Int. J. Oral Maxillofac. Surg. 2020; 49: 361–368
https://doi.org/10.1016/j.ijom.2019.07.005, available online at https://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Clinical Paper
TMJ Disorders

Clinical protocol for managing acute disc displacement without reduction: a magnetic resonance imaging evaluation

J. Lei[1,2,3,4,5], A.U.-J. Yap[1,6,7], Y. Li[1,2,3,4,5], M.-Q. Liu[1,2,3,4,5], K.-Y. Fu[1,2,3,4,5]

[1]Centre for TMD and Orofacial Pain, Peking University School and Hospital of Stomatology, Beijing, China; [2]Department of Oral and Maxillofacial Radiology, Peking University School and Hospital of Stomatology, Beijing, China; [3]National Clinical Research Centre for Oral Diseases, Beijing, China; [4]National Engineering Laboratory for Digital and Material Technology of Stomatology, Beijing, China; [5]Beijing Key Laboratory of Digital Stomatology, Beijing, China; [6]Department of Dentistry, Ng Teng Fong General Hospital, National University Health System, Singapore; [7]Faculty of Dentistry, National University of Singapore, Singapore

J. Lei, A. U. -J. Yap, Y. Li, M. -Q. Liu, K. -Y. Fu: Clinical protocol for managing acute disc displacement without reduction: a magnetic resonance imaging evaluation. Int. J. Oral Maxillofac. Surg. 2020; 49: 361–368.

Abstract. This study investigated the efficacy of a sequential combination of arthrocentesis, mandibular manipulation, and anterior repositioning splint (ARS) in the management of acute temporomandibular joint (TMJ) disc displacement without reduction (DDwoR). Twenty-one consecutive patients diagnosed with acute DDwoR by Diagnostic Criteria for Temporomandibular Disorders and magnetic resonance imaging (MRI) were recruited and managed with this method. Clinical and MRI data were obtained before and at 1 week after treatment. The disc–condyle relationship was determined by disc–condyle angle measurement. Condyle/disc positions were described as x–y coordinates with the summit of the articular fossa as the coordinate origin. Statistical analyses including independent/paired samples t-tests were conducted; significance was set at $P < 0.05$. Clinical success was observed in 95.2% of patients (20/21) with 22 joints affected by acute DDwoR. After combined treatment and ARS insertion, TMJs with DDwoR showed (a) normal disc–condyle relationships with substantial forward and downward condyle movement and significant disc reduction in closed position, and (b) discs with an intermediate zone located between the condylar head and articular eminence in open position. The combined approach was highly effective in 'unlocking' acute TMJ DDwoR and achieving spatial full disc reduction and a normal disc–condyle relationship. The duration of acute DDwoR appears to be critical for success.

Key words: temporomandibular joint; acute disc displacement without reduction; arthrocentesis; mandibular manipulation; anterior repositioning splint; magnetic resonance imaging.

Accepted for publication 10 July 2019
Available online 26 July 2019

Temporomandibular joint (TMJ) disc displacement is an intracapsular biomechanical disorder involving the disc–condyle complex. It is a common type of TMJ disorder with a prevalence of 30–60% in patients with temporomandibular disorders (TMD)[1,2]. TMJ disc displacements can be subdivided into (a) disc displacement with reduction (DDwR), (b) DDwR with intermittent locking, (c) disc displacement without reduction (DDwoR) with limited opening, and (d) DDwoR without limited opening, based on the stage of disc–condyle misalignment and clinical dysfunction[3]. In DDwoR, the

0901-5027/030361 + 08

articular disc cannot be reduced upon mouth opening, and consequently interferes with normal condylar mobility. Once DDwoR occurs, the displaced disc may impede condylar translation leading to increased loading of the anterior surface of the condyle. Subsequently, articular cartilage and subarticular bone abrasion may occur gradually over time.

DDwoR can be a debilitating condition (also known as TMJ closed lock) that negatively impacts patient quality of life due to mandibular dysfunction and TMJ pain[2,4]. Over time, it may culminate in TMJ degenerative joint disease (DJD) in susceptible patients[5]. The occurrence of TMJ DJD has been found to increase considerably (approximately 60%) at 1 month after the onset of DDwoR[5]. The TMJs of children and adolescents are in the process of growth and development[6], and TMJ DJD, if present, may interfere with physiological condylar development and cause abnormalities of the condylar form and structure. Dentofacial deformity, bite derangement, functional impairment, and disability may ensue[7]. Early diagnosis and management of TMJ DDwoR in youths is therefore prudent.

Most conservative and surgical interventions can alleviate symptoms of acute DDwoR including TMJ pain and limited mouth opening. As there is no significant difference in symptomatic relief, conservative and/or minimally invasive treatment modalities should always be employed before surgical interventions[2,8]. Despite improvements in symptoms, comorbid TMJ DJD changes increase significantly[5]. An early intervention for acute DDwoR involves 'unlocking' by mandibular manipulation (MM). If successful, this not only seems to eliminate 'closed lock' symptoms, but also prevents progressive degeneration of the TMJ structures by improving or even re-establishing a normal disc–condyle relationship[9–11].

The MM technique was first introduced by Farrar in 1978 and has since been modified and supplemented with additional therapies including pre-treatment intracapsular anaesthetic injection/arthrocentesis and/or post-treatment stabilization splint/anterior repositioning splint (ARS) wear[10,12–21]. There is, however, much contention about the outcomes of these interventions with regard to joint function and disc position. Studies that have objectively validated the disc position before and/or after MM using magnetic resonance imaging (MRI) are scarce. While some have reported 'disc recapture'[17,20], others have demonstrated merely 'disc reduction'[10,18,19,21]. Although most of these studies showed possible improvements in the disc–condyle relationship with MM, success rates were generally low and ranged from 9% to 23%.

