscopic surgery: a report of 16 cases. J. Cranio-Maxillo-Fac. Surg. 40, 86–91.
González, L.V., López, J.P., Díaz-Báez, D., Martin-Granizo López, R., 2022. Intraoperative complications in temporomandibular joint arthroscopy: a retrospective observational analysis of 899 arthroscopies. J. Cranio-Maxillo-Fac. Surg. 50, 651–656.
Hu, Y.K., Yang, C., Xie, Q.Y., 2016. Changes in disc status in the reducing and nonreducing anterior disc displacement of temporomandibular joint: a longitudinal retrospective study. Sci. Rep. 6, 34253.
Huddleston Slater, J.J., Lobbezoo, F., Onland-Moret, N.C., Naeije, M., 2007. Anterior disc displacement with reduction and symptomatic hypermobility in the human temporomandibular joint: prevalence rates and risk factors in children and teenagers. J. Orofac. Pain 21, 55–62.
Ikeda, K., Kawamura, A., Ikeda, R., 2014. Prevalence of disc displacement of various severities among young preorthodontic population: a magnetic resonance imaging study. J. Prosthodont. 23, 397–401.
Iwasaki, L.R., Crosby, M.J., Gonzalez, Y., McCall, W.D., Marx, D.B., Ohrbach, R., Nickel, J.C., 2009. Temporomandibular joint loads in subjects with and without disc displacement. Orthop. Rev. 1, 90–93.
Iwasaki, L.R., Gonzalez, Y.M., Liu, Y., Liu, H., Markova, M., Gallo, L.M., Nickel, J.C., 2017. Mechanobehavioral scores in women with and without TMJ Disc displacement. J. Dent. Res. 96, 895–901.
Jing, Y., Zhou, X., Han, X., Jing, J., von der Mark, K., Wang, J., de Crombrugghe, B., Hinton, R.J., Feng, J.Q., 2015. Chondrocytes directly transform into bone cells in mandibular condyle growth. J. Dent. Res. 94, 1668–1675.
Li, H., Huang, L., Xie, Q., Cai, X., Yang, C., Wang, S., Zhang, M., 2017. Study on the effects of gradient mechanical pressures on the proliferation, apoptosis, chondrogenesis and hypertrophy of mandibular condylar chondrocytes in vitro. Arch. Oral Biol. 73, 186–192.
Liang, K.Y., Zeger, S.L., 1986. Longitudinal data analysis using generalized linear models. Biometrika 73, 13–22.
Liu, X., Zheng, J., Cai, X., Abdelrehem, A., Yang, C., 2019. Techniques of Yang's arthroscopic discopexy for temporomandibular joint rotational anterior disc displacement. Int. J. Oral Maxillofac. Surg. 48, 769–778.
Liu, Z., Xie, Q., Chen, M., Yang, C., Bai, G., 2020. Measurement of mandibular condylar height based on magnetic resonance imaging. J. Craniofac. Surg. 31, e415–e418.
Loureiro Sato, F.R., Tralli, G., 2020. Arthroscopic discopexy technique with anchors for treatment of temporomandibular joint internal derangement: clinical and magnetic resonance imaging evaluation. J. Cranio-Maxillo-Fac. Surg. 48, 501–507.
Martín-Granizo, R., Millón-Cruz, A., 2016. Discopexy using resorbable pins in temporomandibular joint arthroscopy: clinical and magnetic resonance imaging medium-term results. J. Cranio-Maxillo-Fac. Surg. 44, 479–486.
Martínez-Gimeno, C., García-Hernández, A., Martínez-Martínez, R., 2021. Single portal arthroscopic temporomandibular joint discopexy: technique and results. J. Cranio-Maxillo-Fac. Surg. 49, 171–176.
Millón-Cruz, A., Martín-Granizo López, R., 2020. Long-term clinical outcomes of arthroscopic discopexy with resorbable pins. J. Cranio-Maxillo-Fac. Surg. 48, 1074–1079.
Naeije, M., Te Veldhuis, A.H., Te Veldhuis, E.C., Visscher, C.M., Lobbezoo, F., 2013. Disc displacement within the human temporomandibular joint: a systematic review of a 'noisy annoyance'. J. Oral Rehabil. 40, 139–158.
Nebbe, B., Major, P.W., 2000. Prevalence of TMJ disc displacement in a preorthodontic adolescent sample. Angle Orthod. 70, 454–463.
Ooi, K., Inoue, N., Matsushita, K., Yamaguchi, H., Mikoya, T., Minowa, K., Kawashiri, S., Nishikata, S., Tei, K., 2018. Incidence of anterior disc displacement without reduction of the temporomandibular joint in patients with dentofacial deformity. Int. J. Oral Maxillofac. Surg. 47, 505–510.
Poluha, R.L., Canales, G.T., Costa, Y.M., Grossmann, E., Bonjardim, L.R., Conti, P.C.R., 2019. Temporomandibular joint disc displacement with reduction: a review of mechanisms and clinical presentation. J. Appl. Oral Sci. 27, e20180433.
Schellhas, K.P., Pollei, S.R., Wilkes, C.H., 1993. Pediatric internal derangements of the temporomandibular joint: effect on facial development. Am. J. Orthod. Dentofacial Orthop. 104, 51–59.
Schmitter, M., Zahran, M., Duc, J.M., Henschel, V., Rammelsberg, P., 2005. Conservative therapy in patients with anterior disc displacement without reduction using 2 common splints: a randomized clinical trial. J. Oral Maxillofac. Surg. 63, 1295–1303.
Sembronio, S., Albiero, A.M., Toro, C., Robiony, M., Politi, M., 2008. Is there a role for arthrocentesis in recapturing the displaced disc in patients with closed lock of the temporomandibular joint? Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod. 105, 274–280. ; discussion 281.
Stocum, D.L., Roberts, W.E., 2018. Part I: development and physiology of the temporomandibular joint. Curr. Osteoporos. Rep. 16, 360–368.
Takaoka, R., Yatani, H., Senzaki, Y., Koishi, Y., Moriguchi, D., Ishigaki, S., 2021. Relative risk of positional and dynamic temporomandibular disc abnormality for osteoarthritis—magnetic resonance imaging study. J. Oral Rehabil. 48, 375–383.
Team, R.C.:R., 2021. A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.
Wänman, A., Marklund, S., 2020. Treatment outcome of supervised exercise, home exercise and bite splint therapy, respectively, in patients with symptomatic disc displacement with reduction: a randomised clinical trial. J. Oral Rehabil. 47, 143–149.
Xie, Q., Yang, C., He, D., Cai, X., Ma, Z., Shen, Y., Abdelrehem, A., 2016. Will unilateral temporomandibular joint anterior disc displacement in teenagers lead to asymmetry of condyle and mandible? A longitudinal study. J. Cranio-Maxillo-Fac. Surg. 44, 590–596.
Yang, C., Cai, X.Y., Chen, M.J., Zhang, S.Y., 2012. 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. 41, 1058–1063.
Zhou, X., von der Mark, K., Henry, S., Norton, W., Adams, H., de Crombrugghe, B., 2014. Chondrocytes transdifferentiate into osteoblasts in endochondral bone during development, postnatal growth and fracture healing in mice. PLoS Genet. 10, e1004820.