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The effect of disc repositioning and post-operative functional splint for the treatment of anterior disc displacement in juvenile patients with Class II malocclusion

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ABSTRACT

Purpose: To evaluate the effect of temporomandibular joint (TMJ) disc repositioning and post-operative functional splint for the treatment of anterior disc displacement (ADD) in juvenile patients with Class II malocclusion.
Materials and methods: Juvenile patients (≤20 years) who had bilateral TMJ ADD with and Class II malocclusion treated by disc repositioning and functional splints were included in the study. Magnetic resonance imaging (MRI) and cephalometric radiographs before surgery (T0), immediately after surgery (T1) and more than 3 months after surgery (T3) were obtained in all patients. Cephalometric values including condylar height, overjet, SNA, SNB and pogonion position etc. were measured and compared before and after disc repositioning by statistical analysis. Fourteen patients (13 female, 1 male) were included in this study. Their average age was 16.7 years (range, 12–20 years).
Results: Seven patients with 14 joints had an MRI at least 6 months (6–24 months, mean 14.3) prior to disc repositioning. When compared to the MRI taken just prior to surgery, of those 14 joints, 9 condyles (64.3%) had evidence of bone resorption, 5 condyles (35.7%) had new bone formation mostly at the posterior part of the condyle (21.4%). These MRIs showed the condylar height was reduced 0.81 mm ± 0.61 ($P = 0.013$). Pre-operative cephalometric radiographs showed increased overjet ($P = 0.039$). The mean post-operative follow-up was 9.4 months (range, 4–13 months). Postoperative MRI showed the condylar height increased 1.74 ± 0.98 mm after disc repositioning ($P < 0.001$). Newly generated bone was observed on all condyles. 84.6% of the new bone was formed on the superior and posterior-anterior surfaces. Postoperative cephalometric radiographs showed the SNB angle increased 1.83 ± 1.56°($P < 0.001$), pogonion position (pg'-G′) moved anteriorly 2.18 ± 3.13 mm ($P = 0.028$) and incisor overjet decreased 3.55 ± 1.86 mm ($P < 0.001$), whereas significant changes were not found in SNA, Sn - G Vert, Y-Axis, U1 − SN, IMPA (L1-MP) and U1-L1 ($P > 0.05$).
Conclusion: Conservative treatment for ADD with Class II malocclusion in juvenile patients may cause condyle resorption and aggravate the dentofacial deformity. Disc repositioning combined with post-operative functional splints can effectively promote condylar growth and help correct the dentofacial deformity.

1. Introduction

TMJ anterior disc displacement (ADD) is a common malady that can lead to limited mouth opening, clicking and joint pain (Ogutcen Toller et al., 2002; Ribeiro et al., 1997). Dentofacial deformities such

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as malocclusion, mandibular retrognathia and/or asymmetry can be induced when ADD occurs during the growth period (Nebbe et al., 1998a, b, 2000; Schellhas et al., 1993; Xie et al., 2015, 2016; Zhuo and Cai, 2016; Hu et al., 2016). For the past decades, clinical researchers have reported that untreated ADD may be a critical factor that contributes to degenerative changes and even condylar resorption, which may increase the dentofacial deformity. Through quantitative analysis of magnetic resonance imaging (MRI), Nebbe et al. (Nebbe et al., 1998a, b) found that displaced discs can decrease the height of the ipsilateral mandibular ramus because of condylar degeneration. Previous studies on patients with TMJ internal derangements have shown a high correlation between ADD and mandibular deformity (Nebbe et al., 1998a, b, 2000; Schellhas et al., 1993; Xie et al., 2015, 2016; Zhuo and Cai, 2016; Hu et al., 2016). By evaluation of X-rays and MRI, our previous research found that the more the disc is displaced and misshaped, the shorter the condylar height and the more the mandible is deformed (Xie et al., 2015, 2016; Hu et al., 2016). Furthermore, animal studies have also shown that displaced discs load the condyle and inhibit its growth (Bryndahl et al., 2011; Li et al., 2017). Studies have also shown that conservative therapies including functional splints cannot stop condylar resorption (Fang, 2017; Wolford and Cardenas, 1999). Whether disc repositioning could inhibit condylar resorption and stimulate bone regeneration has drawn increasing attention. Wolford has found that articular disc repositioning could reduce condylar resorption and facilitate bone apposition (Goncalves et al., 2013). Yang et al. found that the increased joint space that occurs after disc repositioning by arthroscopy creates space for condylar regeneration (Hu et al., 2017).

