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Comparison of temporomandibular joint function and morphology after surgical and non-surgical treatment in adult condylar head fractures

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ABSTRACT

Purpose: The aim of this study was to evaluate whether surgical treatment can distinctly improve temporomandibular joint (TMJ) function and morphology in adult patients with condylar head fractures (CHFs) when compared with conservative treatment.
Patients and methods: A retrospective study was performed to evaluate surgical and conservative outcomes in all patients who had suffered CHFs. In this study, all patients were divided into a surgical group and a conservative group. In the surgical group patients were treated by open reduction and internal fixation (ORIF) combined disc anchorage, while in the conservative group patients were treated by a removable splint combined with intermaxillary elastics. Clinical and radiological outcomes were evaluated and functional outcomes were assessed using the Helkimo index score. Paired t-tests, Wilcoxon signed rank tests, independent t-tests and χ^2 tests were used to assess inter-group differences.
Results: 75 TMJs in 56 patients were included in this study and were divided into a surgical group (56 TMJs in 40 patients) and a conservative group (19 TMJs in 16 patients). The results showed that the Helkimo index score for TMJ in the surgical group was better than in the conservative group ($p_{Ai} = 0.032$, $p_{Di} = 0.001$, respectively). Ramus height in the surgical group (61.08 ± 4.04 mm) recovered more than in the conservative group (54.82 ± 3.06 mm) ($p = 0.012$). Discs became shorter, moved further forward, and became severely distorted in the conservative group (disc length = 7.32 ± 1.35 mm). In contrast, discs became longer, retained a normal disc–condyle relationship, and formed a normal shape in the surgical group (disc length = 11.05 ± 2.07 mm) ($p = 0.003$). According to the MRI images, joint effusion, retrodiscal tear, and lateral capsular tear were better cured in the surgical group ($p = 0.001$, $p < 0.001$, $p = 0.012$, respectively).
Conclusion: Based on these results, it seems that surgical treatment of condylar head fractures should be the preferred approach if there are no contraindications for general anesthesia.

1. Introduction

Condylar head fracture (CHF) is one of the most frequent and complicated fractures, due to the weakness of the TMJ. According to previous reports, 65% of open surgeries for TMJ fractures are for CHFs (He et al., 2009; Neff et al., 1999). Magnetic resonance imaging (MRI) — a non-invasive and radiation-free imaging technique with superior soft-tissue resolution — has been described as the gold standard for TMJ examination (Ohnuki et al., 2003; Santler et al., 1993). Based on MRI imaging, there are characteristic findings in CHFs, including bony displacement, disc displacement, retrodiscal tissue tear, lateral

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capsular tear, and a displaced TMJ disc resulting from the displacement of the condylar head (Chuong and Piper, 1988).

CHFs result in clicking, joint pain, restricted mouth opening, masticatory difficulty, mandible dysfunction, and so on (Hlawitschka et al., 2005; Hlawitschka and Eckelt, 2002). If not properly managed, CHFs in adult can give rise to serious problems, such as malocclusion, temporomandibular dysfunction, and ankylosis of the TMJ (Iizuka et al., 1991; Long, 2013; Hlawitschka et al., 2005). Views on treatment procedures for CHFs are far from reaching a consensus. For adult CHFs, there are two principal therapeutic approaches: conservative and surgical methods. It is acknowledged that conservative treatment is recommended mainly for CHF patients without malocclusion and ramus height reduction (Zhao et al., 2014). Usually, patients receiving closed treatments have to undergo a period of passive immobilization by rigid intermaxillary fixation (IMF) with arch bars. Recently, a closed treatment using occlusal splints to lower the stump of the mandibular ramus has been proposed. Nonetheless, poor functional and radiological results for patients with CHF have shown the limitations of closed treatment (Hlawitschka and Eckelt, 2002; Hlawitschka et al., 2005; Landes et al., 2008).

In recent years, an increase in reports on the late complications of soft tissue dislocation has slowed the promotion of closed treatments. In contrast, increasing attention has been given to open treatment, which can decrease late complications and largely restore TMJ functions. It is universally acknowledged that CHFs are always combined with injury of associated soft tissues, such as disc displacement and tears in the capsule and retrodiscal tissue (Choi, 1997; Smets et al., 2003; Hlawitschka et al., 2005; Landes and Lipphardt, 2006; Gerhard et al., 2007; Landes et al., 2008; Vesnaver, 2008; Yang et al., 2015). Notably, disc displacement is the most detrimental problem, causing complications such as ankyloses, lateral deviation, and chronic pain, to name just a few. Surgical treatment allows not only open reduction and internal fixation of the displaced fragment, but also repositioning of the displaced disc and reparation of retrodiscal tissue and capsule injury (Chen et al., 2010; Yang et al., 2015; Neff et al., 1999).

