Open versus Closed

Mandibular condyle fractures

Antoinette Rozeboom

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Content

Chapter 1

General Introduction and Outline

Condylar fractures

Optimal treatment of a fracture of the mandibular condyle is one of the most challenging controversies in maxillofacial trauma care. The mandible is prone to external forces because of its exposed position in the maxillofacial skeleton, so mandibular fractures are particularly common (42%–66%),[1–3] as is involvement of the condyle (25%–35%).[4–6]

From an anatomic perspective, the fractures of the condyle can be divided in several types. Numerous classification systems for these fractures have been published in the recent literature.[7–11] However, for practical purposes, a distinction needs to be made between fractures of the condylar head (intracapsular), condylar neck (extracapsular), and condylar base (subcondylar).[7,12]

Treatment modalities

Treatment options for fractures of the mandibular condyle consist of either closed treatment, i.e., expectative or conservative treatment with or without maxillomandibular fixation, or open treatment, i.e., open reduction with internal fixation.[13,14]

Several studies have reported favorable clinical results with closed treatment of condylar fractures. Some of these studies have even concluded that the closed approach should be regarded as the first choice of treatment for condylar fractures,[15–18] based on the assumption that closed treatment methods are favorable in terms of preventing potential complications arising from surgical treatment.

Historically, closed treatment was the treatment option of choice and has had satisfactory outcomes in the majority of cases.[20] Open treatment, on the other hand, has always been considered to be a more challenging procedure, mainly because of the complex anatomy, e.g. the facial nerve. Furthermore, before the development of modern osteosynthesis material, i.e., for plate and screw fixation, open treatment consisted of an interosseous wire for stabilizing the fracture and a period of maxillomandibular fixation for achieving an osseous union.

Rigid plate and screw fixation dates back to 1886 when the first plate and screw system was developed by the German surgeon Carl Hansmann. Because of the high rate of complications, the system was not generally accepted. It took until 1968 when Hans-Georg Luhr developed the first compression plate for use in the maxillofacial area. Introduction of biocompatible implant materials and development of plating systems with adequate dimensions for use in different areas of the complex facial skeleton, led to a development of osteosynthesis material that was perfected for use in cranio-maxillofacial surgery.[21] Use of plate fixation permitted open reduction and stable internal fixation of fractures of the mandibular condyle without the need for postoperative maxillomandibular fixation (MMF), which made early functional rehabilitation possible.

- ### Closed treatment

Closed treatment may be conservative or expectative. Conservative treatment normally consists of a period of MMF and it is thought that immobilization will maintain and/or reestablish normal occlusion and relieve post-traumatic pain.[22] In contrast, expectative treatment does not involve immobilization and merely entails active mobilization with strict follow-up.[23] Recent studies have generally investigated whether a mandibular condyle fracture should be treated using an open or closed method and have not focused on the outcomes of the different closed treatment procedures available.[24,25] Given the wide variation in the definitions of closed treatment, further elucidation of closed treatment is required, particularly in regard to postoperative treatment strategies such as MMF, the fixation method used, and use of physiotherapy.

Chapter 2.1 focuses on closed treatment of unilateral mandibular condyle fractures in adults. Possible complications of closed treatment include malocclusion, particularly an open bite, diminished posterior facial height, facial asymmetry, chronic pain, and reduced mobility.[14,26]

Chapter 2.2 presents an alternative treatment modality for patients with post-traumatic malocclusion.

- **Open treatment**

The main advantages of open treatment are the ability to restore the condyle to its most ideal anatomic position, thereby preventing diminished posterior facial height and facial asymmetry, immediately restoring occlusion, and potentially allowing immediate mobilization of the joint, leading to more efficient functioning of the joint.[27–30] The strong indications for open treatment have been published.[13–15,19]

Chapter 3.1 provides an overview of the studies published exclusively on open treatment. The existing open treatment modalities and their clinical outcomes i.e., occlusion, mouth opening, range of motion of the mandible, and pain, are discussed.
Open treatment is associated with surgical complications because of the surgical approach used. The approach dictates the exposure, as well as the degree and number of complications arising from the layers of dissection and the surrounding anatomic structures, i.e., the facial nerve, the great auricular nerve, and the parotid gland. It is known that the choice of surgical approach is critical for reducing postoperative complications.[34] The most feared complication is permanent damage to the facial nerve. Other surgical complications include plate fracture and screw loosening, as well as a visible scar.[31–33]

Chapter 3.2 provides an overview of the complications of extraoral approaches in the open treatment of condylar fractures.

Open versus closed

When evaluating either treatment modality, i.e., open or closed, it should be kept in mind that a satisfied surgeon is not necessarily synonymous with a satisfied patient. A striking feature in the relevant literature is that very few studies have considered clinically relevant subjective parameters, with most studies focusing solely on objective outcome measures.[35] Therefore, without becoming involved in the controversy concerning indication, we embarked on a study that focused primarily on subjective and functional outcomes. This cross-sectional study evaluated the results of our treatment of condylar fractures in the Department of Oral and Maxillofacial Surgery at the Academic Medical Center between August 2008 and March 2016.

The details of the above-mentioned study are described in Chapter 4. The subjective and functional outcomes of the treatment of condylar fractures were evaluated by determining the patient's subjective perception of functioning of the mandible and assessing the musculoskeletal function of the orofacial region (Chapter 4.1), and by evaluating the masticatory performance objectively (Chapter 4.2). Pre-treatment and post-treatment imaging was also performed and the findings analyzed (Chapter 4.3).

The highest form of evidence in the 'open versus closed' controversy would be a well-designed and executed randomized clinical trial. Our plans for such a study are discussed in Chapter 4.4.

1

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Chapter 2

Closed

2.1

Closed treatment of unilateral mandibular condyle fractures in adults

This chapter is an edited version of the manuscript:

A. V. J. Rozeboom, L. Dubois, R. R. M. Bos, R. Spijker, J. de Lange

Closed treatment of unilateral mandibular condyle fractures in adults: a systematic review

Published: International Journal of Oral and Maxillofacial Surgery. 2017; 46: 456 - 464

INTRODUCTION

The mandible is prone to external forces as a result of its exposed position in the maxillofacial skeleton. Thus, mandibular fractures are one of the most common facial fractures (42 to 66%).[1-3] Of all mandibular fractures, 25 to 35% are fractures of the mandibular condyle.[4-6] This can be explained by the fact that the mandible is similar to a hunting bow in shape - strongest in the midline (symphysis) and weakest at the ends (condyles).

Treatment options for fractures of the mandibular condyle consist of either closed treatment or open reduction with internal fixation (ORIF).[7,8] Several studies have reported favorable clinical results with closed treatment of condylar fractures.[9] Some of these studies have even concluded that the closed approach should be regarded as the first choice of treatment for condylar fractures,[10-12] based on the assumption that closed treatment methods are favorable in terms of the potential complications arising from surgical treatment.

Potential complications of closed treatment include malocclusion (particularly open bites), reduced posterior facial height, facial asymmetry, chronic pain, and reduced mobility.[8,13]

Conservative treatment normally consists of a period of maxillomandibular fixation (MMF). It is widely held that immobilization is likely to maintain and/or re-establish normal occlusion and relieve post-traumatic pain.[14]

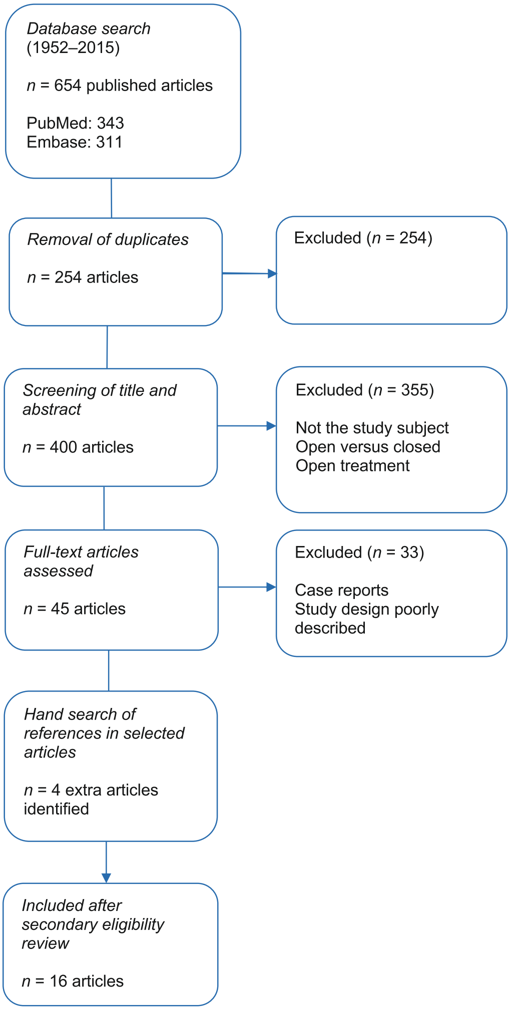
Recent studies have generally focused on whether to treat mandibular condyle fractures via open or closed methods. However, none of these studies has focused on the outcomes of different closed treatment procedures.[15,16] Due to the substantial diversity of definitions of closed treatment, a uniform protocol/guideline for closed treatment is required. Most closed therapy interventions require expert experience.

The aims of this systematic review were to provide an overview of the literature published exclusively on closed treatment, to generate a summary of the existing closed treatment modalities, and to define what the outcomes of these modalities are.

METHODS

Systematic literature searches were performed in PubMed (all indexed years, Appendix 1) and Embase (all indexed years, Appendix 2) on 19 May 2015, with multiple search terms. The searches excluded case reports with 10 or fewer subjects, and only reports in English, German, or Dutch were considered. All remaining prospective and retrospective human clinical studies reporting data relating to any form of closed treatment of unilateral fractures of the mandibular condyle and the outcomes of those treatments were included. A flow diagram of the inclusion process is given in Figure 1.

Figure 1. Inclusion process (flow chart)



In the primary review process, conducted in accordance with the PRISMA criteria, two authors (RB and AR) first screened the titles and abstracts of the articles retrieved to determine potential relevance.[17] Next, the full-text articles were retrieved and relevant articles were designated for inclusion.

The references sections of all these articles were hand-searched for further relevant articles; as a result, four additional articles were identified and assessed. Any disagreements relating to inclusion were resolved by discussion with a third person (LD). The articles included were critically appraised via a checklist of key criteria (Table 1).[18]

Appendix 1. Pubmed search

("Mandibular Condyle"[Mesh] AND (fracture*[tiab] or Mandibular Fractures[mesh])) OR (Mandibular Condyle[tiab] AND fracture*[tiab]) OR Condylar fracture*[tiab] OR (collum mandibula*[tiab] AND fracture*[tiab]) OR (mandibular neck[tiab] AND fracture*[tiab])
AND
(closed[tiab] OR conservative[tiab] OR non invasive[tiab]or non-surgical or nonsurgical) AND (treatment*[tiab] OR therap*[tiab] OR reduction[tiab])

Appendix 2. Embase search in Ovid

1	exp mandible condyle/	7329
2	Fracture reduction/	8180
3	exp mandible fracture/	6326
4	2 or 3	14205
5	1 and 4	1214
6	(((mandibular condyle or collum mandibula* or mandibular neck) adj3 fracture*) or condylar fracture*).ti,ab,kw.	1373
7	5 or 6	1964
8	((closed or conservative or non invasive or non-surgical or nonsurgical) adj5 (treatment* or therap* or reduction)).ti,ab,kw.	80377
9	7 and 8	311

Table 1. Critical appraisal of the studies included

	Criteria[a]							
	1	2	3	4	5	6	7	8
1. Andersson et al.[19]	+	+	+	+	NA	+	-	+
2. Dijkstra et al.[20]	+	+	+	+	NA	+	+	+
3. Knak and Stoehr[27]	+	-	-	+/-	NA	+	-	-
4. Krause and Bremerich[30]	+	-	+	+	NA	+	-	+/-
5. MacLennan[29]	-	-	-	-	NA	+	-	?
6. Marker et al.[21]	+	+	+	+	NA	+	+	+
7. Murakami et al.[22]	+	+	+	+	NA	+	+	+
8. Niezen et al.[23]	+	+	+	+	NA	+	+	+
9. Niezen et al.[25]	+	+	+	+	NA	+	-	+
10. Oikarinen et al.[26]	+	+	+/-	-	NA	+	-	+
11. Rahn et al.[31]	+	+	+/-	+/-	NA	+	-	?
12. Rutges et al.[28]	+	+	+	+	NA	+	-	NA
13. Silvennoinen et al.[24]	+	+	+	+	NA	+	+	+/-
14. Silvennoinen et al.[5]	+	+	+	+	NA	+	-	NA
15. Smets et al.[11]	+	+	+	+	NA	+	-	+/-
16. Yamamoto et al.[32]	+	+	+	+	NA	+	-	+

NA, not applicable

[a] 1 = Clear study objective/question, 2 = Well- defined study protocol, 3 = Explicit inclusion and exclusion criteria for study participants, 4 = Specified time interval for patient recruitment, 5 = Consecutive patient enrollment, 6 = Clinically relevant outcomes, 7 = Prospective outcome data collection, 8 = High follow up rate/drop outs analysed

RESULTS

A total of 16 studies were identified in the systematic search.[5,11,19-32] These studies included a combined total of 1535 patients with mandibular condyle fractures (Tables 2 - 4). The year of publication of the selected studies ranged from 1952 to 2015. The sample size in almost 50% of the studies was more than 100 patients. The mean age of patients in the studies was 31 years, but unfortunately some of the studies did include children. A clear distinction between children and adults was not made in any of the studies. The male to female ratio was 3:1. Both mandibular joints were fractured in 20% of the cases; the fractures were unilateral in 80% of the cases. In the cases of unilateral fracture, 53.6% were on the left side and 46.4% were on the right side. Of these fractures, the location was intracapsular in 17% and extracapsular in 83%. Follow-up periods varied substantially. Silvennoinen et al. reported the shortest mean follow-up period (5.4 months),[5] while Andersson et al. reported the longest (31 years).[19]

Table 2. Overview of the studies included

Author	Year	Title
1. Andersson et al.[19]	2007	Unilateral mandibular condyle fractures: a 31-year follow up of non-surgical treatment
2. Dijkstra et al.[20]	2005	Function impairment and pain after closed treatment of fractures of the mandibular condyle
3. Knak and Stoehr[27]	1967	[Results of the conservative treatment of fractures of the mandibular condyloid process] (Article in German)
4. Krause and Bremerich[30]	1992	[The late results of conservatively treated fractures of the mandibular condylar process] (Article in German)
5. MacLennan[29]	1952	Consideration of 180 cases of typical fractures of the mandibular condylar process
6. Marker et al.[21]	2000	Fractures of the mandibular condyle. Part 2: Results of treatment of 348 patients
7. Murakami et al.[22]	2009	Changes in mandibular movement and occlusal condition after conservative treatment for condylar fractures
8. Niezen et al.[23]	2010	Complaints related to mandibular function impairment after closed treatment of fractures of the mandibular condyle
9. Niezen et al.[25]	2015	Recovery of mouth-opening after closed treatment of a fracture of the mandibular condyle: a longitudinal study
10. Oikarinen et al.[26]	1991	Signs and symptoms of TMJ dysfunction in patients with mandibular condyle fractures
11. Rahn et al.[31]	1989	[Late results of conservative condylar fracture treatment] (Article in German)
12. Rutges et al.[28]	2007	Functional results after conservative treatment of fractures of the mandibular condyle
13. Silvennoinen et al.[24]	1998	Occlusal and temporomandibular joint disorders in patients with unilateral condylar fracture. A prospective one-year study
14. Silvennoinen et al.[5]	1994	Analysis of possible factors leading to problems after nonsurgical treatment of condylar fractures
15. Smets et al.[11]	2003	Non-surgical treatment of condylar fractures in adults: a retrospective analysis
16. Yamamoto et al.[32]	2004	Factors affecting mandibular function after conservative treatment of condylar fractures

Retrospective studies

The majority of the studies assessed were retrospective (11/16 studies, 69%), and included a heterogeneous series of mandibular condyle fractures and treatment modalities. The clinical outcome measurements in these studies were diverse, the study methods were often poorly described, and the follow-up periods were variable. The study populations, types of condyle fractures included, and periods of follow-up of these studies are shown in Table 3.

Table 3. Overview of retrospective studies on closed treatment of mandibular condyle fractures [a]

	Number [b]	Adults	Children (<16 years)	Bilateral	Unilateral	Intra-capsular	Extra-capsular	Follow-up
Andersson et al.[19]	23C/18T	+	+ (5+)	-	+	+	+	31 years
Knak and Stoehr[27]	94	+	+ (10-)	+	+	+	+	5 years (mean)
Krause and Bremerich[30]	128	+	+ (10+)	+	+	+	+	7.8 years (mean)
MacLennan[29]	67C/53T	+	+ (10-)	+	+	+	+	3.1 years (mean)
Niezen et al.[25]	142	+	+	+	+	+	+	1 year
Oikarinen et al.[26]	37	+	+ (13+)	+	+	+	+	44 months (mean)
Rahn et al.[31]	116	+	+ (8+)	+	+	ND	ND	3.8 years
Rutges et al.[28]	28C (60CR)	+	-	+	+	+	+	3.0 years
Silvennoinen et al.[5]	92	+	-	-	+	+	+	5.4 months (mean)
Smets et al.[11]	60	+	-	+	+	+	+	6 months to 4 years
Yamamoto et al.[32]	49	+	-	+	+	+	+	12 months

ND, not described
[a] +,in the study; -, not in the study
[b] C, clinical examination; T: telephone, CR, clinical report files

Prospective studies

As shown in Table 4, five prospective studies were identified via the search criteria applied.[20-24] Four of these were prospective cohort studies and one was a case-control study. No randomized prospective studies were identified at this stage of the review. Few studies adequately described the treatment modalities they applied.[20, 23, 25]

The longest period of follow-up (mean 1.2 years) was reported by Dijkstra et al..[20] The primary outcomes used in that study were function (mandibular function impairment questionnaire; MFIQ[33]) and pain (visual analogue scale; VAS score). They concluded that the most important risk factors for functional impairment were age ≥ 25 years and gross displacement. The most important risk factors for pain identified in their study were being female and intracapsular fractures.

Of all the included studies, Marker et al. had the largest sample size; $n = 348$ patients.[21] They reported that for their patients, non-surgical treatment of the fractures of the condyle was non-traumatic, safe, and predictable, and that serious complications such as continuous pain and malocclusion were only observed in a few cases. Furthermore, they concluded that the most important factors in the development of malocclusion were dislocation of the condylar head and bilateral fractures.

Murakami et al.[22] and Silvennoinen et al.[24] both reported studies with sample sizes of 18. The methods used in these studies were poorly described.

Table 4. Overview of prospective studies on closed treatment of mandibular condyle fractures [a]

	Number	Adults	Children *(<16 years)*	Bilateral	Unilateral	Intra-capsular	Extra-capsular	Follow-up
Dijkstra et al.[20]	116	+	+	+	+	+	+	1.2 years (mean)
Marker et al.[21]	348	+	+ (4+)	+	+	ND	ND	1 year
Murakami et al.[22]	18	+	-	-	+	+	+	6 months
Niezen et al.[23]	114	+	+	+	+	+	+	6 months
Silvennoinen et al.[24]	18	+	-	-	+	ND	ND	1 year

ND, not described
[a] +, in the study; -, not in the study

Overview of the treatment modalities applied in the studies included

Table 5 shows an overview of the treatment modalities applied in the studies. In most studies, the closed treatment of fractures consisted of a period of MMF with elastic bands,[5, 19, 20, 23, 25, 27-29] often fixed on archbars.[20, 21, 23, 25, 27, 30] The mean duration of MMF was approximately 3 weeks, and ranged from 5 days to 49 days.[11]

In the studies included in the final review, little was written about the extent of fixation with elastics. Some studies used elastics primarily for guidance (guiding elastics), while others used elastics in an effort to achieve rigid MMF. In some studies, rigid MMF with stainless steel wires was used.[5, 21, 28-30] Others used both stainless steel wires and elastics, and in some studies the method of MMF was not specified.

In most studies, the choice between expectative and conservative treatment was made based on occlusion. In cases where the patient could potentially reach maximal occlusion, or if the occlusion was only minimally disturbed, expectative treatment was initiated. In most studies this consisted of a soft diet, without MMF, sometimes complemented by functional therapy by a physiotherapist. Other indications for closed treatment with MMF were swelling, deviation on mouth opening, simultaneous mandibular fractures, and pain and restriction associated with mandibular movements.

Table 5. Overview of the treatment modalities applied in the studies included

	Expectative		Conservative				
		Method	MMF	Method	Fixation method	Duration	Additional care
Andersson et al.[19]	+	Soft diet only	+	Elastics	ND	2–6 weeks	2 weeks soft diet
Dijkstra et al.[20]	+	Not further described	+	Guiding elastics	Arch bars	2–3 weeks	3 weeks soft diet, physical therapy if indicated
Knak and Stoehr[27]	+	Head chin cap at night	+	Elastics	Arch bars	3–5 weeks	Activators/ functional orthodontics
Krause and Bremerich[30]	-	Not further described	+	Wires	Arch bars/ernst ligatures	10–21 days	Elastics after release of MMF/ functional therapy
MacLennan [29]	+	Not further described	+	Wires/bandage	ND	most 0–14 days	Elastics/ training flange after release of MMF
Marker et al.[21]	+	Exercises/ liquid diet	+	Wires	Arch bars	4–6 weeks	Elastics after release of MMF/ instructions
Murakami et al.[22]	+	Physiotherapy	+	ND	ND	13–21 days	Physiotherapy
Niezen et al.[23]	+	Not further described	+	Guiding elastics	Arch bars	2–3 weeks	3 weeks soft diet
Niezen et al.[25]	+	Not further described	+	Guiding elastics	Arch bars	2–3 weeks	3 weeks soft diet, physical therapy if indicated
Oikarinen et al.[26]	-	Not further described	+	ND	ND	25.0–33,7 days	Not described
Rahn et al.[31]	+	Functional therapy + activator	+	ND	Head chin cap/ splint	3 weeks	Functional therapy
Rutges et al.[28]	+	Soft diet only	+	Wires/elastics	ND	27 days	Elastics after release of MMF
Silvennoinen et al.[24]	+	Not further described	+	ND	ND	14–30 days	Functional instructions/ physiotherapy
Silvennoinen et al.[5]	+	Soft diet/functional therapy	+	Wires/elastics	ND	2–4 weeks	Elastic traction after release of MMF
Smets et al.[11]	+	Instructions regarding opening exercises	+	ND	Rigid	5–49 days	Guiding elastics, instructions/ physiotherapy
Yamamoto et al.[32]	+	Restriction mandibular movement/ active functional therapy (pivot type splint)	+	ND	biteblock	7–26 days	Active functional therapy

ND, not described

Fixation methods of MMF other than arch bars were also described. Rahn et al. used besides Schuchardt splints and head chin caps to achieve MMF.[31] Yamamoto et al. applied MMF with a bite block in the molar region of the affected side in patients with malocclusion, particularly those with an open bite.[32]

In most cases, functional therapy with guiding elastics was initiated after a period of MMF. Some exceptions were reported. For example, Knak and Stoehr used activators to restore mandibular function after a period of MMF.[27] Others used some form of bandage.[29] Furthermore, MacLennan suggested that where necessary, a training flange could be used.[29] Both of these studies were reported more than 50 years ago. In most reports, however, the functional therapy administered by a physiotherapist and any other additional therapies used were not described in detail.

Outcome measures

Table 6 shows an overview of the outcome measures. The most frequently described outcome measures were occlusion, mouth opening, range of motion of the mandible (ROM), pain, temporomandibular joint (TMJ) sounds, deviation on opening of the mouth, facial deformity, and function of the TMJ. Studies covering the four most clinically important and uniformly reported outcome measures, i.e., occlusion, mouth opening, ROM, and pain are shown in Table 7. Due to the wide variation in the descriptions of 'function', this outcome was not further analyzed.

In these studies, 89% of patients had no occlusal disturbances at the end of the follow-up period. The presence of some form of malocclusion ranged from 0% to 24%. Nonetheless, the need to perform orthognathic surgery was rare. Smets et al. reported that 2 of a total of 60 patients who responded to a request for follow-up examination had obvious malocclusion due to the condylar fracture and conservative treatment; osteotomies were subsequently performed in these 2 cases to achieve adequate results.[11]

The degree of mouth opening considered to constitute a 'good' outcome differed, with some authors reporting this to be more than 30 mm, some using a threshold of more than 35 mm, and others using a threshold of more than 40 mm. Overall, 'good opening' of the mouth was reported in 86% of the cases in the studies included in the final review, and an unlimited ROM was reported in 84%. No cases of ankylosis were reported.

The reported incidence of pain at rest ranged from 0% to 16%. A mean of 92% of patients were free of pain.

Table 6. Overview of outcome measures [a]

	Occlusion	Mouth opening	ROM	Pain	Sounds	Deviation	Bite force	Facial deformity	Function / overall complaints *(Helkimo/ MFIQ)*
Andersson et al.[19]	-	+	-	VAS	+	-	-	-	+
Dijkstra et al.[20]	-	-	-	VAS	-	-	-	-	+, MFIQ
Knak and Stoehr[27]	-	+	+	+	+	+	+	-	+
Krause and Bremerich[30]	+	+	+	+	-	-	-	-	+
MacLennan[29]	+?	-	+	+	-	+	-	+	-
Marker et al.[21]	+	+	+?	+	+	+	-	-	+
Murakami et al.[22]	+	+	+	-	-	+	+	-	-
Niezen et al.[23]	+	+	+	+	+	+	-	-	+, MFIQ
Niezen et al.[25]	-	+	-	-	-	-	-	-	-
Oikarinen et al.[26]	-	+	+	(+)	(+)	-	-	-	+, Helkimo index
Rahn et al.[31]	+	+	+	+	-	+	-	-	+
Rutges et al.[28]	+	+	+	+	-	-	-	-	+, Helkimo index
Silvennoinen et al.[24]	+	+	(+)	+	+	+	-	-	+
Silvennoinen et al.[5]	+	+	+	-	-	+	-	-	+
Smets et al.[11]	+	+	+	(+)	(+)	+	-	+	+
Yamamoto et al.[32]	+	+	+	(+)	(+)	+	-	-	+

ROM, range of motion of the mandible; MFIQ, Mandibular Function Impairment Questionnaire; VAS, visual analogue scale.
[a] +, outcome was measured in the study; -, outcome was not measured in the study, (+), measured as part of 'function'; +?, not described as a self-contained measurement.