The Peking University School and Hospital of Stomatology has employed a combination approach for the management of acute DDwoR comprising arthrocentesis, MM, and ARS wear, for approximately a decade, with much clinical success[9,22]. The objective of this study was to quantitatively and qualitatively examine this combined method for the management of acute DDwoR using MRI. The null hypothesis was that this combination technique is unable to achieve 'disc reduction' even though objective clinical measures and TMJ function are improved.

Materials and methods

Ethical approval for this study was obtained from the Peking University School and Hospital of Stomatology Institutional Ethics Committee. Subject inclusion criteria included (1) adolescents and young adults, 12–30 years old[22]; (2) diagnosis of acute DDwoR with limited opening based on the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD)[3], with a duration of TMJ closed lock of $\leq$3 months; and (3) presence of DDwoR confirmed by MRI. Subject exclusion criteria included (1) prior non-surgical and/or surgical TMD treatment; (2) presence of acute synovitis or suppurative TMJ arthritis; (3) presence of any systemic joint disease (e.g., rheumatoid arthritis); and (4) presence of oral or occlusal conditions that contraindicate ARS therapy (e.g., anterior crossbite). From January to December 2018, consecutive patients attending the Centre for TMD and Orofacial Pain, Peking University School and Hospital of Stomatology, who satisfied the eligibility criteria, were invited to participate. Informed consent was obtained from all patients prior to study involvement. Pre- and post-treatment clinical information including sex, age, history of TMJ clicking, history of TMJ closed lock, maximum unassisted mouth opening (MMO), and TMJ pain/pain relief were gathered.

MRI was performed with a 1.5-Tesla MRI scanner (Novus; Siemens, Munich, Germany) with TMJ surface coils. All joints were scanned with the patient's mouth closed in maximum intercuspation and opened maximally, before treatment and at 1 week after successful MM with the ARS in situ.

Quantitative measurements of disc and condyle positions in closed mouth position

Images were acquired from the MRI scanner, and measurements were performed using Mimics software v. 18.0 (Materialise NV, Leuven, Belgium). Quantitative measurements were obtained from the MRI images by a trained and calibrated radiologist with no knowledge of the patient information. The intra-observer reliability was determined by intra-class correlation coefficient (ICC), which ranged from 0.758 to 0.999 for the different variables, with a mean of 0.949 for all variables (measurements were performed twice with a 1-week interval). The average of the two measurements was used for the statistical analyses.

For measurement of the disc–condyle angle, the sagittal slice perpendicular and through the centre of the horizontal long axis of the condyle was selected for assessment. The disc–condyle angle theta (θ) was determined based on the method described by Drace and Enzmann[23] (Fig. 1a). The normal values for angle θ range from $-15°$ to $15°$, and an angle θ of $>15°$ indicates the presence of anterior disc displacement[24].

For measurements of the condyle and disc positions, the *x*–*y* coordinates of the condyle and disc positions, at point C and point D, respectively, were recorded[23] (Fig. 1b).

Qualitative assessment of the disc–condyle relationship in open mouth position

On maximum unassisted mouth opening, the intermediate zone of the disc is either located between the condylar head and articular eminence (reduced), or anterior to the condylar head (non-reduced). In DDwoR, the articular disc cannot be reduced upon mouth opening[3].

Description of the combined intervention

Step 1 is arthrocentesis. Arthrocentesis of the upper joint cavity was performed under local anaesthesia. About 1–2 ml of physiological saline was injected into the upper joint cavity under pressure, and pumped in and out using the single-needle technique (23-gauge needle). This procedure was repeated three to five times. Upon completion of this procedure, 1 ml of 2% lidocaine was injected into the upper joint cavity[25].

Step 2 is mandibular manipulation. The clinician placed both thumbs directly onto