Although surgical treatment has gradually surpassed conservative treatment as the preferred option for CHFs (He et al., 2014), functional or conservative treatments still play a role in treating adult patients with CHF because condylar remodeling with adaptive changes can lead to functional restitution of the TMJ (Landes et al., 2008; Schneider et al., 2008; Zhao et al., 2014; Lee et al., 2014). However, few studies have been able to demonstrate which one is better for TMJ functional and structural rehabilitation. In our department, we have applied different treatment methods for adult patients with CHF, including conservative and surgical ones. The aim of this study was to evaluate whether surgical treatment can distinctly improve the function and morphology of temporomandibular joints (TMJ) in adult patients with condylar head fractures (CHFs) when compared with conservative treatment.

2. Materials and methods

2.1. Study design

This was a retrospective study, and was approved by the local ethics board of Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine (No. HKDL2019116). It followed the tenets of the Declaration of Helsinki for research involving human subjects, and all participants signed an informed consent agreement. This study included patients with CHF who were treated from June 2015 to June 2017. All fractures were diagnosed by CT plus MRI examination and were separated into two groups (surgical and conservative) according to the two different treatment procedures. The treatment methods used were selected independently by the patients, on condition that they were adequately informed about all the risks and complications of the two approaches. Patients were followed up at 12 months, and results were estimated using the Helkimo index. In addition, CT and MRI examination were carried out at 12 months follow-up. The patients included in this retrospective study were chosen from a consecutive series of patients who had been referred to the Department of Oral and Cranio-Maxillofacial surgery in Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine. All data (including Helkimo index scores, CT, and MRI) were interpreted by a clinical specialist in TMJ surgery and compared by a statistician.

2.2. Procedures in conservative and surgical groups

In the surgical group, all operations were performed under general anesthesia. Minimized preauricular incisions, from the tragus to the auricular lobule (Fig. 1a), were used to approach the fractures, as reported previously (Cai et al., 2017). The fractured fragment, along with the attached lateral pterygoid muscle, was preserved and reduced with 12 mm bicortical screws (Cibei Company, Ningbo, China) (Fig. 1b). Displaced articular discs were noted in all cases in this study. After occlusion and TMJ mobility were checked, repositioning of the disc was performed. The medial and lateral supporting bands were carefully resected to perform a release surgery of the capsule (Fig. 1d), but the anterior attachment with pterygoid muscles was maximally preserved (Fig. 1c). It should be noted that the repositioned disc was anchored tightly to the titanium anchoring screw (Cibei Company, Ningbo, China; diameter 2.0 mm, mattress sutured with non-absorbable polypropylenes), which was placed in the posterior-lateral third of the condylar neck (Fig. 1d and f), to counteract the force coming from the lateral pterygoid muscle and to reposition the articular disc in its anatomical position.

In the conservative group, patients wore a maxillary splint with soft pad(s) on the molars of the affected side(s), thus creating a fulcrum (Fig. 2). Self-drilling mini-screws were inserted into anterior alveolar bone. Vertical traction was applied by elastics (ORMCO, 3/16, 8oz), approximately 500–600 g/side, for more than 22 h per day. Daily physical exercises started 1 month after trauma, and semi-rigid IMF was continued at night, but gradually reduced. If patients reported fractures of the symphyseal, parasymphyseal, or mandibular body, angle, or ramus, ORIF surgery was preferred. Three days after operation, closed treatment for CHF was started (Tang et al., 2017).

2.3. Evaluation of patients using the Helkimo index scoring system

The Helkimo index scoring system is one of the best TMJ functional assessment methods, and includes both Ai and Di indexes (Hlawitschka et al., 2005). The Helkimo Ai classifies TMJ dysfunction according to subjective symptoms, while the Di index classifies TMJ dysfunction through clinical assessment of impaired range of movement, impaired TMJ function, muscle pain, TMJ pain, and pain on movement of the mandible.

