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Clinical Paper
Trauma

Outcomes of anterior disc displacement and condylar remodelling for sagittal fracture of the mandibular condyle in children after closed treatment

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Abstract. The aim of this study was to evaluate the outcomes of temporomandibular joint (TMJ) anterior disc displacement and condylar remodelling for sagittal fracture of the mandibular condyle (SFMC) in children. Disc displacement was observed in 20 patients with 24 SFMCs (age 4–12 years) via magnetic resonance imaging. After 6 months of closed treatment (T1), the joints were categorized based on the displaced disc status as complete reduction (DCR) or incomplete reduction (DICR). Moreover, condylar remodelling was compared between the groups using cone beam computed tomography images of the TMJ obtained at T1 and at the 1-year follow-up (T2; 15 patients with 18 displaced SFMCs). At T1, 17 of 24 joints with SFMC were assigned to the DCR group and six to the DICR group; one unilateral SFMC case developed ankylosis. Condylar depth and height differed significantly between the groups at T1, but not at T2. Intra-group comparison exhibited significant changes in the condylar depth and height over time in the DICR group. Thus, most of the anteriorly displaced discs (17/24, 70.8%) achieved reduction following closed treatment. Although sustained anterior disc displacement was associated with an increased depth and reduced height of the condyle, no clinical impairment was noted unless ankylosis developed.

Key words: mandibular condyle; sagittal fracture; anterior disc displacement; magnetic resonance imaging.

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Fractures of the mandibular condyle involve damage to both bone and soft tissue, due to the special structure of the temporomandibular joint (TMJ). If not appropriately addressed, condylar fracture in growing patients may interfere with normal condylar formation and lead to facial growth disturbances[1–3]. The patient's prognosis may be affected by various

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factors, including age, fracture type, treatment method, and the relative position of the ramus stump and articular fossa[4–6]. Anterior disc displacement is reportedly a major reason for complications after closed treatment in adults[7–9]. However, it is unclear whether this condition affects outcomes in growing patients.

Previous studies have suggested that the condyle has marked potential for regeneration and reshaping in children <12 years of age[10], and that remodelling continues even after clinical healing of the fracture. Although the exact mechanism remains unclear, animal experiments have indicated that the articular disc is involved in condyle regeneration and mandibular growth[11], and that the disc and condyle cartilage express chondromodulin 1 (ChM-1), which plays a role in the remodelling[12]. Moreover, untreated anterior disc displacement in juveniles with mandibular asymmetry is reportedly associated with degeneration and shortness of the condyle[13,14]. Accordingly, it was hypothesized that the disc is associated with condylar remodelling, and that sustained anterior disc displacement might lead to poor condylar remodelling in growing patients with condylar fracture, or even to growth disturbances.

Cases of sagittal fracture account for 9–29% of mandibular condyle fractures[15,16]. The fracture line usually extends from the lateral pole of the condylar surface to the medial pole[17]. The disc is often anteromedially and inferiorly displaced with the condylar fragment, due to the traction of the lateral pterygoid muscle. Closed treatment is the method commonly used for paediatric sagittal fracture of the mandibular condyle (SFMC).

The aim of this study was to evaluate the potential effect of anterior disc displacement on the long-term prognosis of condylar fracture in children, by monitoring disc position and condylar remodelling in SFMC cases following closed treatment. Furthermore, it was sought to propose additional guidance for accurate diagnosis and treatment.

Materials and methods

Patients

Magnetic resonance imaging (MRI) of the TMJ has been used routinely for the assessment of children with condylar fractures in the Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, since September 2014. This retrospective study was approved by the Biomedical Institutional Review Board of Peking University School of Stomatology.

Twenty patients with 31 SFMCs (11 with bilateral fractures and nine with unilateral fractures) were selected from among 63 children who visited the study department with condylar fractures during the period November 2014 to July 2018. Ten were male and 10 were female, and their mean age was 7.55 ± 0.43 years (range 4–12 years). The inclusion criteria were as follows: (1) younger than 12 years; (2) initial visit within 2 weeks of the injury; (3) unilateral or bilateral SFMC confirmed by spiral computed tomography (SCT)/cone beam computed tomography (CBCT); (4) availability of bilateral MRI scans of the TMJ before and after closed treatment; and (5) availability of bilateral CBCT scans of the TMJ after treatment. The exclusion criteria were as follows: (1) presence of any systemic inflammatory disease (e.g. idiopathic arthritis); (2) occurrence of ramus stump dislocation from the articular fossa; and (3) history of concomitant facial fracture in addition to the mandibular fracture.

