

Systematic Review Trauma

Articular soft tissue injuries associated with mandibular condyle fractures and the effects on oral function

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Abstract. The majority of studies debating the optimization of treatment for condylar mandibular fractures focus on the bony aspect first. However, fractures of the mandibular condyle may go together with soft tissue injury of the temporomandibular joint. An electronic literature search for this topic was undertaken. Assessment of quality was carried out using the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. Sixteen articles were included in this review. The reviewed literature showed that intracapsular fractures and dislocated condylar fractures result in more severe injuries. Serious injury to the disc and capsule of the temporomandibular joint is a contributing factor towards development of complications after closed treatment. The results of this review give an overview of the published studies focusing on articular soft tissue injuries caused by condylar mandibular fractures. Additionally, an overview of the magnetic resonance imaging (MRI) settings used to detect these injuries is provided. Until now, the relation between soft tissue injuries and type of condylar trauma and their influence on clinical outcome has been insufficiently investigated. Before considering reduction of soft tissues next to reduction of the fracture, more research is needed into the impact of soft tissue injuries on oral functioning, in which a uniform classification is used.

Key words: mandibular condyle; mandibular fracture; soft tissue injury; disc displacement; hemiarthrosis; disc perforation; disc tear; m. pterygoid lateralis injury; ligament injury.

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Treatment of condylar mandibular fractures remains a subject of discussion. In recent literature, to operate or not to operate is the ongoing question for debate¹. Although it is known that condylar frac-

tures result in trauma of the bony and articular soft tissue, the majority of studies in the literature focus on the bony aspect only, and the role of articular soft tissue injury is often overlooked^{1,2}. The struc-

tures of the temporomandibular joint (TMJ) are intimately related to the mandibular bone, both anatomically and physiologically^{3–5}. Alterations in the position, shape and form of the TMJ struc-

tures may interrupt the function of this integrated mechanism, apart from the bony injury. Because of this intimate relation, knowledge of the effect of condylar mandibular fractures on the structures of the TMJ could support treatment decision-making. The frequency and kind of TMJ injuries depend significantly on fracture localization, level of energy at the bone, and extrusion rate⁶. Most soft tissue injuries of the TMJ described in the literature are disc displacement, disc disruption, hemarthrosis and capsular injury⁷. Undiagnosed or untreated intra-articular trauma or condylar fractures may cause long-term complications such as chronic pain, a clicking joint, limitation of function, ankylosis and osteoarthritic changes because of contact between the residual condyle and the fossa^{2,7,8}.

In a trauma setting, computed tomography (CT) or conventional orthopantomogram (OPG) imaging remains the standard for radiologic evaluation of facial fractures. However, these examinations are optimal for viewing skeletal and dental tissues, whereas magnetic resonance imaging (MRI) is the standard for viewing soft tissues in medical fields⁹. MRI is nowadays considered a reliable diagnostic test for objective and noninvasive imaging of the TMJ and its injuries⁶. MRI can identify capsular injury, disc displacement, disc disruption and retrodiscal tissue injury⁶. However, the use of MRI for examination of the TMJ in an acute setting is discussed because of its cost, availability and insufficient direct contribution to initial treatment⁹.

For all that, when a better understanding of TMJ changes is achieved, a shift of opinion in the management of condylar injuries may be considered. Perhaps reduction of the bony fragments becomes only one aspect of the management of these injuries, and more attention will be given to soft tissue repair to achieve a better clinical outcome.

Therefore, this systematic review was conducted to provide an overview of the published studies focusing on articular soft tissue injuries as a result of mandibular condylar fractures and used MRI settings. The primary aim was to appoint what kind of soft tissue injuries appear after mandibular condylar fractures. The secondary aim was to look into the influence of soft tissue injuries on oral functioning in adults and if there is a relation between soft tissue injuries and oral functions. The third aim was to get insight into the used MRI settings to visualize the damaged tissues for future use in research and clinical use.

Methods

Protocol and registration

This systematic review was registered in the PROSPERO international prospective register of systematic reviews (registration number CRD42017068913) and was conducted in accordance with the Preferred Reporting Item for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Eligibility criteria

Studies focusing on soft tissue injuries, disc displacement, disc tear, disc perforation, hemarthrosis, lateral pterygoid muscle injury and retrodiscal injury after bilateral or unilateral condylar mandibular fractures in adults and detection of these soft tissue injuries by MRI before treatment were eligible for inclusion. Studies were excluded by the following criteria: (1) written in a language other than English, Dutch or German, (2) case reports, reviews, comments or abstracts, and (3) animal and/or cadaver studies.

Information sources

Literature searches to identify studies were performed in the electronic databases PubMed (1966–2018), Embase (1966–2018) and Cochrane (1898–2018). The electronic search was supplemented by snowballing of full articles retrieved. The search was conducted on 3 July 2018. Key words used in the search strategy were: “mandibular condyle”; “mandibular fracture”; “soft tissue injury”; “temporomandibular disc injury”; “disc displacement”; “disc tear”; “disc perforation”; “hemarthrosis”; “lateral pterygoid muscle injury”; “retrodiscal injury” and “magnetic resonance imaging”. In PubMed; a combination of MeSH terms and title/abstract searches was used. The search strategy for Embase and Cochrane required adaptation from the PubMed search strategy (see Appendix 1).

Study records

After removal of duplicates, all titles and abstracts were screened by two authors (F. M.W. and A.J.R.). Afterwards, full-text articles were obtained, and relevant articles were included. If the full text was not available online, the author was contacted. The reference list of these reports was manually searched for additional citations. In case of a conflict, a third author (C.M.S.) was consulted. Agreement was reached in all cases.

Study data

Two authors (F.M.W. and C.M.S.) extracted data on study design, study size, characteristics of study patients (age, sex, follow-up time), characteristics of the condylar trauma (affected side(s), classification), characteristics of the soft tissue injury (type of injury, extent of the injury, detection of the injury) and clinical outcome (see Table 1). Additionally, information about the technology and MRI setting used was collected only for those articles that reported these settings (see Table 2).

Quality assessment

Quality assessment of included studies was carried out by authors F.M.W. and C.M.S. using the National Institutes of Health Quality assessment tool for Observational Cohort and Cross-Sectional Studies¹⁰ (QAT-OCCSS; see also Table 3). QAT-OCCSS is a 14-item quality appraisal tool that classifies study quality on the basis of methodological and reporting parameters. These parameters include the clarity of the study’s research objectives, a participation rate of more than 50%, uniform inclusion and exclusion criteria, sample size justification, exposure of interest measured before outcome, sufficient time frame between exposure and outcome, examination of different levels of exposure in relation to outcome, defined and evenly applied exposure methods, exposure assessed more than once over time, defined and consistently applied outcome measure, blinding of assessors, loss of follow-up less than 20%, and key potential confounding variables measured and adjusted statistically for impact between exposure and outcome. Raters were instructed to indicate whether each of the quality indicators were present (i.e. “yes” or “no”) in the included study, with a greater number of yeses indicative of a higher-quality study.