For this study, the Ai score was obtained through a historical review and divided into the following three grades: Ai 0, symptomless; Ai I, mild symptoms (i.e. at least one of the following: joint noise, muscle fatigue, and/or stiffness in the morning and during the exercise); and Ai II, severe symptoms (i.e. at least one of the following: restriction of mouth opening, joint locking, dislocation, motion-induced mandibular pain, and/or pain in the TMJ or masticatory muscle). For the Di clinical examination, five aspects of

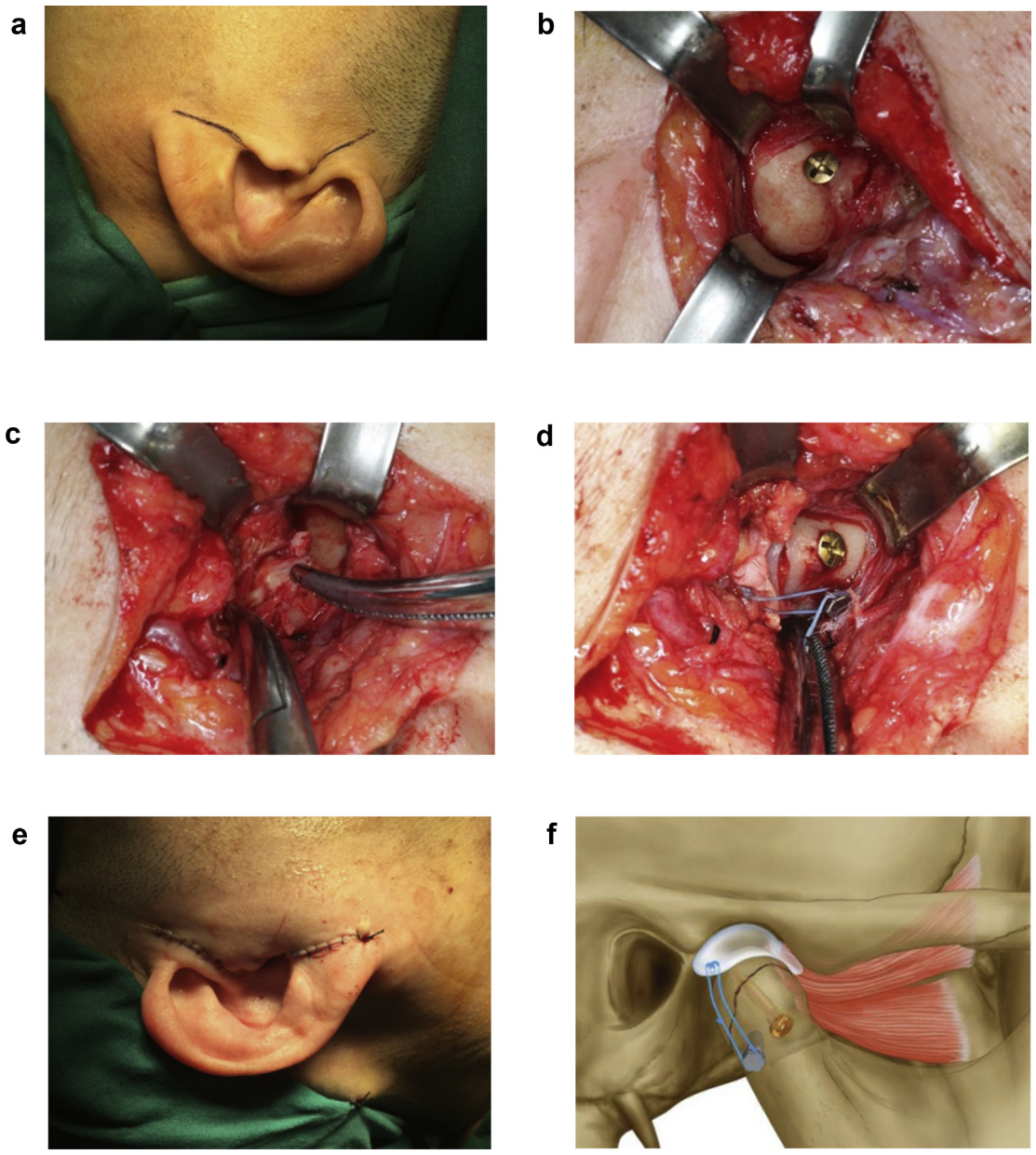

Fig. 1. Modified technique for reduction and fixation of the condylar fragment and soft tissue. a. A minimized preauricular incision from tragus to auricular lobule was used to approach the fractures. b. The fractured fragment along with the attached lateral pterygoid muscle was preserved and reduced with a 12-mm bicortical screw. c. The displaced articular disc (red arrow) was located and the abnormal adhesion around the disc was carefully released, but the anterior attachment with the pterygoid muscle was maximally preserved. d. After occlusion and TMJ mobility were checked, the disc was repositioned. To counteract the force coming from the lateral pterygoid muscle and reposition the articular disc to its anatomical position, the disc was tightly anchored to the anchoring screw (mattress sutured with non-absorbable polypropylene) which was placed in the posterior-lateral third of the condylar neck. e. Occlusion and disc–condyle mobility were re-checked, then the capsules were carefully sutured in position and the wound was closed in layers. f. Schematic diagram showing that the disc was repositioned and anchored to an anchoring screw (mattress sutured with non-absorbable polypropylene) which was placed in the posterior-lateral third of the condylar neck to counteract the force from the attached lateral pterygoid muscles.