Assessments were performed at the following time points: T0, before treatment; T1, at the end of treatment (6 months from T0); T2, at the end of the follow-up (at least 1 year from T0).

Classification of disc position

Bilateral MRI examinations (1.5T, Dual Coil; GE, Milwaukee, WI, USA) with the teeth in habitual occlusion were performed at T0 and T1. Oblique sagittal MRI examinations were performed using a T1-weighted sequence (repetition time (TR) 400–700 ms; echo time (TE) 9–12 ms) and proton density-weighted fast spin-echo sequence (TR 2000–2700 ms; TE 20–23 ms). The image slice thickness was 2 mm.

The line connecting the superior fossa and the inferior fossa along the eminence was divided into three equal parts. No displacement of the disc was considered if the posterior band of the disc was present in the superior third of the eminence, and was recorded as 0 (Fig. 1A2, B2). Disc displacement was classified as follows[18]: (1) displacement of the posterior band of the disc down to the middle third of the eminence (partial disc displacement; Fig. 1B1, C1, C2); (2) displacement of the posterior band down to the inferior third of the eminence (complete disc displacement; Fig. 1A1).

At T1, based on the disc displacement status, joints with continuous disc displacement were assigned to the DICR group (disc with incomplete reduction) and those in which the disc had returned to the normal position were assigned to the DCR group (disc with complete reduction). MRI scans were independently inspected by two blinded radiologists. Consensus was achieved through discussion/consultation with a third senior radiologist in the case of disagreement.

Assessment of the disc–condyle relationship

A normal disc–condyle relationship was defined as the presence of the junction of the posterior band and bilaminar zone immediately above the condylar head, within 10° from the 12 o'clock position in the closed-mouth position[19]. MRI scans at T1 were used for assessment.

Assessment of condylar remodelling

Bilateral CBCT images of the TMJ were obtained at T1 and T2 to assess the condylar remodelling status (J. Morita Corp., Kyoto, Japan; 76–80 kV, 4.2–6.0 mA, field of view 6 × 6 cm). Multiple images of the joints in the axial, coronal, and sagittal planes were acquired at a slice interval of 0.48 mm. Condylar remodelling was assessed both qualitatively and quantitatively. Condyles without a fracture (NF) were referred to as intact condyles and were considered in the measurements.

First, at T1 and T2, the condyle was qualitatively classified as completely, partially, or poorly remodelled[20] (completely remodelled: complete recovery of the shape and height of the condyle, with no difference compared to those of an intact condyle (Fig. 1A3); partially remodelled: partial recovery of the shape and height of the condyle, with a slight difference compared to those of an intact condyle (Fig. 1B3); poorly remodelled: deformity and shortness of the condyle, with a marked difference compared to the shape and height of an intact condyle (Fig. 1C3)). The classification was conducted by a clinician blinded to the MRI results.

Second, at T1 and T2, the condylar width, depth, and height of each condyle were measured in the slice exhibiting the largest condylar diameter[21] (the central slice in most cases) using Proplan CMF 3.0 (Materialise, Leuven, Belgium) (Fig. 2). The maximum mediolateral and anteroposterior lengths in the axial plane were recorded as the condylar width (d1, Fig. 2A) and depth (d2, Fig. 2A). Condylar height included the height of the condylar head (h1, Fig. 2B) and the height of the condylar head and neck (h2, Fig. 2C, D).