Table 7. Most relevant outcome measures

	Number[a]	No occlusal disturbances	Good mouth opening	ROM	Pain	Follow up
Andersson et al.[19]	23C/18T	-	96%	-	13%	31 years
Dijkstra et al.[20]	116	-	-	-	9%	1.2 years (mean)
Knak and Stoehr[27]	94	-	95% (> 35 mm)	85%	15%	5 years (mean)
Krause and Bremerich[30]	128	90%	81% (> 40 mm)	81%	16%	7.8 years (mean)
MacLennan[29]	67C/53T	not calculated	-	100%	2%	3.1 years (mean)
Marker et al.[21]	348	98%	90%	89%	3%	1 year
Murakami et al.[22]	18	not calculated	100% (> 40 mm)	not calculated	-	6 months
Niezen et al.[23]	114	76%	mean 51.9 mm	97%	9%	6 months
Niezen et al.[25]	142	-	mean 52.6 mm	-	-	1 year
Oikarinen et al.[26]	37	-	mean 48.4 mm	not calculated	not calculated	44 months (mean)
Rahn et al.[31]	116	100%	96% (> 30 mm)	100%	4%	3.8 years
Rutges et al.[28]	28C (60CR)	82%	68% (> 40 mm)	65%	11%	3.0 years
Silvennoinen et al.[24]	18	78%	100%		6%	1 year
Silvennoinen et al.[5]	92	87%	100% (> 40 mm)	not calculated	-	5.4 months (mean)
Smets et al.[11]	60	92%	78%	71%	0%	6 months to 4 years
Yamamoto et al.[32]	49	94%	92% (> 35 mm)	88%	4%	12 months

ROM, range of motion of the mandible.
[a] C, clinical examination; T, telephone; CR, clinical report files.

2.1

DISCUSSION

The methods used for the closed treatment of condylar fractures are not adequately described in the literature to date. As revealed in this systematic review, there is substantial heterogeneity with regard to indications, treatment protocols, and the lengths of treatments.

Several classification systems have been used to define fracture types.[34] For practical purposes, the condylar process is often divided into three anatomical levels at which the fracture can occur: the condylar head (intracapsular), the condylar neck (extracapsular), and the subcondylar region.[35, 36] However, most of the reports did not differentiate between subcapsular and intracapsular fractures, or unilateral condylar and bilateral condylar fractures, or fractures in adults and children.

In children, the treatment of mandibular condyle fractures entails substantially different considerations than those that apply when the condition occurs in adults. First, in children there is a difference in surgical anatomy. This is why children have a propensity to fracture through the condylar head, rather than the low neck pattern seen in adults. In addition, the mandible is the last bone in the face to reach skeletal maturity. Fractures of the condyle in children can therefore have consequences for the growth of the mandible.[37] On the other hand, children do have an increased remodeling capacity. While in adults closed treatment mostly results in forced adaptation to the altered anatomy, in children rapid and progressive remodeling of the condylar unit is common.[38]

Closed treatment in general is not a complex procedure, and it is associated with reduced overall morbidity.[39] Ellis stated in a review article that the incidence of post-traumatic dysfunction after condylar fractures varied between 9% and 85%.[40] This percentage reportedly increases with the degree of displacement, duration of MMF, and the age of the patient.

In most of the studies included in the final analysis, the definition of 'closed treatment' was not described in precise terms, and there was a lack of details reported with regard to treatment protocols. This rendered the results of the studies difficult to interpret, and compare. In addition, no randomized controlled trials were identified during this systematic review process, and while four prospective follow-up studies were identified, most of the studies adhering to the inclusion criteria were retrospective.

'Closed treatment' refers to any treatment that does not involve open treatment. In the majority of the studies reviewed, no distinction was made between expectative and conservative treatment. In the authors' opinion, a distinction has to be made between expectative and conservative treatment. In this review, all treatments that did not entail MMF were considered expectative.
The circumstances described in the studies assessed that were deemed to warrant expectative treatment as a treatment modality, i.e., no placement of MMF, were for the most part the same: patients who were able to bring their teeth into normal occlusion and in whom mandibular excursions were assessed as normal.
In some studies, expectative treatment was prescribed in conjunction with the recommendation of a soft diet, and instructions relating to movement of the jaw and associated exercises.[11, 19, 21, 28] Others prescribed physiotherapy.[5, 22, 31, 32] On this basis, it could be argued that the exact demarcation between expectative and conservative treatment remains undefined.

There seems to be a general consensus that expectative treatment (without MMF) may be sufficient in patients who are able to bring their teeth into normal occlusion and/or have normal mandibular excursions.

The need for follow-up was not adequately addressed in the studies assessed. Ellis et al. reported that fractures of the head of the condylar process tend to become more displaced over the first 6 weeks.[41] Therefore, it was concluded that it is imperative to control occlusion during this period.

The need for functional therapy should be made on a case-by-case basis. In cases of restricted function, e.g., for recovery of mouth opening, functional therapy should be initiated as soon as possible.

The closed treatments described in the studies analyzed consisted mainly of a period of MMF, and the choice to use MMF was generally based on the presence of malocclusion. Other reasons for using MMF were swelling, deviation on mouth opening, simultaneous mandibular fractures, pain, and restriction of mandibular movements.

The duration of immobilization reported in prior studies is variable, ranging from 2 weeks to 6 weeks.[5, 42] It has also been suggested that no immobilization is required, and that active physiotherapy with strict follow-up is sufficient.[43] Others recommend early mobilization of the jaw in all cases, and suggest that functional rehabilitation is an essential part of the treatment.[5] Longer periods of immobilization are reportedly associated with an increased risk of ankylosis.[44, 45]
With regard to the mechanism of action of closed treatment, various explanations exist. According to Ellis and Throckmorton,[43] adaptations on three levels are necessary to maintain normal occlusion: the neuromuscular level, the skeletal level, and the dentoalveolar level. Neuromuscular adaptation consists of masticatory adaptations. Skeletal adaptation comprises condylar regeneration and remodeling of the joint.[46] The ability of the condyle to remodel and regenerate is impaired and less predictable following dislocation of the condyle,[47] and is age-dependent.[34] When skeletal growth has ceased, the condylar cartilage is mature and remodeling will generally be absent. In these cases, only functional remodeling will occur.[48] Lastly, fine tuning of the occlusion will occur via extrusion of the anterior teeth and/or intrusion of the posterior teeth.[49]

Where the fixation method for MMF was reported, arch bars were used in the majority of studies. Other choices were Ernst ligatures and head chin caps, or the use of a splint or a bite block. Recently, van den Bergh et al.[50] reported that the use of MMF screws as a closed treatment for condylar fractures led to a higher quality of life during the 6-week period of fracture healing than when arch bars were used. Krause and Bremerich,[30] Marker et al.,[21] and Rutges et al.[28] used stainless steel wires for MMF, whereas Niezen et al.[23] used guiding elastics. The strain of elastics used was not described in most studies, with the exceptions of the reports by Dijkstra et al.[20] and Niezen et al..[23] In the other reports included in the final analysis, the MMF method was not described.

The average period of MMF was approximately 2 to 3 weeks, but ranged from 5 days to 49 days.[11] The reasoning behind the duration of MMF applied in the studies analysed was not explained. It is reported that occlusion must be maintained by MMF until fibrous union of the fractured fragments is established.[51] Longer periods of MMF were in most cases associated with a need to correct the bite in patients with persistent malocclusion.

In recent publications, particularly studies reported after 2005, there seems to be a trend towards less rigid MMF and more functional treatment policies. One exception is Rutges et al..[28] In their study published in 2007, rigid fixation with MMF wiring was used. As shown in Table 7, no clear difference in outcome measures was apparent between those that applied stainless steel wires and those that used elastics.
In agreement with previously published statements, the authors of the current review are of the opinion that in cases of malocclusion, a short period of MMF with guiding elastics is appropriate, so that early mobilization can be realized. Early mobilization of the jaw and functional rehabilitation are reportedly considered to be important.[5, 39, 52-54]

It has been proposed that in some cases it may be best not to use MMF at all, to allow the patient to obtain good mobility in as short a time as possible.[41]
However, Silvennoinen et al. cautioned that one should use a period of MMF in cases of displaced fractures.[5] Whether MMF is necessary remains an unanswered question.[41]

Additional treatment (or the lack thereof) after removal of MMF was poorly described in the studies analyzed. Treatments that were repeatedly mentioned were the use of guiding elastics and physiotherapy. Neither the potential benefits nor the benefits actually achieved via either of these two treatment modalities were clarified in the reports. Zide and Kent stated that appropriate physiotherapy should be started in the early phase of non-surgical treatment.[9] It is important to consider the ultimate aims of physiotherapy, specifically increased mouth opening, reduction of pain during functioning of the jaw, improvement of occlusion, and extension of the range of motion.

The need for follow-up and the duration of follow-up after treatment were not mentioned in the studies. In a study by Throckmorton et al., it was reported that after 12 months of follow-up no substantial reformation could be expected.[55] According to the authors of that study, a minimum follow-up period of 12 months is therefore justified.
To informatively evaluate the results of closed treatment reported in the different studies, the outcome variables need to be compared.

Unfortunately, parameters such as 'overall function' have been described differently in most of the studies reported to date. Some studies used the MFIQ to evaluate the functional outcome, while others used the Helkimo index.[56-58] Other outcome measures of closed treatment reported in the studies analysed included the degree of malocclusion, mouth opening, ROM, and pain.

As shown in Table 7, most studies reported good results with regard to these outcome measures. The recovery of occlusion ranged from 76 to 100%. Similar results were shown for the full recovery of mouth opening, which ranged from 68 to 100%. Lateral movements, which are included in the ROM, were fully restored in 65 to 100% of patients. Pain as a late symptom was not often seen.

However, Krause and Bremerich reported that 16% of patients perceived pain.[30] The study by Rutges et al. reported the most adverse outcomes with regard to mouth opening and ROM,[28] followed by the study by Smets et al..[11]

Nevertheless, the descriptions of these measurements were insufficient in most studies. No clear associations between the adverse outcomes and the treatments applied could be determined.

A potential shortcoming of this review is that the studies included focused on closed treatment only. Therefore, data on closed treatment from studies investigating open versus closed treatment were omitted. On the other hand, it is the authors' opinion that studies on open versus closed treatment tend to focus on the controversy rather than on the separate treatment modalities, and that each center in these studies would most probably have a specific treatment that they focus on, whether open or closed, resulting in a skewed impression.[23]

In conclusion, based on the literature studied in this review, a treatment protocol with respect to closed treatment is proposed, as outlined below. This treatment protocol will be used in a prospective trial implemented in the authors' institution.

First, for patients who are able to bring their teeth into normal occlusion or almost normal occlusion (open bite with a maximum of 2 mm on the non-fractured side) and/or who have normal mandibular excursions, expectative treatment should be recommended. In cases of expectative treatment, patients should be advised to adhere strictly to a soft diet, they should be given instructions regarding active but careful movement of the jaw, and they should be prescribed adequate pain medication. In the authors' department, a non-steroidal anti-inflammatory drug (600 mg ibuprofen three times a day) with a stomach protector (omeprazole 20 mg a day) in combination with paracetamol (maximum 2000 mg per day) is used for two weeks. The use of a patient brochure describing exercises to practice at home is also suggested. The patient should be advised to mobilize the jaw but not load it.

Furthermore, thorough follow-up should be provided, with the first appointment after 5 to 7 days. If there is a change to an open bite, or a persistent open bite, then either orthodontic brackets or MMF screws should be applied; if these are not applicable, arch bars with guiding elastics should be applied for 3 weeks.
Second, in cases of malocclusion with an open bite of more than 2 mm on the non-fractured side, conservative treatment consisting of a short period of MMF should be advised. The MMF should include guiding elastics fixed on brackets or MMF screws, or arch bars if these are not available; this should be done for a duration of 3 weeks so that early mobilization can be achieved. The MMF should put the patient into a correct occlusion, but should never induce total immobilization. Rigid fixation with stainless steel wires or elastics should not be used, otherwise degeneration of the TMJ by immobilization and ultimately fibrous or bony ankyloses can occur.

After this 3-week period of MMF on guiding elastics, the occlusion can be guided with loose elastics for a further 6 weeks if necessary, and active physiotherapy should be started.

As in cases of expectative treatment, patients should be advised to adhere to a soft diet, instructions regarding movement of the jaw should be given, adequate pain medication should be prescribed, and a brochure describing exercises to practice at home should be provided. Again, the patient should be instructed to mobilize the jaw but not load it.

After the first contact, follow-up visits are normally scheduled at 5 to 7 days, 3 weeks, 6 weeks, and 12 weeks. If the patient has recovered well by this time, then follow-up is finished. If there are still complaints such as a persistent open bite, limited mouth opening, or pain, then follow-up can be extended to 6 months or even 1 year.

Due to the heterogeneity of the groups in the studies reviewed, the high loss-to-follow-up rates, the poor descriptions of the different treatments given, and the variability in the methods used to measure outcomes, no solid evidence-based conclusions or guidelines can be formulated with regard to the most appropriate closed treatment. A clear differentiation between expectative and conservative treatment is determined by the use or not of MMF in closed treatment. Further reproducible trials are needed to develop guidelines for closed treatment of fractures of the mandibular condyle.

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2.2

Management of post-traumatic malocclusion: an alternative treatment

This chapter is an edited version of the manuscript:

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Management of post-traumatic malocclusion: an alternative treatment

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INTRODUCTION

Fractures of the mandibular condyle are common facial injuries accounting for 25 to 35% of all mandibular fractures.[1-4] Treatment options for fractures of the mandibular condyle consist of open treatment with internal fixation or closed treatment. Presently, no consensus exists regarding the most appropriate method for the management of fractures of the mandibular condyle. High-quality evidence for the efficacy regarding both treatment options is lacking, and only a few randomized clinical trials exist comparing the two treatment options. Unfortunately these studies do not yield substantially reassuring evidence in support of either of the two treatment options, particularly because of small study groups and a large loss to follow-up.[5]

Closed treatment is the method of therapy most commonly chosen for the management of condylar fractures.[6] Closed treatment is defined as a period of maxillomandibular fixation (MMF) to secure proper occlusion. In some cases, MMF is combined with additional functional rehabilitation therapy, and this approach may be impractical for the patient because of long duration of therapy and considerable limitations associated with functionality during MMF. Literature suggests that articulation/joint movements are beneficial to the outcome of condylar fracture treatment.[6] Despite being often considered a modality with minor complications, closed treatment may yield complications like chronic pain, reduced mobility, and malocclusion.[6]

Malocclusion is a serious post-traumatic sequela and can result in an open bite with functional disturbances, reduced posterior facial height, and facial asymmetry.[6]
An explanation for post-traumatic malocclusion could be that not all patients are capable of physiologically adapting to the sequelae associated with their injury. Malocclusion may also occur if there is non-compliance of the patient to functional rehabilitation, if little instruction is provided to the patient regarding care, or if follow-up is poor.[7] If post-traumatic malocclusion emerges, most clinicians opt for active intervention. Treatment options include occlusal adjustments, orthodontic treatment, temporomandibular joint (TMJ) reconstruction, and/or orthognathic surgery.[7,8] Selecting a treatment modality usually depends on the degree of occlusal disturbance and the patient's preference.

In the present technical note, an alternative non-surgical treatment modality for treating severe long-term post-traumatic malocclusion is presented describing placement of occlusal stops constructed from drops of dental composite.

CASES

In 2013 and 2014, four patients with a long-term post-traumatic malocclusion were treated using occlusal stops (table 1). The time between trauma and the presentation of malocclusion varied from 4 to 8 weeks in these cases. The occlusal stops were constructed from drops of dental composite (Transbond Plus, Light cure band adhesive; 3M Unitek, Monrovia, CA, USA) and bonded to the occlusal plane of the teeth. Occlusal stops were placed between the molars and/or premolars of the fracture site. In all cases, the occlusal stops were 3 to 4 mm thick and patients were able to maintain sufficient jaw extension (open configuration) with the adapted occlusion in exact horizontal orientation. If necessary, additional brackets on the premolars and molars were placed with guiding elastics to adjust the bite.

Orofacial physiotherapy was initiated, which focused on guiding a symmetrical mouth opening and loosening of the fibrous scar tissue around the fractured bone. After 4 to 6 weeks, the occlusal stops were removed and physiotherapy was intensified.

During this period, the physiotherapist trained the patients to achieve symmetrical mouth opening, appropriate function (among other things translation and maximum mouth opening), and a restored occlusion (non-elastic guided closure). Because of the retrospective nature associated with this report, approval by the medical ethics review board was not necessary.

Table 1. Detailed summary and demographic information of the patient cases presented in this technical note (treated by a closed approach using occlusal stops).

Case Number	Gender *(Female/ Male)*	Date of birth *(day-month-year)*	Age at Trauma *(years)*	Trauma *(fractures)*	Treatment	Occlusal Units*	Hypomochlion *start after trauma*	Hypomochlion *(time after trauma) time after placing*
1	F	26-5-1956	57	Mandibular condyle left	Conservative	>6	11 weeks	(17) 6 weeks
				Paramedian mandible right	Brackets & elastics			
2	M	8-12-1965	48	Mandibular condyle left	Conservative	>6	9 weeks	(15) 6 weeks
3	F	6-4-1934	79	Mandibular condyle/capitulum left	Conservative Brackets & elastics	>6	4week	(7) 6 weeks
4	M	6-3-1985	29	Mandibular condyle/capitulum left	Conservative Brackets & elastics	>6	11 weeks	(15) 4 weeks

* Occlusal units: any pair of opposing teeth of the same type was counted as one occlusal unit

2.2

CASE 1

A 57-year-old female patient presented with a mandibular condylar fracture on the left side and a paramedian fracture on the right side. Dental occlusion was disrupted with premature contact on the left side and a midline deviation to the left was seen when opening the mouth. Bilateral MMF with elastic bands was started with brackets on the cuspids and premolars.

After 2 weeks, the patient's occlusion was corrected and the guiding elastics were discontinued. Four weeks post-trauma, the patient developed a malocclusion with premature contact at the molar region on the right side. Physiotherapy was initiated and 8 weeks after trauma occlusal stops were fitted. Four weeks after removal of the occlusal stops, a correct occlusion was achieved.

CASE 2

A 48-year-old male patient presented with a fracture of the left mandibular condyle. Intraoral inspection revealed a premature contact in the left molar region and an open bite on the right side. Brackets and firm elastics were placed on both sides of the maxillary and mandibular cuspids, premolars, and molars.

Three weeks post-trauma, the patient had no complaints of pain; however, a minimal malocclusion persisted and closed treatment was continued with guiding elastics. Nine weeks after trauma, a heavy contact between the molars on the left side was observed. At this point, occlusal stops were placed and physiotherapy was initiated. Six weeks later, the occlusal stops were removed and a correct occlusion was achieved, except for a minimal gliding tendency on the left side. Physiotherapy was continued, and 24 weeks after trauma, the occlusion was completely corrected.

CASE 3

A 79-year-old female patient appeared 3 weeks after fracture of the condylar head on the left side. A unilateral open bite of 3 mm on the right side was identified during examination. Closed treatment was initiated using brackets and firm elastics placed on the premolars and molars. One week later, the patient's occlusion still did not improve, but the open bite was significantly reduced. Occlusal stops were placed and traction with elastics was continued.

After 6 weeks, the occlusal stops were removed and 2 weeks later, the brackets were also removed as the occlusal plane was nearly completely realigned. Physiotherapy was started, and 19 weeks after the initial trauma, the patient's occlusion was corrected.

CASE 4

A 29-year-old male patient (figures 1 - 4) presented with a minor dislocated fracture of the left mandibular condyle and premature contact at the left side. Closed therapy was initiated and brackets were placed to facilitate the use of guiding elastics. The brackets were removed after 8 weeks and 2 weeks later the patient had developed a lateral open bite on the right side. Occlusal stops were placed and the patient was referred to a physiotherapist.

Four weeks later, the occlusal stops were removed and the patient continued treatment with guided closure with the physiotherapist. At follow-up one year after the trauma, the occlusion was completely restored.

Figure 1. Case 4, malocclusion 8 weeks after trauma.

Figure 2. Case 4, mandibular occlusion plane (a) and left buccal aspect (b) of occlusal stop placement after 11 weeks of initial closed therapy.(a)

a)

b)

Figure 3. Case 4, occlusion 24 weeks after trauma and 3 months after removal of occlusal stops.

Figure 4. Case 4, occlusion one year after trauma.

Measurements

The treatment result of case 4 was evaluated. The pre-treatment CT and post-treatment CBCT were exported in DICOM format and subsequently imported into Maxilim (Medicim NV, Mechelen, Belgium). In Maxilim, a hard-tissue reconstruction was generated from the DICOM data. A reference frame was set up for the CT scan.[9] A voxel-based matching algorithm was used to superimpose the post-treatment CBCT scan on the pre-treatment CT scan in the reference frame.[10] Two different matches were generated: one for superimposition of the cranium and one for superimposition of the mandible.

Landmarks were indicated on the coronal slices of the CT and matched CBCT scan on the mesiobuccal cusps of the premolars and molars of the maxilla. Similarly, in the mandible, the mesiolingual cusps of the premolars and molars were identified. The identification of the landmarks was performed twice to assess the influence of intra-observer variability and measurement error on the result. The difference in position of the landmarks pre-treatment and post-treatment was calculated in craniocaudal direction to identify if axial tooth movement had occurred.

Results of the measurements

The mean intra-observer difference between the indicated landmarks of the two measurements was 0.15 ± 0.12 mm. In table 2, the mean difference between pre-treatment and post-treatment is provided for all premolars and molars in the craniocaudal direction. It appears that there is a slight tendency for dental intrusion, this was equally apparent for both the upper and lower dentition. There was no axial tooth movement sufficient enough to explain the correction of the bite.

Table 2. Mean difference between pre-treatment and post-treatment for individual molars and premolars. Measurements are in cranio-caudal direction, where a positive measurement indicates caudal movement of the tooth.

Tooth	Difference pre/post hypomochlion therapy [mm]
14	-0.23
15	-0.17
16	-0.52
17	-0.82
24	-0.56
25	-0.79
26	-0.52
27	-0.81
34	1.10
35	1.36
36	1.14
37	0.94
44	0.57
45	0.23
46	0.66
47	0.80

DISCUSSION

Malocclusion is one of the most common and often difficult-to-manage complications associated with post-traumatic maxillofacial injury.[11] Patients with closed treatment of condylar fractures are reported to have a higher prevalence of developing severe malocclusion compared to patients treated with open treatment.[12] Since malocclusion is one of the factors responsible for mandibular functional impairment, it is important to resolve this complication as early as possible. Treatment options for post-traumatic malocclusion include occlusal adjustments by adjusting the occlusal plane, orthodontic treatment, TMJ reconstruction, and/or orthognathic surgery.[7,8] Orthognathic surgery is most commonly used to correct the malocclusion.[13]

The aim of this case report was to present an alternative non-surgical treatment modality for treating severe long-term malocclusion after fracture of the mandibular condyle. In the four cases presented in this report, post-operative corrective surgery was postponed and occlusal stops were used to attempt malocclusion correction and thereby avoiding corrective surgery altogether.

Normally, occlusal stops can be applied in the early treatment of condylar fractures and are usually placed ipsilaterally between the molars and premolars of the fracture site.[5] The goal then is to distract the posterior mandible caudally along a vertical axis and to rotate the mandible counterclockwise to avoid the fractured parts from overriding when brought to occlusion,[14] hence eliciting a reduction maneuver and proper anatomical alignment simultaneously. Closed treatment, however, will not result in fracture reduction because there is no mode of fixation of the fractured bones, and traction of the muscles will dislocate the bony fragments. Therefore, techniques involving occlusal stops are less frequently used nowadays.

In this report, the occlusal stops were used to correct persistent malocclusion in a later stage of closed condylar fracture treatment. Occlusal stops were used to disrupt the emerging malocclusions that developed during fracture healing and the loading of the joints, and in this way, we were able to gain time in the recovery after trauma. In these cases, occlusal stops were placed up to 11 weeks after trauma (table 1).

The results from the presented cases indicate that post-traumatic malocclusion complications following conservative (closed) treatments of condylar fractures can be successfully resolved without the need for further invasive surgical procedures to correct malocclusion. One way to explain the mechanism underlying the treatment with occlusal stops would be to consider that by placing occlusal stops the occlusion configuration the patient has grown accustomed to in the period of post-traumatic malocclusion can be altered. The occlusal stops will bring the patient out of an occlusal 'comfort zone' and will disrupt the feedback mechanisms that have developed during the period of post-traumatic malocclusion.
This results in a reset of the feedback mechanism enabling the possibility of developing a new-correct-habituation of the occlusion after removal of the occlusal stops. Since self-regulation of dysfunctional habits is unlikely,[15] an important role is reserved for physiotherapy in the period of bite deregulation and in the period after the occlusal stops are removed. After removal of the occlusal stops, the most important task for the physiotherapist is supporting the patient in reaching proper occlusion. The physiotherapist accomplishes this by training adequate rotation and translation of the mandible and by tracing back the correct feedback mechanisms of the patient before trauma.

Occlusal stops or bite-raising adjustments are also applied in the Dahl concept.[16] The Dahl concept refers to the relative axial tooth movement that is observed when a localized appliance or localized restorations are placed in supra-occlusion, the occlusion reestablishes full-arch contacts over a period of time.[16] This technique is used in patients with tooth surface loss. In order to evaluate the possible effects of axial tooth movement on correction of the malocclusion, measurements were performed on the pre-treatment CT and post-treatment CBCT scans.

Landmarks were indicated on the premolars and molars on both the CT and CBCT scans, and repeated measurements showed good reproducibility of the measurement strategy. Indeed, the use of two different imaging modalities may be a source of measurement error; however, the size of the measurement error introduced is expected to be small in comparison to the extent of the malocclusion. Significant axial tooth movement could not be distinguished and thus did not provide an explanation for the correction of the occlusion that occurred in this case. Moreover, axial tooth movement is a long-term process and the contribution of axial tooth movement to correction of occlusion is expected to be limited during short-term occlusal stop treatment.