movement were assessed: reduced lower jaw movement, joint dysfunction, muscle tenderness, joint tenderness, and jaw pain. Each sign was evaluated separately and assigned a score ranging from 0 to 5. The sums of the scores for all five signs were recorded as the following Di grades: 0 = Di 0, 1–4 = Di I, 5–9 = Di II, and 10–25 = Di III (Di 0 indicated normal function and Di III indicated worst function) (see Tables 1 and 2).

2.4. Radiological evaluation

The postoperative evaluation of radiological data was retrospective. Ramus height and disc length were measured on the panoramic radiographs (Figs. 3 and 4) and MRI images, respectively (Hlawitschka et al., 2005). Other qualitative variables for disc displacement, joint effusion, retrodiscal injury (defined as ranging from frequent overstretching to complete rupture of the retrodiscal tissue in some cases), and lateral capsular tear (frequent) were evaluated by examination of the TMJ MRI. On the T1-and T2-weighted images, capsular tears in the TMJ and tears in the retrodiscal tissue were defined by the presence of a dotted, high-signal area. Joint effusions were defined by a dotted, high-signal area on the diffusion-weighted image, and the presence of a dotted, low-signal area on the T1-weighted image (Sullivan et al., 1995; Takaku et al., 1996; Yu et al., 2013) (Fig. 5). In order to address

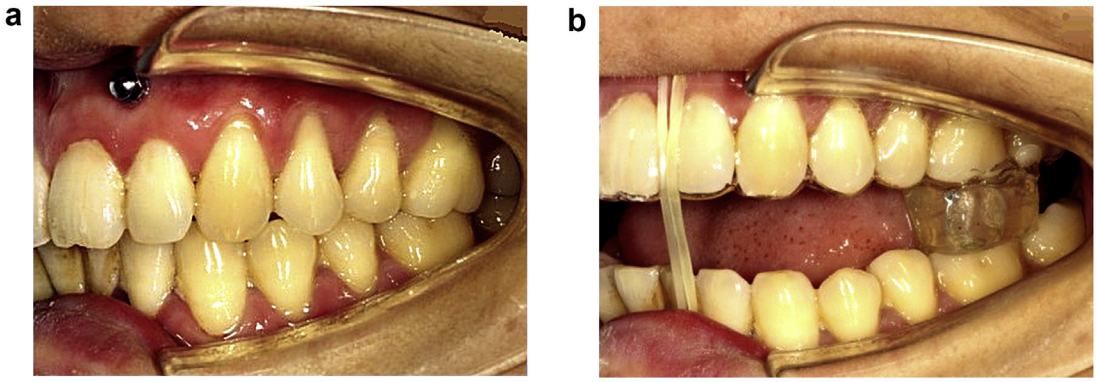

Fig. 2. Conservative treatment procedure by removable occlusion splint and intermaxillary fixation. a. Self-drilling mini-screws implanted in anterior alveolar bone. b. Removable splint with a soft pad between the posterior teeth of the affected side, on mini-screws.

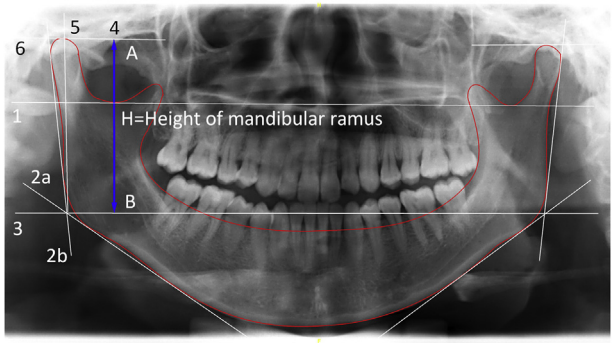

Fig. 3. Definition of mandibular ramus height. Line 5 is parallel; lines 3 and 4 intersect lines 5 and 3 at points A and B respectively,. The distance between point A and point B is defined as the height of the mandibular ramus.

inter-rater and intra-rater reliability for the radiological assessments, all radiological images were interpreted by a clinical specialist and a radiologist well versed in TMJ pathological entities. Both judged the images separately and came to independent conclusions. Any disagreement with respect to the diagnosis was evaluated by a third-party specialist.