The purpose of this study was to evaluate the effect of disc repositioning and post-operative functional splints in the treatment of ADD in juvenile patients with Class II malocclusion.

2. Materials and methods

2.1. Study design

Patients with ADD diagnosed by MRI and Class II malocclusion from March 2016 to March 2018 were collected for this study. The inclusion criteria were: 1) age ≤20 years; 2) TMJ repositioning surgery performed by one senior surgeon (D.H); 3) functional splint treatment by one orthodontist (Z.H) within 2 months after surgery; and 4) MRI and cephalometric radiographs pre-operatively and during follow-up. The exclusion criteria were: 1) follow-up period <3 months after disc repositioning; 2) prior treatment for ADD or orthodontic treatment; 3) poor image quality of MRI or lateral cephalometric images; and 4) history of developmental and/or systemic disorders that might affect craniofacial growth. In order to reduce statistical bias, the selection conditions of the study subjects were limited and the selected subjects were as similar as possible. Stratification was used to make the composition of the experimental group and control group more similar.

2.2. Disc repositioning and post-operative functional splint treatment

Disc repositioning by mini-screw anchors through open incisions were performed for all joints as described previously (He et al., 2015). Patients were asked to perform mouth opening exercises 1 week after operation and to come see the orthodontist 1–2 months later. Functional splints were produced for the patients to gradually move the mandible forward. After 4–6 months of treatment, an MRI was obtained to determine whether the condyle had regenerated. When new bone formed in the joint space, the functional splint was discontinued and orthodontic teeth treatment began. MRI and cephlometric films were taken before operation and during follow-up visits.

2.3. Variables and methods

A 1.5-T imager (Signa; General Electric, Milwaukee, WI, USA) with bilateral 3-inch dual surface coils was used to perform MRI. Images with the largest section of the condyle were selected, and condylar height was determined based on the three-circle method (Xie et al., 2015, 2016) (Fig. 1).

First, at the most curved area between the condylar neck and head, internally tangent circle O1 was drawn. Then, at the narrowest area of the condylar neck, internally tangent circle O_2 was drawn. After that, the long axis of the condylar neck (y) was determined through the circle centers of O1 and O_2. Line x perpendicular to line y and tangent to the condylar outline at A point was drawn. A line parallel to line x was named “x” which was tangent to line y at B point was drawn. The length of AB was designated as condylar height. E-Ruler measurement software was used to obtain parameter values, accurate to 0.01 mm. Condylar height pre-operation (h0) and at follow-up (h1) was recorded and the difference between them was calculated. The positions of regenerated bone was assessed in follow-up MRI tracings.

With the standard cephalometric analysis used at Shanghai Ninth People's Hospital with Dolphin 11.5 software (Dolphin Imaging, Chatsworth, CA, USA), the lateral cephalometric images of patients was assessed (Fig. 2).

Landmarks used for the cephalometric analysis were: S, sella turcica; N, nasion; P, porion: Or, orbitale; Sn, subnasale; A, subspinale; B, supramental; G, glbella; Go, gonion; Me, menton; Pog, pogonion; Pos, pogonion of soft tissue; Gn, gnathion; UIE, upper incisor edge; UIA, upper incisor apex; LIE, lower incisor edge; LIA, lower incisor apex. Distances and planes used in analysis were: SN, sella-nasion line; FH, Frankfort horizontal plane; OP, occlusal plane; MP, mandibular plane; G’, plane perpendicular to FH through glabella; Y-axis, sella-gnathion line; U1, long axis of first upper incisor; L1, long axis of first lower incisor.