We can only speculate at this point that the effect of physiotherapy in tracing back the pre-traumatic propriocepsis of the patient, by finding the correct occlusion, may likely contribute significantly towards correction of the bite. In the long-term, occlusion refinement and control might be achieved through combination of the Dahl concept and training by the physiotherapist.

In the present technical note, only four cases were evaluated. Although these results are promising, a larger study population and a randomized study design are needed to establish the clinical value of occlusal stop treatment in managing post-traumatic malocclusion after closed treatment of condylar fractures. The effect of timing of occlusal stop placement, thickness and location of the occlusal stops, and duration of occlusal stop treatment on the outcome of occlusal stop treatment, merit further investigations. Alternatives for the occlusal stops, such as splints, should also be considered in future research. Finally, a reliable measurement has to be established to quantify the effect of the physiotherapy in malocclusion treatment.

CONCLUSION

An alternative non-surgical treatment to surgical correction of long-term post-traumatic malocclusion after closed treatment in condylar fracture was presented. Occlusal stops were used to disrupt malocclusion emergence during fracture healing. Physiotherapy was initiated during occlusal stop treatment and continued several weeks after removal of the occlusal stops to support the patient in reaching proper occlusion. In the four cases described in this report, proper occlusion was achieved without the need for surgical intervention. A randomized clinical trial is needed to establish the clinical value of occlusal stops in treatment of malocclusion after closed treatment of condylar fracture.

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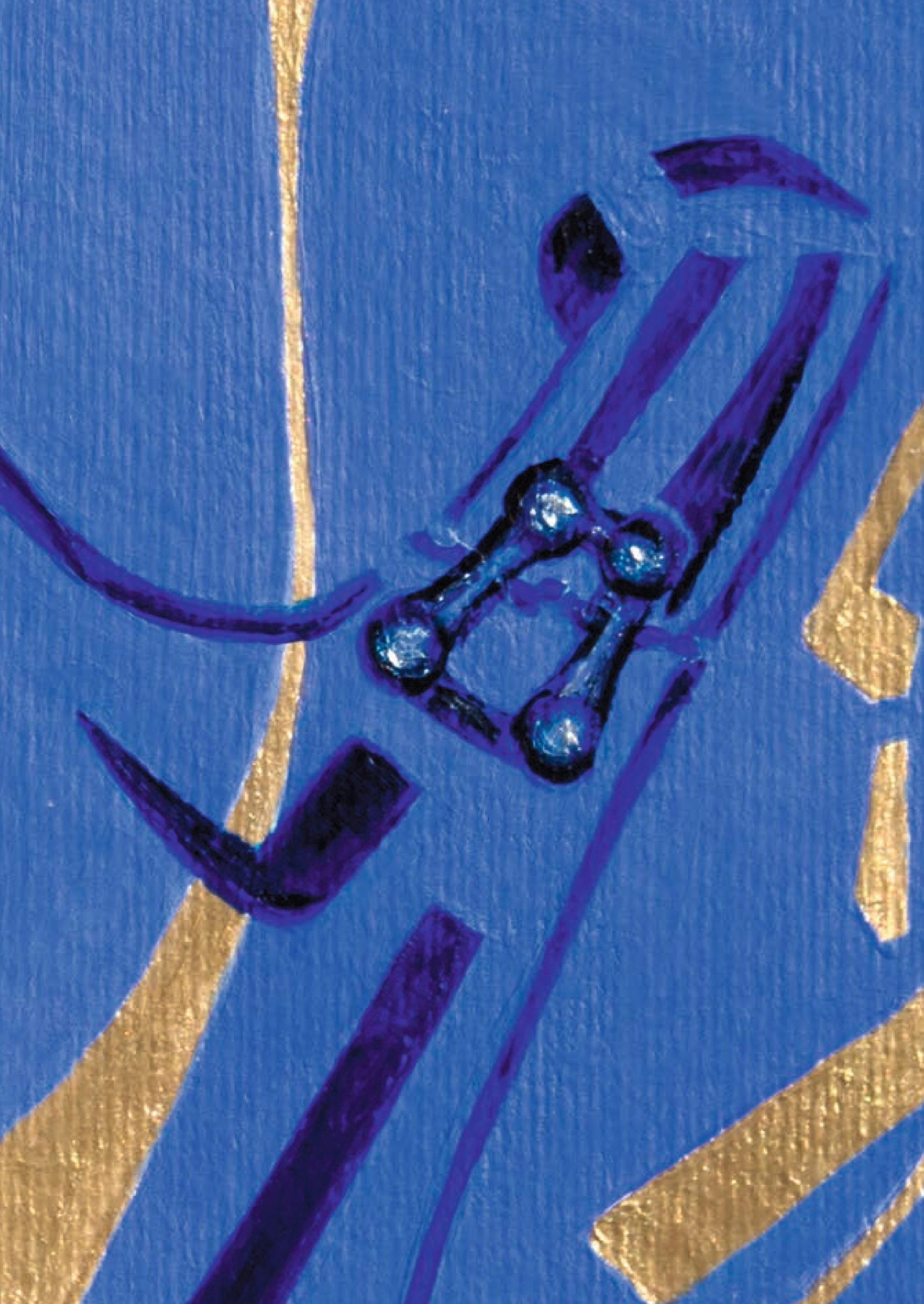
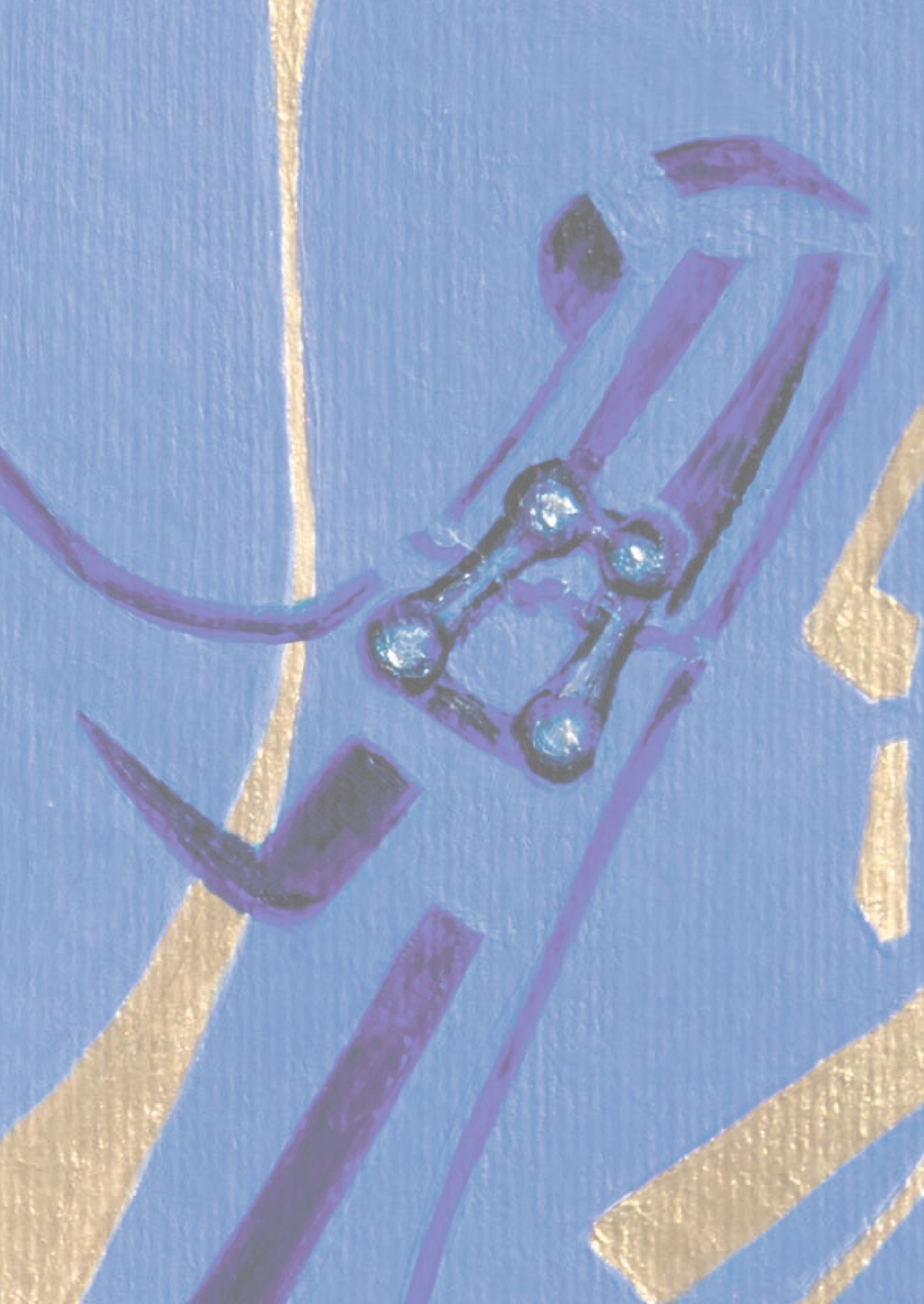


Chapter 3

Open



3.1

Open treatment of unilateral mandibular condyle fractures in adults

This chapter is an edited version of the manuscript:

A. V. J. Rozeboom, L. Dubois, R. R. M. Bos, R. Spijker, J. de Lange

Open treatment of unilateral mandibular condyle fractures in adults: a systematic review

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INTRODUCTION

Since the introduction of rigid internal fixation devices, more and more surgeons favor an open approach to treat condylar fractures of the mandible in adult patients.[1] Different indications for open treatment have been published.[2-5] Based on the literature, strong indications for open treatment are, for example, displacement into the middle cranial fossa, inappropriate occlusal restoration by closed reduction, lateral extracapsular displacement, and foreign material at the fracture site. Although there are other indications, such as bilateral mandibular condyle fractures in edentulous patients who cannot have a splint, where intermaxillary fixation and physical therapy are not possible because of internal disease, bilateral mandibular condyle fractures with comminuted fracture of other facial bones, bilateral mandibular condyle fractures with jaw deformities, and a certain amount of shortening of the ramus and angulation of the condyle, controversies regarding open and closed treatment exist.[2, 6, 7]

The main advantages of open treatment are the ability to restore the most ideal anatomical position. Further, open treatment can prevent complications, such as breathing problems, a pronunciation disorder, or severe nutritional imbalance because of the shorter duration of maxillomandibular fixation (MMF).

This will also potentially allow immediate mobilization of the joint, leading to more efficient functioning of the joint.[7-10]

Because of the technique employed, open treatment is associated with surgical complications. The most concerning complication is permanent damage to the facial nerve. Other surgical complications include malocclusion, pain, reduced mouth opening, restricted range of motion (ROM) of the mandible, weakness of the facial nerve, infection, hemorrhage, Frey syndrome, sialocele/sialofistula, damage of the great auricular nerve, plate fracture and screw loosening, and a visible scar.[11-13]

In this systematic review, studies published on endoscopic or transoral approaches were excluded. Despite the advantages, including absence of scarring (if no transcutaneous trocars are used) and not crossing the facial nerve,[14, 15] it has been found that these intra- and transoral approaches are technically demanding, especially for fractures at higher levels or with medial luxation of the proximal stump.[14, 16, 17] Therefore, in most cases, the intraoral approach is too difficult for both stabilization of fractures and screw fixation. Thus, some say that the intraoral approach can only be used in select cases of low subcondylar fractures, and that this approach requires special instruments, additional training, and a longer operative duration.[18-21] Therefore, we only addressed transcutaneous approaches in this review.

To date, controversies regarding the indications for the open treatment exist. Consequently, this systematic review focuses on the existing open treatment modalities and defines the outcome measures in accordance with our recently published review on closed treatment of mandibular condyle fractures.[22]

METHODS

A systematic literature search was performed on April 29, 2016, using PubMed (all indexed years), Medline (all indexed years), and Embase (all indexed years) with multiple search terms (Appendix 1). The search excluded case reports with 10 or fewer subjects, endoscopic or transoral treatment modalities, and studies in which stainless steel wires for osteosynthesis were used. Reports published in English, German, or Dutch were considered for inclusion.

All prospective and retrospective human clinical studies that reported data relating to any form of open treatment of unilateral fractures of the mandibular condyle and the outcome of that treatment, were included.

The following data were extracted from the selected studies: study design, period of follow-up, patient characteristics (age, gender), details of the fracture, details of the surgical approach, use of MMF, complications of the surgical approach and osteosynthesis material, and treatment outcomes.

Some studies included data on bilateral fractures and children; these data were excluded during data analysis.

Figure 1 shows a flow diagram of the inclusion process. First, two authors (RB, AR) screened titles and abstracts for the potential relevance of the retrieved articles in a primary review process conducted in accordance with PRISMA criteria.[23] Second, full articles were retrieved and relevant articles were designated for inclusion. Disagreement was resolved via discussion with a third person (LD). The included articles were critically appraised using a checklist with key criteria.[24]

Appendix 1.

Pubmed search

(((Mandibular Condyle[tiab] OR collum mandibula*[tiab] OR mandibular neck[tiab]) AND fracture*[tiab]) or ((Condylar[tiab] or subcondylar[tiab]) AND fracture*[tiab]))
AND
(((open[tiab] or rigid[tiab] or internal[tiab] or surg*[tiab] or operati*[tiab]) AND (treatment*[tiab]) OR therap*[tiab] OR reduction[tiab])) or ((open reduction[tiab]) or (internal fixation[tiab]) or ORIF[tiab]))
AND
publisher[sb]

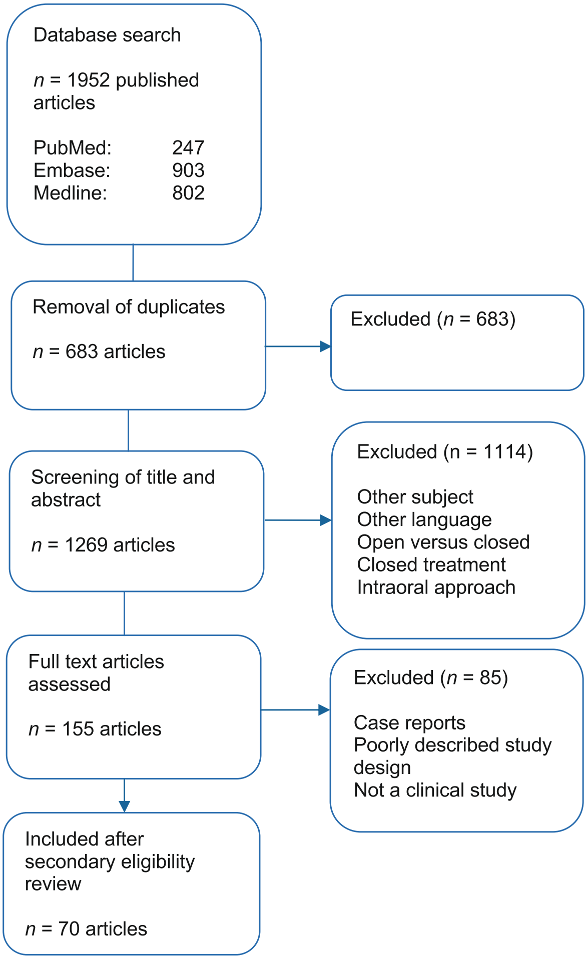
Medline search

((Mandibular Condyle OR collum mandibula* OR mandibular neck) adj3 fracture*).ti,ab,kw or ((Condylar or subcondylar) adj2 fracture*).ti,ab,kw.
((open or rigid or internal or surg* or operati*) adj5 (treatment* OR therap* OR reduction)).ti,ab,kf or ((open adj reduction) or (internal adj fixation) or ORIF).ti,ab,kf or exp fracture fixation, internal/

Embase search

((Mandibular Condyle OR collum mandibula* OR mandibular neck) adj3 fracture*).ti,ab,kw or ((Condylar or subcondylar) adj2 fracture*).ti,ab,kw.
((open or rigid or internal or surg* or operati*) adj5 (treatment* OR therap* OR reduction)).ti,ab,kw or ((open adj reduction) or (internal adj fixation) or ORIF).ti,ab,kw or exp osteosynthesis/

Figure 1. A flow chart demonstrating the inclusion process



RESULTS

A total of 70 studies with a combined total of 3052 patients, ranging from 11 to 230 patients in each study (with a male to female ratio of 2.7:1), were selected.[12, 14, 16, 18, 25-90] The year of publication of the selected studies ranged from 1980 to 2016. The sample size in almost 50% of the studies was fewer than 100 patients. The mean age of patients was 32.2 years, with a range of 4 to 91 years. In 19% of cases, both mandibular joints were fractured, and in 81% of cases, the fractures were unilateral. Of these fractures, 9% were located intracapsularly and 91% extracapsularly. The period of follow-up varied widely, from 5 days to 119 months. Yabe et al.[85] reported the longest period of follow-up at 119 months.

Retrospective studies

Of the assessed studies, 38 (54.3%) were retrospective in nature, and included a heterogeneous series of mandibular condyle fractures and treatment modalities. The clinical outcome measurements in these studies were diverse and the follow-up periods were variable (range: 5 days to 119 months). Of all the included studies, Eckelt and Hlawitschka[52] had the largest sample size (230 patients).

Prospective studies

Thirty-two (45.7%) prospective studies were identified. There were two randomized clinical trials, both comparing different osteosynthetic materials. Rai[66] compared the use of single and double non-compression miniplates and Seemann et al.[73] compared the use of locking and non-locking plates. The follow-up duration ranged from 1 month to 66 months.

Overview of treatment modalities applied in the included studies

The treatments varied in the approach and material used for osteosynthesis. In the order of most frequently employed to the least frequently employed, the treatment approaches were as follows: retromandibular (31.4%), pre-auricular (12.9%), submandibular (7.1%), peri-angular (8.6%), and other (8.6%). In some studies, more than one approach was employed (22.9%; of these, retromandibular 30.3%, pre-auricular 36.4%, submandibular 21.2%, and other 12.1%), and in some studies the approach was not described (8.6%). Retro-auricular, extended bicoronal, rhytidectomy/facelift were also noted to have been employed along with a supratemporal approach, a curved incision in the ear lobule area, or a parotid mini incision.
The approach was transparotid in 37.1% of the studies, non-transparotid in 21.4%, both transparotid and non-transparotid in 7.1%, and 34.3% of the studies did not describe whether the approach was transparotid.

Focusing on the individual approaches, 56.3% of the retromandibular approaches were transparotid, 12.5% were non-transparotid, 9.4% described both transparotid and non-transparotid, and in 21.9% it was not described whether the approach involved the parotid gland. Where the pre-auricular approach was used, 14.3% of the studies reported the involvement of the parotid gland, 19% did not, and in 66.7% of studies involvement of the parotid gland was not defined.

In most studies, osteosynthesis (plates) was used for fixation (80.6%; 5.2% resorbable and 94.8% titanium). Lag screws were used in 6.9% of the studies and a combination of plates and lag screws was used in another 6.9% of the studies. In 5.6% of the studies, the method of fixation was not described.

In 34.3% of the studies, MMF was applied during surgery, but in 60% of the studies, the use of MMF during surgery was not reported. In 26.4% of the studies, MMF was continued after surgery as a standard postoperative therapy. In 22.2% of the studies, MMF was only used in the event of a malocclusion. In 16.7%, no MMF was used postoperatively and in 34.7% the use of MMF was not described.

The duration of postoperative MMF varied from 3 days to a maximum of 4 weeks. The most commonly used method of fixation was guiding elastics; however, Narayanan et al.[62] used stainless steel wires. Most studies recommended a soft diet for 3 to 6 weeks and mouth opening exercises or physiotherapy after open reduction.

Indications mentioned for open treatment included malocclusion, inability to restore occlusion with closed treatment, patient not willing to have MMF, fracture displacement, and shortening of the ramus. Exclusion criteria for open treatment included undisplaced intracapsular and/or comminuted fractures, pediatric patients, or the patient being unfit for surgery.

Outcome measures

Table 1 gives an overview of the most uniformly reported outcome measures: occlusion, mouth opening, ROM of the mandible, and pain.

In the studies that reported these outcome measures, 72.7 to 100% of patients had no occlusal disturbances at the end of the follow-up period. The presence of some form of malocclusion ranged from 0 to 27.3%. Nonetheless, the need to perform orthognathic surgery was not described. The degree of mouth opening considered to constitute a 'good' outcome varied. Some authors reported that it was equivalent to that of more than 30 mm, some used a threshold of more than 35 mm, and others used a threshold of more than 40 mm. Overall, limited mouth opening was reported in 0 to 27.3% of patients and a reduced ROM of the mandible in 0 to 42.1% of patients. No cases of ankylosis were reported. The reported incidences of persistent pain ranged from 0 to 42.1%.

Surgical complications were observed (Table 2), including weakness of the facial nerve (12%; of which approximately 5% of cases were permanent), hematoma (1.7%), wound infections (≥2.9%), Frey syndrome (1.1%), sialocele (2.6%), salivary fistula (≥4.8%), disturbance of the sensory component of the great auricular nerve (7.9%), and unsatisfactory scarring (≥1.6%). Fifty-seven percent of the studies investigated the incidence of fixation failure as an outcome measure. In these studies, 5.5% of patients experienced some form of fixation failure, i.e., plate or screw breakage/loosening.

Table 1. Characteristics of treatment outcomes

Authors	Occlusion *% no malocclusion*	Mouth opening good (%)	Range	Mean *(mm)*	ROM *(% unlimited)*	Pain *(% free of pain)*
Baek	100	100	>30 mm	ND	100	NCD
Benech	100	ND	ND	38	ND	ND
Bhutia	100	100	ND	ND	100	ND
Biglioli	95.2	ND	ND	ND	ND	ND
Biglioli	100	ND	ND	ND	ND	ND
Bindra	100	ND	ND	34	100	100
Bouchard	ND	ND	ND	ND	ND	ND
Chossegros	79	100	>35 mm	ND	Numbers given	100
Colletti	100	99	>38 mm	ND	100	100
Croce	100	100	≥40 mm	ND	100	100
Dalla Torre	100	ND	42–58 mm	44	ND	ND
Downie	100	ND	ND	ND	ND	ND
Dunaway	96	ND	37–50 mm	43	ND	ND
Ebenezer	100	ND	ND	ND	ND	100
Girotto	ND	ND	ND	ND	ND	ND
Hou	100	100	ND	ND	ND	ND
Kanno	100	100	>40 mm	ND	100	100
Kim	100	100	>40 mm	ND	ND	78.57
Klatt	84	ND	33–59 mm	42.37	Numbers given	ND
Kumaran	100	ND	ND	44.84	Numbers given	ND (VAS)
Li	100	ND	ND	34.15	ND	ND
Manisali	ND	ND	ND	ND	ND	ND
Nam	100	ND	38–56 mm	46.6	ND	ND
Narayanan	100	ND	ND	45	Numbers given	ND
Narayanan	100	ND	ND	44	Numbers given	ND
Pilanci	ND	ND	40–50 mm	46	Numbers given	100
Rao	100	ND	30–44 mm	38.33	100	ND
Saikrishna	76.7	100	>40 mm	ND	ND	100
Salgarelli	92.3	ND	30–60 mm	ND	ND	92.3
Shi J	100	ND	30–48 mm	40	ND	100
Sikora	100	ND	45–54 mm	48	ND	ND

Table 1. Continued

Authors	Occlusion *% no malocclusion*	Mouth opening *good (%)*	Range	Mean *(mm)*	ROM *(% unlimited)*	Pain *(% free of pain)*
Tang	88.2	86.1	>37 mm	ND	ND	ND
Trost	80	97.1	to 40 mm	ND	97.1	100
Vesnaver	94	ND	30–61 mm	44	ND	59
Vogt	100	ND	ND	ND	ND	ND
Yabe	100	ND	ND	ND	ND	ND
Yang	93	ND	32–61 mm	44	ND	100
Zhou	92	ND	+/- 40 mm	ND	ND	94
Alexander	100	ND	16–50 mm	30	ND	100
Choi	80	96	≥40 mm	ND	ND	80
Eckelt	100	4	<35 mm	ND	95.5	90.9
Hammer	ND	90	≥35 mm	ND	ND	99.7
Hyde	100	ND	37–52 mm	42	ND	100
Iizuka	100	89	>40 mm, 27–74 mm	44	ND	89.2
Iizuka	ND	ND	22–50 mm	39	Numbers given	76.9
Lima	ND	ND	ND	ND	ND	ND
Petzel	100	ND	ND	ND	ND	ND
Raveh	100	ND	ND	>40 mm	ND	ND
Sargent	92	ND	35–56 mm	45	ND	92.9
Spinzia	80	62.5	>40 mm, 18-50 mm	35.48	Numbers given	72
Widmark	89.50	ND	40–67 mm	51	57.9	57.9
Zrounba	99.3	ND	21–56 mm	42.10	Numbers given	ND
Chaithanyaa	80	≥ 86.7	(≥46.7: 38-40 mm, 40: 30-35 mm)	ND	ND	ND
Chaudhary	100	ND	34–42 mm	36.13	ND	100
Choi	83.8	≤ 91.9	(75.7 >38 mm)	ND	ND	ND
Cortelazzi	100	ND	35–48 mm	41	±100	±100
Derfoufi	ND	ND	ND	ND	ND	ND
Eckelt	ND	100	≥30 mm	ND	92.2	85.4
Eckelt	99.1	91.7	≥35 mm	ND	88.7	ND
Hachem	ND	100	≥30 mm, 68.2 >40 mm	ND	90.9	90.9
Kallela	72.7	90.9	(82 >40 mm)	ND	100	90.9
Meyer	94	100	>40 mm	49.5	100	100
Petzel	ND	ND	32–51 mm	ND	Numbers given	ND
Rai	93.3	ND	ND	ND	ND	ND
Rallis	ND	93.6	>40 mm, (6.4 < 35 mm (28–34 mm))	ND	ND	ND
Seemann	ND	ND	ND	ND	ND	ND
Singh	ND	ND	ND	ND	ND	ND
Sugiura	94.4	ND	ND	42.8	Numbers given	96.3
Xie	80.6	ND	ND	38.3	ND	94.4
Zhang	100	ND	ND	ND	ND	ND

ND: not described

Table 2. Surgical complications associated with the open treatment of unilateral mandibular condyle fractures