Two authors (F.M.W. and C.M.S.) independently completed the appraisal tool for each study and classified study quality according to appraisal guidelines. Finally, the total score was calculated as the number of yeses over the number of questions that applied. A quality indicator did not take part in the quality score if it was “not applicable” (NA). As QAT-OCCSS does not have strict guidance for determining the overall quality rating of observational cohort and cross-sectional studies, the overall study quality was rated for each study as poor, fair or good. This was not only based on the overall (percentage)

Table 1. Characteristics of included studies considering study design, subjects, condylar fractures, soft tissue injuries and clinical outcome.

Study	Design	Number of patients (females)	Age in years (range)	Detection of soft tissue injuries related to condylar mandibular fracture	n: CF	Kind of fractures	Soft tissue injuries	Time of detection of soft tissue injury by MRI	Treatment of the condylar fracture	Post-treatment MRI findings of soft tissue	Clinical outcomes
Cai et al. (2018) ²³	Retrospective cohort study	34 (13)	35 (16–76)	48 Surgical 48 MRI	48	Neffs classification of ICF's 7 type A 35 type B 6 type M	<i>Surgical (48):</i> 48 DDISP <i>MRI (48):</i> 48 DDISP/ CAPT/RDTT/ JE	Pre- and post-treatment	ORIF + disc reduction	40 normal disc position 4 anterior DDISP 3 condylar morphologic abnormalities	2 malocclusion 3 facial nerve injury 7 MO limitation (<2.6 cm) 5 MO deviation 4 TMJ discomfort 5 joint noise
Chen et al. (2010) ²⁰	Retrospective cohort study	129 (39)	32 (4–80)	164 Surgical 42 MRI	164	He & Yang's classification of ICF's: 88 type A 45 type B 9 type C 22 type M	<i>Surgical (164):</i> 4 DDISR 160 DDISP 119 RDTT 87 CAPT <i>MRI (42):</i> 0 DDISR 41 DDISP 29 RDTT 22 CAPT	<i>Surgical:</i> pre-treatment <i>MRI:</i> pre- and post-treatment	ORIF + open functional treatment	40 normal disc position 1 anterior DDISP 1 posterior DDISP	1 week follow-up (129 patients): 15 malocclusion 43 facial nerve injury 1–5 y follow-up (45 patients): 1 fibrous ankylosis 5 MO limitation (<2.5 cm) 3 condyle resorption 3 facial nerve injury 2 TMJ click 7 MO deviation 1 malocclusion mean MO pretreatment: 1.6 cm (0.1–3.5 cm) mean MO post-treatment: 3.3 cm (1.5–5.3 cm) NM
Dwivedi et al. (2012) ¹¹	Prospective cohort study	15 (3)	22 (5–45)	MRI	17	Spiessl & Schroll's classification: 0 grade I (no CF) 12 grade II (type I, II, III) 5 grade III (type IV, V, VI) (2 High CF 15 Low CF)	8 HEM 8 DDISP 2 CAPT	Pretreatment	IMF (CT)	NA	NM
Emshoff et al. (2007) ¹²	Cross-sectional study	11 (6)	46 ± 21 (11–75)	MRI	17	Spiessl & Schroll's classification: 6 type V 11 type VI	17 HEM 1 DDISR 13 CAPT 12 RDTT 0 DAV	Pretreatment	NM	NA	NM
Gerhard et al. (2007) ¹³	Cross-sectional study	19 (9)	42 (11–75)	MRI	27	Spiessl & Schroll's classification: 11 grade I (no CF) 13 grade III (type I, II, III) 14 grade III (type IV, V, VI) (7 Unilateral CF 10 Bilateral CF 2 No fracture)	22 HEM 7 DDISP 17 CAPT	Pretreatment	NM	NA	NM
He et al. (2010) ⁵	Retrospective cohort study	151 (42)	31	61 MRI	204	He & Yang's classification of ICF's: 110 type A 60 type B 9 type C 25 type M, 4 No displacement	58 DDISP (of 61 TMJs)	MRI pretreatment, (n = 43 patients, n = 61 ICFs)	ORIF + disc reduction	NA	2 months–5 y follow-up (35 patients): 0 malocclusion 3 facial nerve injury 1 TMJ clicking 4 condyle resorption MMO: 35.89 mm NM
Kim et al. (2016) ¹⁴	Cross-sectional study	34 (NM)	29	MRI	47	Lindahl's classification: 18 Dislocation 10 Displacement 15 No displacement 2 Lat. displacement 2 Chip fracture 21 Contralat. TMJs	→18 DDISL → 8 DDISL → 7 DDISL → 2 DDISL → 1 DDISL →10 DDISL	Pretreatment	NM	NA	NM