Linear and angular measurements used were: 1.∠SNA, 2.∠SNB, 3.∠ANB, 4.Wits appraisal, 5.Overjet, 6.U1-SN, 7.L1-MP, 8.U1-L1, 9.Y axis, 10.Pos to G Vert, 11.Sn to G Vert.

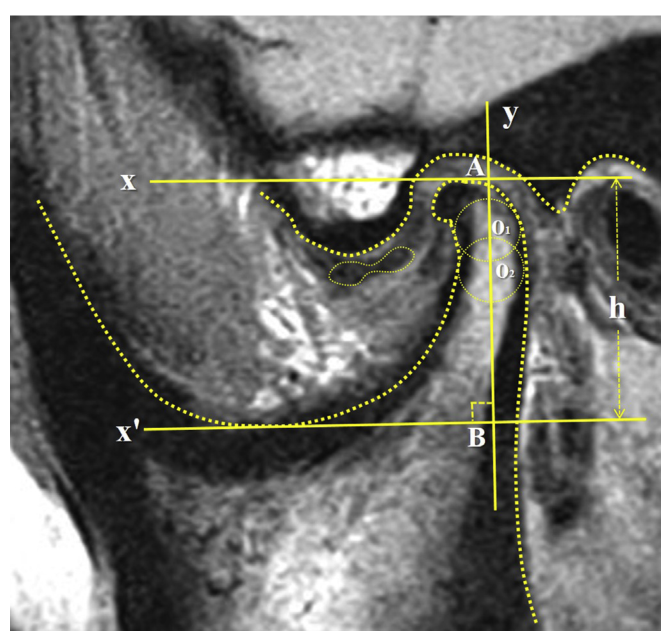

Fig. 1. Measurements of condylar height in MRI image.

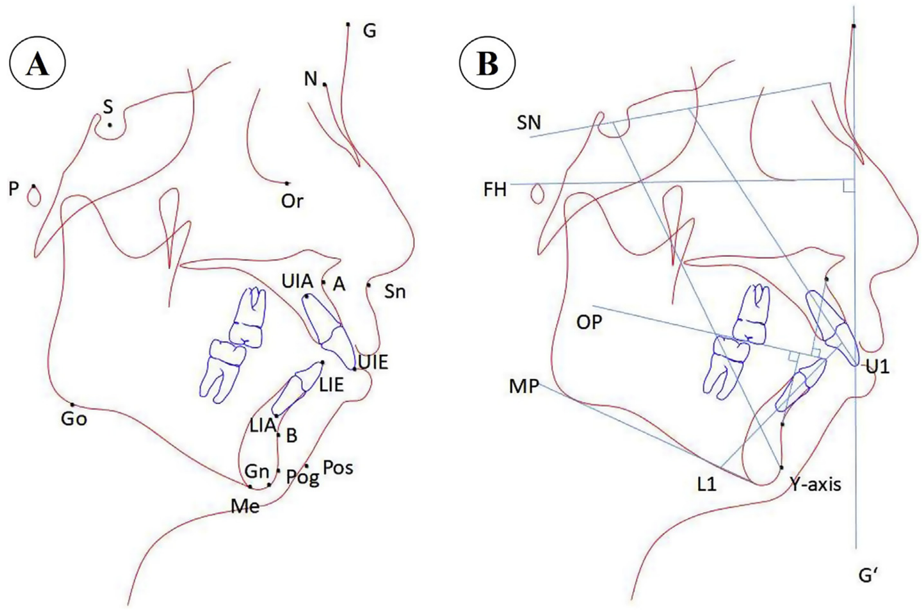

Fig. 2. Cephalometric analysis. A, landmarks; B, planes.

To test accuracy, images of all patients were selected randomly and evaluated by one clinician. MRIs and lateral cephalometric radiographs were retraced and measured again at a 3-week interval by the same person. If a statistically significant difference (P > 0.05) by a paired t-test was discovered in the two data sets, specialists in TMJ and orthodontics were required to repeat the tracings.

