

Condyle-preserved arthroplasty versus costochondral grafting in paediatric temporomandibular joint ankylosis: a retrospective investigation

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Abstract. We aimed to evaluate results of condyle-preserved arthroplasty and costochondral grafting in growing children with temporomandibular joint ankylosis through medium-term follow-up and three-dimensional metric analysis. We assessed 11 patients (14 sides) with type II ankylosis (group A) and 11 patients (13 sides) with type III/IV (group B) from January 2012 to December 2015. Group A patients received condyle-preserved arthroplasty and group B patients received costochondral grafting. Postoperative computed tomography was used to measure condylar height, condylar width, mandibular ramus height and mandibular body length. Changes in maximum mouth opening were evaluated >1 year postoperatively.

Postoperative follow-up showed similar average maximum mouth opening and one case of recurrence in each group. Computed tomography measurements showed that condylar width and mandibular ramus height increased in both groups A and B ($P < 0.05$). Moreover, in group A, condylar angulation of medially displaced malformation decreased by 13.2° ($P < 0.05$), and mandibular body length increased by 5.7 mm ($P < 0.05$). Thus, both condyle-preserved arthroplasty and costochondral grafting were effective surgical methods for treatment of temporomandibular joint ankylosis. Moreover, compared with group B, group A patients manifested more remarkable mandibular growth, at least in the anteroposterior direction of the mandibular body.

Key words: temporomandibular joint ankylosis; arthroplasty; costochondral grafting.

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Temporomandibular joint (TMJ) ankylosis refers to fibrous or bony fusion between the condyle and the fossa, typically manifested as progressive limitation of mouth opening. Ankylosis during childhood affects mandibular development and causes facial deformity and can even cause obstructive sleep apnea syndrome (OSAS).

Therefore, treatment of paediatric patients should be focused not only on release of the limited mouth opening but also on addressing accompanying developmental issues. Based on classifications of TMJ ankylosis^{1,2}, type II represents lateral bony ankylosis of the joint and is treated with condyle-preserved arthroplasty as the preserved residual condyle reserves developmental potential. Types III and IV include complete bony ankylosis and are treated with costochondral grafting (CCG), which has proven regrowth ability.

Previous systematic reviews³⁻⁵ have reported favourable outcomes of aforementioned surgical procedures in improving postoperative maximum mouth opening (MMO). However, only few studies⁶⁻⁹ have reported long-term results in terms of condylar remodelling and mandibular growth. Moreover, the contribution of postoperative condylar remodelling in correcting angulation deformity and abnormal anatomic morphology remains unclear. To our knowledge, no studies have examined postoperative mandibular growth in different directions by means of three-dimensional (3D) metric analysis.

We evaluated results of condylar remodelling and mandibular growth with condyle-preserved arthroplasty and CCG performed in growing children with TMJ ankylosis through medium-term follow-up and 3D metric analysis.

Materials and methods

Patients

Patients with bony TMJ ankylosis admitted to the Department of Oral and Maxillofacial Surgery between January 2012 and December 2015 were included in this study. Basic information including age, gender, time of maxillofacial trauma, and MMO were collected. Panoramic radiography and computed tomography (CT) examinations were performed.

Inclusion criterion were (1) age <12 years, (2) follow-up period >1 year, and (3) bony ankylosis confirmed by imaging. Exclusion criterion included (1) age