Nabil (2016) ¹⁶	Prospective cohort study	100 (0)	(17–35)	MRI	100	Grouped: 20 group 1: UCF 20 group 2: UCF + MF ipsi. 20 group 3: UCF + MF contra 20 group 4: MF without CF 20 group 5: BCF	Group 1: 12 DDISP, 10 JE Group 2: 5 DDISP Group 3: 16 DDISP, 4 JE, 5 DDISP on other TMJ Group 4: 3 DDISP, 2 JE on other TMJ Group 5: 20 DDISP, 15 JE and 20 DDISP and 15 JE on other TMJ	Pretreatment, post-treatment and +5 y	IMF (CT)	Group 1: 14 DDISP Group 2: 2 DDISP Group 3: 10 DDISP, 7 DDISP other TMJ Group 4: 2 DDISP, 2 DDISP other TMJ Group 5: 20 DDISP, 20 DDISP other TMJ	Tenderness (<i>n</i>): post-treatment – 5 y follow-up 10 FS, NFS NM – 8 FS, 4 NFS (group 1) 9 FS, 5 NFS – 10 FS, 6 NFS (group 2) 6 FS, 4 NFS – 9 FS, 6 NFS (group 3) 3 FS, 2 NFS – 6 FS, 4 NFS (group 4) 20 FS, NFS NM – 8 FS, NFS NM (group 5) MO deviation (<i>n</i>): post-treatment – 5 y follow-up 4–6 (group 1) 3–4 (group 2) 2–3 (group 3) 0–1 (group 4) NM – NM (group 5) TMJ clicking (<i>n</i>): post-treatment – 5 y follow-up 2 – 2 FS, 5 NFS (group 1) NM – 4 FS, 7 NFS (group 2) NM – 3 FS, 5 NFS, 2 bilateral (group 3) NM – 2 FS, 5 NFS, 1 bilateral (group 4) NM – 5 FS, 7 bilateral (group 5) 2 limited MO (group 2) 3 anterior open bite (group 5) 4 limited jaw ROM (group 5) NM
Pohranychna et al. (2017) ⁸	Retrospective cohort study	22 (0)	(18–25)	MRI	22	CF, not specified	20 HEM 15 DDISL 12 DDEF 8 adhesion 3 DPERF 15 tension of ligaments 6 breaking of ligaments 5 damage joint surface	Pretreatment	NM	NA	
Takahashi et al. (2004) ²¹	Cross-sectional study	15 (4)	36 (17–71)	MRI	18	MacLennan's classification with modifications: 6 type I 0 type II 5 type III 2 type IV 5 type V Grouped by location: 5 CHF 6 upper CNF 2 lower CNF 5 SCF	7 DDISL 11 JE	Pretreatment	IMF (CT) or ORIF	NA	NM
Takaku et al. (1996) ⁴	Cross-sectional study	10 (3)	30 (7–45)	MRI	12	CF + SCF	12 DDISP 11 CAPT 0 DDISR 0 Disc Tear 8 RDIT 8 JE 12 Swelling	Pre- and post-treatment	ORIF	NM	NM
Tripathi et al. (2015) ¹⁷	Prospective cohort study	54 (13)	30 (17–45)	MRI	54	14 High CF 40 Low CF	42 HEM 37 DDISP 12 CAPT 5 DPERF	Pretreatment	IMF (CT)	NA	5 grade I (HEM): normal ROM + MO, 0 joint noise + pain 20 grade II (HEM + DDISP): 10 ↓ROM, 10 ↓MO, 7 joint noise + pain 12 grade III (HEM + DDISP + CAPT): 8 ↓ROM, 8 ↓MO 5 grade IV (DPERF + grade I/II/III): 5 ↓ROM, 5 joint noise

Table 1 (Continued)

Study	Design	Number of patients (females)	Age in years (range)	Detection of soft tissue injuries related to condylar mandibular fracture	n: CF	Kind of fractures	Soft tissue injuries	Time of detection of soft tissue injury by MRI	Treatment of the condylar fracture	Post-treatment MRI findings of soft tissue	Clinical outcomes
Wang et al. (2009) ¹⁸	Cross-sectional study	80 (30)	31 (5–69)	MRI	118	108 CFs with dislocation 10 CFs without dislocation	108 DDISP 11 DDEF 10 DPERF/DAV 103 Abnormal signal intensities of retrodiscal tissue 101 JE 103 Abnormal inferoposterior attachments of discs 45 Abnormal superoposterior attachments of discs 101 Abnormal joint capsules	Pretreatment	NM	NA	NM
Ying et al. (2018) ²⁴	Prospective cohort study	55 (19)	37 (18–55)	MRI	55	Ying's new classification for ICF's 7 A (no loss of height, no DDISP) 17 B (DDISP without loss of height) 31C (loss of height +/- DDISP)	DDISP: 0 type A 17 type B 31 type C	55 Pre- and 48 post-treatment	IMF (CT in A) ORIF (in B + C)	48 normal disc position	0 malocclusion 1 pain 9 facial nerve injury
Yu et al. (2013) ¹⁹	Cross-sectional study	18 (7)	30 (17–66)	MRI	19	ICF classification: 4 type A 14 type B 0 type C 1 type M	16 DDISP 9 CAPT 16 RDTT 19 JE 16 HEM	Pretreatment	NM	NA	NM
Zheng et al. (2016) ²²	Cross-sectional study	160 (48)	34 (8–52)	MRI	222	He & Yang's classification of ICFs: 75 type A 49 type B 11 type C 25 type M 40 CNF 22 SCF	178 DDISP	222 pre- and 32 post-treatment	ICF: ORIF + disc reduction CNF: ORIF or ORIF + disc reduction SCF: ORIF or ORIF + disc reduction	26 excellent disc position 2 good disc position 4 poor disc position	NM

BCF, bilateral condylar fracture; CAPT, capsular tear; CF, condylar mandibular fracture; CHF, condylar head fracture; CNF, condylar neck fracture; CT, closed treatment; DAV, disc avulsion; DDEF, disc deformation; DDISL, disc dislocation; DDISP, disc displacement; DDISR, disc disruption; DPERF, disc perforation; ECF, extracapsular condylar fracture; F, female; FS, fractured site; HEM, hemarthrosis; ICF, intracapsular condylar fracture; IMF, intermaxillary fixation; JE, joint effusion; Lat., lateral; MF, mandibular fracture; MMO, maximal mouth opening; MO, mouth opening; MRI, magnetic resonance imaging; NA, not applicable; NFS, non-fractured site; NM, not mentioned; ORIF, open reduction and internal fixation; RDTT, retrodiscal tissue tear; ROM, range of motion; SCF, subcondylar fracture; TMJ, temporomandibular joint; UCF, unilateral condylar fracture; y, years.

Grade I = HEM, Grade II = HEM + DDISP, Grade III = HEM + DDISP + CAPT, Grade IV = DPERF + (HEM +/- DDISP +/- CAPT).

Table 2. Magnetic resonance imaging settings.