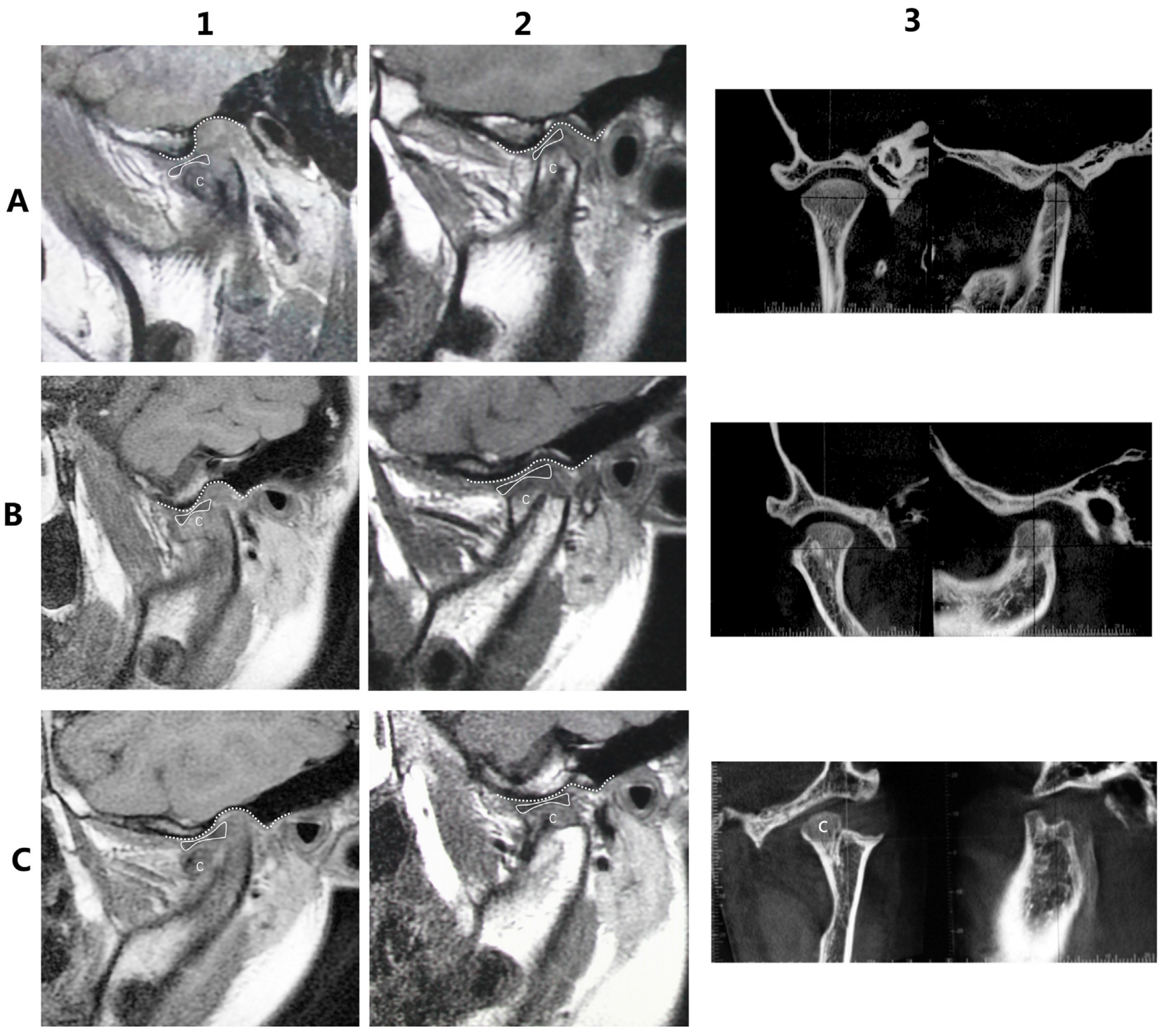

Fig. 1. The cases of two patients exhibiting disc position changes and condylar remodelling. Case 1: a 7-year-old girl with total disc displacement on the right side at T0 (A1), complete reduction at T1 (A2), and complete condylar remodelling at T2 (A3). Case 2: a 6-year-old boy with partial disc displacement on both sides at T0 (B1, C1). The right side exhibited complete disc reduction at T1 (B2) and partial condylar remodelling at T2 (B3), whereas the left side exhibited incomplete disc reduction at T1 (C2) and poor condylar remodelling at T2 (C3). Bone resorption (B3, C3 lateral condyle) and a reformed condyle (C3, 'c') were noted. The disc–condyle positions were found to be normal in all cases at T1 (column 2).

Clinical intervention and follow-up

The fracture in the symphysis was treated surgically in two cases with displacement of the broken ends, and non-surgically in two other cases that were green-stick fractures without displacement. All of the patients wore a removable occlusal splint and were placed on a soft diet for 1–3 months. Mouth-opening exercises were performed for at least 1 month, whereas contralateral excursions and protrusive movements were followed for at least 6 months[22]. Patients were recalled at 3 and 6 months after treatment. At T2, a follow-up CBCT was