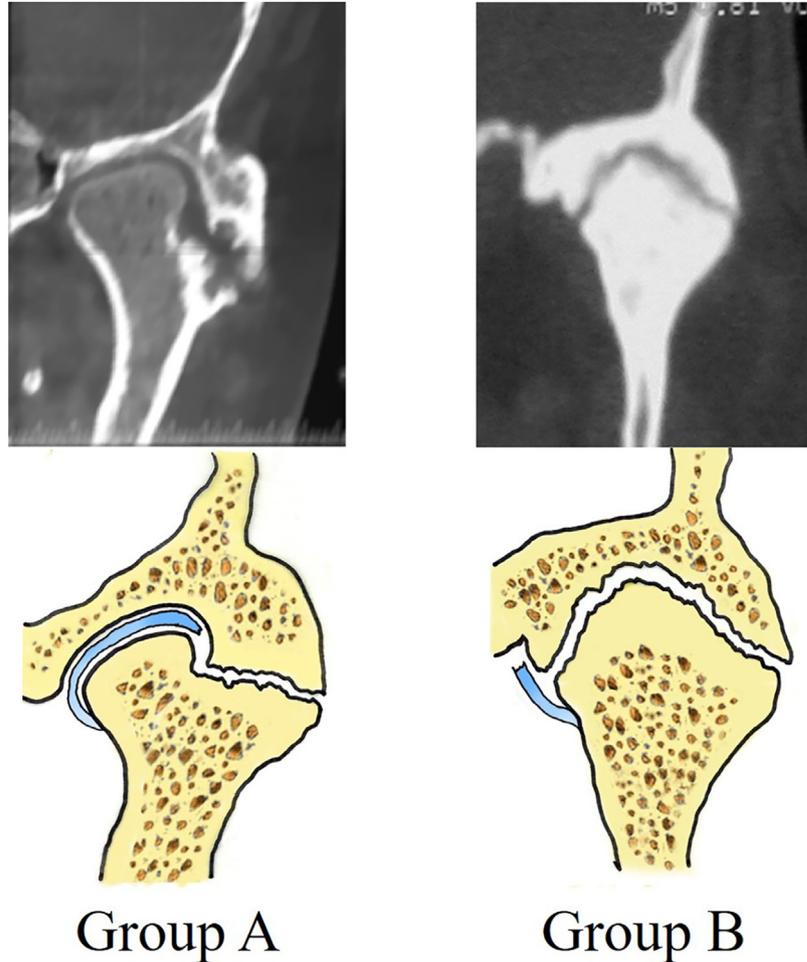


Fig. 1. Computed tomography images and diagrams of the two groups. Group A includes patients with lateral bony ankylosis of the joint, with bony fusion on lateral side of the joint; the medially displaced condyle, residual disc, and fossa form a pseudo-arthrosis. Group B includes patients with complete bony ankylosis of the entire joint with a radiolucent line inside the fusion area but no recognizable condyle and fossa.

>12 years, (2) lost to follow-up, and (3) initial diagnosis of recurrent TMJ ankylosis.

The study sample, including 22 patients with 27 ankylosed joints, was divided into two groups according to coronal CT (*Fig. 1*): condyle-preserved arthroplasty group (group A) and CCG group (group B).

Group A consisted of 11 patients, including five boys and six girls, with an average age of 7.7 (range: 4–11) years. Of these patients, eight had unilateral and three had bilateral ankylosis. All patients had experienced trauma, with a mean post-traumatic duration of 2.1 (range: 0.3–7) years. The mean follow-up duration was 2.3 (range: 1–4) years.

Group B consisted of 11 patients, including six boys and five girls, with nine unilateral and two bilateral cases of anky-

losis. The average age was 6.5 (range: 5–11) years. Seven patients had experienced trauma, with a mean post-traumatic duration of 2.1 (range: 0.3–7) years. Causes for ankylosis in the remaining four patients were unknown. The mean follow-up duration was 2.4 (range: 1–5) years.

Treatment based on classification of TMJ ankylosis

All patients were categorized into two groups based on coronal CT images. Group A was characterized by lateral bony fusion on the lateral side of the joint, which was treated by resecting the lateral bony ankylosis tissue. Medially displaced head and disc were preserved, as these had been in malunion, to maintain the ramus height and occlusion. The articular disc typically could be reduced, and it also