2.4. Statistical analysis

All data were analyzed by IBM SPSS Statistics version 18.0 (IBM Corp., Armonk, NY, USA). Paired-samples and chi-squared tests were performed. Pearson correlation coefficients were calculated for the relationship between overjet, SNB, Pos-G' and new bone height. A level of P < 0.05 was considered statistically significant.

3. Results

Fourteen patients with 28 joints were included in the study. Among them, 13 were female and 1 was male. Their average age was 16.7 years (range, 12–20 years). Seven patients with 14 joints had MRIs taken more than 6 months (range, 6–24 months, mean 14.3 months) before disc repositioning. Between the pre-treatment MRI and the one performed just prior to surgery, 9 joints (64.3%) developed condylar bone resorption, and the other 5 joints (35.7%) had new bone regeneration. Most of the change was located at the posterior border of the condyle (21.4%). MRI measurement showed condylar height had decreased an average of 0.81 ± 0.61 mm (P = 0.013) (Fig. 3A–L, Tables 1 and 2).

Disc repositioning by mini-anchor screws was performed for 28 joints of the 14 patients. The mean post-operation follow-up period was 9.4 months (range, 4–13 months). All data were confirmed to be normally distributed. Pearson correlations indicated that a strong positive correlation existed between Pos-G' and new bone height (r = 0.648, P = 0.012), a strong negative correlation between SNB and new bone height (r = −0.617, P = −0.019), and a weak correlation between overjet and new bone height (r = 0.551, P = 0.041).

MRI showed that all 28 joints had new bone regeneration located on the top and anterior-posterior borders of the condyle (84.6%) (Table 1, Fig. 1I–P). The mean condylar height was 20.65 ± 1.20 mm before the operation and 22.39 ± 2.02 mm during follow-up. Condylar height had significant increased 1.74 ± 0.98 mm after the operation (P < 0.001) (Table 3).

There were no significant changes in SNA, Sn - G Vert, Y-Axis, U1-SN, IMPA (L1-MP) and U1-L1, which largely represents maxillary growth before and after disc repositioning (p > 0.05) (Table 4, Fig. 6). However, SNB was significantly advanced with an average of 1.83° (P < 0.001), and pogonion was advanced by 2.18 mm (P = 0.028) (Fig. 5). The anterior overjet decreased from 8.62 mm to 5.07 mm (P = 0.000) (Fig. 4), which was closer to a normal incisor relationship. Compared with pre-disc repositioning, Wits appraisal showed advancement of the mandible by 3.62 mm (P = 0.000) (Table 5).

4. Discussion

As a common disease in juvenile patients, TMJ ADD was strongly associated with mandibular retrognathia and asymmetry. Nebbe and Major (Nebbe and Major, (2000)) found that more than 50% of males and 70% of females had ADD at different levels, by measuring MRI in all jurvenile patients before orthodontic treatment. Schellhas' (Schellhas et al., 1993) study in 128 orthodontic patients (<14 years old) found that 112 had ADD. There were 60 patients with bilateral ADD; among them, 56 had mandibular retragnathia. Our previous study also revealed a higher incidence of ipsilateral jaw deviation in young unilateral ADD patients (72.12%) than in patients with normal joints (25.64%). Moreover, with time, condylar degeneration and jaw deformity became more severe (Xie et al., 2015, 2016; Zhuo and Cai, 2016; Hu et al., 2016). In this study, we found that the natural course of ADD in juvenile patients with Class II malocclusion can involve worsening of their malocclusion in a high percentage of patients (64.29%) because of continued condylar resorption. Although 35.71% of the untreated condyles had new bone formation, it was located mostly at the posterior border of the condyle (21.42%), not at the superior part, which will elongate the condyle. Hence, for those patients, whether disc repositioning could stimulate condylar growth and alleviate mandibular deformity is worthy of study. Previous studies have shown that