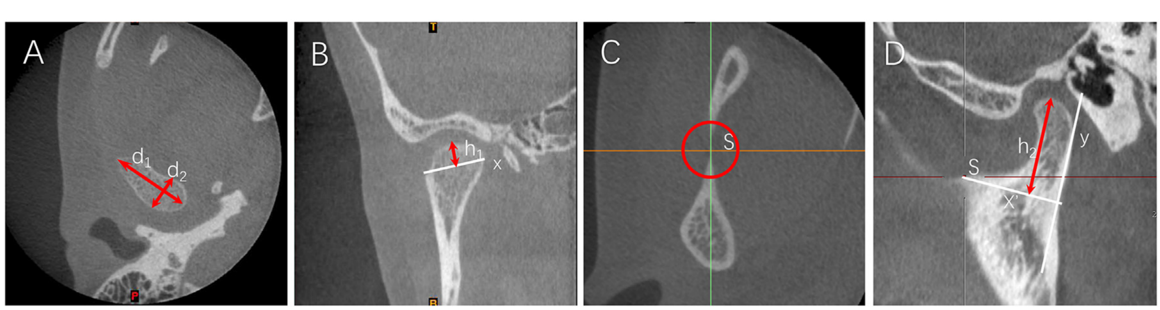

Fig. 2. Analysis of CBCT images. (A) Condylar width (d1) and depth (d2) in the axial plane. (B) Height of the condylar head (h1). (C) The most inferior point in the sigmoid notch (S) is defined in the axial plane; (D) in the sagittal plane, the tangent to the posterior border of the condylar neck is labelled y; a line drawn perpendicular to y through the sigmoid point is labelled x′; the longest distance from the surface of the condylar head to x′ is considered as the height of the condylar head and neck (h2).

Table 1. Disc position status across the groups ($n=24$).

	Complete reduction (DCR)	Incomplete reduction (DICR)	Ankylosis	Total
Partial displacement	12	2	1	15
Complete displacement	5	4	0	9

recommended if the condyle was incompletely remodelled at T1 or any functional problems were noted. Physical complaints, joint pain on palpation, maximum mouth opening, protrusive and lateral movement, and deviation from the midline during opening were also recorded[23].

Data analysis

The kappa test was used to determine agreement regarding the classification of disc position. The Student *t*-test was used to test the age difference between the groups. Fisher's exact test was used to compare categorical variables. Each CBCT image was assessed two times by the same assessor at a 2-week interval, and the mean values were used for statistical analysis. Ten CBCT images were randomly selected and analyzed for a second time. Paired *t*-tests were used to assess the error of the method. Dahlberg's formula was used to compute the measurement error (ME). One-way analysis of variance (ANOVA) was used to compare the differences in condylar depth, width, and height between the groups, as well as the changes from T1 to T2.

Statistical analyses were conducted using IBM SPSS Statistics, version 25.0 (IBM Corp., Armonk, NY, USA) and graphs were drawn using GraphPad Prism version 7.0 (GraphPad Software Inc., La Jolla, CA, USA). $P < 0.05$ was considered significant.

Results

Disc position

Of the 31 SFMC joints, 15 were found to have partial disc displacement and nine were found to have total disc displacement at T0 (mean time since injury 6.8 ± 1.6 days; range 1–14 days); the other seven fractures were non-displaced fractures without any disc displacement and were not included in the statistical analysis. All seven of these fractures achieved complete condylar remodelling at T1; the condylar height and disc position did not differ from those of an intact condyle in the NF group ($P > 0.05$).

At T1, 12 of 15 (80%) partially displaced discs and five of nine (55.6%) totally displaced discs exhibited complete reduction (DCR; $P > 0.05$). In total, six joints with sustained anterior disc displacement were assigned to the DICR group. One unilateral case developed ankylosis (Table 1). The kappa value in general was 0.743. Patient age did not differ significantly between the DICR group (mean 7.7 ± 0.5 years) and the DCR group (mean 7.2 ± 0.9 years) ($P > 0.05$).

Disc–condyle relationship

At T1, a normal disc–condyle relationship was observed in the TMJ in both groups (Fig. 1).

Condylar remodelling

At T1, partial or complete remodelling was observed in all condyles in the DCR group (100%), but in only two of seven condyles in the DICR group (28.6%; $P < 0.05$). At T2, four of five condyles in the DICR group achieved partial or complete remodelling ($P > 0.05$).

When the DCR and DICR groups were compared to the NF group, it was found that the condylar depth in DCR group increased by 3.13 mm and 4.95 mm, the condylar head height was decreased by 0.47 mm and 1.71 mm, and the condylar head and neck height was decreased by 4.33 mm and 7.46 mm, respectively, at T1; these differences were significantly greater in the DICR group than in the DCR group (Table 2, Fig. 3). At T2, the difference in these values between the two groups was not significant (Table 3, Fig. 4).