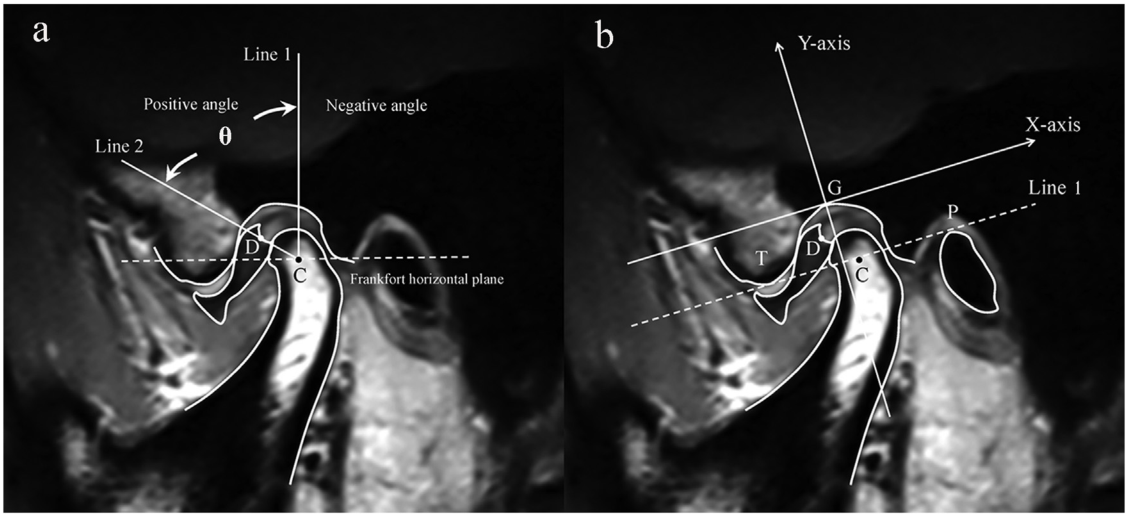

Fig. 1. (a) Measurement of the disc–condyle angle (based on the method described by Drace and Enzmann[23]). The centric point of the condylar head was defined as point C and the mid-point of the posterior margin of the disc posterior band was defined as point D. The line drawn through point C perpendicular to the Frankfort horizontal plane was defined as line 1. The line drawn through point C to point D was defined as line 2. The angle θ formed between line 1 and line 2 was defined as the disc–condyle angle. (b) Coordinate measurement for disc and condyle position. A tangent drawn from the lowest part of the articular eminence (point T) to the highest part of the porus acusticus externus (point P) was defined as line 1. The *x*-axis was drawn through the highest part of the articular fossa (point G) parallel to line 1. The *y*-axis was drawn from point G perpendicular to the *x*-axis. Point G was defined as the origin of the coordinates. The *x*–*y* coordinates of the condyle and disc positions, at point C and point D, respectively, were recorded (Courtesy of Liu et al., J Appl Oral Sci 2017: 25: 486).

the bilateral mandibular molars of the patient and pressed lightly downward or downward/contralaterally. The patient was instructed to open their mouth as wide as possible simultaneously. Clinical criteria for successful MM included (1) the presence of an audible click, along with a marked increase in MMO, and (2) unassisted mouth opening with symmetrical bilateral condylar translation, without any joint sounds. Finally the mandibles were protruded into the edge-to-edge position with the mouth closed[9,10,16]. The mechanism of 'unlocking' the TMJ closed lock is shown in Fig. 2.

Step 3 is immediate chairside ARS. A maxillary full-coverage acrylic ARS with occlusal indentions and anterior lingual guiding ramps was immediately fabricated with the mandible guided into the protrusive position to prevent the 'reduced disc' from being anteriorly displaced again in closed mouth position (re-locked) (Fig. 3).

Step 4 is ARS wear. Patients were required to wear their splint 24 hours a day for 3 months and were allowed to remove the splint only for oral hygiene purposes. For the first 3–5 days after successful MM, the joint may be susceptible to re-locking due to mandibular retrusion during supine sleep. The first 3–5 days are thus considered a 'critical risk stage', as recurrence of TMJ closed lock is high. A provisional intermaxillary fixation splint was thus prescribed when sleeping to force the mandible into the protrusive position (Fig. 4) during this critical stage. During the day, the patients wore their ARS. One week after successful MM, MRI was repeated in both closed and opened mouth positions for all patients with their ARS in situ. After the initial 3 months, the patients were weaned off daytime ARS wear and instructed to wear their ARS only during the night while sleeping[22,26]. No additional jaw exercises were conducted.

Statistical analysis

Data were explored for normality using a quantile–quantile plot (Q–Q plot). Homogeneity of variance was explored with Levene's test. The independent samples *t*-test was used to compare differences in disc–condyle angles and condyle and disc positions between DDwoR and asymptomatic joints. The paired samples *t*-test was used to compare the pre- and post-treatment MMO, disc–condyle angle, and condyle and disc position changes. All statistical analyses were performed using IBM SPSS Statistics version 21.0 (IBM Corp., Armonk, NY, USA); the significance level was set at 0.05.

Results

Twenty-one consecutive patients satisfied the eligibility criteria and were enrolled in the study. Audible clicks indicating successful TMJ closed lock reduction were observed in 20 patients after MM (20/21, 95.2%). Clinical variables and disc–condyle positions of the 20 patients before and after MM were compared.

Of the 20 subjects (40 joints in total), 19 were female and one was male, with a mean age of 18.60 ± 4.60 years (range 12–29 years). They had an average duration of joint clicking of 12.09 ± 14.15 months (range 0–42 months) and an average duration of closed lock of 1.18 ± 0.79 months (range 0.10–3 months). A total of 22 joints with acute DDwoR (unilateral in 18 and bilateral in two patients) and 18 asymptomatic contralateral joints with no history of clicking and closed lock were appraised. MMO improved immediately following MM, from 30.05 ± 6.22 mm to 51.10 ± 2.77 mm ($P < 0.001$). No significant difference in MMO was observed between the measurement obtained immediately after MM and that obtained 1 week later ($P = 0.892$). All patients reported no pain or significant pain relief 1 week later.

Quantitative changes in disc–condyle angle

Discs in all 22 joints with DDwoR were fully reduced post-treatment (Fig. 5). Pre-treatment MRI examination showed a mean disc–condyle angle of $55.59 \pm 9.90°$ for joints with DDwoR. This was significantly