MRI-setting	Vendor	Field strength	TMJ coil used?	Mouth positions	Planes	Matrix	Field of view	Repetition time	Echo time	Slice thickness	3D	Other settings
Dwivedi et al. (2012) ¹¹	NM	NM	Y	Open and closed	S, C	256 × 256	15 × 15 cm	800 ms	28 ms	5 mm	Y	Imaging time: 6.8 min
Emshoff et al. (2007) ¹²	Siemens	1.5 T	Y	Closed	PC, PS	252 × 256	14.5 cm	TSE-PD seq: 2800 ms	15 ms	3 mm	Y	Flip Angle in DESS-3D seq: 25° Inversion time in TIRM seq: 150 ms
Gerhard et al. (2007) ¹³	Siemens	1.5 T	Y	Closed	PC, PS	252 × 256	14.5 cm	TIRM seq: 4000 ms DESS-3D seq: 22 ms TSE-PD seq: 2800 ms	30 ms 7 ms 15 ms	3 mm NM 3 mm	Y	Flip Angle in DESS-3D seq: 25° Inversion time in TIRM seq: 150 ms
Kim et al. (2016) ¹	Siemens	1.5 T	Y	NM	A, S, C	224 × 256 240 × 256	150 cm	TIRM seq: 4000 ms DESS-3D seq: 22 ms PWI: 2000 ms	30 ms 7 ms 15 ms	3 mm NM 3 mm	NM	NM
Nabil (2016) ¹⁶	Siemens	1.5 T	Y	Open and closed	S	NM	20 cm	T2WI: 4000 ms 660	90 ms 15 ms	3 mm 2 mm	NM	NM
Pohranychna et al. (2017) ⁸	NM	NM	Y	NM	A, C, OC, S	NM	NM	NM	NM	1.5–2.5 mm	NM	NM
Takahashi et al. (2004) ²¹	General Electric	1.5 T	Y	Open and closed	S, C	256 × 256	12 cm	T1WI: 500 ms	17 ms	3 mm	NM	NM
Takaku et al. (1996) ⁴	Siemens	1.5 T	Y	Closed	S, C	256 × 256	NM	T2WI: 3000 ms PWI: 2000 ms FISP-3D: 30 ms	92 ms 23 ms 12 ms	2 mm	Y	Acquisition: 5 times Imaging time: 10 min Flip Angle in FISP-3D seq: 40° Imaging time: 6.8 min
Tripathi et al. (2015) ¹⁷	NM	NM	Y	NM	S	256 × 256	15 × 15 cm	800 ms	28 ms	5 mm	NM	
Wang et al. (2009) ¹⁸	General Electric	1.5 T	Y	NM	OS, OC	320 × 192	10 × 10 cm	PAW-FSE: 1360–2000 ms T2WI (FSE): 3760–4300 ms	20–26 ms 82–90 ms	1.5 mm 2 mm	NM	
Yu et al. (2013) ¹⁹	General Electric	1.5 T	Y	Open and closed	OS, OC	256 × 160	14 × 14 cm	T1WI (FSE): 440 ms PDWI (FSE): 2700 ms T2WI (GRE): 340 ms	13.4 ms 13.4 ms 15 ms	2 mm 2 mm 2 mm	NM	Flip angle in GRE seq: 20°

A, axial; C, coronal; DESS-3D, double echo in steady state – 3 dimensional; FISP-3D, fast imaging with a steady procession sequence – 3 dimensional; FSE, fast spin echo; GRE, gradient echo; MRI, magnetic resonance imaging; NM, not mentioned; OC, oblique coronal; OS, oblique sagittal; PAW, proton attenuation weighted; PC, paracoronal; PDWI, diffusion weighted images; PS, parasagittal; PWI, proton weighted images; S, sagittal; seq, sequence; T, Tesla; T1WI, T1 weighted images; T2WI, T2 weighted images; TIRM, turbo inversion recovery magnitude; TSE-PD, turbo spin echo-proton density; Y, yes.

Table 3. National Institutes of Health Quality assessment tool for Observational Cohort and Cross-Sectional Studies.

Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Quality score	Quality (in%)	Overall study quality
Cai et al. (2018) ²³	Y	Y	CD	Y	N	Y	Y	Y	Y	NA	Y	NA	Y	N	9/12	75	F
Chen et al. (2010) ²⁰	Y	Y	N	NM	N	N	N	Y	Y	NA	Y	N	N	N	5/13	38	P
Dwivedi et al. (2012) ¹¹	Y	Y	CD	Y	N	N	N	Y	Y	NA	Y	NA	NA	N	6/11	55	F
Emshoff et al. (2007) ¹²	Y	Y	CD	Y	N	N	N	Y	Y	NA	Y	NA	NA	N	6/11	55	F
Gerhard et al. (2007) ¹³	Y	Y	CD	Y	N	N	N	Y	Y	NA	Y	NA	NA	N	6/11	55	F
He et al. (2010) ¹⁵	N	Y	Y	NM	N	N	N	Y	Y	NA	Y	N	N	N	5/13	38	P
Kim et al. (2016) ¹⁴	Y	Y	CD	Y	N	N	N	Y	Y	NA	Y	NA	NA	N	6/11	55	F
Nabil (2016) ¹⁶	Y	Y	CD	Y	N	Y	Y	Y	N	NA	N	NA	Y	N	7/12	58	F
Pohranyychna et al. (2017) ⁸	Y	Y	CD	NM	N	Y	Y	N	N	NA	Y	NA	N	N	5/12	42	F
Takahashi et al. (2004) ²¹	Y	Y	CD	NM	N	N	N	Y	Y	NA	Y	NA	NA	N	5/11	45	F
Takaku et al. (1996) ⁴	N	Y	CD	NM	N	N	N	N	N	NA	Y	NA	NA	N	2/11	18	P
Tripathi et al. (2015) ¹⁷	Y	Y	CD	Y	N	Y	Y	Y	Y	NA	Y	N	N	N	8/13	62	F
Wang et al. (2009) ¹⁸	Y	Y	Y	Y	N	N	N	NA	N	NA	Y	NA	NA	N	5/10	50	F
Ying et al. (2018) ²⁴	N	Y	CD	Y	N	Y	Y	Y	Y	NA	Y	Y	N	N	8/13	62	F
Yu et al. (2013) ¹⁹	N	Y	Y	Y	N	N	N	Y	Y	NA	Y	NA	NA	N	6/11	55	F
Zheng et al. (2016) ²²	Y	Y	Y	Y	N	Y	Y	Y	Y	NA	Y	NA	NA	N	9/11	82	G

Was the research question or objective in this paper clearly stated? **2.** Was the study population clearly specified and defined? **3.** Was the participation rate of eligible persons at least 50%? **4.** Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants? **5.** Was a sample size justification, power description, or variance and effect estimates provided? **6.** For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured? **7.** Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed? **8.** For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)? **9.** Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants? **10.** Was the exposure(s) assessed more than once over time? **11.** Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants? **12.** Were the outcome assessors blinded to the exposure status of participants? **13.** Was loss to follow-up after baseline 20% or less? **14.** Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?

N = no; Y = yes; CD = cannot determine; NA = not applicable; NM = not mentioned P = poor quality (<40%); F = fair quality (40-80%); G = good quality (>80%).

score, but also on the risk of bias for each question which was answered with ‘no’. This ultimately meant that a study was rated ‘poor’ when the overall score was 40% or lower, ‘fair’ when between 40% and 80%, and ‘good’ when 80% or higher.