From T1 to T2, the condylar depth decreased significantly by 0.77 ± 0.72 mm, and the condylar head and neck height increased by 2.05 ± 1.32 mm in the DCR group ($P < 0.05$); however, in the DICR group, the condylar depth decreased significantly by 2.79 ± 0.94 mm, and the condylar head and neck height increased by 3.09 ± 0.68 mm ($P < 0.05$). The decrease in condylar depth was significantly greater in the DICR group than in the DCR group ($P < 0.001$; Fig. 5).

Paired *t*-tests of the repeated measurements did not indicate any significant difference; the ME varied from 0.48 mm to 0.71 mm.

Clinical examination results

One case with a concomitant minor fracture in the articular surface of the temporal bone developed ankylosis. No other patients complained of malocclusion or functional disturbance during the follow-up. Clinical examination at T1 indicated some deviation from the midline during opening in patients with unilateral anterior disc displacement, although the deviation was 3–4 mm. At T2, the deviation was <3 mm in all of the patients. For all patients, at T1 and T2, the maximum mouth opening measurement was >40 mm, protrusive range was 5–11 mm, and lateral movement range was 6–12 mm. There was no significant difference in these values between patients with ($n=6$) and without ($n=11$) anterior disc displacement classified by MRI taken at T1 ($P > 0.05$). The one patient who developed ankylosis and the two patients without disc displacement on both sides at T0 were not included in the comparison.

Discussion

This study is novel in confirming that anteriorly displaced discs may return to their normal position following closed treatment. In contrast to this finding, Yang et al. reported that 17 fractured joints in patients aged >18 years continued to exhibit disc displacement at 3 months after closed treatment[24]. We believe that age is an important factor for reduction, as tissue is more elastic in children than in adults,

Table 2. Quantitative comparison of condylar remodelling among groups at T1; mean ± standard deviation values.

Condylar distance at T1 (mm)	NF ($n=9$)	DCR ($n=17$)	DICR ($n=6$)	*P*-value[a]
Depth	6.80 ± 1.05	9.93 ± 1.06	11.75 ± 1.11	0.003
Width	15.71 ± 1.03	16.81 ± 0.86	15.96 ± 1.12	0.163
Condylar head height	4.69 ± 0.73	4.22 ± 0.75	2.98 ± 0.41	0.002
Condylar head and neck height	20.65 ± 1.92	16.32 ± 1.95	13.19 ± 1.14	0.003

T1, at 6 months of closed treatment; NF, non-fractured; DCR, complete disc reduction; DICR, incomplete disc reduction.

[a] Significant at $P < 0.05$.