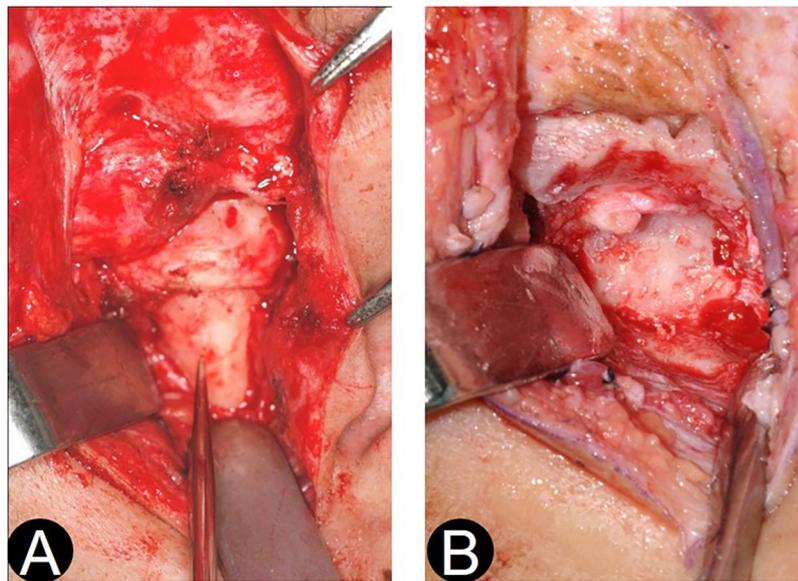


Fig. 2. Surgical procedure of condyle-preserved arthroplasty. (A) Exposure of lateral bony ankylosis tissue. (B) Resection of bony fusion with retention of medially displaced condylar head.

served as an interposition between the condyle and the fossa. Abdominal dermis fat was transplanted to fill in the cavity formed by osteotomy. For all instances, an average mouth opening of >35 mm was achieved during surgery (Fig. 2).

Group B was characterized by the entire joint presenting with bony fusion without recognizable condyle and fossa. A modified preauricular incision was made and the bony fusion was removed to form at least a 1.5-cm wide gap for bone graft. A passive maximum incisal opening of at least 35 mm was achieved during surgery. The costochondral graft was harvested from the seventh rib on the right side with a cartilage cap

of 5–10 mm. The native articular disc, if available, was retained and repositioned to align with the glenoid fossa; if the articular disc was not available, a temporalis myofascial flap was rotated as an interpositional graft to fill the cavity of the condylectomy. MMO of >35 mm was also achieved during surgery (Fig. 3).

Outcome assessment

Data acquisition

CT examinations were performed and multiplanar reformation was used to generate coronal and 3D images of the TMJ

(helix with 1.25-mm slice thickness; Bright Speed 16, GE Healthcare, Buckinghamshire, UK).

Metric analysis

Using iPlan CMF (BrainLAB, Feldkirchen, Germany), CT data were used to construct a 3D coordinate system based on the exact craniofacial midsagittal plane. Regarding the lower edge of the sigmoid notch as lower bounds of the condylar head, the width and height of the condyle was defined as the maximum measured distance in the horizontal and vertical directions in different slices of the

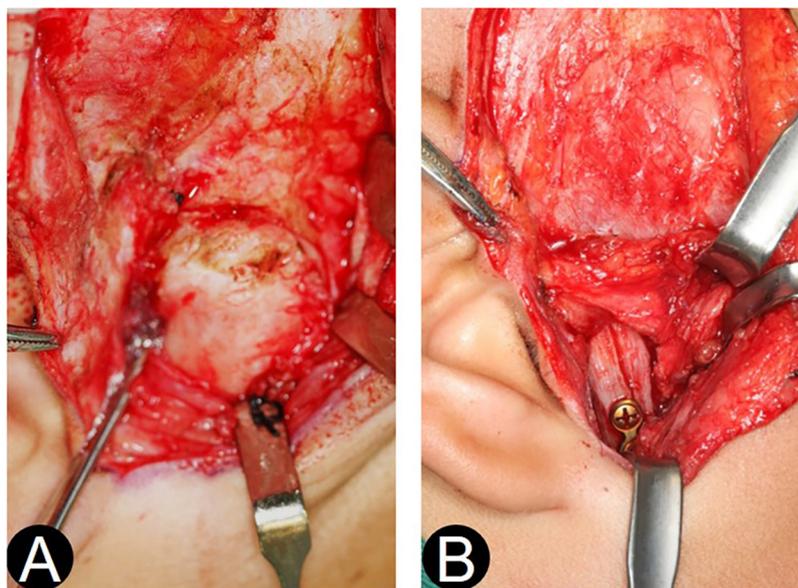


Fig. 3. Surgical procedure of costochondral grafting. (A) Exposure of bony ankylosis tissue. (B) Reconstruction of condyle with costochondral graft.