2.5. Statistical analysis

Data were analyzed using SPSS 17.0 statistical software packages (Chicago). A p-value of <0.05 was accepted as statistically significant. Functional outcomes (Helkimo scores) were compared between the surgical and conservative groups using Wilcoxon signed rank tests. Paired t-tests and Wilcoxon signed rank tests were also used to assess differences in soft tissue injury and in ramus height restoration.

3. Results

3.1. Patients' information

A total of 85 joints in 71 patients were enrolled in our study, but 15 patients were excluded due to incomplete medical information, such as poor-quality images, short follow-up times, and changing treatment methods. Thus 75 joints in 56 patients were finally included in this study, which included 36 males and 20 females whose ages ranged from 18 to 76 years (mean 36.64 ± 17.18 years). According to the different treatment methods, 56 TMJs in 40 patients were allocated to the surgical group and 19 TMJs in 16 patients to the conservative group. All the patients were followed up for at least 6 months. In the surgical

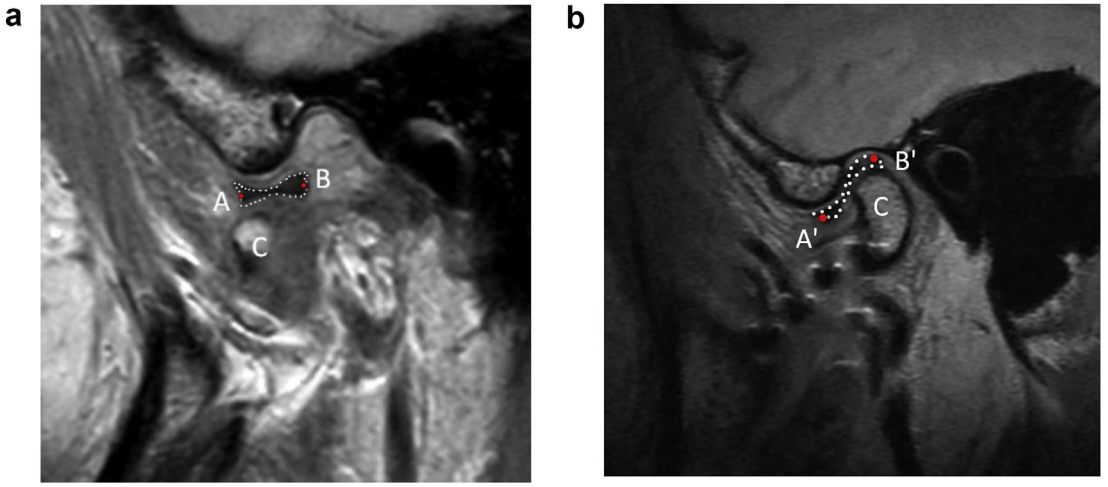

Fig. 4. Disc length was defined as the distance between points A (A′) and B (B′), which were the anterior and posterior points of the disc, respectively. (L1 = AB, L2 = A'B', C = condyle). a. T1-weighted sagittal preoperative MRI image. b. T1-weighed sagittal postoperative MRI image.