Results

Literature search

The selection process for the included studies is summarized in Fig. 1. The search and selection process was displayed according to the PRISMA 2009 flow Diagram²⁸. The search strategy resulted in 560 unique publications with one additional article retrieved from reference tracking. Unfortunately, none of the authors contacted responded to our request for full text. In total, 44 articles were selected based on title and abstract for full-text screening. Based on the full text of these articles, 28 articles were excluded, mainly because they were not about imaging of soft tissue injuries right after trauma. Finally, 16 studies were included for this review^{4,8,11-24}. This total included two articles focusing on soft tissue reduction during open treatment^{20,23}, two articles focusing on internal fixation for intracapsular condyle fracture^{15,24}, one article on outcome of functional management related to soft tissue injury¹⁷, and the other 11 articles focusing on imaging of soft tissue injuries after condylar fracture^{4,8,11-14,16,18,19,21,22}. All studies included were in English. Eight studies were cross-sectional^{4,12-14,18,19,21,22}, four were prospective cohort studies^{11,16,17,24}, and four were retrospective cohort studies^{8,15,20,23}.

General study characteristics

The general characteristics of the 16 included studies are listed in Table 1. The selected studies were conducted in seven different countries (China = 7^{5,18-20,22-24}, India = 2^{11,17}, Austria = 2^{12,13}, Japan = 2^{4,21}, South Korea = 1¹⁴, Egypt = 1¹⁶, Ukraine = 1⁸). The publication dates of the included studies spanned two decades, with the earliest published in 1996⁴ and the most recent published in 2018²⁴. Approximately 94% (n = 15) of the included articles were published since 2004^{8,11-24}, with eight (50%) published within the last 5 years^{8,14,16,17,19,22-24}.

The total number of patients included in all studies was 907. The number included varied from 10⁴ to 160 patients²², with a mean of 57 patients per study.

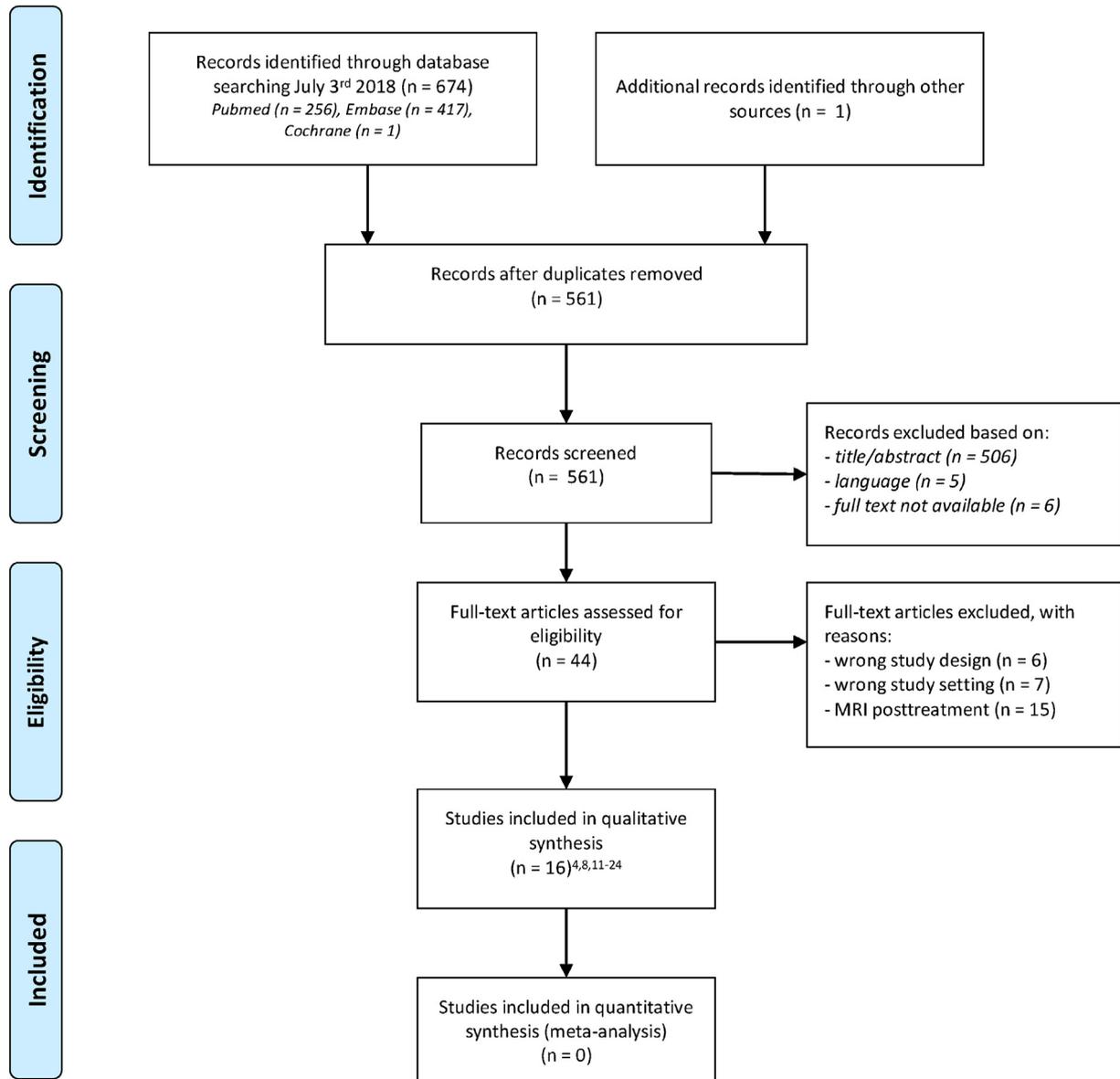


Fig. 1. Flowchart of search and selection according to PRISMA 2009 flow diagram.

Most studies did not mention or did not have a follow-up visit^{4,11–14,18,19,21,22}, while two studies had a 5-year follow-up visit with imaging of the soft tissue by MRI^{16,20}.

Condylar fractures

The number of condylar fractures included in each study varied from 12⁴ to 222²² with a mean of 72 fractures per study, and a total sum of 1144 condylar fractures. A wide variety of classification systems was used (see also Table 1). Four studies used the ABCM-classification of intracapsular condylar fractures (ICFs) described by He and Yang^{15,19,20,22}. One used the classification of Neff²³. Three studies used clas-

sification according to Spiessl and Schroll^{11–13}, and two of them further classified depending on the severity of injury as grade I, II or III^{11,13}. Lindahl's classification was used in one study¹⁴. One study used MacLennan's classification²¹. One study did not specify the type of condylar fracture; however, groups of condylar fracture with or without other mandibular fractures were made¹⁶. In two studies, no further specification of the condylar fracture was made^{4,8}, and in one study a distinction was made between high and low condylar fractures¹⁷. One study divided the condylar fractures into two groups: fractures with dislocation and fractures without dislocation¹⁸. One study proposed its own classification for ICFs²⁴.