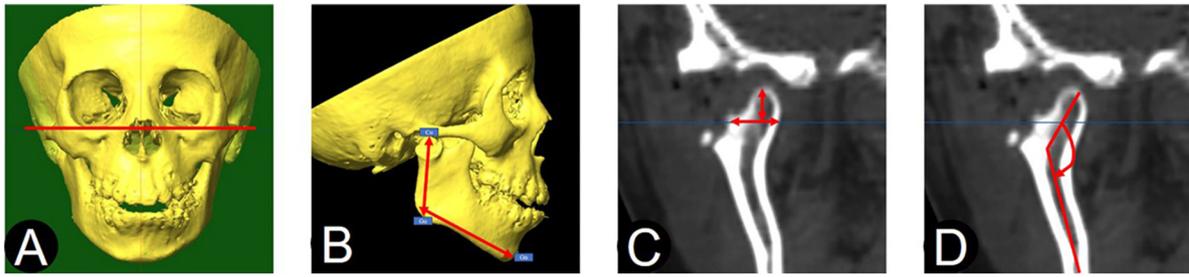


Fig. 4. Method of metric analysis. (A) Adjust Frankfort plane parallel to horizontal plane. (B) Ramus height was measured as distance from condylin (Co) to gonion (Go), and mandibular body length was measured as distance from gonion to gnathion (Gn). (C) Condylar height and width on the coronal plane. (D) Angulation deformity on the coronal plane.

coronal plane. A deformity angle on the condylar contour was identified as the angle between the central axes between the condylar heads and the mandibular ramus in the coronal view. Similarly, ramus height was measured as the distance from condylin (Co) to gonion (Go), and mandibular body length was measured as the distance from Go to gnathion (Gn) (Fig. 4). All these parameters were measured thrice each by three separate examiners (blinded method). The minimum measurement interval was 1 week.

Clinical evaluation and follow-up

Patients who underwent arthroplasty or CCG were required to perform mouth opening exercises over a period of 3 months, starting at 1 week after surgery. All patients were followed up for >1 year to review changes in MMO and mandibular remodelling. When comparing the time immediately after surgery with that at follow-up, differences were defined as (1) significant growth (>2 mm); (2) significant resorption (≤-2 mm); or (3) no significant change (≥-2 but <2 mm).

Statistical analysis

Data were analysed using paired *t*-tests for statistical significance of longitudinal comparison. Independent sample *t*-test was used for intergroup comparisons of

changes between the contralateral side and the healthy side. Moreover, variance analysis, χ^2 , and Fisher’s exact tests were used for intergroup comparisons. Statistical analysis was conducted using IBM SPSS Statistics for Windows, version 19.0 (IBM Corp., Armonk, NY, USA). *P* < 0.05 was considered significant.

Results

Results of classification therapy

The mean MMO was 9.7 (range 5–30) mm before surgery, 39.2 (range 35–45) mm during surgery, and 37.5 (range 25–50) mm at follow-up (except for two recurrent cases). Both groups (Table 1) showed significant improvements in MMO and a low recurrence rate. All patients showed good occlusal relationship. No surgical complications such as infections and facial nerve injury were reported. Of the 22 cases, we report two cases in detail, with distinctive aspects of facial deformity features and the treatment approach used (Figs 5 and 6).

Measurement results

In the 10 group-A patients without re-ankylosis, the affected ramus height and mandibular body length were significantly increased and were 49.5 and 72.0 mm, respectively, at the last follow-up CT

(*P* < 0.05). On an average, condylar width increased by 3.2 mm and condylar angulation deformity decreased by 13.2° (*P* < 0.05), representing modifications towards the upright direction (Table 2).

On the other hand, in the 10 group-B patients without re-ankylosis, the affected ramus height and condylar width increased by 2.5 and 2.1 mm, respectively (*P* < 0.05). No significant differences were noted in condylar height or mandibular body length between 1 week after surgery and at the last follow-up (*P* > 0.05) (Table 3).

Intergroup comparisons of mandibular body length

Overall, 11 of 13 sides of the mandibular body showed significant growth (>2 mm) in group A, whereas only five of 12 sides of the mandibular body showed significant growth (>2 mm) in group B, with significant between-group differences (*P* < 0.05) (Fig. 7).

Discussion

TMJ ankylosis can be detected at any age but usually develops in growing children, with a reported constituent ratio of up to 60.4%^{10–12}. When ankylosis occurs during childhood, it destroys growth centres in condyles and affects mandibular development, causing facial deformity and even OSAS. Therefore, treatment of paediatric patients should be focused not only on limited mouth opening but also on developmental deformities. Although various procedures have proven effective in children, how the affected mandible remodels after surgery in growing children with different types of ankylosis remains unclear.