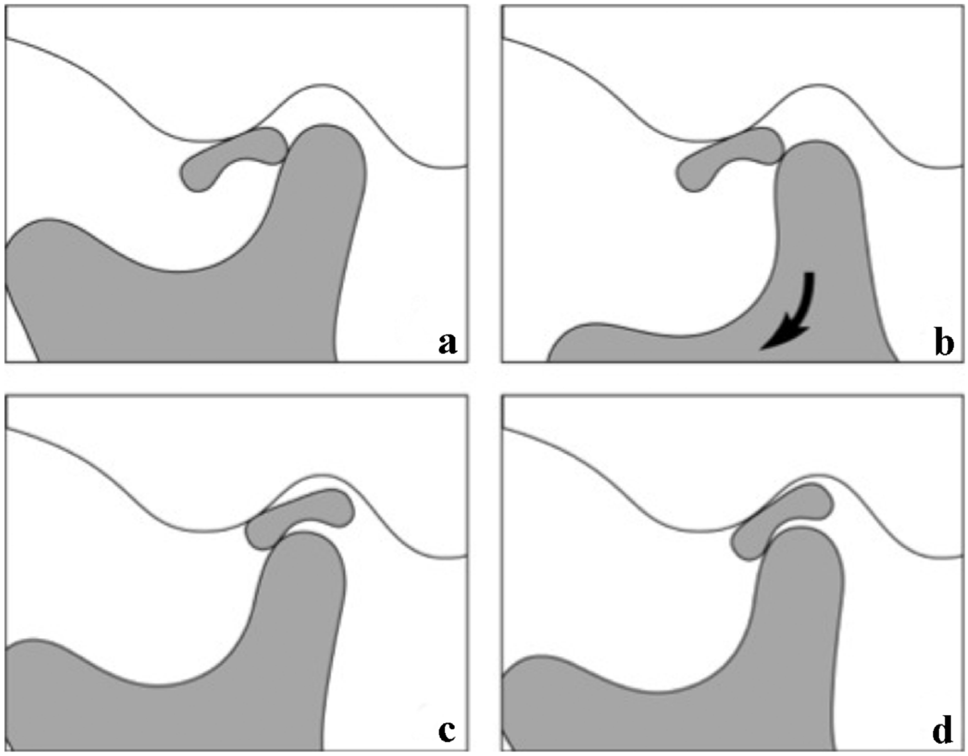

Fig. 2. (a) Disc displaced anteriorly without reduction. (b) The condyle is gently forced downward or downward/contralaterally by the manipulator while the patient is instructed to open his/her mouth as wide as possible, making space for the disc to 'reduce' itself during mouth opening. (c) Concurrent backward movement of the disc: the disc has been reduced back to the fossa during wide mouth opening. (d) Immediate insertion of an anterior repositioning splint manufactured at the chairside: the condyle is guided in a forward position to prevent the 'reduced disc' from being anteriorly displaced again in the closed mouth position.

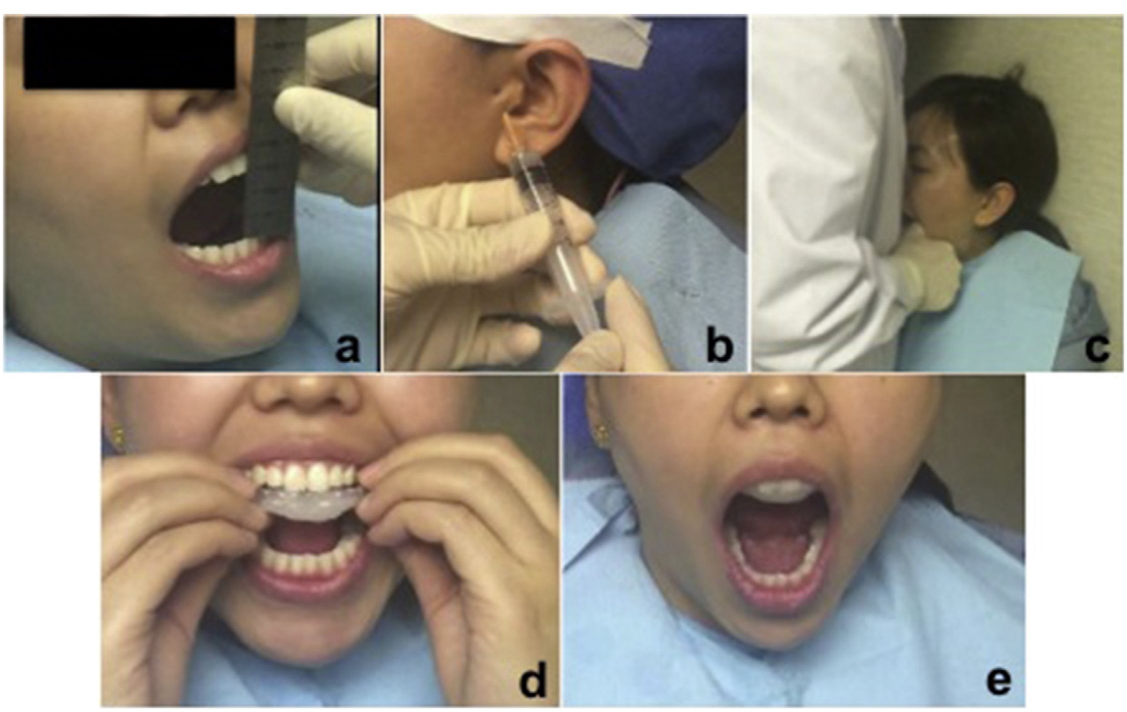

Fig. 3. Images showing mandibular manipulation and anterior repositioning splint (ARS) wear. (a) The patient with DDwoR with limited mouth opening before treatment. (b) Arthrocentesis using a single needle technique. (c) Mandibular manipulation. (d) Immediate ARS insertion after successful disc reduction. (e) Significant increase in maximum mouth opening, and symmetrical bilateral condylar translation with no joint sounds.

Fig. 4. A provisional device for intermaxillary fixation using self-curing resin to bond the anterior regions of the maxillary and mandibular splints, in order to force the mandible into a protrusive position (in an edge-to-edge relationship).