Three studies reported unilateral condylar fractures only^{8,17,24}, while the rest had a mixed patient group with both unilateral and bilateral condylar fractures. Treatment of the condylar fracture was mentioned in 10 studies^{4,11,15–17,20–24}. Overall three different treatment modalities were mentioned; open reduction and internal fixation (ORIF) of the fracture, ORIF combined with reduction of one or more articular soft tissues and closed treatment with intermaxillary fixation.

Soft tissue injury

Soft tissue injuries were diagnosed in all studies by MRI. Two studies also reported soft tissue injuries identified during surgi-

cal reduction^{20,23}. All studies had pretreatment MRI, since this was an inclusion criterion for this review. In six studies, additional post-treatment MRI was performed^{4,16,17,22–24}.

Not all studies focused on the same types of soft tissue injuries. One study mentioned that all ICF sides had soft tissue changes such as disc displacement, capsular tears, retrodiscal tissue tears and joint effusion, but did not mention specific numbers²³.

Disc displacement and dislocation

Eleven studies with a total of 727 fractured condyles reported disc displacement^{4,11,13,15–20,22,24}. This disc displacement was detected with MRI in 591 TMJs (81%). Two studies reported the surgical detection of disc displacement^{20,23}. In addition, one study reported eight cases of disc displacement in non-fractured TMJ sides¹⁶. Three studies mentioned disc dislocation measured by MRI^{8,14,21}.

Injury to the disc

A wide variety of definitions for injury to the disc was used: disc perforation, disc avulsion^{8,17,18}, disc deformation⁸, disc disruption and disc tear^{4,12,20}. Three studies with a total of 71 fractured condyles reported one case of disc disruption detected with MRI^{4,12,20}. One study reported the surgical detection of disc disruption in four of the 164 fractured condyles²⁰. Disc tear was discussed in one article, and was not detected in 12 joints⁴. The absence of disc avulsion was mentioned in one study¹². Disc avulsion or disc perforation was mentioned in one study and was detected in 10 of the 108 fractured sites¹⁸. Disc perforation was mentioned in 14%⁸ and in 9%¹⁷ of cases.

Capsular injury

Capsular tear was reported in seven studies, with a total of 86 capsular tears detected by MRI in 188 fractures sites (46%)^{4,11–13,17,19,20}.

Retrodiscal tissue tear was diagnosed by MRI in four studies^{4,12,19,20}. In one study, it was surgically detected in 119 of the 164 fractured sites (73%) and detected by MRI in 29 of the 42 sites (69%)²⁰. In the other studies, it was detected in 67%⁴, 71%¹² and 84%¹⁹ of the fractured sites.

Disc deformity (9%), abnormal signal intensities of retrodiscal tissue (87%), abnormal inferoposterior (87%) or superoposterior (38%) attachments of discs, and

abnormal joint capsules (86%) were discussed in one study with 118 condylar fractures¹⁸.

Hemarthrosis and joint effusion

Five studies discussed hemarthrosis^{11–13,17,19} and five joint effusion^{4,16,18,19,21}. The presence of hemarthrosis in total was 78%, with variation from 47%¹¹ to 100%¹². The presence of joint effusion in total was 59%, with variation from 24%¹⁶ to 100%¹⁹. One study reported both hemarthrosis and joint effusion¹⁹. In this study, joint effusion was detected in all fractured sites, and hemarthrosis was detected in 16 of the 19 fractured sites.

Classification of soft tissue injuries

One study further classified articular soft tissue injuries from grade I to IV¹⁷: grade I, hemarthrosis only (five of 54 patients); grade II, hemarthrosis and disc displacement (20 patients); grade III, hemarthrosis, disc displacement and capsular tear (12 patients); and grade IV, disc perforation in association with grade I, II or III (five patients). Another study proposed a classification based on both bony and soft tissue injury, with type A: no loss of mandibular height or disc displacement, type B: no loss of mandibular height with disc displacement, and type C: reduction of mandibular height with or without disc displacement²⁴.

Post-treatment MRI findings of soft tissue

In Table 1 MRI findings of the six studies that performed a post-treatment MRI are listed. In one study, however, these findings were not mentioned⁴. Four of the remaining five studies performed ORIF with or without reduction of the disc^{20,22–24}. In the majority of these, the discs were seen in normal position. One study used closed treatment with intermaxillary fixation (IMF) only¹⁶. In this study the position of most discs remained displaced after treatment.

Link between condylar fracture and soft tissue injury

A link between the severity of condylar injury and damage to the soft tissue was found in seven studies^{4,11–13,18,21,22}. In one study, significant differences were found in the number of displaced discs between ICFs on the one hand and those of the condylar neck and subcondylar region on the other ($p < 0.001$)²². One study reported a significant relation between

the degree of condylar injury and the MRI finding of hemarthrosis, but there was no significant correlation with capsular tear detected by MRI¹¹. Another study reported good diagnostic agreement between the degree of condylar injury and the MRI findings of capsular tear and hemarthrosis; however, no significant relationship was found for disc displacement detected by MRI¹³. In one study, hemarthrosis was found in all condylar fractures classified as type V and VI according to Spiessl and Schroll¹². In another study, the relation between the position of the condylar fracture and MRI findings of joint effusion was statistically significant²¹. A further study mentioned 97.2% disc displacement in the group of condylar fractures with dislocation compared to 30% disc displacement in the group of condylar fractures without dislocation ($p < 0.01$)¹⁸. In this study, abnormal retrodiscal tissue was significantly more present in the group of condylar fractures with dislocation compared to the group of condylar fractures without dislocation. One study mentioned 100% disc displacement when the fractured condylar process was dislocated⁴.

Clinical outcomes

Six studies discussed the clinical outcome^{15–17,20,23,24}. One study reported tenderness over the TMJ, deviation of the mandible and clicking over the TMJ in the follow-up period of 5 years¹⁶.

Five studies reported functional outcome by maximal mouth opening (mean range of 3.32–4.2 cm)^{15,17,20,23,24}. Three of these studies also reported joint noise, range of movement and mouth opening, and pain during movement^{17,23,24}. The other two studies also discussed post-treatment complications in the long-term follow-up period: fibrous ankyloses (0.8%²⁰), mouth-opening limitation/restricted movement (3.9%²⁰), condylar resorption that required plate removal (2.3%²⁰–11.4%¹⁵), facial nerve injury (2.3%²⁰–8.6%¹⁵), TMJ clicking (1.6%²⁰–2.9%¹⁵), mouth opening with deviation (5.4%²⁰), mouth opening with deviation due to discontinued growth of the condyle after fixation (36.8%), and malocclusion (0%¹⁵–0.8%²⁰) were reported.