Author	Wound infection	Hematoma formation	Sialocele	Salivary fistula	Scar	Facial nerve *(total)*	*percentage*	Recovery *time*	Permanent	Auricular anesthesia	Frey syndrome
Baek	None	NCD	ND	1 (5.3%)	Not disturbing	2	11.8	3 months	None	None	ND
Benech	None	None	None	None	Not disturbing	1	7.1	1.6 months	None	None	None
Bhutia	None	ND	ND	3 (6.8%)	Not disturbing	9	21.9	3–6 months	None	ND	ND
Biglioli	2 (8%)	ND	ND	ND	2 (8%) unsatisfactory	None	0	NA	None	ND	ND
Biglioli	2 (5.3%)	ND	ND	ND	2 (5.3%) unsatisfactory	None	0	NA	None	ND	ND
Bindra	None	ND	ND	None	Not disturbing	None	0	NA	None	ND	None
Bouchard	14 (11.9%)	ND	2 (1.7%)	4 (3.4%)	ND	35	29.7	NA	1 (0.8), (6.8 unknown)	ND	1 (0.9%)
Chossegros	1 (5.2%)	ND	ND	ND	2 (11%) unsatisfactory	2	10.5	3.6 weeks	None	2 (10.5%) transient	ND
Colletti	3 (3%)	ND	1 (1%) (trans)	ND	2 (2%) unsatisfactory	4 (ND)	4.6	2 months	None	ND	ND
Croce	ND	None	None	4 (22.2%)	Not disturbing	6	46.2	4–8 weeks	None	ND	1 (5.6%)
Dalla Torre	ND	ND	7 (6.8%)	None	Not disturbing	4	3.9	3–6 months	None	ND	ND
Downie	1 (2%)	ND	1 (2%)	1 (2%)	ND	7	14	NA	None	ND	ND
Dunaway	ND	1 (3.4%)	ND	ND	Not disturbing	3	12	6 weeks	None	ND	ND
Ebenezer	None	ND	ND	3 (15%) (trans)	4 (20%) unsatisfactory (1 sub, 3 after fistula)	NCD	NCD	NCD	NCD	ND	None
Girotto	None	ND	ND	None	Not disturbing	2	8	1–2 weeks	None	None	ND
Hou	None	ND	ND	3 (4.2%) (1 min, 2 ret)	ND	4 (retro)	6.7	ND	1 (1.7)	ND	ND
Kanno	None	ND	ND	1 (5.3%)	Not disturbing	2	11	3 months	None	ND	None
Kim	None	ND	ND	3 (10.7%)	Not disturbing	9	32.1	6–20 weeks	None	1 (3.57%) transient	ND
Klatt	None	None	ND	2 (4%)	ND	4	10	6 weeks	None	5 (16%) lasting > 6 months	ND

Table 2. Continued

Author	Wound infection	Hematoma formation	Sialocele	Salivary fistula	Scar	Facial nerve *(total)*	*percentage*	Recovery *time*	Permanent	Auricular anesthesia	Frey syndrome
Kumaran	ND	ND	1 (2.9%) (retro)	ND	Disturbing in pre-auricular group (n=12)	4 (3 pre, 1 retro)	12.9	ND	ND	ND	ND
Li	None	ND	ND	ND	ND	7	8.3	ND	2 (2.4)	ND	None
Manisali	ND	ND	1 (4%)	ND	2 (8%) unsatisfactory	6	30	3 months	None	2 (8%) transient	ND
Nam	ND	ND	ND	ND	ND	4	16	1–2 months	None	ND	ND
Narayanan	2 (5.7%)	ND	ND	4 (11.4%)	2 (5.7%) unsatisfactory	1	32.3	2 weeks	None	ND	None
Narayanan	1 (0.7%)	ND	None	None	ND	None	0	NA	NA	ND	None
Pilanci	1 (5%)	None	None	None	Not disturbing	1	6.3	6 weeks	None	None	ND
Rao	None	ND	ND	3 (17.6%)	Not disturbing	2	13.3	4–3 months	None	ND	None
Saikrishna	None	1 (3.3%)	3 (10%)	ND	6 (40%), 1 hypertrophic (3.3%) unsatisfactory (retro)	4	13.3	ND	None	1 (3.3%) transient	ND
Salgarelli	ND	ND	ND	ND	Not disturbing	1	7.7	1 week	None	ND	ND
Shi J	ND	1 (2.8%)	1 (2.8%)	ND	Not disturbing	None	0	NA	NA	ND	ND
Sikora	ND	ND	ND	ND	Not disturbing	3	7.9	3 months	None	ND	ND
Tang	ND	ND	ND	None	ND	4	7.8	1–3 months	None	ND	ND
Trost	1 (2.6%)	ND	ND	ND	1 (2.6%) unsatisfactory	None	0	NA	NA	ND	ND
Vesnaver	ND	2 (6%)	ND	5 (14%)	Not disturbing	8	22	4–8 weeks	1 (2.8)	5 (14%) transient	ND
Vogt	None	ND	ND	4 (7.8%)	Not disturbing	10	19.6	6 months	None	ND	ND
Yabe	1 (6.7%)	ND	ND	None	Not disturbing	None	0	NA	NA	ND	None
Yang	None	2 (4.2%)	ND	3 (6.3%)	Not disturbing	8	19	3–4 weeks	None	None	ND
Zhou	None	ND	ND	None	Not disturbing	7	8	1 month	None	ND	ND
Alexander	None	ND	ND	ND	ND	7	31.8	1–3 months	None	ND	ND
Choi	≥2 (7.4%)	ND	ND	≥2 (7.4%)	Not disturbing	5	20	3 months	None	5 (18.5%) transient	ND

Table 2. Continued

Author	Wound infection	Hematoma formation	Sialocele	Salivary fistula	Scar	Facial nerve *(total)*	*percentage*	Recovery *time*	Permanent	Auricular anesthesia	Frey syndrome
Eckelt	ND	ND	ND	ND	ND	2	9.1	ND	ND	ND	ND
Hammer	≥3 (10%)	ND	ND	≥3 (10%) (ND)	ND	1	0.3	8 weeks	None	ND	ND
Hyde	ND	ND	ND	ND	ND	3	12	3 weeks	None	ND	ND
Iizuka	ND	ND	ND	ND	ND	2	7.4	2–6 weeks	None	ND	ND
Iizuka	ND	ND	ND	ND	1 (4.8%) unsatisfactory (sub)	2	15.4	6 months	1 (7.7)	ND	ND
Lima	3 (4.6%)	ND	1 (1.5%)	None	Not disturbing	3	5.2	6 months	1 (1.7)	ND	None
Petzel	ND	ND	ND	ND	ND	ND	ND	ND	None	ND	ND
Raveh	ND	ND	ND	ND	ND	None	0	NA	NA	ND	ND
Sargent	None	ND	ND	ND	ND	1	7.1	Weeks	None	ND	ND
Spinzia	1 (3.8%)	ND	ND	None	3 (12%) unsatisfactory (ND)	22	12	3 years	None	ND	3 (11.5%)
Widmark	1 (5%)	ND	ND	ND	Not disturbing	1	5.3	4 weeks	None	3 (15%)	ND
Zrounba	ND	1 (0.6%)	ND	ND	Not disturbing	7	4.9	ND	1 (0.7)	ND	1 (0.6%)
Chaithanyaa	2 (13.3%)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chaudhary	ND	ND	ND	ND	ND	ND	ND	1 month	None	ND	ND
Choi	≥3 (7.5%)	ND	ND	≥3 (7.5%)	ND	7	18.9	3 months	None	ND	ND
Cortelazzi	6 (9.7%)	ND	ND	10 (16.1%) (retro trans)	ND	18 (11 retro, 7 pre)	29	3–4 weeks	None	ND	ND
Derfoufi	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Eckelt	ND	ND	ND	ND	ND	8	7.8	ND	8 (7.8)	ND	ND
Eckelt	3 (1.2%)	1 (0.4%)	ND	ND	Few unsatisfactory	54	21	ND	1 (0.4)	ND	ND
Hachem	≥1 (3.3%)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Kallela	ND	ND	ND	ND	1 (7.7%) unsatisfactory	3	27.3	1–5 months	None	ND	ND
Meyer	1 (1.4%)	ND	ND	ND	1 (1.4%) unsatisfactory	None	0	NA	NA	ND	ND

Table 2. Continued

Author	Wound infection	Hematoma formation	Sialocele	Salivary fistula	Scar	Facial nerve *(total)*	*percentage*	Recovery *time*	Permanent	Auricular anesthesia	Frey syndrome
Petzel	ND	ND	ND	ND	ND	None	0	NA	NA	ND	ND
Rai	2 (13.3%)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Rallis	ND	ND	ND	ND	ND	5	10.6	1–2 months	None	ND	ND
Seemann	1 (0.8%)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Singh	None	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sugiura	1 (1.7%)	ND	ND	ND	ND	6	11.1	>6 months	ND	ND	ND
Xie	ND	ND	ND	ND	ND	3	8.3	ND	None	ND	ND
Zhang	ND	ND	ND	1 (1%)	ND	4	4	3 months	None	ND	ND

ND: not described

DISCUSSION

The ideal outcome of an open treatment of a condylar fracture would be restoration of occlusion, unrestricted mouth opening and ROM of the jaw, and no pain. Further, the treatment should be minimally invasive, without surgical complications, and the period of recovery should be short without use of prolonged MMF.

This systematic review found that most studies reported good results with regard to the outcome measures of open treatment. Instances of good recovery of occlusion ranged from 72.7 to 100%. Similar results were observed for full recovery of mouth opening, which ranged from 72.7 to 100%. Lateral movements, which are included in the ROM, were fully restored in 57.9 to 100% of patients, and 57.9 to 100% of patients were free of pain at their last visit.

Surgical complications including hematoma, wound infection, weakness of the facial nerve, sialocele, salivary fistula, sensory disturbance of the great auricular nerve, unsatisfactory scarring, and fixation failure were reported in the studies.

Facial nerve weakness occurred in 12% of patients; these weaknesses were seen in 55.4% of patients after using the transparotid approach, in 40.5% using a non-transparotid approach, and in 3.9% the approach was not described. With regard to permanent facial nerve weakness, 26.7% of cases occurred after a transparotid approach, but 73.3% occurred after a non-transparotid approach. No explanation for these outcomes was given, but one possible cause for this damage to the facial nerve might be traction on the nerve.

With respect to sialoceles and salivary fistulae, one could argue that the likelihood of these complications is higher when an approach through the parotid gland is used than when the parotid gland is avoided. Indeed, in the studies included in this review, sialoceles and salivary fistulae were only seen in patients in whom a transparotid approach was used. One exception was a patient with a salivary fistula in the study reported by Hou et al.[37] after an anterior parotid approach. Most authors report that tight closure of the parotid fascia will prevent these complications.

Of patients who were dissatisfied with their scar, 58.5% underwent a retromandibular approach, 22.6% a pre-auricular approach, 5.7% a submandibular approach, a minority underwent a peri-angular approach, and one patient had an anterior parotid approach. The rhytidectomy (or facelift approach) produced no unsatisfactory results.

No clear difference was found between fixation failure in the studies published recently and the studies published in earlier years. While one would expect that the hardware has developed over the years, some studies pointed out that one miniplate is not stable and that two miniplates,[66] or at least a 2.0 mm-plate[81] should be used.

As mentioned earlier, the potential advantages of an open treatment are restoration of correct anatomical position and a shorter duration of MMF, which would lead to immediate mobilization and more efficient functioning of the joint.[7-9]

Strikingly, MMF was used in the majority of studies involving open treatment, although it could be argued that the main advantage of open treatment is that MMF should not be needed, and mobilization of the jaw could be initiated straight after surgery. Additional treatment in the form of MMF was described in 65.3% of the studies; MMF was applied routinely after surgery in 26.4% of the studies, MMF was only applied in cases of malocclusion in 22.2%, no MMF was used in 16.7%, and was not described in 34.7%. If MMF was used, the duration varied from 3 days to a maximum of 4 weeks.

Additional treatments, such as physiotherapy, were poorly described. Most studies recommended a soft diet for 3 to 6 weeks and mouth opening exercises or physiotherapy after open reduction. However, it is not clear in the reports what these treatments constituted and what their potential or actually achieved benefits were.

Hence, given that there seems to be no significant difference in outcomes between the open and closed treatment modalities, and taking into account that the open treatment of condylar fractures is associated with surgical complications and the advantages such as early mobilization and recovery seem small, in most cases MMF is still used, and the aftercare protocol for open and closed treatment does not seem to differ substantially, it is difficult to see the benefits of open treatment and what its indications should be.

A potential shortcoming of this study is that the studies included were focused on open treatment only. Therefore, it is possible that data on open treatment from studies investigating open versus closed treatment were omitted.

However, we are of the opinion that open versus closed studies tend to focus on the controversial aspects of this treatment and its indications rather than discussing separate treatment modalities, and that each hospital/center in these studies would most likely have a specific treatment that they focus on, whether open or closed, resulting in a skewed impression.[91]

There was substantial heterogeneity in the study populations included in this systematic review. Most studies did not differentiate between unilateral and bilateral condylar fractures, subcapsular and intracapsular fractures, or fractures in adults and children, nor did the studies in most cases clearly address any additional trauma/fractures. These data deficiencies made it difficult to interpret the data in a uniform manner. Moreover, there was substantial diversity with regard to indications for open treatment and the treatment protocols used. Further, the outcome measures and the way in which these were evaluated were often inadequately described and variable between studies. Owing to this heterogeneity of the groups, fractures, and approaches, as well as the variability in outcome measurements, no evidence-based conclusions or guidelines can be formulated with regard to the most appropriate open treatment.

At present, there is no consensus regarding the most appropriate method for management of fractures of the mandibular condyle. Despite an inability to directly compare the outcomes noted in this systematic review on open treatment with the outcomes of the systematic review on closed treatment,[22] we can state that both studies had good outcomes in general (Table 3). However, there is a lack of high-quality evidence for the effectiveness of either approach. The indications for open treatment are not conclusive. If open treatment is contemplated, to date there is no clear treatment protocol outlining the best approach and hardware, use of MMF, or the indication for and nature of aftercare.

The aim of this systematic review was to provide an overview of the studies published exclusively on open treatment, and to summarize the existing open treatment modalities and their clinical outcomes. A uniform protocol/guideline for open treatment could ensure better clinical practice. In order to construct such a treatment protocol, it is necessary to compare the results of open treatment reported in the different studies.

Further research in the form of a randomized clinical trial comparing the two treatment options is necessary to be able to make an informed choice between open and closed treatment for unilateral mandibular condyle fractures.

Table 3. A comparative analysis of open versus closed treatments for unilateral mandibular condyle fractures

	Occlusion	Unlimited	Unlimited ROM	Late pain
	(% cases with no malocclusion)	mouth opening (% cases)	(% cases)	(% cases)
Open	72.7 to 100%.	72.7 to 100%	57.9 to 100%	0 to 42.1 %
Closed	76 to 100%	68 to 100%	65 to 100%	0 to 16%

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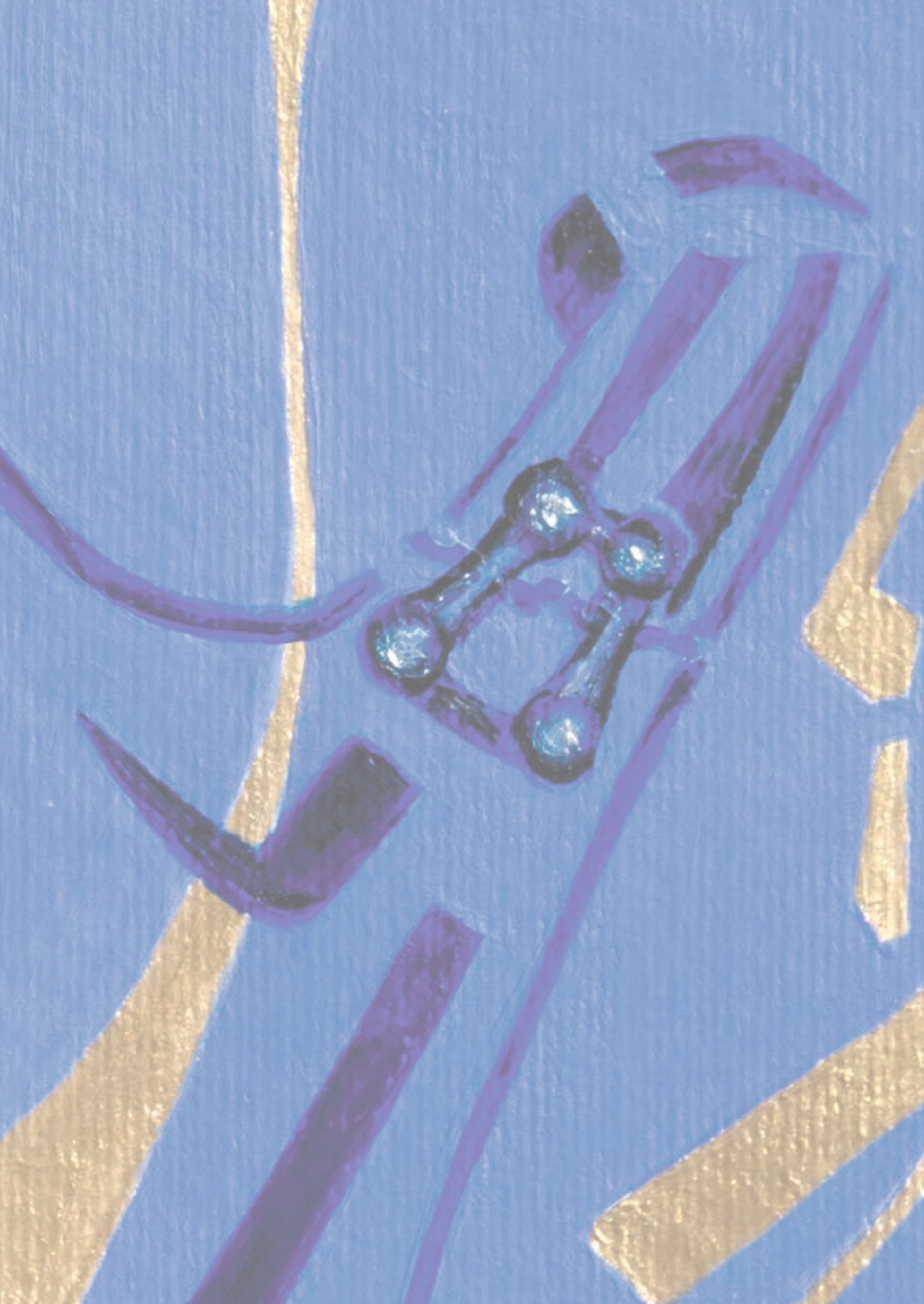

3.2

Open treatment of condylar fractures: extraoral approaches

This chapter is an edited version of the manuscript:

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Open treatment of condylar fractures via extraoral approaches:
a review of complications

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INTRODUCTION

Anatomical reduction and adequate fixation rely on good surgical exposure of the fracture site.[1] Thus, the ideal approach should allow enough exposure to reduce the fracture and position the hardware, but also have the lowest rate of surgical complications, be the least invasive, result in the least conspicuous postoperatively scarring, and be performed easily and rapidly.[2-4]

The treatment of condylar fractures is a controversial subject in numerous scientific reports.[5,6] Even when there is a clear indication for treating these fractures, the appropriate approach becomes another subject of debate. In order to achieve anatomic reduction, it is essential to obtain complete exposure of the surgical field for direct visualization of the fracture and mobilization of the displaced segment.[7] To establish this, different approaches to the mandibular condyle are described; the three most used are the pre-auricular, retromandibular, and submandibular approaches.[2,8] The choice of approach is often based on the level of fracture. Fractures are subdivided into condylar base, condylar neck (extracapsular), and condylar head (intracapsular) fractures.[9-12]

With respect to the level of the fracture, one could argue for using the pre-auricular or perilobular approach for high condylar fractures,[13] the retromandibular approach for middle-height fractures,[13-16] and the retromandibular, or a variety of submandibular approaches for low condylar fractures.[13-17] Although the open approach is superior in terms of restoring anatomy, open treatment can potentially result in surgery-related complications. The greatest risk is damage to the facial nerve.

The approach dictates the exposure, but also the degree and number of complications, due to the layers of dissection and anatomical structures present, i.e., the facial nerve, the great auricular nerve, and the parotid gland. It is said that the choice of surgical approach is of vital importance in reducing postoperative complications.[7] In this matter, the focus of debate is not on the skin incision, but rather the subcutaneous dissection.

The aim of this study was to provide an overview of the complications of extraoral approaches in the open treatment of condylar fractures to enable a well-founded choice for one or more approaches.

METHODS

A systematic literature search (April 29, 2016) was performed on PubMed (all indexed years), Medline (all indexed years), and Embase (all indexed years), using multiple search terms. The search excluded case reports with 10 or fewer subjects and studies in which stainless steel wires were used for osteosynthesis. Furthermore, studies published on endoscopic or transoral approaches were excluded. Despite their advantages, i.e., no scarring (if no transcutaneous trocars are used) and no crossing of the facial nerve,[18,19] it has been found that these intra- and transoral approaches are technically demanding, especially for fractures at higher levels or with medial dislocation of the proximal fragment.[18,20,21] Therefore, in most cases, the intraoral approach is too difficult for most surgeons for both reduction of fractures and fixation. Some authors indicate that the intraoral approach can only be used in selected cases of low subcondylar fractures, and that this approach requires special instruments, additional training, and a longer operative duration.[3,22-24]

Only reports in English, German, or Dutch were considered. Prospective and retrospective human clinical studies that reported data relating to open treatment for unilateral fractures of the mandibular condyle, and the outcome of that treatment, were included. Our study was conducted using the data of a systematic review on open treatment of condylar fractures by the same authors.[6] In our study, concerning solely the outcome of the approaches, we did include the bilateral fractures that were also described in the included studies.

First, two authors (RB and AR) screened the titles and abstracts of the retrieved articles for potential relevance. Second, full articles were retrieved and relevant articles were designated for inclusion. Disagreement was resolved via discussion with a third person (LD). The included articles were critically appraised by a checklist with key criteria (Table 1).[25]

Table 1. Critical appraisal of the studies included [a]

	Criteria[b]							
	1	2	3	4	5	6	7	8
Baek	+	+/-	+/-	-	+	+	+	+
Benech	+	+	+/-	+	+	+	-	-
Bhutia	+	+	+	-	+/-	+	+	+
Biglioli	+	-	-	+	NA	+	-	-
Biglioli	+	-	-	+	NA	+	-	-
Bindra	+	+	+	-	+/-	+	+	+/-
Bouchard	+	+	+	+	NA	+	-	+
Chossegros	+	+	+/-	+	+/-	+	+	+
Colletti	+	+	+/-	+	NA	+	-	-
Croce	+	+/-	+/-	+	NA	+	-	+
Dalla Torre	+	+	+	+	NA	+	-	NA
Downie	+	+	+/-	-	+	+	+	+
Dunaway	+	+	+	-	NA	+	-	+/-
Ebenezer	+	+	+	+	+/-	+	+	-
Girotto	+	+/-	-	+	NA	+	-	-
Hou	+	+	+	+	NA	+	-	-
Kanno	+	+	+	+	+	+	+	+
Kim	+	+	+/-	+	NA	+	-	-
Klatt	+	+	+/-	+	+/-	+	+	+
Kumaran	+	+	+/-	+	+/-	+	+	+/-
Li	+	+	+	+	+/-	+	+	+/-
Manisali	+	+	+/-	+	+	+	+	+
Nam	+	+	-	+	NA	+	-	+/-
Narayanan	+	+	+	-	NA	+	-	+/-
Narayanan	+	+	+	-	+/-	+	+	+/-
Pilanci	+	+/-	-	+	NA	+	-	-
Rao	+	+	+	-	+/-	+	+	+/-
Saikrishna	+	+	+/-	-	+/-	+	+	+/-
Salgarelli	+	+	+	-	NA	+	-	+/-
Shi J	+	+	+	+	+/-	+	+	+
Sikora	+	+	+	+	+/-	+	+	+/-
Tang	+	+	-	+	+/-	+	+	+/-
Trost	+	+	+/-	-	+/-	+	+	+/-
Vesnaver	+	+	+/-	+	+/-	+	+	+/-
Vogt	+	+	+/-	-	+/-	+	+	+/-
Yabe	+	+/-	-	+	NA	+	-	+/-
Yang	+	+	+/-	+	+/-	+	+	+
Zhou	+	+	+	+	NA	+	-	+/-
Alexander	+	+	+/-	+	NA	+	-	+
Choi	+	+	+/-	+	+	+	+	+/-
Eckelt	+	+	+/-	-	NA	+	-	-
Hammer	+	+	+/-	+	NA	+	-	+
Hyde	+	+	+	+	+	+	+	+

Table 1. Continued

	Criteria[b]							
	1	2	3	4	5	6	7	8
Iizuka	+	+	+/-	+	NA	+	-	+
Iizuka	+	+	+/-	+	-	+	+	+
Lima	+	+	+/-	+	NA	+	-	-
Petzel	+	+	-	+	+/-	+	+	+/-
Raveh	+	+	+	+	NA	+	-	+/-
Sargent	+	+	+/-	-	NA	+	-	+
Spinzia	+	+	+	+	NA	+	-	+/-
Widmark	+	+	+	+	NA	+	-	+
Zrounba	+	+	+/-	+	NA	+	-	+
Chaithanyaa	+	+	-	-	NA	+	-	-
Chaudhary	+	+	+	-	+/-	+	+	+/-
Choi	+	+	+/-	-	NA	+	-	+/-
Cortelazzi	+	+	+	+	+/-	+	+	+
Derfoufi	+	+	+/-	+	+	+	-	-
Eckelt	+	+	+/-	-	NA	+	-	+/-
Eckelt	+	+	+	+	NA	+	-	+
Hachem	+	+	+/-	+	NA	+	-	-
Kallela	+	+	+/-	+	NA	+	-	+
Meyer	+	+	+	+	+/-	+	+	+
Petzel	+	+	+/-	+	+/-	+	+	+/-
Rai	+	+	+	+	+/-	+	+	+/-
Rallis	+	+	+/-	-	NA	+	-	+/-
Seemann	+	+	+	+	+/-	+	+	-
Singh	+	+	+	-	+/-	+	+	+/-
Sugiura	+	+	+	+	NA	+	-	+
Xie	+	+	+/-	+	NA	+	-	+/-
Zhang	+	+	+	+	NA	+	-	+/-

NA, not applicable

[a] +, yes; -, no; +/-, uncertain

[b] 1 = Clear study objective/question, 2 = Well- defined study protocol, 3 = Explicit inclusion and exclusion criteria for study participants, 4 = Specified time interval for patient recruitment, 5 = Consecutive patient enrollment, 6 = Clinically relevant outcomes, 7 = Prospective outcome data collection, 8 = High follow up rate/drop outs analysed

Definitions

Clear definitions were essential for preventing further disagreements. In defining an extraoral approach, a discrimination between skin incision and subcutaneous dissection was made. Three main skin incisions/approaches were distinguished: pre-auricular, retromandibular, and submandibular (Figure 1). In general, the pre-auricular approach uses an incision to approach the condylar fracture by incising 3 to 4 cm from the inferior border of the tragus towards the external auditory canal, along the skin crease of the anterior part of the external ear. The retromandibular approach approaches the condylar fracture by dissecting the skin and subcutaneous tissue vertically to the mandibular angle, using a 3-cm incision line 5 mm inferior to the auricular lobe.