One of the main types of ankylosis is lateral bony ankylosis, with bony fusion on the lateral side of the joint. The medially displaced condyle, residual disc, and fossa form pseudoarthrosis. Ferretti et al.¹³

Table 1. Treatment results.

	Group A <i>n</i> = 11	Group B <i>n</i> = 11	<i>P</i>
Age (years)	7.7 ± 1.6	6.5 ± 1.9	0.113
Follow-up time (years)	2.3 ± 1	2.4 ± 1.5	0.936
MMO (mm)			
Preoperation	10 ± 4	9.7 ± 7.6	0.894
Intraoperation	38.8 ± 2.3	40.9 ± 3.7	0.072
Postoperation	38.2 ± 8.8	34 ± 10.1	0.421
Recurrence			
Numbers	1	1	–
Rate (%)	10	10	–

Significant at *P* < 0.05.

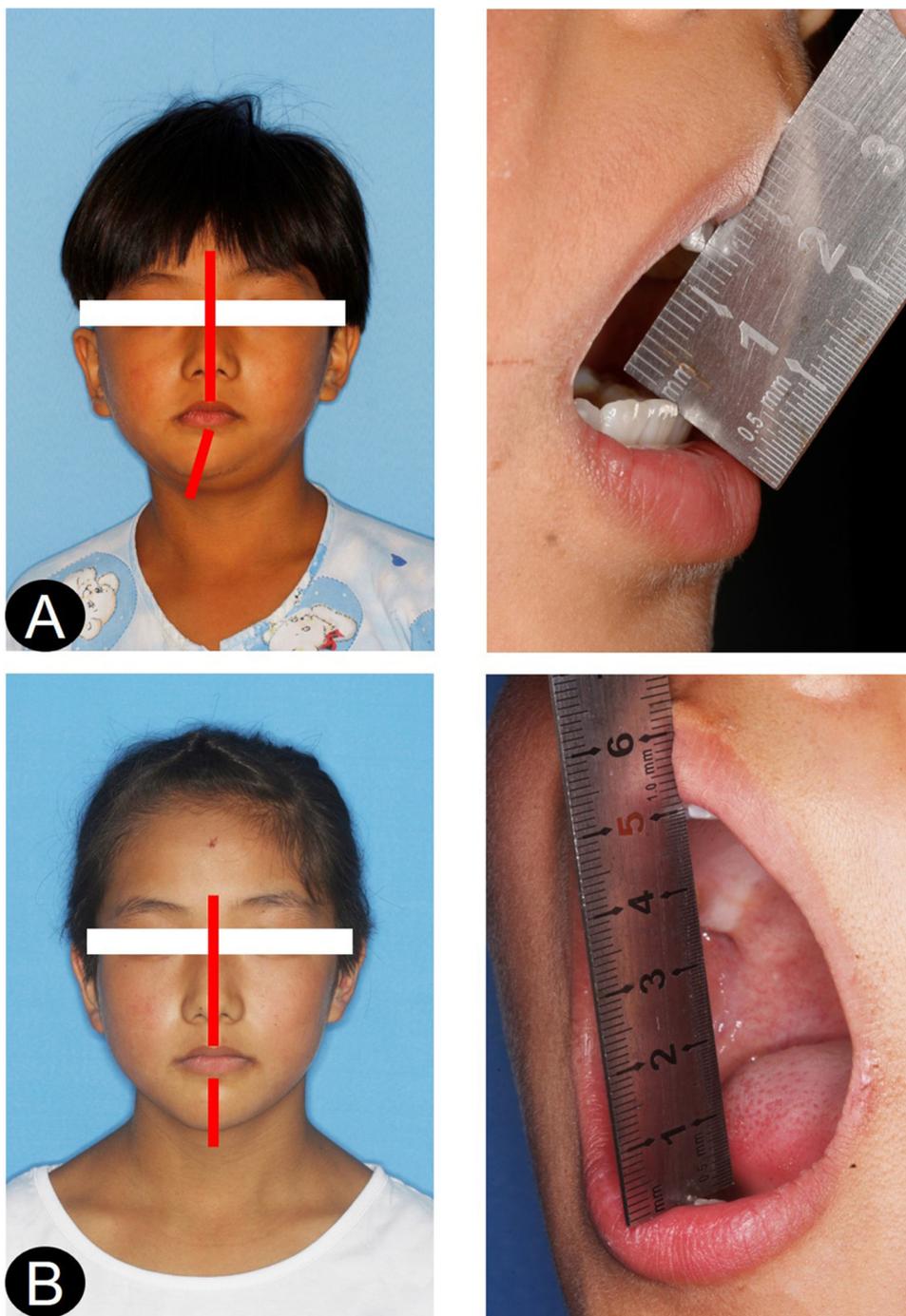


Fig. 5. Case 1: A girl had suffered right condylar fractures after falling from a height 2 years ago. She had received conservative treatment and mouth opening exercises at a local hospital but gradually became unable to open her mouth. Three years after condyle-preserved arthroplasty and intensive physiotherapy, the patient presented with substantial improvement in facial symmetry with minor deviation of the mandible and normal maximum mouth opening (MMO) without deviation. (A) Facial asymmetry with deviation of mandible to right and limited mouth opening. (B) Marked improvement in facial symmetry and MMO 3 years after surgery.

evaluated joint morphology on coronal CT images and reported an ossification pattern of fusion occurring at extra-articular sites lateral to the condylar position. Zheng et al.¹⁴ investigated the disc using magnetic resonance imaging and showed that the disc was discernible in all joints in lateral bony ankylosis but with a certain

degree of deformity and an intermediate position. He et al.¹⁵ and Yan et al.¹⁶ have proposed classifications of ankylosis based on characteristics of the condylar remnants.

In our study, lateral bony ankylosis was treated using condyle-preserved arthroplasty, which was first recommended by

Nitzan et al.¹⁷; they had performed this surgical procedure in four patients and suggested that the displaced condyle and disc should be retained to promote normal function and growth. Subsequent studies^{18–20} have proven that it markedly improves facial patterns and MMO with an extremely low recurrence rate. With