A link between the grade of soft tissue injury and clinical outcome was found in only one study¹⁷. This study reported restricted movement and joint noise in 100% of patients with a grade IV soft tissue injury, in 75% of patients with a grade III injury, in 50% of patients with a grade II injury, and no complications after

14 days in patients with a grade I injury. All these patients were treated with inter-maxillary fixation. There was no statistical analysis done in this study.

MRI settings

In two studies, MRI planes alone are mentioned^{8,22}. Specific MRI settings were described in 10 studies^{4,11-14,16-19,21}. These settings are presented in Table 2. In eight studies, a 1.5-Tesla MRI-scan was used^{4,12-14,16,18,19,21}; in two studies, this was not discussed^{11,17}. In all 10 studies, a coil was placed over the TMJ. All 10 studies mentioned which planes and which sequences were obtained.

Quality assessment

The methodological quality of all studies was assessed, and is presented in Table 3. Overall, the methodological quality was fair. The reviewers came to an agreement on all quality assessments. Total quality scores ranged from 18%⁴ to 82%²², with an average quality rating of 52.8%. Three studies were of poor quality^{4,15,20}, one of good quality²² and 11 of fair quality. With respect to specific QAT-OCCSS items, 12 studies had clearly articulated a research question or objective (criterion 1)^{8,11-14,16-18,20-23}, all of the studies clearly specified their study population (criterion 2)^{4,8,11-24} and 69% of the included studies adequately described their sample inclusion and exclusion criteria (criterion 4)^{11-14,16-19,22-24}. A participation rate could not be determined for 69% of the included studies (criterion 3)^{4,8,11-14,16,17,21,23,24}, and one study reported a participation rate of less than 50%²⁰. None of the included studies provided justification for their sample size, nor a power analysis (criterion 5). In only six studies was the exposure variable of interest measured prior to the soft tissue injury (criterion 6)^{8,16,17,22-24}. For cross-sectional studies, this is not possible according to the manual of the QAT-OCCSS.

In six studies there was a sufficient timeframe (criterion 7)^{8,16,17,22-24}. Thirteen studies reported different levels of exposure as related to the outcome (criterion 8) of which in 12 studies the exposure measures were clearly defined, valid, reliable, and implemented consistently across all study participants (criterion 9)^{11-15,17,19-24}. Because diagnosis of the condylar fracture was done logically only once, the indicator “was the exposure(s) assessed more than once over time?” was not applicable for all (criterion 10). In 15 studies the outcome measures were clearly

defined, valid, reliable, and implemented consistently across all study participants (criterion 11)^{4,8,11-15,17-24}. In only one study were the outcome assessors blinded to the exposure status of participants (criterion 24). Two studies reported a clear loss to follow-up after baseline of 20% or less (criterion 13)^{16,23}. In none of the studies were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s) (criterion 14).

Discussion

Fractures of the mandibular condyle often go together with soft tissue injury of the TMJ. When a better understanding of these changes of the soft tissues in the TMJ is achieved, a shift of opinion in the management of condylar fractures may be considered. An overview of the published studies focusing on soft tissue injuries as a result of mandibular condylar fractures and their influence on oral functioning in adults is given in this review. Also, an overview is provided of the detection of soft tissue injuries.

Soft tissue injuries as a result of mandibular condylar fractures

In the studies included in this review, many different types of soft tissue injury were discussed. An effect of condylar fractures on the adjacent soft tissue was found in this review, with evidence ranging widely from one poor-quality study (18%)⁴ and eight fair-quality studies (42–62%, $n = 8$)^{4,8,11-13,18,21-24} to one study of good quality (82%)²².

Intracapsular fractures are more likely to cause disc displacement than subcondylar or condylar neck fractures^{22,24}. Additionally, it is true that if the condylar fracture is dislocated, disc displacement is more often expected¹⁸. Besides mentioning this injury to the disc, no specific relation was reported between the type of fracture and the disc injury. Dislocated condylar fractures are more likely to result in more severe injuries of retrodiscal tissues than non-dislocated fractures¹⁸. Diagnostic agreement between capsular tear and both dislocated condylar fractures and dislocated condylar head fractures is of fair reliability¹³. Thereby, joint effusion is more likely to be present in head and upper neck fractures and condylar fractures with dislocation²¹. Hemarthrosis is more likely to be present in grade III condylar injury (i.e. condylar head and high and low condylar fractures with dislocation)^{11,13}.

A limitation is that, as there is logically no imaging done before trauma, we cannot be sure if a pathological finding is new or pre-existing. In one study the authors clarified how they differentiate acute traumatic disc displacement from chronic pre-existing disc displacement¹¹. They examined the disc morphology and ancillary changes in the TMJ as over time a displaced disc is deformed to a biconvex or rounded disc.

Influence of soft tissue injuries on oral functioning

An effect of soft tissue injuries due to condylar trauma on oral functioning was found in only one study included in this review¹⁷. The authors could relate clinical outcome directly to the degree of soft tissue injury. This study was of fair quality (62%) and no statistical analysis (and thus a significant correlation) substantiated this relation¹⁷. It suggests that serious injury to the disc and capsule of the TMJ is a major contributing factor towards the development of complications after closed treatment of condylar fractures, such as decreased mouth opening, restricted range of movement, joint noise and pain. The authors concluded that hemarthrosis alone plays a small role in the development of postoperative complications as long as early mobilization of the joint is instituted. More severe soft tissue injury affects condylar translation and rotation due to greater shrinkage of the capsule. Unfortunately, in this study, no connection was made between the degree of soft tissue injury and classification of condylar fracture; therefore, no direct link could be made between the degree of condylar trauma and the clinical outcome.

A limitation is that no uniform classification was used when reporting condylar fractures, which makes it difficult to compare these studies with each other. Moreover, some studies did not use any classification system, thus it remains unclear what kind of condylar fracture was studied or whether the claimed classification was used wrongly. Only one study used a classification for the grade of soft tissue injury¹⁷.

Although we can conclude that hemarthrosis and disc displacement are most commonly present in condylar fractures, unfortunately not all studies reported them^{12,14,15,20,22}. In the majority of studies, the definition of the type of soft tissue injury and how its diagnosis was made on MRI was not further specified.