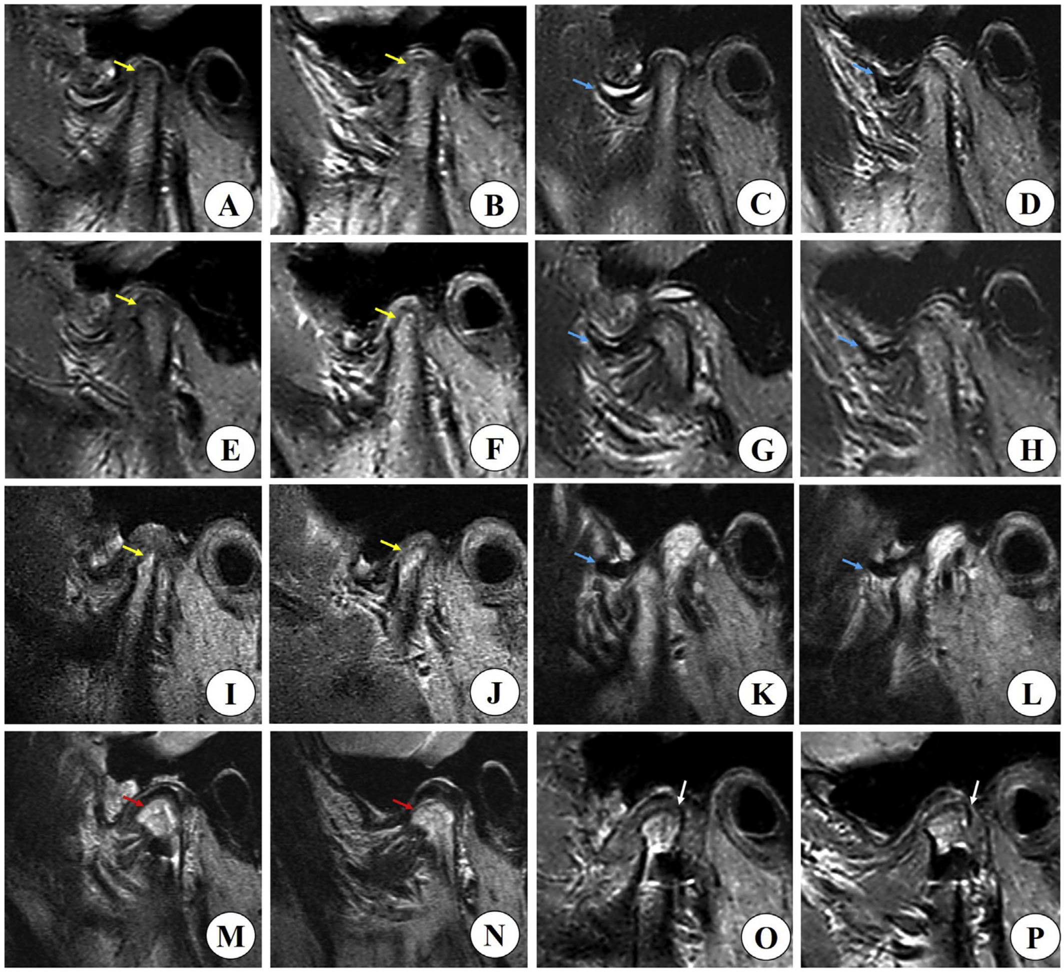

Fig. 3. Male, 14 years old, treated by disc repositioning and post-operative functional splint. Condyle changes before and after disc repositioning by MRI. A, B, discontinuous bone cortex (yellow arrows) of right and left sides at initial visit in closing position; C, D, anterior displaced disc without reduction (blue arrows) in opening position at initial visit; E–L, 6 months (E–H) and 1 year follow-ups (I–L): degenerative remodeling on condylar head (yellow arrows), further shortened and distorted discs (blue arrows); M, N, 3 months after treatment: new bone formation were observed (red arrows). O, P, 6 months after treatment: gradually regenerated bone cortex (white arrows).

Table 1
Condylar bone changes before and after disc repositioning by MRI.