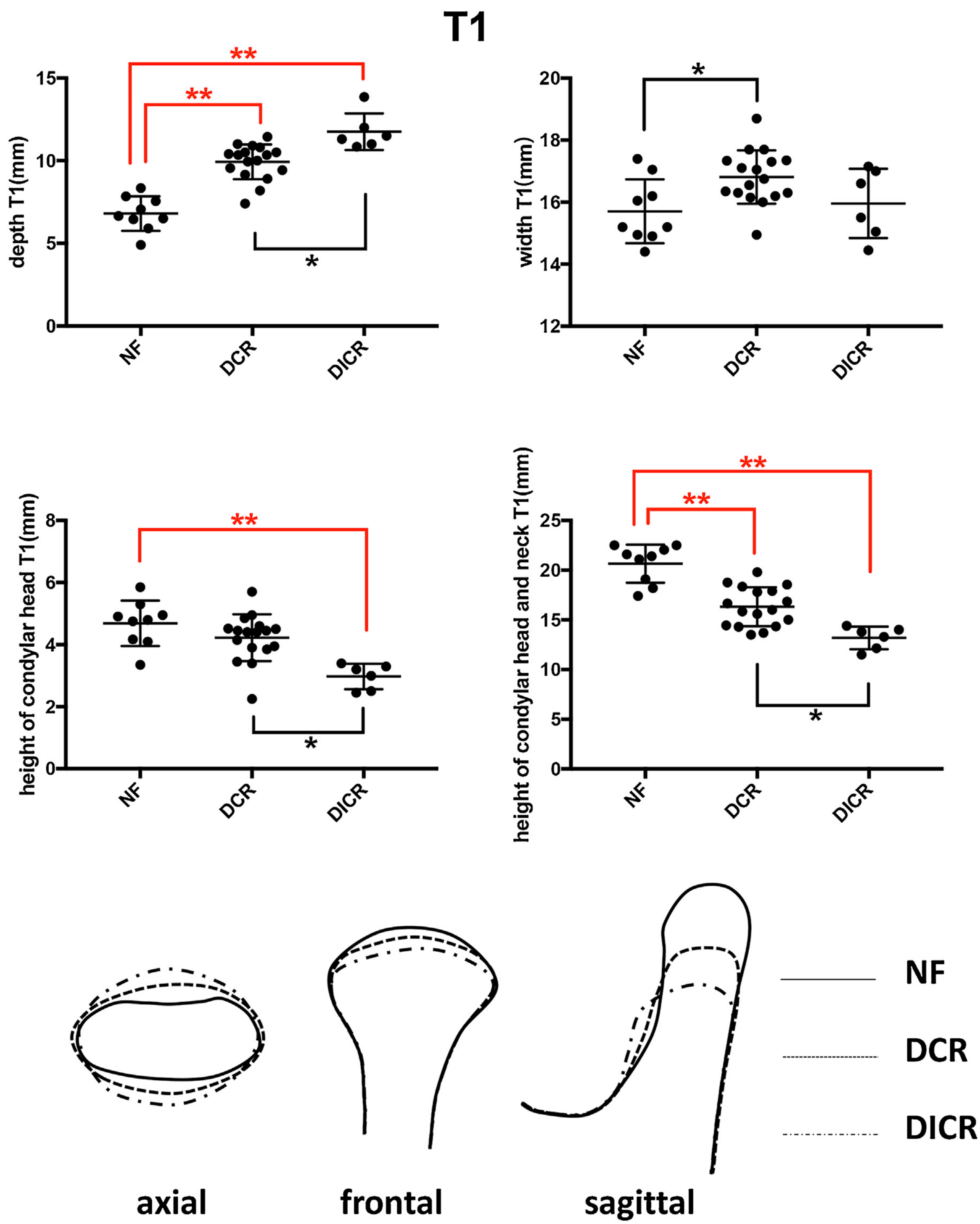

Fig. 3. Quantitative comparison of condylar remodelling among groups at T1 (*$P < 0.05$, **$P < 0.001$).

hence rupture of the posterior attachment of the disc is less likely to occur. The use of splints may also play an important role by cushioning against stress, thus avoiding further damage to the disc and enlarging the joint space to promote the reduction. Cases with partial disc displacement appear to exhibit easier repositioning as compared to those with total disc displacement, although the difference is not significant. Nevertheless, all four cases with concomitant symphysis fractures exhibited sustained anterior disc displacement at T1, which supports the argument that the severity of damage and delayed functional exercises may be disadvantageous for achieving reduction. One patient developed ankylosis, possibly due to a concomitant minor fracture of the temporal surface.

The association between anterior disc displacement and decreased condylar height has been suggested previously in patients with mandibular asymmetry[13,14,25,26]. Cai et al. reported that the condylar height will decrease over time, as the disc remains anteriorly displaced[27]. In

Table 3. Quantitative comparison of condylar remodelling among groups at T2; mean ± standard deviation values.

Condylar distance at T2 (mm)	NF ($n = 7$)	DCR ($n = 13$)	DICR ($n = 5$)	P-value[a]
Depth	6.20 ± 0.92	9.04 ± 1.09	9.05 ± 0.94	0.999
Width	16.39 ± 1.27	17.18 ± 0.85	16.63 ± 1.49	0.612
Condylar head height	5.47 ± 0.83	4.48 ± 0.48	4.20 ± 0.68	0.671
Condylar neck and head height	21.85 ± 1.52	18.34 ± 1.97	16.04 ± 1.50	0.056

T2, at ≥1 year of follow-up; NF, non-fractured; DCR, complete disc reduction; DICR, incomplete disc reduction.
[a] Significant at $P < 0.05$.

the present study, the condylar height decreased significantly in the DICR group; however, the decrease in the condylar height as a result of the fracture itself should also be carefully considered. To assess the long-term effect of anterior disc displacement on condylar remodelling, the data at T2 were analyzed and it was unexpectedly found that the difference in condylar height and depth between the DCR and DICR groups tended to decrease