The information on oral functioning is reported very heterogeneously. To get in-

sight into oral functioning, valid and reliable measurements of both objective measurements (e.g., maximum mouth opening, chewing ability) and patient reported outcomes should be used, however, none of the included studies reported systematically such outcomes. None of the studies mentioned a relation between subjective outcomes and soft tissue injury. This hampers the conclusion regarding what subjective consequences could be expected after condylar trauma with soft tissue damage. Furthermore, the clinical long-term follow-up on oral functioning was insufficient, only three studies reported a 5-year follow-up in only a small part of the initial population^{15,16,20}. In the current studies it remains unclear whether these objective outcomes are related to bone or articular soft tissue damage as these three studies all treated the fractures in a different way. None of the studies used control groups and it was impossible to compare these studies with each other.

MRI

MRI is effective in demonstrating TMJ soft tissue changes. However, the differences in MRI findings might be related to the diagnostic criteria references for soft tissue injuries on MRI. This could explain the differences in surgical findings of soft tissue injury. For fractures where the condyle is intact, it is acceptable to access the position of the disc based on the condyle, whereas it is harder when the condyle is displaced²². If the MRI planes cannot show the disc and stump simultaneously, retrodiscal tissue tear and lateral capsular tear will not be diagnosed and will be missed²⁰. The differences in MRI findings may also be related to the different MRI settings that are used as seen in the overview, depicted in Table 2. Though it is accepted that for different vendors different naming in settings is used, we still see a variety of used settings, planes and positions. It would be preferable if research specific to these settings could clarify the best settings.

Several studies used MRI to investigate soft tissue injury in condylar trauma patients^{4,16,20,22}. Still, most of these studies investigated this injury after treatment of the fracture. Therefore, one cannot determine whether the MRI findings are due to trauma or to treatment of the condylar fracture. One author reported that the post-treatment MRI scans showed a better anatomical reduction of the TMJ after surgical therapy compared to conservatively treated patients. Although their study population was small, the functional

recovery seems not to be dependent on complete anatomical restoration of the TMJ structures as can be achieved by functional open treatment³. Another study reported that open reduction of condylar fractures does not always lead to recapturing of the disc, seen on post-treatment MRI. They suggest that the disc has to be inspected during surgery. Simultaneous discal repositioning should be considered once the displaced disc is detected²⁵.

TMJ effusion on MRI is also reported in TMJ sides with no signs of condylar injury. More data are necessary if TMJ effusion is to become generally accepted as a sign of hemarthrosis in patients with condylar injury. Further, one study found that trauma causes more delayed TMJ derangement on the non-fractured side than on the fractured side of the mandible in the follow-up MRI that was made¹⁶. A possible explanation for this is that direct trauma can cause condylar fractures that involve the structures of the TMJ, while the contralateral TMJ may be affected by indirect trauma. The TMJ receives less direct trauma when the mandible fractures than when the mandible remains intact, and presumably transmits the full force of the blow to the joint of the non-fractured side. Damage to the fractured condyle can also lead to derangement of the contralateral joint secondary to overloading, hypermobility, and disc displacement of the uninjured joint¹⁶.

The question remains as to whether it is conceivable that there would be an indication for performing an MRI in every case of condylar (head) fractures in the future. However, this should be carried out pre- and post-treatment in a research setting to find out what is a good indication for performing functional open treatment.

Functional open treatment

The key factor in failure of recapturing a displaced disc after trauma is the state of either the joint capsule or the disc. Both can be disrupted by trauma or can be damaged by surgical procedures. Overall, authors claim that anatomically correct reduction is of advantage for disc restoration. Repair and reconstruction of the joint's soft tissues is called functional open treatment and demonstrated good clinical outcomes on oral functioning in one study²⁰. It means that reduction and fixation of the condylar segment and disc was carried out as well as repair of retrodiscal tissue, the lateral capsule and reattachment of the posterior ligament to the disc. These are crucial steps to reduce post-treatment complications. Improve-

ment of the soft tissues was confirmed by the follow-up MRI²⁰. However, the disc was still anteriorly or posteriorly displaced in 5% of the TMJs after this intervention and complications due to the extra-oral approach such as weakness of the facial nerve are still existing. In the literature, successful cases without complications were reported of surgical reduction by extra-oral approach of the articular soft tissues in patients with chronic non-traumatic TMJ dislocations^{26,27}.

Even if a correlation between soft and bony injury was reported, because there is still an ongoing discussion about the most favourable treatment for condylar fractures, it is hard to conclude whether any outcome or complication is due to the treatment modality or to soft tissue injury. If complications such as ankyloses and limited range of motion of the mandibular condyle are the direct result of soft tissue injury, repair of the soft tissues might be a good indication for treatment⁷.

Strengths and limitations of this review

This review is strengthened by its methodology, conduction in accordance with the PRISMA guidelines and the use of quality assessment.

A limitation of this review is the overall quality of the studies included; most were of poor or fair methodological quality. Only one study was of good quality. Overall statistical analysis was insufficiently performed; also, some studies only included a few study patients, therefore, the power and thereby conclusions overall could be questioned.

Another limitation of this review is the heterogeneity in reporting outcomes in the included studies. This limits the comparability of results and conclusions. Because of the general lack of statistical analysis and this wide variety on reported outcomes, the information provided from this review was insufficient to aggregate information to perform a meta-analysis.

As we limited our literature search for this review by use of database and publication language, selection bias might have occurred.

Because we did not make attempts to find unpublished studies (which are more likely to report negative findings), publication bias might have occurred.

Future research

In future research a prospective study design is needed.

Pre- and post-treatment registration of clinical and functional status will be re-

quired to determine the possibility of a prediction model for later functional deficits. Thereby, if it is clear which diagnosis of condylar fracture on a CT scan has a high a priori chance of having a certain soft tissue injury with impairing functional outcome, surgical reduction of soft tissue injury might be justified. It would also be preferable if research specific to MRI settings could clarify the best settings as we still see a variety of used settings.

Finally, we recommend the use of a classification for condylar fractures where there is at least a differentiation between condylar head, neck and base fractures and dislocated and non-dislocated fractures combined with a classification of soft tissue injury.

In conclusion, the results of this review give an overview of the reported soft tissue injuries caused by condylar fractures. Yet its influence on clinical outcome has been insufficiently investigated. Before considering reduction of soft tissue injuries next to reduction of the fracture, more research is definitely needed. Future research should include a good clinical controlled study, with uniform condylar fracture classification (fi AOCMF), with a control group for treatment, with decent follow-up and report of objective and subjective outcomes and accurately description and classification of the soft tissue injuries. MRI is an efficient way to diagnose soft tissue injury of the TMJ in an acute setting.

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