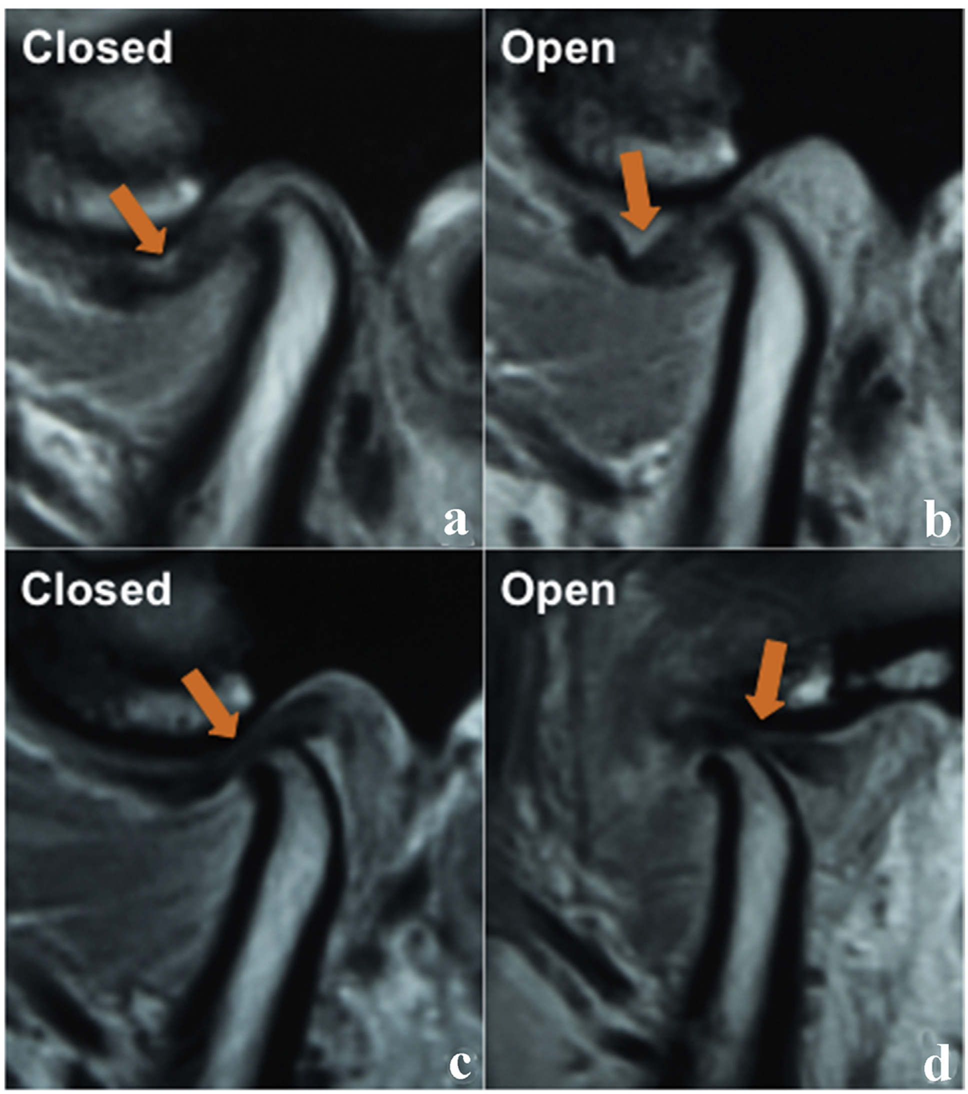

Fig. 5. MRI images showing successful disc reduction in a joint with DDwoR. Images (a) and (b) show the pre-treatment condition, with the disc displaced anterior to the condylar head in both the closed and open mouth positions. Images (c) and (d) show the post-treatment condition, with a normal disc–condyle relationship in both the closed and open mouth positions. Note that the posterior band of the disc is located underneath the highest point of the glenoid fossa in the closed position.

greater than the angle in asymptomatic joints (27.89 ± 19.18°) ($P < 0.001$). After successful MM and with ARS wear, all joints with DDwoR (22/22) were found to have a normal disc–condyle relationship with a mean disc–condyle angle of −22.65 ± 29.06°. This did not differ significantly from the angle in asymptomatic joints (−29.35 ± 25.62°) ($P = 0.449$).

Quantitative changes in condyle position

Point C represented the condyle position in *x–y* coordinates (Fig. 1b). There was no significant difference in condyle position between the DDwoR and asymptomatic joints, either before or after treatment ($P > 0.05$).

After successful MM and with ARS wear, condyles of joints with DDwoR moved antero-inferiorly when compared to the initial pre-treatment position ($P < 0.001$). Similarly, asymptomatic joints also moved antero-inferiorly when compared to the initial pre-treatment position ($P < 0.001$) (Table 1).

Quantitative changes in disc position

Point D represented the disc position in *x–y* coordinates (Fig. 1b). Before treatment, discs in joints with DDwoR were displaced antero-inferiorly when compared to asymptomatic joints ($P < 0.05$). However, no significant difference in disc position was observed between joints with and without DDwoR after treatment.

With the combined approach, discs in joints with DDwoR moved backwards when compared to the initial pre-treatment position ($P < 0.001$). Similarly, for asymptomatic joints, the disc also moved backwards when compared to the initial pre-treatment position ($P < 0.001$). All discs showed notable posterior movement (2–3 mm), and were 'reduced' towards the highest part of the articular fossa (Fig. 5) (Table 1).

Qualitative assessment of the disc–condyle relationship in open mouth position

On maximum unassisted mouth opening, the intermediate zone of all discs (40/40 joints) was located between the condylar head and the articular eminence (Fig. 5).

Discussion

In this study, a combination approach comprising arthrocentesis, MM, and ARS for the management of acute DDwoR was quantitatively and qualitatively evaluated. The disc–condyle angle and condyle and disc positions before and after treatment were determined. After successful MM and with ARS wear, all joints with DDwoR were found to have a normal disc–condyle relationship with the discs reduced 2–3 mm back towards the articular fossa, while the condyles moved forwards and downwards. A high rate of successful TMJ closed lock reduction (95.2%) was observed when MM was performed with arthrocentesis. Subsequent to the improvement in disc condition from non-reducible to reducible, ARS therapy minimized relapse of the closed lock, as it positioned the condyle forwards to maintain a normal disc–condyle relationship. Considering these findings, the null hypothesis was rejected.