	Condylar bone status	Joints	%
Follow-ups before operation	Bone regeneration (new bone position)	5	35.7%
	Superior	1	7.1%
	Posterior	3	21.4%
	Anterior	1	7.%
	No change	0	0
	Bone resorption	9	64.3%
	Total	14	100%
Follow-ups after disc repositioning and functional splint	Bone regeneration (new bone position)	28	100%
	posterior or/and superior	15	57.7%
	anterior-superior-posterior	7	26.9%
	Anterior	2	7.7%
	No change	0	0%
	Bone resorption	0	0%
	Total	28	100%

Table 2
Measurement of condylar height before and after follow-ups without disc repositioning by MRI (mm).

No.	Gender	Age	h0	h1	h0–h1
1	F	13	19.12	19.35	0.23
2	M	14	22.01	21.40	−0.61
3	F	15	23.37	22.35	−1.02
4	F	18	21.49	20.01	−1.48
5	F	20	24.34	23.65	−0.69
6	F	19	21.15	19.61	−1.54
7	F	19	21.56	21.01	−0.55
Average		16.86	21.86 ± 1.67*	21.05 ± 1.56*	−0.81 ± 0.61

h0, condylar height at the first visit; h1, condylar height before disc repositioning; *P = 0.013.

functional splints, eg, Herbst, twin-block or activator, could stimulate condylar growth and mandibular development in ADD with reduction by holding the mandible forward to adjust the disc–condyle relationship (Rohida and Bhad, 2010; Ruf et al., 2001; Ruf and Pancherz, 1999; Yildirim et al., 2014). However, for ADD without reduction, functional splints may aggravate disc displacement and cause condylar resorption. In this study, we first reduced the displaced TMJ disc, then used functional splints within 2 months after operation to position the mandible forward. The results showed that all condyles in these patients had new bone formation located mostly at the superior and posterior parts of the condyle. The condylar height increased 1.74 ± 0.98 mm on average, which demonstrated that the mandible grew downward and forward. Also, SNB increased 1.83 ± 1.56°, and pogonion moved

Table 3
Measurements of condylar height before and after follow-ups with treatment by MRI (mm).

No.	Gender	Age	h1	h2	h1–h2
1	F	13	19.35	21.50	2.15
2	F	14	20.15	22.60	2.45
3	M	14	21.40	23.80	2.40
4	F	15	20.35	24.25	3.90
5	F	16	18.24	19.5	1.26
6	F	16	18.15	19.25	1.10
7	F	16	21.90	22.70	0.80
8	F	17	18.35	19.58	1.23
9	F	17	22.70	23.50	0.80
10	F	18	20.01	21.05	1.04
11	F	18	23.10	24.20	1.10
12	F	19	18.55	21.60	3.05
13	F	20	23.15	25.50	2.35
14	F	20	23.65	24.38	0.73
Average		16.64	20.65 ± 1.20*	22.39 ± 2.02*	1.74 ± 0.98

h1, condylar height before disc repositioning; h2, Condylar height during follow-ups; *P = 0.000.

forward an average of 2.18 ± 3.13 mm. Overjet decreased 3.55 ± 1.86 mm.

There are two surgical methods to reposition the displaced TMJ disc: one is by arthroscopy, and the other is by open surgery (He et al., 2015; Yang et al., 2012). The arthroscopic technique is more suitable for TMJ discs with normal shape without hyperplastic posterior bands, whereas a thick, inflexible, and distorted disc and thick posterior bands are difficult to treat arthroscopically and are more suitable for open repositioning by mini-screw anchors (Yang, 2017). Our previous MRI study has shown that 5-year stability of disc repositioning was 89%, and it was further increased to 93.7% after technique modifications (He et al., 2015). The current study also showed that disc repositioning could stimulate bone regeneration. Compared with no treatment and solely functional splint treatment, disc repositioning by surgery can significantly increase condylar height. In this study, 92.3% of the condyles had new bone formation, which was located mostly at the superior-posterior part of the condyle. This can alleviate mandibular retrusion and decrease incisor overjet.