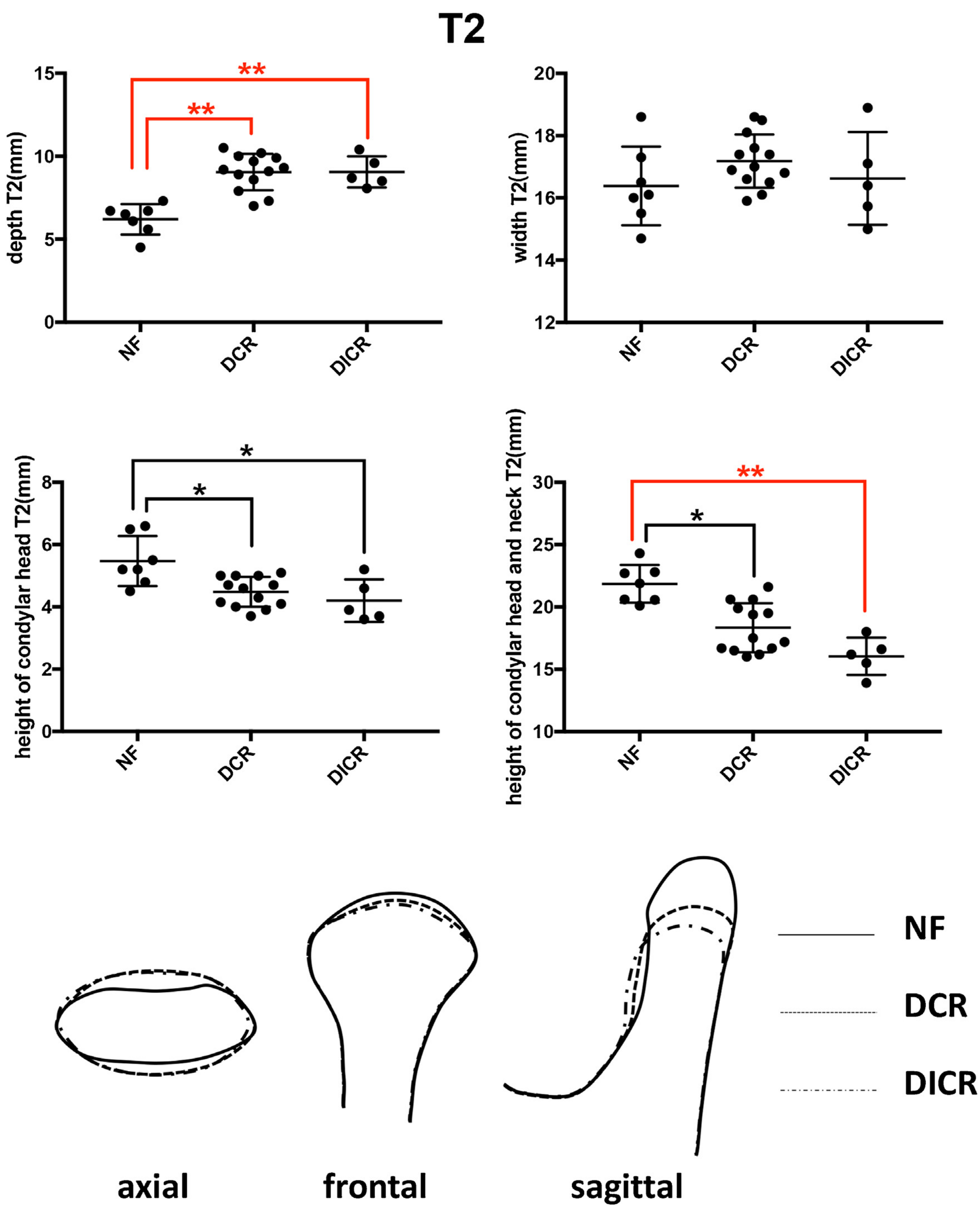

Fig. 4. Quantitative comparison of condylar remodelling among groups at T2 (*$P < 0.05$, **$P < 0.001$).