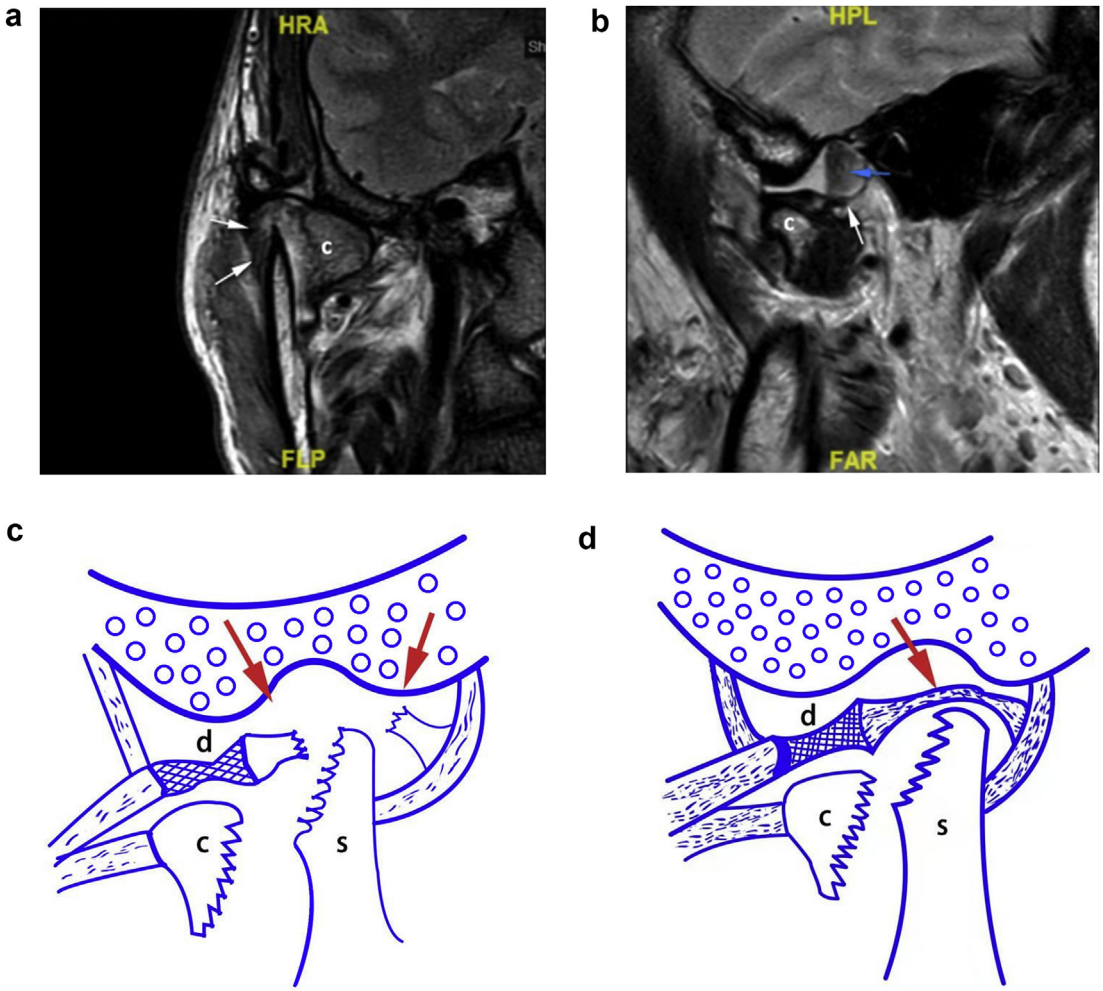

Fig. 5. Capsular tears in the TMJ and tears in the retrodiscal tissue are shown by the presence of a dotted, high-signal area on the T1-and T2-weighted images. Joint effusions are shown by a dotted, high-signal area on the diffusion-weighted image, and the presence of a dotted, low-signal area on the T1-weighted image. (c = condyle, s = stump, d = disc). a. Lateral capsular tear (white arrow). b. Joint effusion (blue arrow) and retrodiscal tear (white arrow). c. Retrodiscal tear (retrodiscal tissue was split; red arrow). d. Retrodiscal tear (retrodiscal tissue was overstretched; red arrow).

group, there was one patient who suffered from facial nerve weakness postoperatively, but recovered well 3 months after surgery following oral intake of methycobal. Two young female patients disrupted the postoperative scar and its treatment by applying scar-eliminating silica gel. There was no failure of fixations or formation of fistulas.

In terms of CHFs, several classifications have been proposed but Neff's classification is one of the most informative (Neff et al., 2000; Loukota et al., 2010), so this was used for patients in this study. Patient information is summarised in Table 3.

Table 1
Ai Helkimo index score.

Ai index	Subjective symptoms	
Ai 0	Symptomless	None
Ai I	Mild symptoms	At least one of the following symptoms: joint noise, muscle fatigue and/or stiffness in the morning and during the exercise
Ai II	Severe symptoms	At least one of the following symptoms: limitation of mouth opening, joint locking, dislocation, motion-induced mandibular pain and/or pain in the TMJ or masticatory muscle

3.2. Helkimo scores for the two groups

Most of the conservative group patients were in Ai I (75% Ai I, 5% Ai II, and 18.75% Ai 0), while a majority of the surgical group patients were in Ai 0 (52.5% Ai 0, 42.5% Ai I, and only 5.0% Ai II) ($p = 0.032 < 0.05$) (see Table 4). Di II (81.25%) was the main type in the conservative group at follow-up, whereas in the surgical group it was Di I (50.0%), followed by Di II (42.5%), and Di 0 (7.5%) ($p = 0.001 < 0.05$). There was a significant difference in both Ai index and Di index between these two groups.(see Table 4).