With the exception of one subject for whom MM was unsuccessful, all patients with acute DDwoR were managed with the same sequential protocol: (1) pre-treatment MRI examination, (2) arthrocentesis on the affected side, (3) MM, (4) ARS therapy, (5) and post-treatment MRI examination. The asymptomatic contralateral joints were not subjected to arthrocentesis or MM. Audible clicking with a significant improvement in mouth opening provided subjective evidence for the efficacy of MM in 'unlocking' TMJ closed lock. Objective MRI appraisal confirmed that previously anteriorly displaced discs were successfully 'reduced' back to the articular fossa, achieving a normal disc–condyle relationship upon ARS insertion in both closed and open mouth positions. The concept for this combined management approach to acute DDwoR is to 'unlock' the TMJ closed lock, 'reduce' it to DDwR, and then manage DDwR with ARS therapy[9,22,26,27].

Arthrocentesis, a treatment modality for various TMJ disorders, involves saline injection and lavage of the upper joint cavity to reduce intra-articular friction and adhesive forces. This does not always improve disc position and deformity[25]. MRI-based studies have actually reported worse disc deformation and further disc displacement several months after arthrocentesis in patients with DDwoR, despite improvements in joint pain and mandibular dysfunction[19,28]. Therefore arthrocentesis was carried out before MM to facilitate disc reduction by decreasing the adhesive forces resulting from joint viscosity[9,12,25]. Intra-articular fine fibrillation and adhesion, which increases viscosity in the upper joint cavity, was widely observed with arthroscopy in the patients with disc displacement. The severity often increases with more advanced stages and a longer duration of locking[29]. Furthermore, arthrocentesis and intra-articular anaesthesia can alleviate the TMJ pain caused by synovitis, enhancing patient cooperation during MM. A few studies have highlighted the importance of arthrocentesis before MM[9,12,20]. Others have only utilized intra-articular anaesthetic injection[13,16], which might be insufficient to overcome the frictional and adhesive joint forces, due to the lack of lavage[25].

The results of MM for DDwoR have been controversial for decades. Traditionally, MM is used to 'recapture' a displaced disc, and to locate the condyle on the anteriorly displaced disc by pulling the affected condyle antero-inferiorly[2,17]. Researchers thus called it 'disc recapture'[17,20]. In contrast, others considered this as either 'reduction of the disc', 'successful disc reduction', or 'non-

Table 1. Condyle and disc coordinates in asymptomatic and DDwoR joints before and after treatment; mean ± standard deviation values in millimetres.

Coordinates		Condyle (mm)		Disc (mm)	
		Asymptomatic joints	DDwoR joints	Asymptomatic joints	DDwoR joints
x	Before treatment	1.52 ± 0.91^{A}	1.61 ± 0.83^{C}	−0.12 ± 1.53^{E,a}	−1.79 ± 0.72^{G,a}
	After treatment	−0.75 ± 1.52^{A}	−1.44 ± 1.25^{C}	2.51 ± 1.59^{E}	1.65 ± 2.17^{G}
y	Before treatment	−6.51 ± 1.04^{B}	−6.02 ± 0.89^{D}	−2.05 ± 0.63^{F,b}	−2.77 ± 0.58^{H,b}
	After treatment	−8.32 ± 1.12^{B}	−8.45 ± 1.03^{D}	−4.04 ± 1.94^{F}	−3.92 ± 1.57^{H}

DDwoR, disc displacement without reduction.
Lowercase letters in the same row indicate a significant difference between asymptomatic and DDwoR joints ($P < 0.001$).
Uppercase letters in the same column indicate a significant difference between the mean value obtained before treatment and that obtained after treatment ($P < 0.001$).

reducible to reducible disc'[10,13,18,19,21]. All of these studies performed qualitative assessments using MRI or arthrograms and most reported low success rates with MM. In the current work, changes in disc–condyle position before and after MM and ARS were quantified and the results showed that the disc moved back to the articular fossa by 2–3 mm. This corroborates the concept of 'disc reduction' during MM[10,13,18,19,21].

The success rate of disc reduction with MM in the present study (approximately 95%) is substantially higher than the rates reported in previous studies. In addition to the use of arthrocentesis and intra-articular anaesthesia, another plausible reason for this variability in success rate is the indication for MM treatment. Effective disc reduction may depend on the duration of the locking that denotes the acute phase of DDwoR. In previous studies, the duration of TMJ closed lock varied significantly from 0.07 to 180 months[10,13,18,19,21], while in the present study, the duration of closed lock in all the subjects was no more than 3 months. The superior retro-discal tissue is composed of elastic fibres and is attached to the articular disc. It is stretchable and capable of retracting the disc posteriorly during wide mouth opening. The elasticity of the retro-discal tissue is critical for achieving the retractive forces needed to 'reduce' the disc[30]. With prolonged and more advanced disc displacement, the retro-discal tissue may deteriorate, lose its elasticity, and deform considerably. In addition, intra-articular fibrillation and adhesion may well intensify over time with DDwoR[29]. The success rate of MM is conceivably higher with recent onset DDwoR considering the aforementioned and the disc being more likely to maintain its original shape as well as function[20]. Given the high success rate of disc reduction with MM in the present study, it is conceivable that 3 months is the time point for defining the 'acute phase' of DDwoR[11,13].