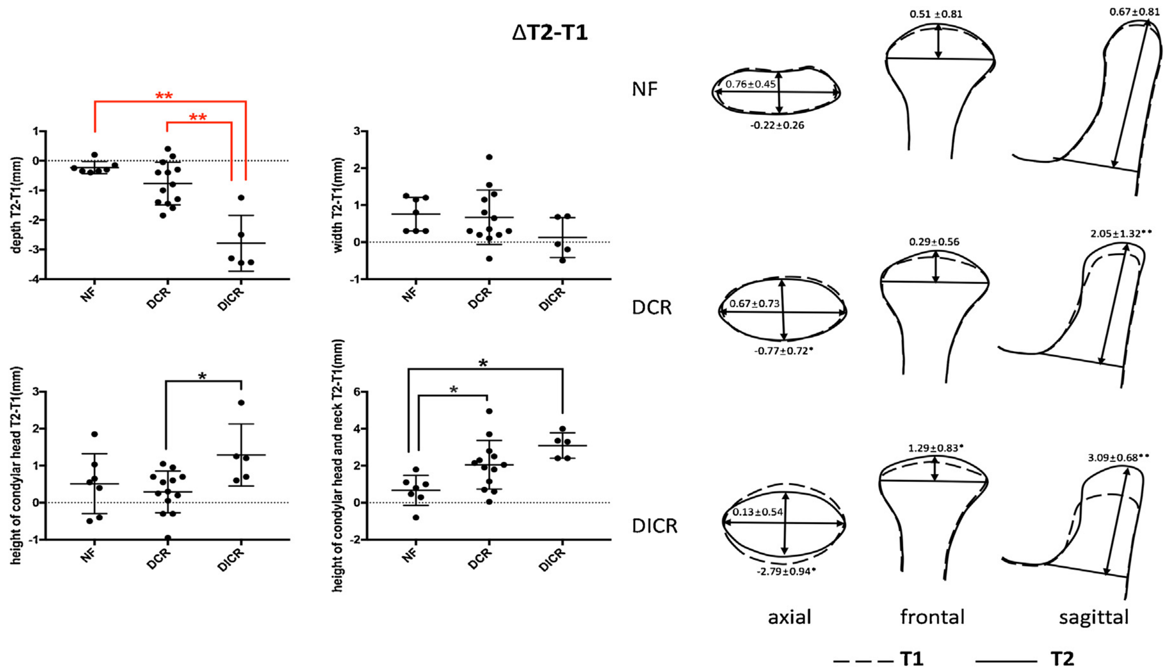

Fig. 5. Quantitative comparison of condylar remodelling between T1 and T2 in each group and among the groups ($*P < 0.05$, $**P < 0.001$).

over time. Furthermore, the condylar height in the DICR group from T1 to T2 exhibited the greatest increase. It is believed that the reduction of the displaced disc in the DICR group would continue, and could accelerate condylar remodelling. In fact, two of six cases in the DICR group underwent MRI at T2, and the findings supported this hypothesis.

The morphological changes in the condyles (particularly in depth) from T1 to T2 were most significant in the DICR group (Fig. 5). In addition, it was found that the fracture fragment covered by the articular disc exhibited condylar morphology (Fig. 1C3); in the area without disc coverage, bone resorption occurred (Fig. 1B3, C3). Therefore, it is predicted that the articular disc possesses the ability to induce condylar repair and regeneration, consistent with that noted in animal experiments[11].

Based on these observations and previous findings[20,21], it is believed that the condyle, articular disc, and joint fossa may change in an adaptive manner after injury. The condyle develops into an immature shortened form and the articular fossa flattens, which facilitates the normal repositioning of the displaced condyle and disc. The restoration of the normal disc–condyle relationship could facilitate the recovery of TMJ function, which might be beneficial for further growth. These hypotheses could explain why closed treatment always achieves better outcomes in children.

Growth disturbance of the mandible was not evaluated in this study, as mandibular growth is slower at a younger age until mid-adolescence. Björk found that mandibular growth was significantly accelerated at 14.5 years of age[28]. Another reason was the compensatory growth of the mandible on the fractured side[6]. Furthermore, a possible fluctuation during growth is known to cause significant mandibular asymmetry in healthy young subjects aged <16 years[29,30]. These findings make it difficult to conclude that anterior disc displacement is responsible for mandibular growth restriction prior to the completion of facial development. However, it is believed that if the TMJ functions well, most children will achieve normal growth of the mandible, consistent with the findings of many previous studies.

In this study, MRI could effectively depict TMJ soft tissue changes in children with condylar fractures. Detailed information of the soft tissue injury could help clinicians make an accurate diagnosis and optimal treatment decision. Nevertheless, it was found that the clinical outcomes were good despite disc displacement; hence we do not recommend MRI as a regular examination in children with condylar fracture, unless they have severe complications such as TMJ dysfunction or mandibular dysplasia.

The present study has certain limitations. First, the results were limited due to the small sample size and the high dropout rate. Second, the follow-up period was short and none of the patients in this study had reached the most accelerated phase of pubertal growth of the mandible. Third, the disc position was only observed in the sagittal plane. Coronal evaluations should also be performed to achieve a better understanding of disc displacement.

In conclusion, the anteriorly displaced disc after SFMC in children younger than 12 years of age returned to the normal position in most cases following closed treatment. Sustained anterior disc displacement was associated with poor condylar remodelling. Finally, the clinical outcomes were satisfactory, without any TMJ function problems, even in cases with disc displacement, which may be facilitated by the normal disc–condyle position.

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Competing interests

None.

Ethical approval

This study was approved by the Ethics Committee of Peking University School and Hospital of Stomatology (No. PKUSSIRB-201735072).

Patient consent

Not required.

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