3.3. Morphology of TMJ in the two groups

Compared with the conservative group, the average ramus height was restored more effectively by the surgical method, and the difference was significant ($p = 0.012 < 0.05$). Similarly, there was a significant difference in disc length between the surgical and conservative groups ($p = 0.003 < 0.05$) (see Tables 5). The reason for these differences was that both the ramus and disc could be repaired during ORIF, while the displaced fracture and disc were difficult to reposition using conservative treatment.

Table 2
Di Helkimo index score.

Di index	Score
Range of mandibular movement	
Normal	0
Slightly impaired	1
Severely impaired	5
TMJ function	
No sounds or deviation	0
TMJ sounds and or deviation ≥ 2 mm	1
TMJ locking and or luxation	5
Muscle pain	
No tenderness	0
Tenderness in 1–3 palpation sites	1
Tenderness in at least 4 palpation sites	5
TMJ pain	
No tenderness	0
Tenderness to palpation laterally	1
Tenderness to palpation posteriorly	5
Pain on mandibular movement	
No pain	0
Pain on one movement	1
Pain on two or more movements	5

Table 3
Demographic data of 56 patients with CHFs.

Group	Surgical		Conservative	
Demographics	*n* (TMJs)	%	*n* (TMJs)	%
Gender				
Male	24	60.0%	12	75.0%
Female	16	40.0%	4	25.0%
Follow-up				
3 ≤ F ≤ 6	7	17.5%	2	12.5%
6 <F ≤ 12	12	30.0%	3	18.75%
F > 12	21	52.5%	11	68.75%
Fracture type				
A	6	10.7%	6	31.6%
B	42	75.0%	9	47.4%
C/M	8	14.3%	4	21.0%
Causes of injury				
Falling down	18	45.0%	7	43.8%
Traffic accident	7	17.5%	5	31.3%
Tumble	5	12.5%	3	18.8%
Other	10	25.0%	1	6.3%

Table 4
Comparison of Helkimo index scores for both groups.

Di	Conservative	Surgical	***p***
Di 0	0 (0)	3 (7.5%)	0.001
Di I	2 (12.5%)	20 (50.0%)	
Di II	13 (81.25%)	17 (42.5%)	
Di III	1 (6.25%)	0 (0)	
Ai			
Ai 0	3 (18.75%)	21 (52.5%)	0.032
Ai I	12 (75%)	17 (42.5%)	
Ai II	1 (6.25%)	2 (5.0%)	

p-value by Wilcoxon signed rank test ($\alpha = 0.05$).

As revealed by χ^2 and Fisher's exact tests, there were significant differences in disc displacement, retro-discal injury, lateral-capsular tear, and joint effusion between the two groups ($p < 0.01$, $= 0.001$, <0.001, $= 0.0125$, respectively) (see Table 5).

Table 5
Comparison of radiological evaluations for both groups.

Group	Surgical ($n = 56$)	Conservative ($n = 19$)	***p***
Ramus height	61.08 ± 4.04	54.82 ± 3.06	0.012
Disc length	11.05 ± 2.07	7.32 ± 1.35	0.003
Disc displacement (postoperatively)			
yes	2	16	<0.01
no	54	3	
Retro-discal injury,*n* (%)			
yes	4 (7.14%)	18 (94.74%)	0.001
no	52 (92.86)	1 (5.26%)	
Lateral-capsular tear,*n* (%)			
yes	0 (0%)	12 (63.16%)	<0.001
no	56 (100%)	7 (36.84%)	
Joint effusion,*n* (%)			
yes	1 (1.79%)	15 (78.95%)	0.0125
no	55 (98.21%)	4 (21.05%)	

p-value by t-test, χ^2 test and Fisher's exact test ($a = 0.05$).

4. Discussion

The management of subcapsular mandibular fractures by ORIF in adult patients is increasingly the method of choice for surgeons (Kommers et al., 2015). However, controversy remains regarding ORIF for the fractured condylar head. Recovery of mastication, on the basis of adaptive processes in the TMJ, is achieved in most cases of closed functional treatment, although complete remodeling of the fractured condyle is not achieved with closed functional treatment beyond 10 years of age (Zhao et al., 2014). Moreover, closed treatment also avoids potential complications, such as facial nerve injury, loss of osteosynthesis material, and scarring. However, extensive condylar deformation, height reduction of the mandibular ramus, disc displacement, dysfunctional complaints (such as limitation of mandibular mobility, crepitation, lateral deviation during mouth opening) and occlusal disturbances also need to be considered. Neff et al. describe 'irreversible displacement of the entire disco-ligamentous unit' after fracture, which explains the unfavourable functional results in this fracture type after closed functional treatment (Neff et al. 1999, 2000). Since the 1990s, the technical aspects of ORIF for CHF have improved following the development of specialized instruments, miniature osteosynthesis systems, and new materials. Neff et al. reported good radiological and clinical results for patients exclusively treated for CHF using open techniques (Neff et al., 2000). Our department has also studied and explored the ORIF technique for the CHFs, with the results previously reported and published (Cai et al., 2017; Ren et al., 2018).