Table 4
Celphalometric measurements before and after disc repositioning.

Landmarks	Pre-treatment	Follow-up	Mean Change (pre-po)	Standard deviation	P value (α = 0.05)
Overjet (mm)	9.02	5.08	3.93	1.56	0.000**
SNA	80.12	80.18	−0.07	0.35	0.941
SNB	72.37	74.24	−1.87	1.64	0.001**
ANB	7.56	6.16	1.40	2.06	0.003**
Sn to G Vert (mm)	3.94	3.08	0.86	2.88	0.314
Pg' to G Vert (mm)	17.50	14.43	3.07	5.10	0.028*
Wits Appraisal (mm)	5.07	2.14	2.93	4.95	0.000**
Y-Axis (SGn-SN)	77.01	76.14	0.88	6.41	0.808
U1 − SN	108.74	106.93	1.81	1.64	0.055
IMPA (L1-MP)	93.56	94.28	−0.72	3.77	0.744
Interincisal Angle (U1-L1)	112.23	114.06	−1.83	5.79	0.309

*P < 0.05, **P < 0.01.

Fig. 4. Intra-oral photos of patient in Fig. 3. A, deep incisor overjet shown in pre-operative intra-oral images; B, C, personalized functional splint was applied 3 months after treatment; D, 6 months after treatment showed significantly reduced overjet.

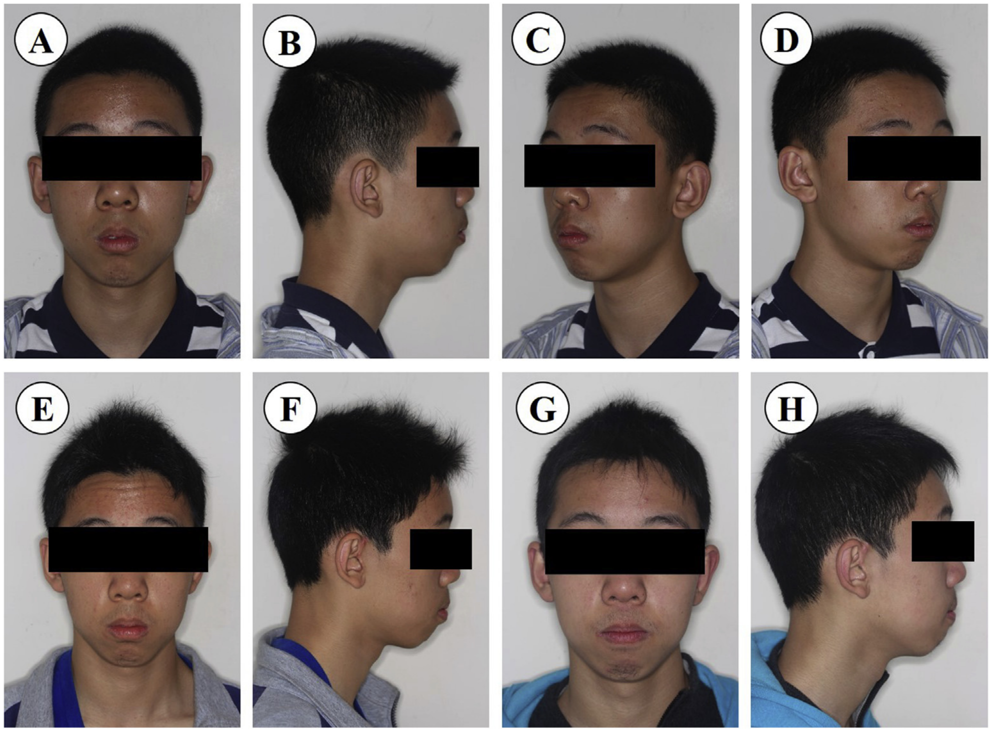

Fig. 5. Photographs of patient in Fig. 3. A–D, front and lateral view before operation showed mandibular retrusion; E, F, 3 months after treatment; G, H, 6 months after operation showed improvement of menton retrusion.