The submandibular approach is conducted by performing an incision at a site 2 to 3 cm inferior to the inferior mandibular border, parallel to the inferior mandibular border, or along the skin crease.[26]

Subcutaneous dissections were divided into transparotid and non transparotid (i.e., transmasseteric and anteroparotid/posteroparotid) (Figure 2).

Figure 1.

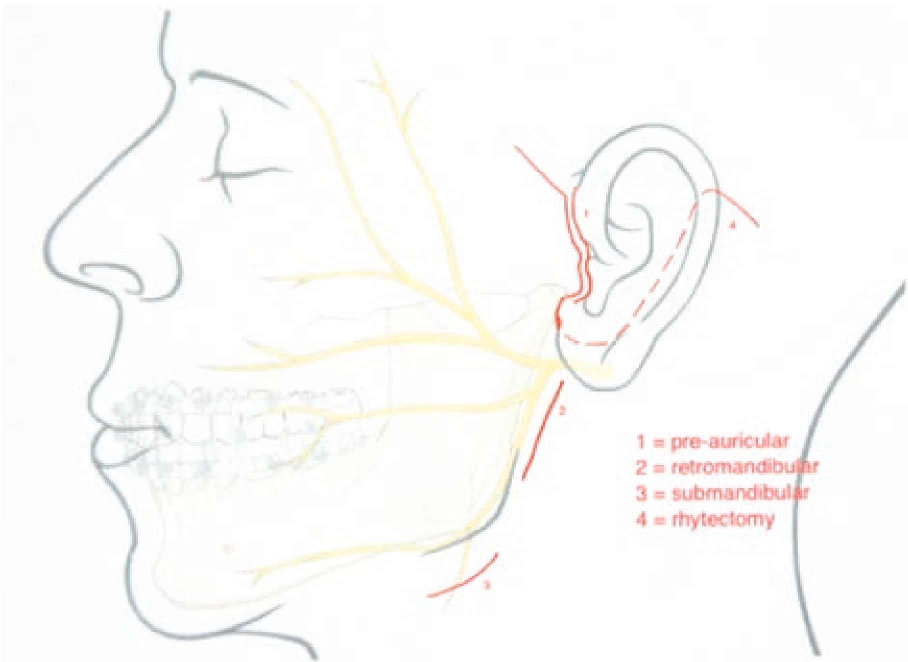
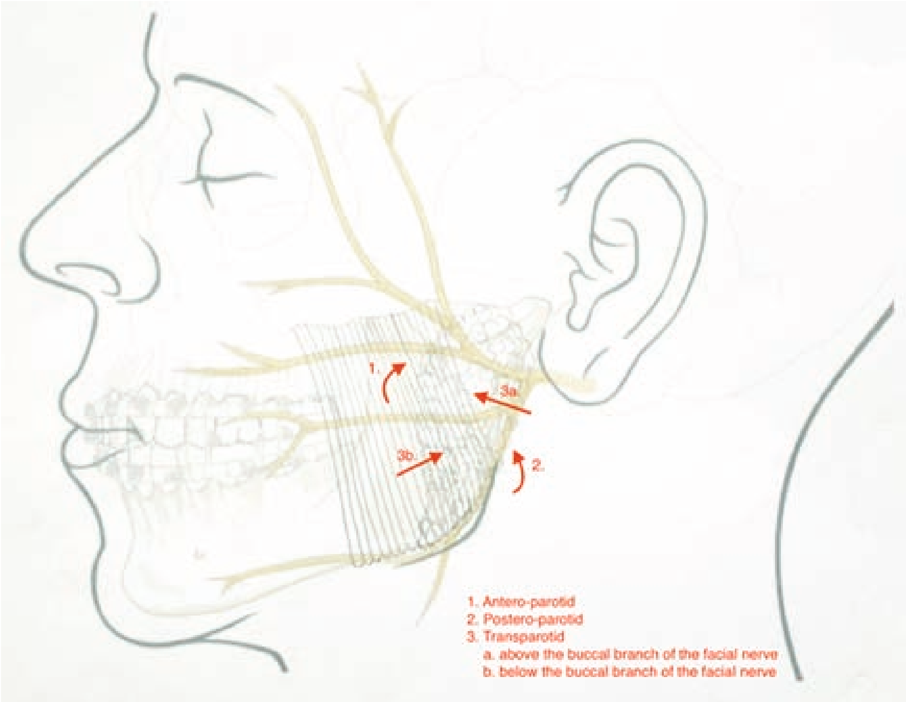


Figure 2.



RESULTS

The 70 selected studies were published between 1980 and 2016.[1-4,7,13,15,16,18,20,27-86] In these studies, there was a total of 3052 patients (men : women, 2.7 : 1) with a mean age of 32.5 years.

In 19% of the cases, both mandibular joints were fractured, and in 81% of the cases, the fracture was unilateral. In 9%, the location of these fractures was intracapsular (condylar head), and in 91% extracapsular. The duration of follow-up varied substantially, ranging from 5 days to 119 months.

Retrospective studies

Of the selected studies, 38 (54.3%) had a retrospective design. These studies included a heterogeneous series of mandibular condyle fractures and various treatment modalities. The clinical outcome measures were variable, as well as the follow-up durations (range, 5 days to 119 months).

Prospective studies

Of the assessed studies, 32 (45.7%) were prospective in nature. The duration of follow-up ranged from 1 month to 66 months.

Overview of the treatment modalities applied in the included studies

Table 2 shows an overview of the approaches used in the included studies. Based on the literature, the most frequently used skin incision was retromandibular (36.4%), followed by pre-auricular (25.0%), submandibular (13.6%) and peri-angular (6.8%). In some studies, other skin incisions were used or the skin incision was not described (18.2%).

The subcutaneous dissection was transparotid in 35.2% of the studies, non-transparotid in 21.5%, and both transparotid and non-transparotid in 4.5%. It was not specified whether the approach was transparotid in 38.6% of the studies. Focusing on the individual approaches, 59.4% of the retromandibular approaches were transparotid, 12.5% were non-transparotid, 12.5% described both transparotid and non-transparotid approaches, while in 15.6% it was not described whether the approach involved the parotid gland. When the pre-auricular approach was used, 13.6% of the studies reported involvement of the parotid gland, 22.7% did not involve the parotid gland, and involvement of the parotid gland was not defined in 63.6%. In the submandibular and periangular approaches, logically no transparotid procedures were described.

Overall, the data showed a tendency toward an increase in the use of the transparotid approach in recent years. Among the 35.2% of the studies that used a transparotid approach, 96.8% were published after the year 2000.

In most studies, osteosynthesis plates were used for fixation (80.6%; 5.2% resorbable and 94.8% titanium). Lag screws were used in 6.9% of the studies and a combination of plates and lag screws was used in another 6.9% of the studies. In 5.6% of the studies, the method of fixation was not described.

Table 2. An overview of the surgical procedures employed for the treatment of unilateral mandibular condyle fractures

Authors	Incision	Parotid approach
Baek	Curved incision (ear lobule area)	Trans
Benech	Retro-auricular	Trans
Bhutia	Retromandibular	Trans
Biglioli	Retromandibular	2x Trans, others not
Biglioli	Retromandibular	2x Trans, others not
Bindra	Retromandibular	Trans
Bouchard	Retromandibular	Trans
Chossegros	Retromandibular	Not
Colletti	Retromandibular	Some trans
Croce	Pre-auricular	Trans
Dalla Torre	Retromandibular	Trans
Downie	ND	Trans
Dunaway	Extended bicoronal	Not
Ebenezer	Pre-auricular, submandibular, retromandibular	Retro: both, pre-auricular ND, sub not
Girotto	Retromandibular	Trans
Hou	Parotid anterior or retromandibular	Parotid ant.: not, retro: trans
Kanno	Retromandibular	Trans
Kim	Retromandibular	Trans
Klatt	ND	Trans
Kumaran	Pre-auricular or retromandibular	Pre-auricular: not, retro: trans
Li	Supratemporal or pre-auricular	Not
Manisali	Retromandibular	Trans
Nam	Submandibular	Not
Narayanan	Retromandibular	Trans
Narayanan	Anterior parotid	Not, anterior
Pilanci	Pre-auricular	NCD
Rao	Retromandibular	Trans
Saikrishna	Rhytidectomy or Retromandibular	Trans
Salgarelli	Retromandibular	Not
Shi J	Parotid mini- incision	Trans
Sikora	ND	Trans
Tang	Retromandibular	Not
Trost	Anterior parotid	Not
Vesnaver	Facelift or retromandibular	Trans
Vogt	Retromandibular	Trans
Yabe	Pre-auricular	Trans
Yang	Retromandibular	Trans
Zhou	Pre-auricular	Not
Alexander	Pre-auricular or submandibular	ND
Choi	Pre-auricular	Trans
Eckelt	Peri-angular	ND
Hammer	Pre-auricular, submandibular or combination	ND
Hyde	Retromandibular or pre-auricular	ND

Table 2. Continued

Authors	Incision	Parotid approach
Iizuka	Pre-auricular-temporal	ND
Iizuka	Submandibular or retromandibular	ND
Lima	Pre-auricular or retromandibular	Pre-auricular: NCD, retro.: Trans
Petzel	Subangular	Not
Raveh	Pre-auricular-temporal	ND
Sargent	ND	ND
Spinzia	Retromandibular or pre-auricular	Not
Widmark	Submandibular	Not
Zrounba	High submandibular approach or pre-auricular approach	ND
Chaithanyaa	Retromandibular	ND
Chaudhary	Retromandibular	ND
Choi	NCD	Trans
Cortelazzi	Pre-auricular or retromandibular	Pre-auricular ND, retro trans
Derfoufi	ND	ND
Eckelt	Peri-angular	Not
Eckelt	Peri-angular	Not
Hachem	Peri-angular	ND
Kallela	Submandibular	ND
Meyer	High submandibular	ND
Petzel	Peri-angular	Not
Rai	Submandibular	ND
Rallis	Submandibular approach, pre-auricular or combination	ND
Seemann	Pre-auricular	ND
Singh	Retromandibular	ND
Sugiura	Pre-auricular or submandibular	ND
Xie	Pre-auricular	NCD
Zhang	Retromandibular	Trans

ND, not described; NCD, not clearly described

Outcome measures

Table 3a and 3b show an overview of complications. Of the 2,783 patients who were studied with respect to facial nerve function, 328 (11.8%) experienced some form of weakness. In most of these cases - 311 (95%) - full recovery was achieved within a period of 1 week to more than 6 months. In 17 cases (5%), 0.6% of the total group of patients, the paralyses were permanent; 9 (52.9%) of these occurred after a peri-angular approach, 2 (11.8%) after a pre-auricular approach, 1 (5.9%) after a submandibular approach, 3 (17.6%) after a retromandibular approach, and in 2 cases (11.8%) the approach after which permanent facial nerve damage was noted was not described.

Looking at the group of patients with transient weakness of the facial nerve, 42.4% of patients had been operated by a transparotid approach, 34.5% by a non-transparotid approach, and in 23.2% the approach was not described. With regard to permanent facial nerve weakness, 11.8% of cases occurred after a transparotid approach, while 64.7% occurred after a non-transparotid approach. Of the total group of patients, 0.07% had permanent damage of the facial nerve after a transparotid approach, and 0.4% after a non-transparotid approach. No explanation for these outcomes was given, but one possible cause for damage to the facial nerve might be traction on the nerve.

Table 3a. Facial nerve weakness associated with the open treatment of unilateral mandibular condyle fractures

Authors	Facial nerve weakness *total in number*	Recovery *time*	Permanent *number (percentage)*
Baek	2	3 months	None
Benech	1	1.6 months	None
Bhutia	9	3–6 months	None
Biglioli	None	NA	None
Biglioli	None	NA	None
Bindra	None	NA	None
Bouchard	35	NA	1 (0.8), (6.8 unknown)
Chossegros	2	3.6 weeks	None
Colletti	4 (ND)	2 months	None
Croce	6	4–8 weeks	None
Dalla Torre	4	3–6 months	None
Downie	7	NA	None
Dunaway	3	6 weeks	None
Ebenezer	NCD	NCD	NCD
Girotto	2	1–2 weeks	None
Hou	4 (retro)	ND	1 (1.7)
Kanno	2	3 months	None
Kim	9	6–20 weeks	None
Klatt	4	6 weeks	None
Kumaran	4 (3 pre, 1 retro)	ND	ND
Li	7	ND	2 (2.4)
Manisali	6	3 months	None
Nam	4	1–2 months	None
Narayanan	1	2 weeks	None
Narayanan	None	NA	NA
Pilanci	1	6 weeks	None
Rao	2	4–3 months	None
Saikrishna	4	ND	None
Salgarelli	1	1 week	None

Table 3a. Continued

Authors	Facial nerve weakness *total in number*	Recovery *time*	Permanent *number (percentage)*
Shi J	None	NA	NA
Sikora	3	3 months	None
Tang	4	1–3 months	None
Trost	None	NA	NA
Vesnaver	8	4–8 weeks	1 (2.8)
Vogt	10	6 months	None
Yabe	None	NA	NA
Yang	8	3–4 weeks	None
Zhou	7	1 month	None
Alexander	7	1–3 months	None
Choi	5	3 months	None
Eckelt	2	ND	ND
Hammer	1	8 weeks	None
Hyde	3	3 weeks	None
Iizuka	2	2–6 weeks	None
Iizuka	2	6 months	1 (7.7)
Lima	3	6 months	1 (1.7)
Petzel	ND	ND	None
Raveh	None	NA	NA
Sargent	1	weeks	None
Spinzia	22	3 years	None
Widmark	1	4 weeks	None
Zrounba	7	ND	1 (0.7)
Chaithanyaa	ND	ND	ND
Chaudhary	ND	1 month	None
Choi	7	3 months	None
Cortelazzi	18 (11 retro, 7 pre)	3–4 weeks	None
Derfoufi	ND	ND	ND
Eckelt	8	ND	8 (7.8)
Eckelt	54	ND	1 (0.4)
Hachem	ND	ND	ND
Kallela	3	1–5 months	None
Meyer	None	NA	NA
Petzel	None	NA	NA
Rai	ND	ND	ND
Rallis	5	1–2 months	None
Seemann	ND	ND	ND
Singh	ND	ND	ND
Sugiura	6	>6 months	ND
Xie	3	ND	None
Zhang	4	3 months	None

ND, not described; NA, not applicable

Unsatisfactory scarring stood out in about 2.4% of patients. This occurred in 31.0% after a pre-auricular incision, in 28.6% after a retromandibular incision, in 4.8% after a submandibular incision, and in 0.0% after a peri-angular incision. In 35.7% the skin incision was not clearly described.

A sialocele was seen in 2.3% of all operations sides, of which all occurred after a transparotid approach, and a salivary fistula in about 4.3%, of which 93.7% were after a transparotid approach. Sialoceles and salivary fistulae occurred mostly after retromandibular skin incisions (61.1% and 46.0% respectively).

Frey syndrome was present in 0.7% of the sides, 33.3% of which were transparotid, and 50.0% non-transparotid; 16.7% were unknown. The skin incision used in most cases was the retromandibular incision (66.7%), after which came pre-auricular (16.7%), and the submandibular (16.7%).

An infection of the wound occurred in about 2.7% of the operations sides, in 39% of these cases a transparotid approach was used. Retromandibular skin incision resulted in the highest rate of wound infections (44.1%), followed by pre-auricular (10.2%), submandibular (6.8%) and peri-angular (6.8%).

A hematoma occurred in 1.3% of the operations sides. In 66,7% of these cases a transparotid approach was used, in 11.1% a non-transparotid approach, and in 22.2% the subcutaneous approach was not described. A retromandibular skin incision was used in 22.2%, in 11,1% a periangular incision, and in 66,7% the incision was not specified.

Sensory disturbance of the great auricular nerve occurred in 6.7%, in the majority of the cases after a transparotid approach (79.2%).

Table 3b. Surgical complications associated with the open treatment of unilateral mandibular condyle fractures

	Wound infection	Hematoma formation	Sialocele	Salivary fistula	Scar	Frey syndrome	Auricular anesthesia
Baek	None	NCD	ND	1 (5.3%)	Not disturbing	ND	None
Benech	None	None	None	None	Not disturbing	None	None
Bhutia	None	ND	ND	3 (6.8%)	Not disturbing	ND	ND
Biglioli	2 (8%)	ND	ND	ND	2 (8%) unsatisfactory	ND	ND
Biglioli	2 (5.3%)	ND	ND	ND	2 (5.3%) unsatisfactory	ND	ND
Bindra	None	ND	ND	None	Not disturbing	None	ND
Bouchard	14 (11.9%)	ND	2 (1.7%)	4 (3.4%)	ND	1 (0.9%)	ND
Chossegros	1 (5.2%)	ND	ND	ND	2 (11%) unsatisfactory	ND	2 (10.5%) transient
Colletti	3 (3%)	ND	1 (1%) (trans)	ND	2 (2%) unsatisfactory	ND	ND
Croce	ND	None	None	4 (22.2%)	Not disturbing	1 (5.6%)	ND
Dalla Torre	ND	ND	7 (6.8%)	None	Not disturbing	ND	ND
Downie	1 (2%)	ND	1 (2%)	1 (2%)	ND	ND	ND
Dunaway	ND	1 (3.4%)	ND	ND	Not disturbing	ND	ND
Ebenezer	None	ND	ND	3 (15%) (trans)	4 (20%) unsatisfactory	None	ND
Girotto	None	ND	ND	None	Not disturbing	ND	None
Hou	None	ND	ND	3 (4.2%) (1 min, 2 ret)	ND	ND	ND
Kanno	None	ND	ND	1 (5.3%)	Not disturbing	None	ND
Kim	None	ND	ND	3 (10.7%)	Not disturbing	ND	1 (3.57%) transient
Klatt	None	None	ND	2 (4%)	ND	ND	5 (16%) lasting > 6 months
Kumaran	ND	ND	1 (2.9%) (retro)	ND	Disturbing (pre-auricular group, n=12))	ND	ND
Li	None	ND	ND	ND	ND	None	ND
Manisali	ND	ND	1 (4%)	ND	2 (8%) unsatisfactory	ND	2 (8%) transient
Nam	ND	ND	ND	ND	ND	ND	ND
Narayanan	2 (5.7%)	ND	ND	4 (11.4%)	2 (5.7%) unsatisfactory	None	ND
Narayanan	1 (0.7%)	ND	None	None	ND	None	ND

3 2

Table 3b. Continued

	Wound infection	Hematoma formation	Sialocele	Salivary fistula	Scar	Frey syndrome	Auricular anesthesia
Pilanci	1 (5%)	None	None	None	Not disturbing	ND	None
Rao	None	ND	ND	3 (17.6%)	Not disturbing	None	ND
Saikrishna	None	1 (3.3%)	3 (10%)	ND	6 (40%), 1 hypertrophic (3.3%)	ND	1 (3.3%) transient
Salgarelli	ND	ND	ND	ND	Not disturbing	ND	ND
Shi J	ND	1 (2.8%)	1 (2.8%)	ND	Not disturbing	ND	ND
Sikora	ND	ND	ND	ND	Not disturbing	ND	ND
Tang	ND	ND	ND	None	ND	ND	ND
Trost	1 (2.6%)	ND	ND	ND	1 (2.6%) unsatisfactory	ND	ND
Vesnaver	ND	2 (6%)	ND	5 (14%)	Not disturbing	ND	5 (14%) transient
Vogt	None	ND	ND	4 (7.8%)	Not disturbing	ND	ND
Yabe	1 (6.7%)	ND	ND	None	Not disturbing	None	ND
Yang	None	2 (4.2%)	ND	3 (6.3%)	Not disturbing	ND	None
Zhou	None	ND	ND	None	Not disturbing	ND	ND
Alexander	None	ND	ND	ND	ND	ND	ND
Choi	≥2 (7.4%)	ND	ND	≥2 (7.4%)	Not disturbing	ND	5 (18.5%) transient
Eckelt	ND	ND	ND	ND	ND	ND	ND
Hammer	≥3 (10%)	ND	ND	≥3 (10%) (ND)	ND	ND	ND
Hyde	ND	ND	ND	ND	ND	ND	ND
Iizuka	ND	ND	ND	ND	ND	ND	ND
Iizuka	ND	ND	ND	ND	1 (4.8%) unsatisfactory	ND	ND
Lima	3 (4.6%)	ND	1 (1.5%)	None	Not disturbing	None	ND
Petzel	ND	ND	ND	ND	ND	ND	ND
Raveh	ND	ND	ND	ND	ND	ND	ND
Sargent	None	ND	ND	ND	ND	ND	ND
Spinzia	1 (3.8%)	ND	ND	None	3 (12%) unsatisfactory	3 (11.5%)	ND
Widmark	1 (5%)	ND	ND	ND	Not disturbing	ND	3 (15%)

Table 3b. Continued

	Wound infection	Hematoma formation	Sialocele	Salivary fistula	Scar	Frey syndrome	Auricular anesthesia
Zrounba	ND	1 (0.6%)	ND	ND	Not disturbing	1 (0.6%)	ND
Chaithanyaa	2 (13.3%)	ND	ND	ND	ND	ND	ND
Chaudhary	ND	ND	ND	ND	ND	ND	ND
Choi	≥3 (7.5%)	ND	ND	≥3 (7.5%)	ND	ND	ND
Cortelazzi	6 (9.7%)	ND	ND	10 (16.1%) (retro trans)	ND	ND	ND
Derfoufi	ND	ND	ND	ND	ND	ND	ND
Eckelt	ND	ND	ND	ND	ND	ND	ND
Eckelt	3 (1.2%)	1 (0.4%)	ND	ND	Few unsatisfactory	ND	ND
Hachem	≥1 (3.3%)	ND	ND	ND	ND	ND	ND
Kallela	ND	ND	ND	ND	1 (7.7%) unsatisfactory	ND	ND
Meyer	1 (1.4%)	ND	ND	ND	1 (1.4%) unsatisfactory	ND	ND
Petzel	ND	ND	ND	ND	ND	ND	ND
Rai	2 (13.3%)	ND	ND	ND	ND	ND	ND
Rallis	ND	ND	ND	ND	ND	ND	ND
Seemann	1 (0.8%)	ND	ND	ND	ND	ND	ND
Singh	None	ND	ND	ND	ND	ND	ND
Sugiura	1 (1.7%)	ND	ND	ND	ND	ND	ND
Xie	ND	ND	ND	ND	ND	ND	ND
Zhang	ND	ND	ND	1 (1%)	ND	ND	ND

ND: not described

DISCUSSION

The debate on which is the best way to treat condylar fractures is an ongoing one. Outcomes of both open and closed treatment have been critically reviewed.[5,6] The major drawback of open treatment remains the surgery-related complications. A better definition of the most appropriate approach and knowledge of the exact risks for specific complications are essential in the decision-making process.

The most serious complication is probably damage to the facial nerve. Fortunately, this is transient in most cases, with a reported incidence of between 12% and 48%,[14-16, 26,34] when the most commonly used incision (the retromandibular transparotid approach) is used. In the studies included in this review, the incidence of temporary weakness was higher with transparotid dissection than with non-transparotid dissection. The recovery rate was significantly higher with the transparotid approach compared with anterior or posterior parotid approach. A possible explanation might be, as mentioned earlier, the necessity for less traction of the nerve. Taking this into account, the incidence of permanent facial nerve damage was 0.4% with a non-transparotid approach and 0.07% with the transparotid approach. Differences in the subcutaneous approaches, i.e., with or without retrograde nerve dissection with identification of the nerve, could have biased these outcomes.

Recently a comprehensive systematic review and meta-analysis were published on facial nerve injuries related to surgical approaches for treating mandibular condyle fractures.[87] With respect to the condylar neck and base fractures, no differences between the non-transparotid and transparotid approach were found. In our study, there seems to be a preference for the transparotid approach. This difference could be a result of the different inclusion criteria used in the two studies, and therefore the use of non-identical literature.

Though Al-Moraissi et al. did emphasize the importance of traction on the nerve and the risk of damaging the nerve by either approach, it was stated that the choice of approach was highly related to the level of the fracture and therefore different approaches were recommended for different condyle fractures.

In addition to this, Al-Moraissi et al.[87] concluded that for condylar head fractures the retro-auricular approach or deep subfascial pre-auricular approach was the safest in terms of protecting the facial nerve, for condylar neck fractures the safest was the transmasseteric anteroparotid approach with retromandibular and pre-auricular extension, and for condylar base fractures they suggested high submandibular incisions with either transmasseteric anteroparotid approach (with retromandibular), or transmasseteric subparotid approach.

Every incision creates a scar. Hiding the scar is an important step in facial reconstruction. Based on the outcomes it can be stated that the risk of unsatisfactory scarring is small and was noted in about 2.4% of patients. Of patients who were dissatisfied with their scar, 31.0% underwent a pre-auricular approach, 28.6% underwent a retromandibular approach, 4.8% underwent a submandibular approach, and a minority underwent another approach (e.g. peri-angular approach or rhytidectomy).

It has been noted that signs of poor pre-auricular incision planning include visible pre-auricular incision lines, an unnatural tragal appearance, and loss of earlobe definition with a 'pixie-ear' configuration.[88] A rhytidectomy (or facelift incision) produced no unsatisfactory result and, based on this review, could therefore be the incision of preference.