Although ARS can re-establish a normal disc–condyle relationship in joints with DDwR with or without intermittent locking[26,27], it could also exacerbate DDwoR by pushing the disc even more forward as the condyle moves antero-inferiorly. For this reason, successful disc reduction is paramount before ARS therapy[26,27,30]. After successful disc reduction, the affected TMJ would readily re-lock if the mandible moves back to the intercuspal position. An ARS manufactured chairside was thus inserted immediately to prevent re-lock[10]. The use of the ARS resulted in forward and downward condylar movement and minimized the reduced disc from sliding anteriorly again. This maintains the ideal spatial disc–condyle relationship and promotes adaption and healing of the retro-discal tissues over time[26,27]. Unlike other studies[10,13,17,18,21,30], continuous 24-h ARS wear, including at meal times, was recommended for 3 months. The shape of the disc and retro-discal tissues might become compatible with the condyle and fossa after continuous ARS wear during functional movements[30]. While no major skeletal change ensues, a mild posterior open bite may occur at the end of 3 months; however, this would gradually resolve after 1–2 weeks of only night wear and would usually be followed by restitution of the occlusion[26].

Although this study established a noteworthy clinical approach for managing acute DDwoR, it has several limitations. The current work only showed good clinical outcomes with ARS in the short term. A previous study demonstrated relatively low efficacy (about 40%) in maintaining a normal disc–condyle relationship upon ARS removal in patients with DDwR over the long term[26]. Recurrence of disc displacement is a common issue even after arthroscopic and open surgery. Future work involving more subjects should focus on the long-term stability of the ideal disc–condyle relationship after ARS removal as well as methods to maintain it. Outcomes with other occlusal splint types including stabilization splints should also be investigated. As this preliminary work only involved the short-term assessment of 20 subjects, a longer term study with a larger sample size is warranted.

In conclusion, the efficacy of a sequential combination of arthrocentesis, MM, and ARS for the management of acute DDwoR was determined both quantitatively and qualitatively using MRI. Successful disc reduction with arthrocentesis and MM, as indicated by audible clicking together with a marked increase in mouth opening, was observed in 95.2% of patients. Together with ARS therapy, TMJs with DDwoR showed a normal disc–condyle relationship with substantial antero-inferior condyle movement and significant disc reduction in closed position. Moreover, the intermediate zone of the disc was observed to be located between the condylar head and the articular eminence in open position. The 'acute phase' of DDwoR appears to be $\leq$3 months and may be critical for successful management.

Funding

This work was supported by the Program for New Clinical Techniques and Therapies of Peking University School and Hospital of Stomatology (PKUSSNCT-18B03) and the Capital Clinical Research Project (Z141107002514157) of the Beijing Municipal Science and Technology Commission.

Competing interests

None.

Ethical approval

Peking University School and Hospital of Stomatology Institutional Ethics Committee (PKUSSIRB-201414054).

Patient consent

Patient consent was obtained.

References

1. Manfredini D, Guarda-Nardini L, Winocur E, Piccotti F, Ahlberg J, Lobbezoo F. Research Diagnostic Criteria for Temporomandibular Disorders: a systematic review of axis I epidemiologic findings. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011;**112**:453–62. http://dx.doi.org/10.1016/j.tripleo.2011.04.021.
2. Miernik M, Wie?ckiewicz W. The basic conservative treatment of temporomandibular joint anterior disc displacement without reduction—review. *Adv Clin Exp Med* 2015;**24**:731–5. http://dx.doi.org/10.17219/acem/35165.
3. Schiffman E, Ohrbach R, Truelove E, et al. Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) for clinical and research applications: recommendations of the International RDC/TMD Consortium Network and Orofacial Pain Special Interest Group. *J Oral Facial Pain Headache* 2014;**28**:6–27. http://dx.doi.org/10.11607/jop.1151.
4. Dahlström L, Carlsson GE. Temporomandibular disorders and oral health-related quality of life. A systematic review. *Acta Odontol Scand* 2010;**68**:80–5. http://dx.doi.org/10.3109/00016350903431118.
5. Lei J, Han J, Liu M, Zhang Y, Yap AU, Fu KY. Degenerative temporomandibular joint changes associated with recent-onset disc displacement without reduction in adolescents and young adults. *J Craniomaxillofac Surg* 2017;**45**:408–13. http://dx.doi.org/10.1016/j.jcms.2016.12.017.
6. Lei J, Liu MQ, Yap AU, Fu KY. Condylar subchondral formation of cortical bone in adolescents and young adults. *Br J Oral*