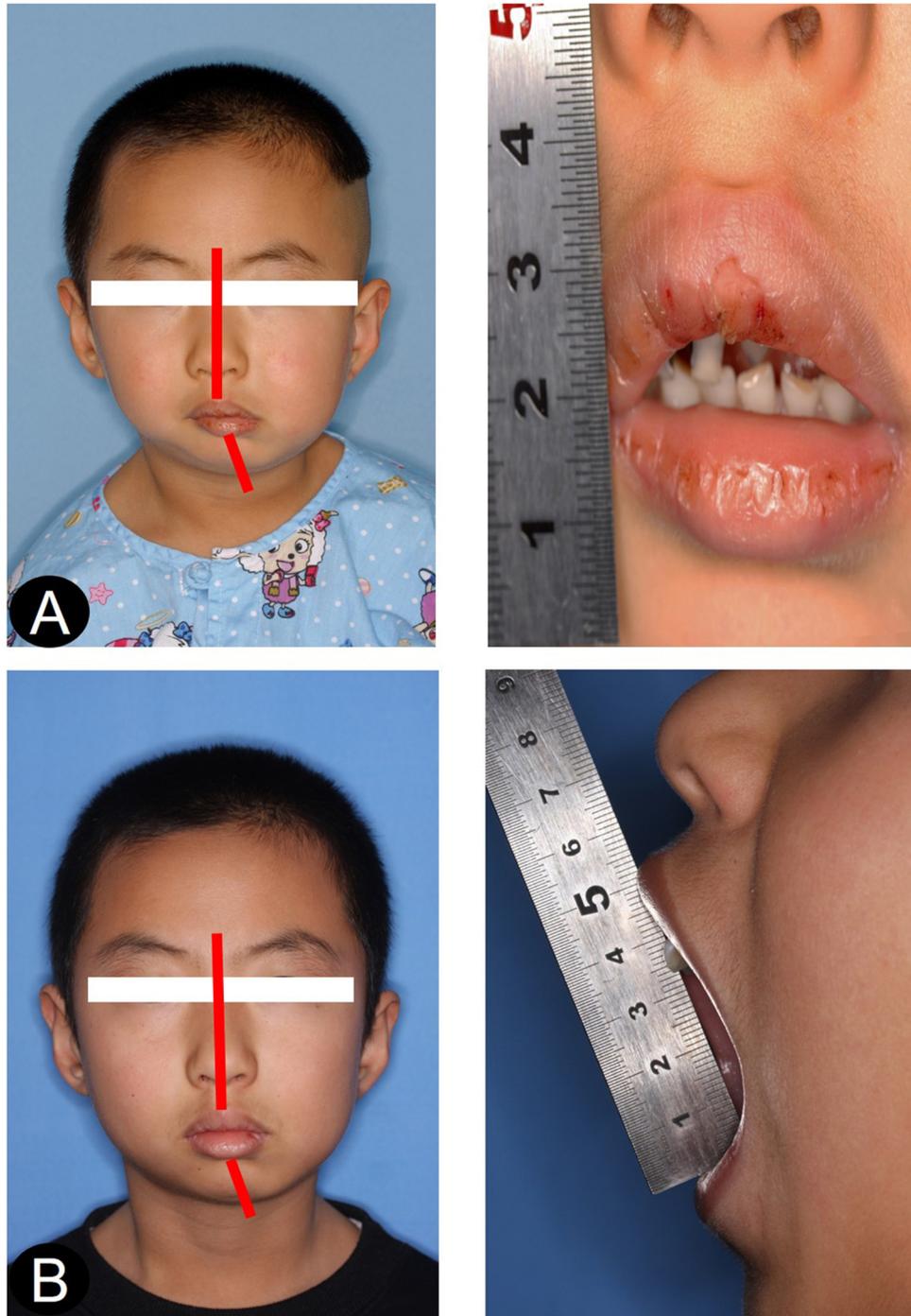


Fig. 6. Case 2: A 6-year-old boy was diagnosed with left temporomandibular joint ankylosis. His maximum mouth opening (MMO) was 0 mm with no movement of mandible. Five years after costochondral grafting and physiotherapy, the patient presented with definite improvements in MMO, while facial asymmetry persisted with deviation of mandible to the left. (A) Facial asymmetry with deviation of mandible to left and limited mouth opening. (B) Facial asymmetry and with improvement in MMO 5 years after surgery.

navigation-guided technology, accurate excision can be easily achieved²¹. Our study confirms that the preserved condyle remodelled in an upright direction as well as the mandible grew both horizontally and vertically, which advocates preservation of the displaced remnant condyle to achieve optimal outcomes.

The scope of application of condyle-preserved arthroplasty is always an issue worthy of discussion. At present, there is no consensus regarding which type of residual condylar head should be preserved. In this study, type III/IV refers to complete bony ankylosis of the entire joint. More attention should be paid to

how to treat complete bony ankylosis with condyle-preserved arthroplasty under computer-assisted navigation.

Type III/IV of ankylosis was characterized by the entire joint presenting with bony fusion without recognizable condyle and fossa. In fact, in such severe cases of ankylosis, it is most important to control