An alternative could be the retro-auricular incision, where the incision is hidden behind the earlobe. Although the complication rates seem to be low,[2] strictures of the external auditory canal have been described. The focus of debate is most likely not the choice of skin incision, but rather the choice of subcutaneous dissection.

Based on the literature, use of the transparotid approach has gained popularity as a more straightforward approach, with direct visibility of the fracture and the shortest distance between the skin and the mandibular condyle. Because of the shorter working distance, there is less need to forcefully retract the soft tissues, implying a limited complication rate, in particular with reference to facial nerve weakness.[33]

A sialocele was seen in 2.3% and a salivary fistula in about 4.3% of patients. In the studies included in this review, sialoceles and salivary fistulae were only seen in patients in whom a transparotid approach was used. One exception was a patient with a salivary fistula in the study reported by Hou et al.[36] after an anterior parotid approach.

It is believed that this complication can be avoided in most cases by careful closure of the parotid capsule with running sutures.[18,29,30] If sialoceles or fistulae did occur, these were managed in most studies by aspiration and collection, and placement of a compression dressing.[28,37,45,86]

To further reduce the risk of developing Frey syndrome, sialoceles, and salivary fistulae, approaches were elaborated by locating the dissection plane through the masseter muscle instead of the parotid gland.[42,49] In the study by Narayanan et al.[42], in which the transmasseteric anterior parotid approach was used, none of these complications was observed. A possible disadvantage of this approach is that a longer incision is needed than those used in other approaches.

Surgery is always associated with a certain number of wound infections. Based on the systematic review, on average, 2.7% of patients had a wound infection. The infection rate was quite variable among the studies (range, 0 - 13.3%), most presumably due to differences in surgical and antibiotic protocols.[29,30] Unfortunately, in the majority of the studies, the use of antibiotics was not described. Therefore, it is impossible to determine whether antibiotics were helpful in decreasing the rate of this complication.

Currently, surgeons are using more minimally invasive surgery (MIS).[36] The suggested advantages of small incisions include: less surgical trauma, less bleeding, fewer and smaller scars, reduction in infection risk, and shorter hospital stays.[36] Some use the mini retromandibular approach, limited to 20 mm, for fractures at every level, from high-neck to low-subcondylar fractures.[3,4,18] Colletti et al.[18] stated that this broad application is possible because the view is limited by the deeper part of the access, not by the skin incision.

Nevertheless, Biglioli and Colletti[3] described difficulty with the use of this limited incision in overweight patients with redundant soft tissues of the cheek. Transient facial nerve weakness was explained by the relatively greater stretching of the soft tissues resulting from a small incision, and increased likelihood of excessive stretching of the nerve fibers and therefore of transient facial nerve weakness.[4]
Hou et al.[36] designed the minor parotid anterior approach to treat medial and low condylar fractures. They describe three advantages of this approach: first, there is a lower risk of injuring the facial nerve; second, the length of the incision used is short (2 to 2.5 cm, compared with, for example, 3 to 3.5 cm in the retromandibular approach), and therefore, scarring is reduced; and third, because the location of the incision overlies the fracture site, it provides excellent visual exposure of the fracture fragments and makes the procedure quick and simple.

The great diversity in fractures, approaches, and surgical techniques makes it difficult to generate an objective, clear and usable comparison of surgical techniques for condylar fractures and their complications.[15,39]

To establish more evidence for the best approach to an open treatment, more research will be needed on, for example, different extraoral approaches and their comparisons, the use of antibiotics, the development of advanced and less technically demanding endoscopic techniques, the role of nerve integrity monitoring during surgery (e.g. the NIM stimulator; Medtronic, Minneapolis, MN),[29] and perhaps in the future, the use of intraoperative surgical navigation. In this way, an evidence-based protocol for the treatment of this complex fracture will be accomplished.[30]

CONCLUSION

In our opinion, a clear treatment protocol is needed to attain predictable clinical practice. In cases of open treatment of condylar fractures, such a protocol should be interpreted and implemented by taking the skills of the surgeon into consideration. Based on the literature studied in this review, we would like to propose a treatment protocol with respect to open treatment approaches.

Concerning the skin incision, no real preference exists, although the submandibular and peri-angular skin incision showed the best results. Subcutaneously, a transparotid approach is recommended, because, it is straightforward, with direct visibility of the fracture and the shortest distance between the skin and the mandibular condyle and therefore results in less traction on the facial nerve.

Most important for the surgeon is a sufficient view of the fracture site. With regard to the skin incision, one could argue for using the pre-auricular, retro-auricular or perilobular approach for high condylar fractures,[13] the retromandibular or pre-auricular approach for middle-height fractures,[13-16] and the retromandibular, high submandibular, peri-angular approach, or rhytidectomy modifications for low condylar fractures.[13-17] After the open reduction and fixation, the parotid capsule is sutured with care.

When there is a high level of experience, MIS could be used. On the other hand, especially for surgeons with limited experience, it is prudent to discourage approaching the fracture with a small incision and forcible opening of the dissected tissues.[52] Furthermore, the use of a neurostimulator during surgery is advised.

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Chapter 4

Open versus Closed

4.1

Clinical outcome in treatment of unilateral condylar fractures

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Clinical outcome in treatment of unilateral condylar fractures: a cross-sectional study

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INTRODUCTION

The treatment of mandibular condyle fractures has been the subject of considerable discussion, in particular whether open or closed treatment should be used, with multiple studies published on this topic.[1–6] Since fractures of the mandibular condyle are common facial injuries, accounting for 25 to 35% of all mandibular fractures,[7,8] and no clinical guidelines exist, there is a need for practical, evidence-based guidelines. In order to produce such guidelines, a more detailed description of both the population and the treatments used is needed. However, most studies have not differentiated between children and adults, or between unilateral and bilateral fractures, and they have lacked details on postoperative treatment strategies, such as the use of maxillomandibular fixation (MMF), the fixation method used, and the use of physiotherapy.[9]

Furthermore, with respect to the outcome measures, objective parameters have been applied to analyze the treatment modalities, e.g., the degree of malocclusion, maximum mouth opening, laterotrusion, protrusion, and pain.[9,10] To date, few studies have considered clinically relevant subjective parameters.[11] In an ideal study design, more subjective and functional parameters should be measured. Therefore, the goal of this study was two-fold: (1) to evaluate the subjective and functional outcomes of the treatment of condylar fractures using (a) the Mandibular Function Impairment Questionnaire (MFIQ) to determine the patient's subjective perception of mandible functioning and (b) the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) to assess the musculoskeletal function of the orofacial region; and (2) to compare the open and the closed treatment modalities, and thereby derive practical advice for daily practice.

MATERIALS AND METHODS

Patients

This research was approved by the ethics committee of the Academic Medical Centre of Amsterdam. The cases of patients with unilateral or bilateral condylar fractures who were treated at the Department of Oral and Maxillofacial Surgery of the Academic Medical Centre of Amsterdam between August 2008 and March 2016 were reviewed.

Patients were excluded from the study if they were younger than 18 years of age, were unable to understand and read Dutch, had any intellectual disability, or had a history of psychiatric disorders. Patients, with a follow-up period since the trauma of at least 1 year were invited by letter to attend an additional appointment. If the patient did not respond within 2 months after the letter was sent, they were contacted by telephone. All patients who participated received a patient ID number and signed an informed consent form.

At the extra follow-up appointment, each patient completed the MFIQ,[12,13] an instrument to determine patient's subjective mandible functioning. They were also examined according to Axis I and Axis II of the DC/TMD to assess musculoskeletal pain and dysfunction in the orofacial region.[14] These axes consist of clinical examinations and questionnaires about the patient's symptoms and psychosocial background. Facial nerve function was assessed using the Sunnybrook Facial Grading System (SB), and a cone-beam computed tomography (CBCT) scan was acquired to assess the healing morphology (field of view (FOV) 26 cm, diameter 23 cm, scan time 18 s, voxel size 0.4 mm at 96 kV and 10 mA).

Mandibular Function Impairment Questionnaire (MFIQ)

The MFIQ is a validated and reliable instrument that measures a patient's subjective perception of mandible functioning.[12,13] The instrument consists of 17 items; social activities (item 1), speech (item 2), masticatory performance (items 3, 4, 5, 9, 12, 13, 14, 15, 16, and 17), daily activities (item 6), drinking (item 7), laughing (item 8), yawning (item 10), and kissing (item 11). These are scored from 0 to 4 on a Likert scale by the patient, thus providing a total score for all items ranging from 0 to 68, in which '0' is a good functional outcome and '68' is a poor functional outcome.[13]

Diagnostic criteria for TemporoMandibular Disorders (DC/TMD)

The patients were examined according to the DC/TMD,[14] a validated diagnostics system for the assessment of musculoskeletal pain and dysfunction in the orofacial region. The DC/TMD outcome consists of two axes, one for clinical examination, evaluation, and diagnosis (Axis I) and the second for the psychosocial background of the patient (Axis II).

In the Axis I assessment, the Symptom Questionnaire was completed by all participants. Furthermore, patients were asked questions related to their highest level of education and their parents' places of birth.

Functional parameters were also assessed, including the range of motion (ROM) of the mandible (i.e., maximum active and passive mouth opening (MMO), protrusion and laterotrusion (left and right lateral movements) measured in mm using a caliper), the presence of joint sounds, and the diagnosis regarding muscular and/or articular TMD pain.

The Axis II assessment was used to appraise the patient's psychosocial status and to rate the pain-related impairment, i.e., disability and limitations in an individual's everyday life.[15] The following questionnaires were completed for this assessment: the Graded Chronic Pain Scale version 2.0 (GCPS), Jaw Functional Limitations Scale 20 items (JFLS-20), Patient Health Questionnaire (depression) (PHQ-9), Generalized Anxiety Disorder Scale (GAD-7), Patient Health Questionnaire (somatization) (PHQ-15), and Oral Behaviors Checklist (OBC).

Sunnybrook facial grading system (SB)

The SB scale is a weighted scale used to assess facial nerve function, based on the evaluation of different regions of the face.[16] The examination, which includes the assessment of the resting symmetry, the symmetry of voluntary movement, and the severity of synkinesis, results in a composite score ranging from 0 to 100, in which a higher score indicates better facial nerve function.

Additional information

In addition, seven other parameters were measured: the cause of trauma, coexistence of other facial fractures, the patient's dental state (dentate or edentulous), subjective perception of occlusion, objective occlusion (as assessed by a maxillofacial surgeon, i.e., the existence of a clinical open bite or not), and the presence of lateral deviation of more than 2 mm on mouth opening.

Furthermore, the patients were checked for 9 types of surgical complications: temporary weakness of the facial nerve, permanent weakness of the facial nerve, hematoma, wound infection, sialocele, salivary fistula, disturbance of the sensory component of the great auricular nerve, material failure, and unsatisfactory scarring.

Treatment

The treatment protocol followed, was that described in a previous study by the present investigator group.[9]

In short, closed treatment was divided into expectative and conservative treatment. An expectative treatment policy was applied if the patients could bring their teeth into an (almost) normal occlusion or had normal mandibular excursions. These patients were recommended to follow a strict soft diet. They were instructed on active but careful movements of the jaw (without loading it) and prescribed sufficient pain medication. Thorough follow-up was provided, with the first appointment after 5 to 7 days.

Conservative treatment was given in the case of a persistent or developing malocclusion, with an open bite of more than 2 mm. Conservative treatment consisted of a short period of MMF, using brackets, MMF screws, or arch bars, including the use of guiding elastics for three weeks. The MMF only ensured correct occlusion, but never induced total immobilization. Patients were advised to follow a strict soft diet, to engage in active but careful movements of the jaw, and were provided sufficient pain medication.

If necessary, after this 3-week period of MMF on guiding elastics, the occlusion was further guided using loose elastics up until 6 weeks, and active physiotherapy consisting of exercises and guided closure was started.

Follow-up appointments after the first contact were scheduled at 5 to 7 days, 3 weeks, 6 weeks, and 12 weeks. If the patient had recovered well, follow-up was ended. If symptoms such as an open bite, limited mouth opening, or pain persisted, the follow-up was extended to 6 months or even 1 year.

In case of severe malocclusion, uncontrolled pain, or poor patient compliance, open treatment was considered. Open treatment was performed via a pre-auricular skin incision and a transparotid approach. In general, the protocol included no postoperative MMF; the patients were advised to maintain a strict soft diet, were given instructions on active but careful movement of the jaw, and were prescribed sufficient pain medication. Follow-up appointments after the first contact were scheduled at 5 to 7 days, 3 weeks, 6 weeks, and 12 weeks. If the patient had recovered well, follow-up was ended.

STATISTICS

The patient population was described using means and percentages. For mandibular movement, the mean ranges were described in millimeters together with the standard deviation. The MFIQ was considered a continuous variable. Normality was determined using the Kolmogorov-Smirnov test. The T-test (continuous data) and Mann-Whitney U test (ordinal data or non-normally distributed continuous data) were used to compare the results from the clinical measurements and questionnaires between the open and closed treatment group to determine if there was a significant difference for either of the treatment modalities.

Correlations of the MFIQ with gender, age, the presence of other fractures, cause of the trauma, fracture type, treatment method, use of MMF, presence of dentition, subjective occlusion, physiotherapy, education level, and length of follow-up were calculated (Spearman's correlation).

A comparison was made between the patients who were included and those who were excluded regarding age, gender, fracture level related to the mandibular joint capsule (intracapsular or extracapsular), site of the fracture, other fractures, and open and closed treatment, using the T-test (continuous data) and the Mann-Whitney U test (ordinal data). This was done to make sure that the patients included were representative of the total population.

IBM SPSS Statistics version 24 (IBM Corp., Armonk, NY, USA) was used for the data analysis. The significance level was set at $P = 0.05$.

RESULTS

In total, 74 patients were included in this study, i.e., 43.3% of the total 171 patients approached. The included and excluded patients did not differ significantly in age ($P = 0.864$), gender ($P = 0.751$), fracture level related to the mandibular joint capsule (intracapsular or extracapsular) ($P = 0.104$), site of the fracture ($P = 0.225$), other fractures ($P = 0.130$), or open and closed treatment ($P = 0.431$). Forty-nine of the 74 patients were male (66.2%) and 25 were female (33.8%).

Their mean age was 43.2 years. Fifty-eight (78.4%) had a unilateral fracture (29 on the left, 29 on the right; 11 intracapsular and 47 extracapsular) and 16 patients (21.6%) had bilateral fractures. With regard to other fractures interfering with the occlusion, there were 36 patients with mandibular fractures and 3 with bimaxillary fractures; 35 patients had no other fractures. There were five causes of trauma: bike accidents ($n = 30$; 40.5%), non-bike-related traffic accidents ($n = 8$; 10.8%), violence ($n = 12$; 16.2%), fall ($n = 19$; 25.7%) and sports ($n = 5$; 6.8%). Open treatment was performed in 14 patients (18.9%), while 60 patients (81.1%) received closed treatment. Within the closed treatment group, 24 patients (40.0%) received expectative treatment and 36 (60.0%) conservative treatment.

The fixation method for MMF was arch bars in 17 patients (28.3%), brackets in 16 patients (26.7%), and intermaxillary fixation screws in two patients (3.3%); the method of fixation was not described for one patient (1.7%). Sixty-nine of the included patients (93.2%) were dentate and 5 (6.8%) were edentulous. To improve the MMO, ROM, and/or occlusion, 35 patients (47.3%) underwent physiotherapy. In the comparison of those who did undergo physiotherapy and those who did not, physiotherapy was found not to have a significant influence on MMO ($P = 0.764$), left laterotrusion ($P = 0.32$), right laterotrusion ($P = 0.19$), or protrusion ($P = 0.56$). The mean duration of follow-up was 50.9 months (range 13 - 104 months).

OCCLUSION

On objective assessment, 62 patients (83.8%) had a stable occlusion and five (6.8%) had a malocclusion; occlusion could not be assessed in seven patients, including the edentulous patients (9.5%). The subjective evaluation of occlusion showed 10 patients (13.5%) with malocclusion, nine (12.2%) with a changed or mediocre occlusion, and 53 (71.6%) with a good occlusion. It was not possible to determine the occlusion for two patients.

Separate analysis of the open and closed treatment groups showed that the open group had one patient (7.1%) with an objective malocclusion and 12 (85.7%) with a stable occlusion. As one patient (7.1%) was edentulous, no occlusion could be quantified. Three patients (21.4%) subjectively reported their occlusion as compromised, one (7.1%) as changed or mediocre, and 10 (71.4%) as good.

In the expectative group, three patients (12.5%) had an objective malocclusion and 17 (70.8%) had a stable occlusion. The occlusion could not be quantified in four patients (16.7%). Subjectively, four patients (16.7%) had a malocclusion, one (4.2%) had changed or mediocre occlusion, and 18 (75.0%) had a good occlusion; occlusion could not be quantified in one patient. In the conservative group, one patient (2.8%) had a malocclusion and 33 patients (91.7%) had a stable occlusion. The occlusion could not be quantified in two patients (5.6%). In three patients (8.3%), subjective occlusion was defined as compromised, in seven patients (19.4%) as changed or mediocre, and in 25 (69.4%) as good; occlusion could not be quantified in one patient.

There was no significant difference in objective (P = 0.729) or subjective (P = 0.846) occlusion between the open and closed treatment groups for those with unilateral fractures (Table 1).

Table 1. Subjective and objective occlusion per treatment (unilateral fractures)

	Open treatment (*n* = 10)	Closed treatment (*n* = 48)	*P*-value [a]
Subjective			0.846
Good	8	34	
Mediocre/changed	1	8	
Bad	1	4	
Not determined	0	2	
Objective			0.729
Stable occlusion	9	41	
Malocclusion	1	3	
Not determined	0	4	

[a] Chi-Square test

Deviation

With regard to MMO, four patients in the open treatment group (28.6%) had a deviation of more than 2 mm, while 10 (71.4%) demonstrated no deviation. In the closed treatment group, 26 patients (44.8%) demonstrated deviation and 32 (55.2%) did not. On comparing the open and closed treatment groups, these results were not significant (P = 0.236).

MFIQ

The MFIQ did not have a normal distribution (P = 0.000). The mean MFIQ score in patients with unilateral fractures in the open treatment group was 10.70 (standard error 2.9), while the mean score in the closed group was 4.96 (standard error 1.3). The difference in MFIQ between the open and closed treatment groups in the patients with unilateral fractures was statistically significant (P = 0.023).

When the MFIQ for the patients with a unilateral fracture was correlated with gender, age, the presence of other fractures, cause of trauma, fracture type, use of MMF, presence of dentition, subjective occlusion, physiotherapy, education level, and length of follow-up, a significant effect was seen with subjective occlusion ($P = 0.028$), in which a better subjective occlusion resulted in a better result for the MFIQ, and also for the treatment received ($P = 0.039$), in which the outcome was in favor of the closed treatment methods.

DC/TMD

With regard to the Axis I assessment, myalgia was present in 5 (6.8%) patients: two had local myalgia, one had myofacial pain, and two had myofacial pain with referral. Of these five patients, two received open and three received closed treatment. Arthralgia was found in seven (9.5%) patients, of whom three were in the open group and four in the closed group; 67 (90.5%) patients were pain-free. No patient received a diagnosis of headache attributable to TMD. According to the DC/TMD, 66 (89.2%) patients did not receive a diagnosis of degenerative joint disorder. Eight (10.8%) patients did have a form of degenerative joint disorder, with most cases involving the contralateral side to the condyle fracture (62.5%). Two of these patients received open treatment and six closed treatment. No intra-articular joint disorders were seen in 56 (75.7%) patients. The other 18 (24.3%) patients had disc displacement with reduction, which showed no correlation with the fracture site.

When corrected for overbite, the mean MMO for unilateral fractures was 53.9 mm (standard deviation (SD) 5.0 mm) after open treatment and 53.3 mm (SD 7.4 mm) after closed treatment ($P = 0.799$). The mean protrusion was 7.7 mm (SD 1.8 mm) after open treatment and 8.8 mm (SD 2.7 mm) after closed treatment ($P = 0.214$).

The mean maximum laterotrusion movements were as follows: left 9.3 mm (SD 3.1 mm), right 10.5 mm (SD 2.7 mm) after open treatment, and left 10.6 mm (SD 3.3 mm), right 10.7 mm (SD 3.2 mm) after closed treatment ($P = 0.265$ and $P = 0.864$, respectively). There were no cases of ankylosis.

With regard to the Axis II assessment, the results from the questionnaires are given in Table 2. No significant difference between the open and the closed treatment groups was found for any of the questionnaire scores.

Table 2. Results of DC/TMD Axis II questionnaires; values are presented as the mean (SD)

Questionnaire	Closed treatment	Open treatment	*P*-value [a]
Graded Chronic Pain scale version 2.0 (GCP)	0.8 (± 0.6)	0.4 (±0.7)	0.789
Jaw Functional Limitations Scale 20 items (JFLS-20)	6.8 (± 3.8)	2.3 (± 0.7)	0.358
Patients Health Questionnaire (PHQ-9)	3.2 (± 1.0)	2.8 (± 0.6)	0.553
General Anxiety Disorder (GAD-7)	1.9 (± 0.8)	2.2 (± 0.5)	0.458
Patients Health Questionnaire (PHQ-15)	5.0 (± 1.6)	4.0 (± 0.5)	0.845
Oral Behaviors Checklist (OBC)	18.7 (± 4.0)	20.4 (± 1.6)	0.553

DC/TMD, Diagnostic Criteria for Temporomandibular Disorders; SD, standard deviation.
[a]Mann–Whitney U-test.

Sunnybrook facial grading system

All patients scored the maximum score on the SB; no permanent facial nerve weakness was found in the patients included in this study.

Surgical complications after open treatment

The following results were found in the assessment of surgical complications: temporary weakness of the facial nerve in 7.1% (*n* = 1), permanent weakness of the facial nerve in 0%, hematoma in 0%, wound infection in 0%, sialocele in 7.1% (*n* = 1), salivary fistula in 7.1% (*n* = 1), disturbance of the sensory component of the great auricular nerve in 0%, material failure in 7.1% (*n* = 1), and unsatisfactory scarring in 0% (Table 3).

Table 3. Complications found in patients who underwent open treatment (n = 14)

	Number of patients	Percentage
Facial nerve temporary weakness	1	7.1%
Facial nerve permanent weakness	0	0%
Hematoma	0	0%
Wound infection	0	0%
Sialocele	1	7.1%
Salivary fistula	1	7.1%
Greater auricular nerve weakness	0	0%
Material failure	1	7.1%
Unsatisfactory scarring	0	0%

DISCUSSION

When using the MFIQ as a benchmark, closed treatment was found to be preferable to open treatment (P = 0.023).

A possible explanation for the greater success of closed treatment in this regard is the use of a strict treatment protocol, especially the use of guiding elastics rather than firm elastics or steel wires; strict follow-up also favors a successful outcome. Compared to a healthy population, this study population performed well with respect to MMO and ROM.[17] ROM, determined by laterotrusion and protrusion, was not significantly different from the laterotrusion measured in the normal population (female: left 11.5 mm (SD 2.4 mm), right 10.9 mm (SD 2.1 mm); male: left 12.1 mm (SD 2.3 mm), right 11.0 mm (SD 2.6 mm)).[18] No cases of ankylosis were found.

The use of the DC/TMD in this field of maxillofacial surgery is new. The DC/TMD represent a well-described, evidence-based system for the assessment of TMD complaints and jaw dysfunction. The data showed that 90,5% of patients were pain-free, which is comparable to earlier findings.[9,10] A systematic review showed a prevalence of myofascial pain of 6% to 12.9 %, intra-articular joint disorders of 8.9% to 15.8%, and arthralgia diagnoses of 2.6%.[19] This indicates that the findings of this cross-sectional study are similar to those in the general population with regard to prevalence rates. The importance of psychosocial symptoms in TMD patients has been stated in different studies, showing an association between TMD pain and disorders such as depression, somatization, and anxiety.[20,21] The axis II assessment in this study showed no difference between the open and closed treatment groups. Since the prevalence of Axis I TMD diagnoses was not different from the general population and no difference was found in Axis II data between the two groups, it appears that the treatment approach does not affect Axis I and II parameters.

The complications of open treatment reported in this study (Table 3) were minimal compared to the complications reported in the literature, i.e., temporary weakness of the facial nerve (12%, of which approximately 5% of cases were permanent), hematoma (1.7%), wound infections (≥ 2.9%), sialocele (2.6%), salivary fistula (≥ 4.8%), disturbance of the sensory component of the great auricular nerve (7.9%), and unsatisfactory scarring (≥1.6%).[10] An explanation for the absence of facial nerve damage, as well as the prevalence of sialocele and salivary fistula, is most likely the use of a transparotid approach. In a systematic review it was stated that the rate of recovery of the facial nerve is significantly higher with the transparotid approach (97.5%) than with the anterior or posterior parotid approach (90.5%).[22] Nevertheless, the percentages of sialocele and fistula in the present study are likely higher than those reported previously due to the use of the transparotid approach as well as the limited number of patients in the open treatment group.

None of the cases in this study reported unsatisfactory scarring. Esthetically acceptable outcomes were promoted using a pre-auricular and retromandibular skin incision.[22] Despite the treatment protocol, in which no MMF was prescribed for patients after open treatment, some form of MMF was used postoperatively in 71.4% of the study patients. This is in accordance with a recently published review on open treatment.[10] However, the type of MMF used was often not clearly documented and it therefore remains unknown whether elastic traction was used as MMF or as a guide for occlusion.

The use of physiotherapy in these patients did not significantly improve the outcome. This may be due to the lack of a standardized physiotherapy treatment protocol; the development of such a protocol may be useful. Nevertheless, the small number of patients included in the open treatment group in this study and the fact that this study has a cross-sectional design should be taken into consideration. Still, Dijkstra et al. had already published good results after closed treatment with one year of follow-up.[23]

Furthermore, the duration of follow-up did not influence the outcome measures, indicating that the outcomes at the 1-year follow-up are indicative of the long-term results.