This cohort study presents patients with the same condition treated consistently with either a surgical or non-surgical technique, and evaluated by the same examination method. The indication for selecting open treatment of the CHF was based upon age and fracture type. Only adult patients with displaced, condylar head mandibular fractures, with a loss of vertical height of the mandibular ramus, were treated surgically. Even with sufficient closed functional treatment of comminuted fractures of the mandible head, this patient group displayed the worst radiological, clinical, and radiographic results. The repositioning and fixation of comminuted fractures is technically complicated. Kermer reported that only CHF with a single fragment can be repaired using screw osteosynthesis (Kermer et al., 1998).

At the same time, conservative treatment methods have also improved following the development of specialized instruments and new materials. From functional training, to IMF, and then to intermaxillary elastic traction with removable splint, the effectiveness of conservative treatment has improved considerably.

Closed treatments are commonly recommended for CHF patients with unchanged occlusal relationships. Patients need to undergo a period of rigid IMF with arch bars. However, Ellis III and Edward (2000) found that absolute passive immobilization was unfavorable for functional rehabilitation of the jaw. Thus, IMF was

gradually abandoned and replaced by active immobilization of the mandible, requiring a period of liquid diet and restricted talking. Physiotherapeutic exercises are then started. Recently, another closed treatment for CHF, using an occlusal splint, has been reported. This technique inserts a fulcrum between the posterior teeth on the affected side and then applies elastic traction on self-drilling titanium screws inserted into the anterior alveolar bone. This method aims to lower the stump of the mandibular ramus while decreasing the vertical drop between the stump and the fragment of the condyle. It has been shown to improve the healing shape of condylar fractures, however, some researchers have observed condylar fragment movement during fracture repair.

Different techniques for treating mandibular CHFs have been widely reported, including ORIF (microplates, miniplates, lag screws, resorbable pins, and small-fragment screws) and conservative treatment (functional training, removable splint, intermaxillary fixation, intermaxillary elastic traction) (Pilling et al., 2006; Müller-Richter et al., 2011; Kolk and Neff, 2015). For this study, we used screw-based ORIF and intermaxillary elastic traction with removable splint. Compared with ORIF, intermaxillary elastic traction is safe, simple, and easy to apply, but makes it hard to restore the anatomical TMJ morphology. ORIF is technically difficult, and carries the risk of facial nerve injury and scarring, but was shown to be better for restoring TMJ structure. Regarding TMJ functional rehabilitation, both approaches were found to be effective.

Functional impairment of the TMJ can be assessed by different scoring systems, such as the Helkimo index and the mandibular function impairment questionnaire (MFIQ) (Helkimo et al., 1979; Stegenga et al., 1993). The MFIQ scoring is more detailed than the Helkimo index. However, previous studies evaluating functional outcome after ORIF for CHF have mainly used the Helkimo index (Hlawitschka et al., 2005; Kolk and Neff, 2015). Therefore, Helkimo index scoring system was used in our study, with scores for patients in the surgical group (ORIF + disc anchorage) better than those for the conservative group (removable occlusion splint + intermaxillary elastics), for both Ai and Di indexes.

In terms of TMJ morphology evaluation, the injured joints in both groups rehabilitated well. However, the injured TMJ (including condylar head and disc) of the patients in the surgical group showed better rehabilitation than in the conservative group. The results of our study are similar to those presented by Kolk and Neff. This implies that good functional results can be expected after ORIF combined with disc anchorage in cases of mandibular CHF.

5. Conclusion

In conclusion, both surgical treatment (ORIF of CHF combined with disc anchorage) and conservative treatment (removable occlusion splint + intermaxillary elastics) offer reliable results in terms of TMJ morphology and functional outcome for adult patients with CHF. However, surgical treatment appears to distinctly improve TMJ function and morphology in adult patients with CHF when compared with conservative treatment. Although ORIF with disc anchorage seems more effective in this short-term study, long-term follow-up is required to confirm the results.

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Declaration of Competing Interest

None.

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