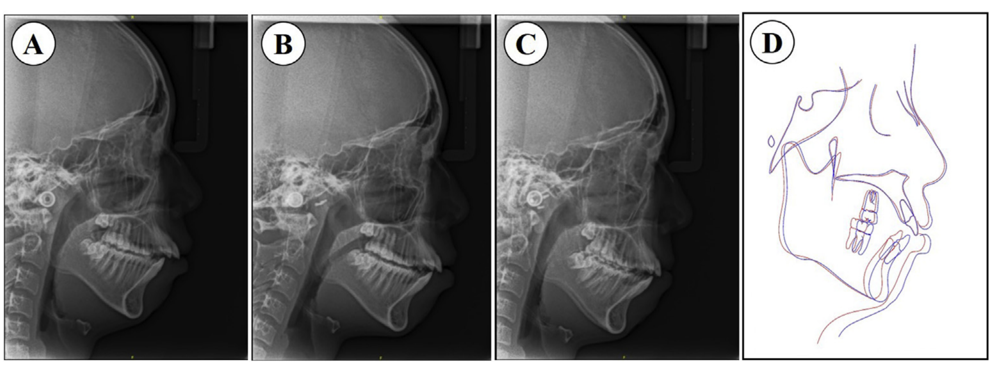

Fig. 6. Cephlometric measurements of patient in Fig. 3. A, pre-operation; B, 3 months after operation; C, 6 months after operation; D, superimposition of the images showed no maxillary position changes but significant advancement of the mandible and reduced anterior overjet.

Table 5
Celphalometric measurements without treatment.

Landmarks	First visit	Pre-operation	Mean Change (first-pre)	Standard deviation	P value ($\alpha = 0.05$)
Overjet (mm)	8.68	9.40	0.73	0.56	0.039*
SNA	81.23	81.65	0.43	0.29	0.060
SNB	74.75	74.23	−0.52	0.33	0.486
ANB	6.45	7.45	1.00	1.53	0.283
Sn to G Vert (mm)	3.48	3.98	0.50	1.90	0.636
Pg' to G Vert (mm)	11.95	15.23	3.28	3.02	0.119
Wits Appraisal (mm)	5.00	6.65	1.65	3.14	0.370
Y-Axis (SGn-SN)	74.45	75.08	0.63	1.39	0.434
U1 − SN	113.83	114.40	0.57	6.20	0.865
IMPA (L1-MP)	94.35	97.50	3.15	4.52	0.258
Interincisal Angle (U1-L1)	109.95	105.48	−4.48	5.03	0.173

*$P < 0.05$.

We used orthodontic functional splints within 2 months after disc repositioning to adjust the mandibular position and create space for condylar growth. We believe that the earlier the splint is used, the better the results, possibly because the regional acceleratory phenomenon (RAP) works in a limited time period (Frost, 1983; Wilcko et al., 2008; Yaffe et al., 1994). The function of the splint is to bring the jaw gradually forward and to hold the space created by disc repositioning. After confirming on MRI that new bone had formed and filled the joint space (usually 4–6 months), the functional splint can be removed and orthodontic treatment for the teeth can begin.

Bell and Wolford et al. (Bell 1992; Wolford et al., 2001a, 2001b) showed that the growth of the mandible is delayed relative to maxillary growth in juveniles. The peak velocity of mandibular growth appears at 12.5 years in girls and at 14.5 years in boys. In girls, approximately 98% of facial growth is usually completed by age 15 years, and in boys by approximately age 17 or 18 years. Therefore, for skeletal Class II malocclusion juvenile patients with bilateral ADD, positive treatment such as disc repositioning with post-operative functional splint therapy can promote condylar regeneration, which will alleviate jaw deformity and make the final orthodontic treatment easier.

5. Conclusion

Conservative treatment for ADD with Class II malocclusion in juvenile patients may cause condyle resorption and aggravate the dentofacial deformity. Disc repositioning combined with post-operative functional splints can effectively promote condylar growth and help correct the dentofacial deformity.

Conflicts of interest

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

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