Maxillofac Surg 2013;**51**:63–8. http://dx.doi.org/10.1016/j.bjoms.2012.02.00.
7. Ooi K, Inoue N, Matsushita K, Yamaguchi H, Mikoya T, Minowa K, Kawashiri S, Nishikata S, Tei K. Incidence of anterior disc displacement without reduction of the temporomandibular joint in patients with dentofacial deformity. *Int J Oral Maxillofac Surg* 2018;**47**:505–10. http://dx.doi.org/10.1016/j.ijom.2017.11.017.
8. Schiffman EL, Velly AM, Look JO, Hodges JS, Swift JQ, Decker KL, Anderson QN, Templeton RB, Lenton PA, Kang W, Fricton JR. Effects of four treatment strategies for temporomandibular joint closed lock. *Int J Oral Maxillofac Surg* 2014;**43**:217–26. http://dx.doi.org/10.1016/j.ijom.2013.07.744.
9. Fu K, Zhang H, Ma X, Zhang Z, Zhao Y. Manipulation aided by joint cavity extension followed by occlusal splint for treatment of acute anterior disk displacement without reduction. *Zhonghua Kou Qiang Yi Xue Za Zhi* 2002;**37**:36–8.
10. Chiba M, Echigo S. Longitudinal MRI follow-up of temporomandibular joint internal derangement with closed lock after successful disk reduction with mandibular manipulation. *Dentomaxillofac Radiol* 2005;**34**:106–11. http://dx.doi.org/10.1259/dmfr/29080712.
11. Al-Baghdadi M, Durham J, Steele J. Timing interventions in relation to temporomandibular joint closed lock duration: a systematic review of 'locking duration'. *J Oral Rehabil* 2014;**41**:24–58. http://dx.doi.org/10.1111/joor.12126.
12. Murakami KI, Lizuka T, Matsuki M, Ono T. Recapturing the persistent anteriorly displaced disk by mandibular manipulation after pumping and hydraulic pressure to the upper joint cavity of the temporomandibular joint. *Cranio* 1987;**5**:17–24.
13. Segami N, Murakami K, Iizuka T. Arthrographic evaluation of disk position following mandibular manipulation technique for internal derangement with closed lock of the temporomandibular joint. *J Craniomandib Disord* 1990;**4**:99–108.
14. Minagi S, Nozaki S, Sato T, Tsuru H. A manipulation technique for treatment of anterior disk displacement without reduction. *J Prosthet Dent* 1991;**65**:686–91.
15. Jagger RG. Mandibular manipulation of anterior disc displacement without reduction. *J Oral Rehabil* 1991;**18**:497–500.
16. Mongini F. A modified extraoral technique of mandibular manipulation in disk displacement without reduction. *Cranio* 1995;**13**:22–5.
17. Martini G, Martini M, Carano A. MRI study of a physiotherapeutic protocol in anterior disk displacement without reduction. *Cranio* 1996;**14**:216–24.
18. Kurita H, Kurashina K, Ohtsuka A. Efficacy of a mandibular manipulation technique in reducing the permanently displaced temporomandibular joint disc. *J Oral Maxillofac Surg* 1999;**57**:784–7.
19. Ohnuki T, Fukuda M, Nakata A, Nagai H, Takahashi T, Sasano T, Miyamoto Y. Evaluation of the position, mobility, and morphology of the disc by MRI before and after four different treatments for temporomandibular joint disorders. *Dentomaxillofac Radiol* 2006;**35**:103–9. http://dx.doi.org/10.1259/dmfr/25020275.
20. Sembronio S, Albiero AM, Toro C, Robiony M, Politi M. Is there a role for arthrocentesis in recapturing the displaced disc in patients with closed lock of the temporomandibular joint? *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;**105**:274–80. http://dx.doi.org/10.1016/j.tripleo.2007.07.003.
21. Muhtaroğullari M, Ertan AA, Demiralp B, Canay S. Correlation between clinical and magnetic resonance imaging findings in the treatment of anterior disc displacement. *Int J Prosthodont* 2013;**26**:138–42. http://dx.doi.org/10.11607/ijp.2692.
22. Liu MQ, Chen HM, Yap AU, Fu KY. Condylar remodeling accompanying splint therapy: a cone-beam computerized tomography study of patients with temporomandibular joint disk displacement. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2012;**114**:259–65. http://dx.doi.org/10.1016/j.oooo.2012.03.004.
23. Drace JE, Enzmann DR. Defining the normal temporomandibular joint: closed-, partially open-, and open-mouth MR imaging of asymptomatic subjects. *Radiology* 1990;**177**:67–71. http://dx.doi.org/10.1148/radiology.177.1.2399340.
24. Ahmad M, Hollender L, Anderson Q, Kartha K, Ohrbach RK, Truelove EL, John MT, Schiffman EL. Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD): development of image analysis criteria and examiner reliability for image analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009;**107**:844–60. http://dx.doi.org/10.1016/j.tripleo.2009.02.023.
25. Nitzan DW. Arthrocentesis—incentives for using this minimally invasive approach for temporomandibular disorders. *Oral Maxillofac Surg Clin North Am* 2006;**18**:311–28. http://dx.doi.org/10.1016/j.coms.2006.03.005.
26. Chen HM, Liu MQ, Yap AU, Fu KY. Physiological effects of anterior repositioning splint on temporomandibular joint disc displacement: a quantitative analysis. *J Oral Rehabil* 2017;**44**:664–72. http://dx.doi.org/10.1111/joor.12532.
27. Liu MQ, Lei J, Han JH, Au Yap, Fu KY. Metrical analysis of disc–condyle relation with different splint treatment positions in patients with TMJ disc displacement. *J Appl Oral Sci* 2017;**25**:483–9. http://dx.doi.org/10.1590/1678-7757-2016-0471.
28. Grossmann E, Poluha RL, Iwaki LCV, Santana RG, Iwaki Filho L. The use of arthrocentesis in patients with temporomandibular joint disc displacement without reduction. *PLoS One* 2019;**14**:e0212307. http://dx.doi.org/10.1371/journal.pone.0212307.
29. Zhang S, Liu X, Yang C, Cai X, Chen M, Haddad MS, Yun B, Chen Z. Intra-articular adhesions of the temporomandibular joint: relation between arthroscopic findings and clinical symptoms. *BMC Musculoskelet Disord* 2009;**10**:70. http://dx.doi.org/10.1186/1471-2474-10-70.
30. Okeson JP. *Management of temporomandibular disorders and occlusion*, 2–20. St. Louis: Elsevier Mosby; 2013. p. 317–61.

Address:
Kai-Yuan Fu
Centre for TMD and Orofacial Pain and Department of Oral and Maxillofacial Radiology
Peking University School and Hospital of Stomatology
No. 22 Zhong Guan Cun South Ave
Beijing 100081
China
Tel.: +86 10 82195342;
Fax: +86 10 62173402
E-mail: kqkyfu@bjmu.edu.cn