Table 2. Measurement results in group A (10 patients with 13 joints).

	1 week after surgery	Follow-up period	P
Condylar height (mm)	10.0 ± 2.8	10.6 ± 3.1	0.521
Condylar width (mm)	10.7 ± 2.2	13.9 ± 3.9	0.002
Ramus height (mm)	44.5 ± 3.6	49.5 ± 3.8	0.000
Mandibular body length (mm)	66.3 ± 4.0	72.0 ± 4.3	0.001
Condylar angle of deformity (°)	143.2 ± 6.2	156.4 ± 5.0	0.000

One recurrence case in group A was not included. Significant at $P < 0.05$.

Table 3. Measurement results in group B (10 patients with 12 joints).

	1 week after surgery	Follow-up period	P
Condylar height (mm)	5.8 ± 2.4	7.1 ± 2.0	0.159
Condylar width (mm)	5.9 ± 2.3	8.0 ± 3.5	0.006
Ramus height (mm)	36.5 ± 3.1	39.0 ± 4.7	0.011
Mandibular body length (mm)	62.3 ± 7.6	64.0 ± 7.5	0.133

One recurrence case in group B was not included. Significant at $P < 0.05$.

the recurrence rate by removing at least a 1.5-cm wide gap²⁹. Such patients were treated with CCG, first applied by Gillies et al.²² for TMJ reconstruction. Previous studies have reported favourable therapeutic effects of CCG on TMJ ankylosis, with a recurrence rate of 4.6–39%^{18,23,24}. He et al.¹⁵ combined CCG with temporalis myofascial flap or masseter muscle flap, which decreased the recurrence rate. Moreover, CCG has several advantages over other TMJ reconstruction methods, such as easy accessibility and adaptation²⁵. Most important of all is the intrinsic growth potential, making it suitable for growing children^{9,24,26}.