To date, the literature on condylar fractures has reported good outcomes for both open and closed treatment methods.[9,10] This study found a significant difference in the MFIQ, but not in the other outcomes, between open and closed treatments. Although good outcomes are achieved with both treatments, it would appear preferable to avoid surgery and the concomitant surgery-related complications. In addition, closed treatment avoids operating room time, more expensive hardware, a longer general anesthesia time, hospitalization and sickness leave costs.[24]

In conclusion, closed treatment should not be overlooked and should be considered for those cases in which this treatment can be performed by a competent surgeon following a strict treatment protocol, and where proper patient compliance is assured.

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4.2

Mixing ability test

This chapter is an edited version of the manuscript:

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Is masticatory performance affected after a unilateral condylar fracture? A cross sectional study

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INTRODUCTION

Chewing is of vital importance to humans. The physiological process of chewing food, together with several chemical processes, helps to break down large particles of food, reduces stress on the esophagus, and helps the stomach to metabolize food.[1-3] Trauma to the oral cavity and the surrounding structures, such as the temporomandibular joint, could possibly compromise masticatory ability (e.g., by creating malocclusion, by reducing the mobility of the joints, or by creating chronic pain). Since the mandible is prone to external forces, due to its exposed position in the maxillofacial skeleton, mandibular fractures are one of the most common facial fractures (42% - 66%),[4-6] with the condyle being involved in approximately 25% - 35% of mandibular fractures.[7-9] From an anatomical perspective, the condyle can be divided in several fracture types. Numerous classification systems are published in recent literature. [10-14]

How to optimally treat a fracture of the mandibular condyle is one of the most challenging controversies in maxillofacial trauma care. Studies examining the most appropriate treatment modality for condylar fractures are ongoing.[15-17] Treatment options for fractures of the mandibular condyle consist of either closed treatment (i.e., a period of maxillomandibular fixation; MMF) or open treatment (i.e., open reduction with internal fixation; ORIF).[18,19]

Several studies have reported favorable clinical results with closed treatment of condylar fractures,[17,20-22] whereas others have reported favorable results for open treatment.[17-19,23] Some of these studies concluded that the closed approach should be regarded as the first choice of treatment for condylar fractures,[17,20-22] based on the assumption that closed treatment methods are favorable in terms of the potential complications arising from surgical treatment. On the other hand, others have published different indications for open treatment.[17-19,23]

Historically, closed treatment was the treatment option of choice, with, in the majority of cases, satisfactory outcomes.[24] Open treatment, on the other hand, has always been considered as a more challenging treatment procedure, mainly because of the complex anatomy, e.g., the facial nerve. Additionally, in the past, before the development of plate and screw fixation, open treatment consisted of an interosseous wire for stabilizing the fracture and a period of MMF for realizing an osseous union.

Thus, open treatment did not seem to have extra benefits over closed treatment. The development of rigid fixation permitted open reduction and stable internal fixation of mandibular condyle fractures, without the need for post-operative MMF, which made early functional rehabilitation possible.

In the literature, there are reports describing masticatory function as an outcome measure after the treatment of condylar fractures. These studies mostly focus on particular elements, e.g., bite force, chewing cycles, or (distribution of) masticatory muscle activity.[25-28] Though, it is said that masticatory performance is the outcome of complex simultaneous interrelationships in which, among others, the bite force and the height of mastication cycles are confirmed as key predictors.[2,29-32] The Mixing Ability Test (MAT), which is a clinically validated, relatively simple and inexpensive test, can be used to objectively measure the masticatory performance of patients recovering from a mandibular condyle fracture.[1,2]

Till now, no study has focused on this mixing ability in relation to mandibular (condyle) fractures; the mixing ability which is the actual masticatory performance, i.e., the ability to mix a food bolus.

Therefore, the aim of this study was to evaluate objectively measured masticatory performance in patients treated for a unilateral condylar fracture and to assess whether it has a relationship with patients' self-reported mandibular function (mandibular functional impairment). The influence of demographic and clinical parameters (i.e., maximum mouth opening, dental state, and self-perceived occlusion) on objective masticatory performance was also investigated. A cross-sectional study was performed to compare open and closed treatment modalities.

METHODS

Patients

Patients with unilateral condylar fractures who were treated at the Department of Oral and Maxillofacial Surgery of the Academic Medical Center (AMC, University of Amsterdam, Amsterdam, The Netherlands) between August 2008 and March 2016, were recruited for this study.

Patients who were younger than 18 years of age, or patients unable to understand and read Dutch, or patients that experienced bilateral condylar fractures, or patients that reported limited mouth opening (< 35 mm) before the condylar fracture, or patients with an intellectual disability, or patients with a history of psychiatric disorder(s) were excluded. Patients with a follow-up of at least 1 year were invited by letter for an additional appointment. If patients did not respond within 2 months after the letter was sent, they were contacted by telephone. The Ethics Committee of the AMC approved the study protocol. All patients who participated received a patient identification number and signed an informed consent form.

Gender, age (in years), and education level (primary up to university) were reported. The cause of trauma, fracture type (intra- or extra-articular), coexistence of other facial fractures, the use of physiotherapy, and length of follow-up (in months) were noted. The included and the excluded patients were compared regarding age, gender, fracture level related to the mandibular joint capsule (intracapsular and extracapsular), site of the fracture, other fractures, and open and closed treatment. This calculation was done, to make sure the included patients were a representation of the total population.

Measurements

Mixing Ability Test

The Mixing Ability Test (MAT) and method of analysis have been described previously.[2,3] Briefly, the MAT measures how well a patient can mix a wax tablet by chewing on it for 15 strokes. The tablet consists of two, 3-mm layers of red and blue wax, and has a diameter of 20 mm. The wax (Plasticine modelling wax, non-toxic DIN EN-71, art. nos. crimson 52801 and blue 52809, Stockmar, Kalten Kirchen, Germany) is a soft material that forms a compact bolus during chewing. The chewed wax is flattened to a thickness of 2.0 mm using a hydraulic hand press and photographed from both sides using a high-quality scanner (Epson V750, Long Beach, CA, USA).

The images of the wax are analysed and processed using Photoshop CS3 (Adobe, San Jose, CA, USA). The spread of the color intensities in the combined image of both sides is used as a measure of mixing, which is termed the Mixing Ability Index (MAI). A lower MAI score represents a better mixed tablet, and hence, better masticatory performance.

Mandibular Function Impairment Questionnaire

The Mandibular Function Impairment Questionnaire (MFIQ)[33,34] is a validated and reliable instrument used to measure a patient's self-perceived mandibular function. Seventeen items describing mandibular function related to, social activities (item 1), speech (item 2), masticatory performance (items 3, 4, 5, 9, 12, 13, 14, 15, 16, and 17), daily activities (item 6), drinking (item 7), laughing (item 8), yawning (item 10), and kissing (item 11), are scored from 0 to 4 on a Likert scale. A total-item score ranging from 0 to 68 is possible, in which '0' represents a good functional outcome and '68' a poor functional outcome.[34]

Maximum mouth opening

Active maximum mouth opening (MMO) without pain (in mm) was measured using a ruler, from the incisal edge of tooth #11 in a straight line to the opposing incisor in the lower jaw, with the patient sitting in a dental chair, and corrected for overbite. In cases of edentulous patients, MMO was measured with their dentures in situ.[35]

Dental state and self-perceived occlusion

The patient's dental state (dentate or edentulous) and self-perceived occlusion (bad, mediocre/changed, good) were determined.

Treatment

The treatment protocol described in a previous study by the authors' group was used in the present study.[24] There were two main treatment modalities: open and closed. In open treatment, the fracture was approached via a pre-auricular skin incision and a transparotid approach.

The open protocol included no post-operative maxillomandibular fixation (MMF), but a strict soft diet, instructions on active but careful movement of the jaw, and the prescription of sufficient pain-killing medication.

The closed treatment generally consisted of a short period of MMF (using brackets, MMF screws, or arch bars), including the use of guiding elastics for approximately three weeks. Similarly, patients were advised to adhere to a strict soft diet, to engage in active but careful movement of the jaw, and were provided sufficient pain-killing medication.

There were no strict indications for either treatment; the choice was principally based on the preference of the surgeon. In both groups, if rehabilitation was delayed or patients had persistent complaints after 6 weeks, active physiotherapy was started. Follow-ups after the first contact were scheduled at 5 to 7 days, and at 3, 6, and 12 weeks. If the patient had recovered well, follow-up was ended. If symptoms, such as an open bite, limited mouth opening or pain, persisted, follow-up was extended to 6 months or even 1 year. In cases of severe malocclusion, uncontrolled pain, or poor patient compliance, open treatment was considered.

STATISTICS

The patient population was described using percentages, means, and standard deviations (SDs) for continuous data. The normality of the continuous data was assessed using the Kolmogorov-Smirnov test. The independent t-test (continuous data), the chi-squared test (categorical data), and the Mann-Whitney U test (ordinal data or not normally distributed continuous data) were used to determine whether there was a significant difference between the two treatment modalities and included and excluded patients. The Spearman test was used to assess the correlation between the MAI and MFIQ.

Linear regression was used to explore the effects of gender, age, education level, cause of trauma, fracture type, presence of other fractures, physiotherapy, duration of follow-up, MMO, dental status, self-perceived occlusion, and treatment modality, on the MAI. Backward elimination in stepwise regression was used to create a definitive model. The data were analysed using SPSS version 24 (IBM Corporation, Armonk, NY, USA), and $P < 0.05$ was considered to be statistically significant.

RESULTS

In total, 58 patients with a unilateral fracture were included, i.e., 33.9% of the 171 patients (unilateral and bilateral fractures) who were approached. The included and excluded patients with a unilateral condyle fracture did not differ significantly in age ($P = 0.205$), gender ($P = 0.574$), fracture level related to the mandibular joint capsule (intracapsular and extracapsular) ($P = 0.769$), site of the fracture ($P = 0.165$), other fractures ($P = 0.618$), and open and closed treatment ($P = 0.060$).

The open and closed group did not differ significantly in age, gender, fracture level related to the mandibular joint capsule (intracapsular and extracapsular), or cause of fracture (Table 1).

The MFIQ was analysed as a continuous variable, since no cut-off points exist; however, the data were not normally distributed ($P < 0.0001$). In contrast, data from the MMO ($P = 0.200$) and the MAI ($P = 0.200$) were normally distributed.

A significant correlation between the MAI and total MFIQ score was found ($r = 0.250$; $P = 0.033$). There was a significant difference in the MFIQ between patients who underwent open versus closed treatment; however, no significant differences were found for MAI, MMO, dental state, and self-perceived occlusion between these treatment groups.

Gender, physiotherapy, presence of other fractures, and self-perceived occlusion had a significant effect on MAI (Table 1). Worse results were found on MAI for women than men, physiotherapy had a positive influence, having more than one fracture had a deteriorating effect, and a better perception of the patient on their occlusion had a positive effect on MAI.

DISCUSSION

Male patients with a unilateral condylar fracture, who receive physiotherapy, and/or have satisfactory self-perceived occlusion, exhibited the best recovery of masticatory performance in daily practice. Moreover, a positive correlation was observed between masticatory performance and patient-reported mandibular functioning (i.e., MFIQ-score).

Overall, at least 1 year after treatment, individuals who experienced a unilateral fracture of the mandibular condyle, exhibit masticatory capacity comparable with that of individuals who have not suffered such injuries.[2] This improvement of masticatory function was also seen in other studies; measured as bite force and muscle activity.[27,28]

Table 1. Demographic and clinical factors, and outcomes according to treatment group

Characteristic	Open	Closed	P-value
Age, years, mean (SD)	39.5 (17.9)	42.1 (17.4)	0.672†
Gender, (n)			0.592‡
Female	4	15	
Male	6	33	
Relation to the mandibular joint capsule, n (%)			0.093‡
Intracapsular	11 (50)	11 (50)	
Extracapsular	10 (21.3)	37 (78.7)	
Cause fractures, n (%)			0.566‡
Cycling accident(s)	5 (20)	20 (80)	
Non-cycling-related traffic accident(s)	0 (0)	5 (100)	
Violence	3 (27.3)	8 (72.7)	
Falls	1 (7.7)	12 (92.3)	
Sports	1 (25)	3 (75)	
Mixing ability index, mean (SD)	16.9 (3.1)	18.4 (2.3)	0.102†
MFIQ, mean (SD)	10.70 (2.9)	4.96 (1.3)	0.023§*
Maximum mouth opening, mean (SD)	53.9 (5.0)	53.3 (7.4)	0.799†
Dental state, n (%)			0.344‡
Edentulous	1 (50)	1 (50)	
Dentate	9 (17)	44 (83)	
Self-perceived occlusion, n (%)			0.846‡
Bad	1 (20)	4 (80)	
Mediocre/changed perception	1 (11.1)	8 (88.9)	
Good	8 (19)	34 (81)	

MFIQ, Mandibular Function Impairment Questionnaire
*Statistically significant (i.e., $p < 0.05$); ‡Chi-squared test; †Independent t-test; §Mann-Whitney U test;

Furthermore, no difference was found between the open and closed treatment groups. Which is in accordance with the study of Throckmorton et al.,[26] which concludes that surgical correction of unilateral condylar process fractures has relatively little effect on the more standard measures of masticatory function.

In a prospective cohort study, it was found that women of older age experienced a less favorable outcome, as observed by the MFIQ scores, after closed treatment of a mandibular condyle fracture.[36] Furthermore, masticatory performance of healthy young subjects (24.0 ± 4.2 years) was, in a cross-sectional study, better than that of healthy elderly subjects (72.1 ± 7.5 years).[1] These data confirm our findings that women experience a worse mandibular function outcome; however, we found that age did not appear to have a significant effect on masticatory performance.

In this study, dental status did not have a significant effect on masticatory performance (according to the MAI), which is contradictory to the findings of a previous cohort study in healthy participants. In this cohort study, the presence of natural dentition had a positive effect on the masticatory performance (according to the MAI).[2] On the other hand, satisfactory self-reported occlusion positively influenced masticatory performance in the present study. In another clinical study involving 44 participants, a correlation was found between mixing ability and occlusal and near contact areas (up to 200-µm interdental space).[37] Furthermore, Wang et al.,[38] reported that occlusal contact is crucial for efficient mastication, and that the occlusal contact area of the premolars and molars in this context is important for dentate adults.[39] Though, Bourdiol et al.,[40] stated that only severe malocclusion correlates with poor masticatory performance and that most patients seem to adapt to some degree of malocclusion.

In this matter, it would be interesting to be able to select the non-adapting patients. Maybe, not only malocclusion diminishes the masticatory function, but also other factors, e.g., decreased bite force and small lateral amplitudes of the masticatory cycles.[40]

The presence of other fractures appears to negatively impact masticatory performance. Sybil et al.[25] reported comparable results and found that there was a reverse relationship between the bite force values and the number of fractures of the mandible. This is a plausible outcome, given the simple fact that it is more difficult to recover from multiple fractures than from a single fracture and, moreover, multiple fractures carry the associated risk for more biomechanical complications.

Physiotherapy applied in the context of condylar fractures had a significant positive effect on masticatory performance. A possible explanation for this would be that patients receiving physiotherapy become more aware of their mouth and chewing functions.

This warrants further exploration because a standardized protocol for physiotherapy in this particular patient population does not yet exist.

The many subgroups, the relatively small number of patients, and the missing data on the reason for the treatment choice are possible sources of bias in this study. Since, for example, the chance exists that the more displaced fractures were treated open, this latter group could therefore have worse outcomes. Still, the patients included were a proper reflection of the total group of patients that were approached.

In conclusion, 1 year after treatment, masticatory capacity and mandibular function in individuals with unilateral condylar fractures were comparable with that of individuals who have not suffered such injuries, independent of the chosen treatment. Male patients with satisfactory self-perceived occlusion, without other fractures, and who received physiotherapy demonstrated the best masticatory performance. Because gender, self-perceived occlusion, and the presence of other fractures appeared to be important in determining the ability to masticate, extra attention should be devoted to these particular patients during clinical treatment evaluation.

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4.3

Cone beam computed tomography analysis

This chapter is an edited version of the manuscript:
A. V. J. Rozeboom, R. Schreurs, L. M. L. Helmer, L. Dubois, T. J. J. Maal, F. Lobbezoo, J. de Lange
Volumetric outcomes of treatment for unilateral condylar fractures: a pilot study

Submitted

INTRODUCTION

The condyle of the mandible is prone to fractures because of the slender nature of the condylar neck.[1] Such fractures may be treated via a closed (non-surgical) or open (surgical) approach.[2–5] The association between the morphology of the condyle and post-treatment functional impairment is unclear.[6]

Most studies focusing on radiologic outcomes use two-dimensional analysis.[3,7] However, with 3D imaging, changes in condylar volume and morphology can be assessed.[6,8,9,10]

The goal of this study was to analyse the volume and changes in volume in both condyles after a unilateral condylar fracture. The effect of the treatment modality used on condylar volume and the relationship between condylar volume and mandibular function was evaluated at least one year after the traumatic event.

PATIENTS AND METHODS

Patients

The medical records of patients who were treated for a unilateral condylar fracture at the Department of Oral and Maxillofacial Surgery of our institution between 2008 and 2016 were reviewed. Patients whose trauma occurred at least 1 year earlier were invited by letter to attend an additional appointment. If available, the CT scans acquired when the patient initially presented to the hospital were collected (pre-treatment scan). At the follow-up appointment, a CBCT scan (field of view 26 cm, diameter 23 cm, scan time 18 s, voxel size 0.4 mm at 96 kV, and 10 mA) was acquired (post-treatment scan). Each patient completed the MFIQ,[11] and performed the MAT.[13] Patient gender and age, cause of trauma, type of fracture, presence of other fractures, physiotherapy, duration of follow-up, maximum mouth opening (MMO), dental status, self-perceived occlusion, treatment modality, and maxillomandibular fixation (MMF) method were recorded.

Treatment

The treatment protocol used by our study group has been described elsewhere.[12] In short, there is a choice of two main treatment modalities, i.e., open (surgical procedure with internal fixation) and closed (expectative treatment or MMF).

Mandibular Functional Impairment Questionnaire

The MFIQ[11] is a validated and reliable instrument that measures a patient's subjective perception of the mandibular function. The instrument consists of 17 items, all of which are scored from 0 to 4 on a Likert scale by the patient (total-item score: 0 to 68; '0' = good functional outcome and '68' = poor functional outcome).

Mixing Ability Test

The MAT and the method of analysis have been described elsewhere.[13] This test measures how well a patient can mix a two coloured wax tablet by chewing on it for 15 strokes. The spread of the colour intensity values is used as a measure of mixing; the Mixing Ability Index (MAI). A lower MAI score represents a better mixed tablet, and thus a better masticatory performance.

CBCT Analysis

The condylar volumes were analysed using the validated method introduced by Xi et al.[10,14] A graphical user interface was built around the algorithm in C++. The DICOM (Digital Imaging and Communications in Medicine) dataset was imported in the software and segmentation of the condyle was performed in the axial direction. A virtual 3D hard-tissue model of the DICOM dataset was made using Maxilim software (v. 2.3.0, Medicim NV, Mechelen, Belgium). A hard-tissue reconstruction of the segmentation was generated to augment the condylar reconstruction of the DICOM set. A plane parallel to the Frankfurt plane through the most caudal point of the sigmoid notch (C-point) was used as a cut-plane for measurement of the condylar volume.[10] The pre-treatment and post-treatment condylar regions were superimposed using an iterative closest point approach.[15]

STATISTICS

The non-continuous data were described by numbers and percentages, and the continuous data by the mean (and standard deviation). The normality of the condylar volumes was assessed using the Shapiro-Wilk test. The independent *t*-test was used to assess if there was a significant difference in volume between the two treatment modalities.

A paired-samples *t*-test was used to detect a significant difference between the pre-treatment and post-treatment volumes. The Pearson test was used to assess the correlation of condylar volume and the MAI and MFIQ scores.

Linear regression was used to explore the effects of gender, age, cause of trauma, type of fracture, presence of other fractures, physiotherapy, duration of follow-up, MMO, dental status, self-perceived occlusion, and treatment modality, on the condylar volumes. Backward elimination in stepwise regression was used to create a definitive model. The data were analysed using SPSS version 24 (IBM Corp., Armonk, NY, USA). A P-value < 0.05 was considered statistically significant.

RESULTS

Seventy-four (43.3%) of the 171 patients who were contacted to participate in this cross-sectional study were enrolled. The post-treatment volumes were analysed in 49 patients, 22 of whom had a CT scan on presentation. The post-treatment CBCT scans for 25 patients could not be analysed because of poor quality (e.g., scattering osteosynthesis material).

The cause of trauma was a sports-related injury in 26 cases (53.1%), a fall in 10 (20.4%), a physical assault in 8 (16.3%), and a road traffic accident in 5 (10.2%). Forty-one patients (83.7%) received closed treatment and 8 (16.3%) received open treatment.

Arch bars (9 patients, 21.4%), brackets (14 patients, 33.3%), or intermaxillary fixation screws (2 patients, 4.8%) were used for MMF. All patients in the study were dentate. Twenty-four patients (49%) underwent physiotherapy to improve their MMO, range of movement, and/or occlusion. The mean follow-up duration was 4.8 (range 1 - 8.7) years.

The pre-treatment and post-treatment volumes (Table 1) were normally distributed (pre-treatment: non-fractured P = 0.557; post-treatment: fractured P = 0.196; non-fractured P = 0.380). There were no significant differences in volume between the intracapsular and extracapsular fractured condyles (Table 2).

The condylar volume in patients with intracapsular fractures tended to be smaller than in those with extracapsular fractures, but the difference was not statistically significant (pre-treatment P = 0.842, post-treatment fractured P = 0.090, post-treatment non-fractured P = 0.707). In view of the small number of patients, the intracapsular and extracapsular fractures were considered as one group for all other analyses.

Table 1. Tests of normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk test		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-treatment NF	0.135	22	0.200*	0.963	22	0.557
Post-treatment NF	0.078	49	0.200*	0.975	49	0.380
Post-treatment F	0.080	49	0.200*	0.968	49	0.196

*Lower bound of the true significance. a. Lilliefors Significance Correction. F, fractured side; NF, non-fractured side

Table 2. Intracapsular and extracapsular condylar volumes

	Pre-T				Post-T			
	F		NF		F		NF	
	Intra	Extra	Intra	Extra	Intra	Extra	Intra	Extra
Volume (mm^3)	-	-	(n=5) 1980.80	(n=17) 1911.47	(n=9) 1448.44	(n=40) 1788.85	(n=9) 1788.89	(n=40) 1874.28
SD (mm^3)	-	-	339.13	733.97	390.96	558.17	361.41	652.03
Paired *t*-test (pre-post)	-	-	P=0.014	P=0.000				
Independent *t*-test (intra-extra)	-	-	P=0.842		P=0.090		P=0.707	
Open (mm^3)	-	-	-	-	(n=1) 1939.00	(n=7) 1982.14	(n=1) 2224.00	(n=7) 1831.43
SD (mm^3)	-	-	-	-	-	520.58	-	787.57
Closed (mm^3)	-	-	-	-	(n=8) 1387.13	(n=33) 1747.85	(n=8) 1734.5	(n=33) 1883.36
SD (mm^3)	-	-	-	-	368.79	564.79	344.74	633.52
Independent *t*-test	-	-	-	-	P=0.201	P=0.319	P=0.223	P=0.851

F , fractured side; NF, non-fractured side; Pre-T, pre-treatment; Post-T, post-treatment; SD, standard deviation

Analysis of CBCT scans

Pre- treatment and post-treatment scans

On the pre-treatment scans, the mean condylar volume on the non-fractured side was 1927 ± 658 mm^3 (n=22) (Table 3). It was not possible to calculate the condylar volume on the fractured side because of the presence of multiple fragments.

Regression analysis did not identify any significant effect of gender, age, type of trauma, type of fracture, or presence of other fractures on the pre-treatment condylar volume on the non-fractured side.

On the total of 49 post-treatment scans, the mean condylar volume was 1726 ± 544 mm^3 on the fractured side and 1879 ± 607 mm^3 on the non-fractured side. Regression analysis revealed that patient gender and MMO had a significant effect on the volume of the non-fractured condyle post-treatment ($b = 0.409$, $P = 0.002$ and $b = 0.321$, $P = 0.013$, respectively).

Women tended to have smaller condyles, and an association was seen between a larger post-treatment condylar volume on the non-fractured side and a wider MMO. Patient gender also had a significant effect on the post-treatment condylar volume on the fractured side ($b = 0.413$, $P = 0.003$), whereby women tended to have a smaller condylar volume post-treatment.

No significant difference in condylar volume was found between the open and closed treatment groups (non-fractured volume, open versus closed, $P = 0.900$; fractured volume, open versus closed, $P = 0.182$).

Pre- and post-treatment non-fractured matches/couples

When looking at the pre- and post-treatment non-fractured matches/couples (n=22), the mean condylar volume on the non-fractured side was 1927 ± 658 mm^3 (n=22) pre-treatment and 1751 ± 630 mm^3 (n=22) post-treatment (Table 3). The mean difference in condylar volume between the pre-treatment and post-treatment condylar volumes on the non-fractured side was 177 ±127 mm^3, which represents a 9.2% decrease in volume.

Significantly smaller non-fractured condyles were found on the post-treatment scans in both the open and closed treatment groups (open: pre-treatment 1668 mm^3 and post-treatment 1497 mm^3; $P = 0.039$, closed: pre-treatment 1985 mm^3 and post-treatment 1807 mm^3; $P < 0.001$).

When the open and closed treatments were compared, no significant difference in the volume, i.e., pre-treatment and post-treatment volumes of the non-fractured condyles, was found ($P = 0.922$).

Table 3. Condylar volumes for the total study group

			Post-treatment			
			F (n=49)	NF (n=49)		
Volume (mm^3)			1726	1879		
SD (mm^3)			544	607		
Indep. *t*-test OvC			P = 0.182	P = 0.900		
	Pre-treatment		Post-treatment			
Pre and post 'couples' (n=22)	F	NF (n=22)	*F (n=22)*	NF (n=22)		
Volume (mm^3)	-	1927	*1663*	1751		
SD (mm^3)	-	658	*543*	630		
Paired *t*-test (pre NF, post F and NF)			_P = 0.010*_	P = <0.001*		
Open (n=4) (volume mm^3)	-	1668	-	1497		
SD (mm^3)		670		712	P = 0.039*	
Closed (n=18) (volume mm^3)		1985	-	1807		
SD (mm^3)	-	661		618	P = <0.001*	
Open (pre minus post NF)						
(volume mm^3)						171
SD (mm^3)						97
Closed (pre-post NF)						
(volume mm^3)						178
SD (mm^3)						135
Indep. T-test OvC (pre minus post NF)						P = 0.922

F, fractured side; NF, non-fractured; OvC, open vs closed; SD, standard deviation; *P≤0.05

Relationship between condylar volume, MFIQ scores, and the MAT

No correlation was found between the post-treatment MFIQ scores and condylar volume on either the non-fractured side (P = 0.235) or the fractured side (P = 0.477) (Table 4). There was no significant correlation between the outcome of the MAT and post-treatment condylar volume on the non-fractured side (r = -0.248, P = 0.085). However, there was a significant correlation between performance on the MAT and the post-treatment condylar volume on the fractured side (r = -0.332, P = 0.020). The MAT result was significantly better in patients with larger condyles, i.e., with more volume.