A major disadvantage of CCG was its unpredictability of growth pattern, with three possible outcomes, including resorption, remaining unchanged, and overgrowth. Previous studies^{7,9,27} have considered that overgrowth patterns of CCG are related to overlong cartilaginous

cap of the flap. However, Yang et al.²⁸ reviewed 68 cases of overgrowth following CCG and concluded that it was influenced by complex factors such as mandibular function, inherent growth capacity, and possibly hormonal factors. In this study, we did not find any case of overgrowth, maybe because of only 2.3 years of follow-up, limited sample size, and inaccurate measurement of cartilage based on CT. Therefore, studies with larger patient samples and longer follow-ups are needed to confirm this.

Measurements showed that both preserved and reconstructed condyles showed significant remodelling. The difference is that mandibles in group A grew both horizontally and vertically, while those in group B grew only vertically. Lack of mandibular growth in the anteroposterior direction in group B could be attributed to any of the following: (1) type III and type IV ankylosis affected mandibular devel-

opment; (2) growth centre was resected through condylectomy; (3) CCG was short of growth potential in the horizontal direction; and (4) the growth of costochondral grafting begins only after its complete healing which takes more than 1 year. Future studies should aim to clarify these with wider patient samples and longer follow-ups.

In conclusion, both condyle-preserved arthroplasty and CCG showed similar postoperative MMO in treatment of TMJ ankylosis. On follow-up, paediatric patients showed condylar remodelling and mandibular growth in terms of height. Moreover, compared with type III/IV patients who received CCG, type II patients who received condyle-preserved arthroplasty manifested more remarkable mandibular growth, at least in the anteroposterior direction of the mandibular body.

Funding

None.

Competing interests

None.

Ethical approval

This study was approved by the ethics committee of Peking University School and Hospital of Stomatology (No. PKUS-SIRB-201416095).

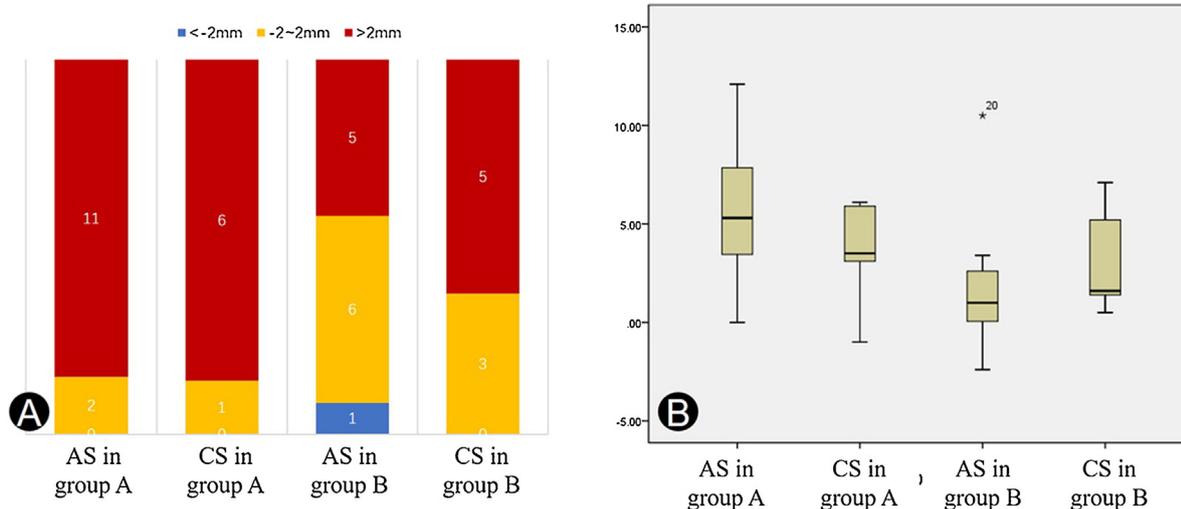


Fig. 7. Intergroup comparison of mandibular body length. (A) Constituent ratio of the side of mandibular body length, defined as (1) significant growth (≥ 2 mm), (2) significant resorption (≤ -2 mm); and no significant change (> -2 but < 2 mm). (B) Distribution of the computed tomography measurement data in the two groups. AS, affected side; CS, contralateral side.

Patient consent

All patients or their legal guardians have signed informed consents for publication of clinical photographs.

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