No correlation was found between the MFIQ score and the difference in condylar volume between pre-treatment and post-treatment on the non-fractured side (P = 0.484). There was also no significant correlation between performance on the MAT and the difference in condylar volume between pre-treatment and post-treatment on the non-fractured side (P = 0.178).

Table 4. MFIQ and MAT

Correlations (Pearson)	Significance	
MFIQ - Post-treatment, non-fractured	P = 0.235	
MFIQ - Post-treatment, fractured	P = 0.477	
MFIQ - Pre minus post, non- fractured	P = 0.484	
MAT - Post-treatment, non-fractured	P = 0.085	
MAT - Post-treatment, fractured	*P = 0.020**	*Pearson Correlation -.332*
MAT - Pre minus post, non-fractured	P = 0.178	

*P≤0.05

DISCUSSION

In this study, there was a significant mean decrease in condylar volume of 9.2% after a fracture of the mandibular condyle as well as significant remodelling of the non-fractured condyle. Ellis and Throckmorton stated that, because of the neuromuscular adaption after trauma, the non-fractured condyle is loaded more heavily during mastication than the fractured condyle in order to prevent loading on the damaged part of the temporomandibular joint.[16] It is conceivable that this increase in loading of the non-fractured condyle causes remodelling of the condyle. Moreover, development of dysfunction in the non-fractured temporomandibular joint has been reported in patients with unilateral condyle fractures and is thought to reflect a change in chewing patterns to prevent loading of the fractured joint.[17,18]

In terms of skeletal adaptations, a new temporomandibular articulation occurs after trauma, i.e., regeneration of the fractured condyle with a change in the temporal component and loss of the posterior vertical dimension.[16] This regeneration causes remodelling not only of the fractured condyle but also the contralateral condyle. The changes that were observed in this study seemed to occur independent of the treatment method used, although patients who undergo open treatment tend to have less neuromuscular adaptation.[19]

In the present study, there was no significant difference in condylar volume between patients who were treated using the open method and those who underwent closed treatment. However, the condylar volume on the fractured side was notably smaller after closed treatment than after open treatment, indicating more adaptation in the condyles treated using the closed method. Segmentation difficulties were encountered in the open treatment group because of the presence of osteosynthesis materials.

3D-condylar volume is often evaluated in orthognathic surgery research.[8,9,20] In the relevant studies, the same process of loss of condylar volume is seen after orthognathic surgery. In a study by da Silva et al.,[20] the condylar volume after orthognathic surgery was significantly smaller than before surgery. In a study of 50 patients by Xi et al,[9] there was a mean pre-treatment condylar volume of 1728 ± 498 mm^3 before orthognathic surgery and a post-treatment condylar volume of 1703 ± 552 mm^3. The pre-treatment and post-treatment volumes were similar in our study. Unfortunately, we were not able to compare pre-treatment and post-treatment volumes in fractured condyles. Most of the preoperative images were obtained by CT imaging and most of the post-treatment images were acquired by CBCT imaging, which might have had an effect on the segmented 3D condylar volume.[21]

Use of the condyle on the non-fractured side as a control against which to compare the post-treatment volume on the fractured side is questionable, given the existing difference between the left and right condylar volumes. Safi et al.[22] found a significant difference between the volume of the left and right condyles ($P<0.01$) and Tecco et al.[23] reported a difference in volume of 3.9% between the left and right condyles.

In the study by Xi et al.,[9] the condylar volume was found to be significantly larger in men than in women. We also found a relationship between patient gender and condylar volume in the post-treatment scans, i.e., men had larger condylar volumes than women. It has been stated that patient gender is one of the most important risk factors for pain after treatment of condylar fractures.[24]

Notable in our study was the finding that the larger post-treatment volume of the fractured condyle, the better the masticatory performance. A smaller condylar volume could explain the differences in pain between men and women after condylar fractures. Nevertheless, the functional significance of this volume is debatable. Da Silva et al.[20] found that changes in condylar volume did not correlate with joint space, indicating that there is no correlation between condylar volume and function. In contrast, Ahn et al.[25] found a correlation between condylar volume and function, suggesting a relationship between decreased condylar volume and dysfunction.

In summary, a significant amount of resorption was seen after trauma in both affected and non-affected condyles in this study. However, there was no significant difference in condylar volume between the open and closed treatment methods. A larger condylar volume was associated with better chewing ability, and patient gender and MMO influenced post-treatment condylar volumes. Unfortunately, no further insight could be gained into morphology, joint space, or angulation/ shortening because of the small sample size and various aspects of the study design.

In the authors' opinion, imaging may be helpful to stratify pathophysiological adaptations and can help us to improve our ability to provide individualized treatments for our patients.

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4.4

Problems in starting a randomized controlled trial

This chapter is an edited version of the manuscript:

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Letter to the editor: Randomized clinical trial on condylar fractures: 'open or closed'

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This letter concerns a major controversy in maxillofacial trauma care: whether to perform open or closed treatment of a mandibular condyle fracture. A Randomized Clinical Trial (RCT) on this subject has been underway since 2013 at the Academic Medical Center in Amsterdam, University Medical Center in Groningen, Erasmus Medical Center in Rotterdam, Spaarne Hospital in Haarlem, and Isala Clinics in Zwolle. Other researchers have tried to do this before.[1,2] Until now, no research group has succeeded in executing a RCT with sufficient power to answer the question as to whether one should perform surgery on a mandibular condyle fracture or not. During the 4 years of research to date, we have met many challenges, as outlined below:

1. A multicenter trial was designed in order to include an adequate number of patients and to have a study with sufficient power. However, due to the inadequate existing definitions of the separate treatment modalities, setting up a uniform study protocol that every center could agree on was the first obstacle.[3,4]

2. Following the implementation of the study, coordination and planning of the protocol at the different centers, with many different consultants involved, turned out to be difficult.

3. The inclusion of patients was the next hurdle. First, for ethical reasons, the inclusion criteria for this study were strict, e.g. fracture with dislocation confirmed radiographically, no other fractures interfering with the occlusion and malocclusion present. The reported number of dislocated fractures with a malocclusion were very small. Second, patients now like to make their own decision on which treatment they wish to receive. Therefore, convincing them to take part in a RCT, in which the treatment is determined by randomization, is difficult, and this is not acceptable in most patients.

4. Furthermore, good results are achieved with closed treatment and this raises the question of what the necessity of the surgical treatment procedure would be. During night and weekend shifts, the temptation to select the relatively simple closed treatment option and not follow the study protocol has appeared to be a reality.

If we want to answer the question of how to treat mandibular condyle fractures, the study design is probably the pivotal factor. As mentioned, a RCT - the golden standard for evaluating the effects of medical interventions - is challenging in terms of logistics, planning, and costs.[5] A promising alternative to the conventional pragmatic RCT is the cohort multiple Randomized Controlled Trial (cm-RCT) approach, which is designed to facilitate randomized trials for the pragmatic evaluation of interventions.[5,6] In a cm-RCT, all patients will undergo 'standard treatment'. This group of patients will be named 'the observational cohort'. Eligible patients within this observational cohort are identified, and some of them will be selected at random and offered the open intervention. The other eligible patients will not be approached and will undergo the standard treatment. In this way, two randomly compiled groups are formed and the two treatment modalities can be compared.

In conclusion, the answer to the question 'open or closed?' lies ahead, and by learning from each other's difficulties during this journey, maybe someday we will be able to solve this major controversy.

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Chapter 5

General Discussion and Future Prospects

Nowadays, quality of life and patient satisfaction are becoming increasingly important in clinical decision-making. Therefore, the subjective outcomes of treatment are also becoming more important. However, it is striking that so few studies in literature have considered clinically relevant subjective parameters, with most focusing on objective outcome measures, such as occlusion, mouth opening, range of motion, and pain.[35] Most of the objective outcomes of both open and closed treatment have been critically reviewed.[20,36]

Two systematic reviews (Chapters 2.1 and 3.1) revealed substantial heterogeneity in the contemporary literature with regard to assessment of outcomes, indications for different treatment methods, treatment protocols, and duration of follow-up. This heterogeneity rendered the treatment modalities used and their clinical success hard to interpret and compare. Most of the studies have reported good results in general for both the open and closed treatment methods. However, there is still a lack of high-quality evidence for the effectiveness of either approach.

Chapter 3 discusses open treatment and states that this should be minimally invasive with minimal risk of surgical complications and that the recovery period should be shorter without use of maxillomandibular fixation (MMF). Chapter 3.1 shows that most studies reported good results with regard to the outcome measures of open treatment, i.e., occlusion, mouth opening, range of motion, and pain. Chapter 3.2 outlines the approach and surgical complications in more detail. Most likely, the focus of debate should not be on the choice of skin incision but rather the choice of subcutaneous dissection. According to the literature, the transparotid approach has gained popularity on the basis that it is more straightforward with direct visibility of the fracture and the shortest distance between the skin and the mandibular condyle. The shorter working distance means there is less need to forcefully retract the soft tissues, implying a limited complication rate, particularly with regard to facial nerve weakness.[37]

In the studies included in this review, the incidence of temporary weakness was higher with transparotid dissection than with non-transparotid dissection. However, the recovery rate was significantly higher with the transparotid approach than with the non-transparotid approach. A possible explanation might be that there is less need for traction on the nerve. Taking this into account, the incidence of permanent facial nerve damage was 0.4% with a non-transparotid approach and 0.07% with the transparotid approach. Differences in the subcutaneous approaches used, i.e., with and without retrograde nerve dissection for identification of the nerve, could have contributed to these outcomes.

The open and closed treatment modalities were compared in the cross-sectional study outlined in Chapter 4. When using the Mandibular Function Impairment Questionnaire (MFIQ) as the main outcome, closed treatment was preferable to open treatment ($P = 0.023$). This conflicts with the study reported by Eckelt et al., in which the open group (2.4 [standard deviation (SD) 0.76]) performed better than the closed group (10.5 [SD 2.2]; $P = 0.001$)[38]. A study by Schneider et al. also reported that their MFIQ results favored open treatment over closed treatment (2.7 vs 8.6; $P = 0.009$).

A possible explanation for the success of our closed treatment is the use of a strict treatment protocol, especially for guiding elastics rather than firm elastics or steel wires. Strict follow-up, as realized in our center, also favors a successful outcome.

Compared with the normal population, our study population performed well with regard to MMO[39] and range of motion. The range of motion, determined by laterotrusion and protrusion, was not significantly different from the laterotrusion measured in the normal population (left, 11.5 mm [SD 2.4], right, 10.9 mm [SD 2.1] in female subjects; left, 12.1 mm [SD 2.4], right, 11.0 mm [SD 2.6] in male subjects).[40] No cases of ankylosis were found.

Use of the Diagnostic Criteria for Temporomandibular Disorders in this field of maxillofacial surgery is relatively new. These criteria are a well-described, evidence-based system for assessment of temporomandibular joint complaints and jaw dysfunction.

The data show that 90.5% of patients in our study population were pain-free, which is comparable with earlier findings in the general population without trauma.[20,36] A systematic review showed prevalence rates of 6%–12.9% for myofascial pain, 8.9% - 15.8% for intra-articular joint disorders, and 2.6% for arthralgia diagnoses,[41] indicating that the findings of our cross-sectional study with regard to prevalence are similar to those in the general population. The importance of psychosocial symptoms in patients with temporomandibular dysfunction (TMD) has been mentioned in studies that have shown an association between the pain of TMD and disorders such as depression, somatization, and anxiety.[42,43] In our study, there was no difference in the frequency of Axis II symptoms between the open and closed treatment groups.

As described in Chapter 4.2, after 1 year of treatment, masticatory capacity and mandibular function as determined by the mixing ability test were comparable with levels in the normal population, independent of the chosen treatment. Male patients with satisfactory self-perceived occlusion and no other fractures, as well as those who received physiotherapy demonstrated the best masticatory performance. Patient gender, self-perceived occlusion, and the presence of other fractures appeared to be important in determining the ability to masticate, so extra attention should be devoted to these patients when evaluating the outcome of clinical treatment.

In Chapter 4.3, 3D analysis showed a significant amount of resorption after trauma in both affected and non-affected condyles. However, there was no significant difference in condylar volume between the open and closed treatment methods.

A larger condylar volume was associated with better chewing ability and patient gender and MMO influenced post-treatment condylar volumes. Unfortunately, no further insight could be gained into morphology, joint space, or angulation/ shortening because of the small sample size and various aspects of the study design.

Our cross-sectional study indicates that there is a significant difference in the MFIQ results between open and closed treatments. Although good outcomes are achieved by each type of treatment, it seems preferable to avoid surgery and the concomitant surgery-related complications as long as the indications for surgical repositioning are not evident. Closed treatment also avoids a protracted operating time, use of more expensive hardware, a protracted general anesthesia time, hospitalization, and sickness leave costs.[44] Therefore, closed treatment should not be overlooked but rather advocated when it can be performed by a competent surgeon following a strict treatment protocol with appropriate patient compliance. Clearly, there are strong indications for open treatment, e.g., displacement into the middle cranial fossa, lateral extracapsular displacement of the condylar head, and bilateral mandibular condyle fractures in dentulous and edentulous patients who cannot have a splint, comminuted fractures involving other facial bones, jaw deformities, foreign material at the fracture site, and inappropriate occlusal restoration by closed reduction.

Future perspectives

The evidence-based pyramid teaches us that the choice of study design is a pivotal factor if we truly want to determine how to treat mandibular condyle fractures. A randomized controlled trial (RCT) is the golden standard for evaluating the effects of medical interventions but is challenging in terms of logistics, planning, and costs.[45]

Few RCTs have been published on this topic,[25,38,46–50] most of which have had limiting inclusion criteria, e.g., fracture angulation or shortening of the height of the ascending ramus, small populations, a high rate of loss to follow-up, and included no subjective outcome measures. A promising alternative to the conventional pragmatic RCT is the cohort multiple RCT concept, which is designed to facilitate randomized trials for pragmatic evaluation of interventions.[45,51] In a cohort multiple RCT, all patients would undergo 'standard treatment' and be known as an 'observational cohort'. Within this observational cohort, eligible patients would be identified and randomly selected for an offer of open intervention. In this way, two groups can be formed in a random manner for comparison of two treatment modalities. Until this research concept becomes established in the clinical setting, the best option would be to refine our current treatment methods.

Further development of closed treatment protocols, including a schedule for strict follow-up, use of less demanding MMF methods, e.g., (blocked) brackets with elastics, further understanding of adaptation mechanisms of the (contralateral) condyle and (guiding) physiotherapy, will bring this treatment method to a higher level, and would be expected to have a higher success rate.

Future opportunities for open treatment need to be explored, including the development of advanced and less technically demanding endoscopic and intraoral techniques, the role of nerve integrity monitoring during surgery (e.g., the NIM stimulator; Medtronic, Minneapolis, MN),[52] and perhaps the use of intraoperative surgical imaging or augmented reality.

For now, closed treatment seems to be a safe and appropriate treatment modality for most unilateral condylar fractures. Although open treatment in general showed similar outcomes, it should be reserved for limited indications. Adequate clinical decision-making is the pivotal factor for avoiding unwanted surgery-related complications.

In conclusion, the answer to the question of 'open or closed?' lies ahead, and by learning from each other's difficulties during this journey, we may eventually resolve this controversy.

Chapter 6

Appendices

6.1

Summary

Open versus Closed, Mandibular condyle fractures

Chapter 2 **describes the closed treatment modality.**

In chapter 2.1, a systematic review provides an overview of the studies exclusively pertaining to closed treatment published to date and summarizes the existing closed treatment modalities and their clinical outcomes. A systematic search identified 16 studies with a total of 1535 patients with mandibular condyle fractures. The most frequently described outcome measures were occlusion, mouth opening, range of motion of the mandible (ROM) and pain. In these studies, 89% of patients had no occlusal disturbances by the end of the follow-up period. The presence of some form of malocclusion ranged from 0 to 24%. Overall, in these studies, the final review reported 'good opening' of the mouth in 86% of cases and an unlimited range of motion of the mandible in 84%. No cases of ankylosis were reported. The reported incidences of pain at rest ranged from 0 to 16%. Ninety-two percent of patients were free of pain. However, because of the heterogeneity of the study groups, high rates of loss to follow-up, poor descriptions of the different treatments given, and variability in the methods used to measure the outcome, no clear association between the treatments applied in the studies and outcomes could be determined. The present research confirms that there is currently no uniform standard for closed treatment of condylar fractures that ensures good clinical results, mainly because of a low level of evidence. Establishment of such a standard could potentially improve treatment outcomes.

In chapter 2.2, an alternative non-surgical procedure for managing malocclusion complications associated with closed treatment of condylar fractures is presented. Four patients with post-traumatic malocclusion following conservative treatment were referred to our center in 2013 and 2014 and treated with hypomochlions or occlusal stops to modulate the feedback mechanism that had developed in these patients.

After removal of the occlusal stops and a period of physiotherapy to restore proprioception, stable functional occlusion was achieved within 6 weeks in all patients. This result indicates that post-traumatic malocclusion complications following conservative (closed) treatments can be successfully resolved without the need for further invasive surgical procedures.

Chapter 3 focuses on the open treatment modality.

In chapter 3.1, the systematic review on open treatment provides an overview of the studies published exclusively on open treatment and summarizes the existing open treatment modalities and their clinical outcomes. Seventy studies were selected for detailed analysis. Most studies reported good results with regard to outcome measures. Surgical complications including hematoma, wound infection, weakness of the facial nerve, sialocele, salivary fistula, sensory disturbance of the great auricular nerve, unsatisfactory scarring, and fixation failure were reported. This review suggests a high level of methodologic variance in the relevant studies published to date, such that no evidence-based conclusions or guidelines can be formulated with regard to the most appropriate open treatment at present. Establishment of such standards could potentially improve treatment outcomes.

Chapter 3.2 focuses on the approach used in the open treatment modality and provides an overview of the complications of extraoral approaches to condylar fractures. Given the diversity in fractures, approaches, and surgical techniques, it is difficult to objectively compare the surgical techniques used for condylar fractures and their complications. The literature suggests that there is no preference in terms of the skin incision but that a transparotid approach is advocated.

Chapter 4 discusses the 'open versus closed' controversy.

The outcomes of a cross-sectional study are presented. The outcomes of the treatment of condylar fractures according to responses on the MFIQ for (subjective) self-reported mandibular function, the Diagnostic Criteria for Temporomandibular Disorders for TMD complaints and jaw dysfunction (chapter 4.1), mixing ability test for masticatory performance (chapter 4.2), and cone beam computed tomography scans (chapter 4.3) were used to compare the open and closed treatment modalities. In total, 74 of 171 patients participated in this study. The mean MFIQ score was 10.70 (standard error 2.9) in the open group and 4.96 (standard error 1.3) in the closed group ($P = 0.013$), and thus an outcome in favor of the closed treatment group. Examination according to the Diagnostic Criteria for Temporomandibular Disorders did not reveal a significant prevalence of TMD complaints. The correlation between objective masticatory performance and self-reported mandibular function was positive ($r = 0.250$; $P = 0.033$).

Patients who were male, received physiotherapy, had no other mandibular fractures, and/or had satisfactory self-perceived occlusion were found to better masticatory performance. No significant difference in the Mixing Ability Index (MAI) was found between open and closed treatment.
No significant difference in condylar volume between the open and closed treatment methods was found. But, a larger condylar volume was associated with better chewing ability and patient gender and MMO influenced post-treatment condylar volumes. Overall, good results were achieved with both open and closed treatments.

Chapter 4.4 presents a promising alternative to the conventional pragmatic RCT, which is presently the golden standard for evaluating the effects of medical interventions. A RCT to address the question of 'open versus closed' has been proven to be challenging in terms of logistics, planning, and costs.[45] A cohort multiple RCT approach, which is designed to facilitate randomized trials for pragmatic evaluation of interventions,[45,51] may be a feasible research option.

6.2

Samenvatting

Open versus Gesloten, Collum mandibulae fracturen

Hoofdstuk 2 beschrijft de gesloten behandelingsmodaliteit.

In hoofdstuk 2.1 wordt een systematische review gepresenteerd om een overzicht te geven van de tot nu toe gepubliceerde studies die uitsluitend betrekking hebben op de gesloten behandeling. De bestaande gesloten behandelingsmodaliteiten en hun klinische uitkomsten worden besproken. Uit de systematische zoekactie werden in totaal zestien onderzoeken met een totaal aantal van 1535 patiënten met collum mandibulae fracturen geselecteerd. De meest frequent beschreven uitkomstmaten waren occlusie, mondopening, bewegingsbereik van de onderkaak (ROM) en pijn. In deze onderzoeken had 89% van de patiënten aan het einde van de follow-upperiode geen malocclusie. De aanwezigheid van enige malocclusie varieerde van 0 tot 24%. Over het algemeen werd in 86% van de gevallen bij het laatste follow-up moment een goede mondopening gerapporteerd en in 84% werd een onbeperkt bewegingsbereik van de onderkaak gemeld. Er werden geen gevallen van ankylose beschreven. De gerapporteerde incidentie van pijn in rust varieerde van 0 tot 16%. Een gemiddelde van 92% van de patiënten was pijnvrij. Vanwege de heterogeniteit van de groepen, de hoge uitval van patiënten in de follow-up, de slechte omschrijvingen van de verschillende behandelmethoden en de verschillende uitkomstmaten, kon geen duidelijk verband worden vastgesteld tussen de behandelingen en de uitkomsten die in de onderzoeken werden toegepast. Deze systematische review laat zien dat, vooral vanwege het lage bewijsniveau van de studies, er momenteel geen gouden standaard is voor de gesloten behandeling van collum mandibulae fracturen. Het opstellen van een dergelijke standaard zou mogelijk de behandelresultaten kunnen verbeteren.

In hoofdstuk 2.2 wordt een alternatieve niet-chirurgische procedure besproken voor het behandelen van malocclusie, ten gevolge van een gesloten behandeling van collum mandibulae fracturen. Vier patiënten met post-traumatische malocclusie na een conservatieve behandeling werden in 2013 en 2014 verwezen naar ons centrum en behandeld met hypomochlions, i.e., occlusale stops om het post-traumatische feedbackmechanisme dat deze patiënten hadden ontwikkeld te moduleren. Na verwijdering van de occlusale stops en een periode van fysiotherapie om de propriosepsis te herstellen, werd binnen een tijdspad van 6 weken een stabiele functionele occlusie bij alle patiënten bereikt. Dit resultaat geeft aan dat post-traumatische malocclusiecomplicaties na een conservatieve behandeling in sommige gevallen met succes kunnen worden opgelost zonder de noodzaak voor verdere invasieve chirurgische procedures.

Hoofdstuk 3 richt zich op de open behandelingsmodaliteit.

In hoofdstuk 3.1 wordt een systematische review beschreven; een overzicht van studies die uitsluitend zijn gepubliceerd over de open behandeling wordt gegeven en de bestaande open behandelmodaliteiten en hun klinische resultaten worden samengevat. Een totaal van zeventig studies werd geselecteerd voor gedetailleerde analyse. De meeste studies rapporteerden goede resultaten van de open behandeling. Chirurgische complicaties zoals hematomen, wondinfecties, zwakte van de aangezichtszenuw, sialocèles, speekselfistels, veranderde sensibiliteit van de nervus auricularis magnus, ontsierende littekens en falen van het osteosynthesemateriaal, werden in de onderzoeken beschreven. Door, onder andere, de hoge mate van methodologische variantie in de huidige literatuur, kan er vooralsnog geen evidence-based conclusie of richtlijn worden geformuleerd voor de meest geschikte open behandeling. Het vaststellen van dergelijke standaarden kan mogelijk de behandelresultaten verbeteren.

Hoofdstuk 3.2 richt zich op de chirurgische benadering van de open behandelmodaliteit en biedt een overzicht van de complicaties van extraorale benaderingen van collum mandibulae fracturen. Vanwege de grote diversiteit in fracturen, benaderingen en chirurgische technieken, is het moeilijk om behandeltechnieken voor collum mandibulae fracturen en hun complicaties objectief te vergelijken. Gebaseerd op de literatuur in deze review is er geen directe voorkeur met betrekking tot de incisie van de huid. Wat betreft de subcutane dissectie, wordt een transparotideale benadering voorgesteld.

Hoofdstuk 4 bespreekt de controverse 'open versus gesloten'.

De resultaten van een cross-sectionele studie worden gepresenteerd. De uitkomsten van de verschillende behandelmethoden, i.e., open en gesloten, van collum mandibulae fracturen worden beschreven met behulp van, de Mandibular Function Impairment Questionnaire (MFIQ) voor (subjectieve) zelf-gerapporteerde mandibulaire functie, de diagnostische criteria voor temporomandibulaire aandoeningen (DC/TMD) voor TMD-klachten en kaakdysfunctie (hoofdstuk 4.1), Mixing Ability Test (MAT) voor kauwprestaties (hoofdstuk 4.2) en analyses van CBCT-scans (hoofdstuk 4.3) voor objectieve volumemetingen. In totaal namen 74 van de in totaal 171 patiënten deel aan deze studie. De gemiddelde MFIQ-score in de open groep was 10,70 (SE 2,9) en in de gesloten groep 4,96 (SE 1,3) (P = 0,013), een uitkomst ten gunste van de gesloten behandelingsgroep.

Onderzoek naar DC/TMD bracht geen significant verschil van TMD-klachten in beide groepen aan het licht. De correlatie tussen objectieve kauwprestaties en zelf-gerapporteerde mandibulaire functie van de patiënt was positief (r = 0,250; P = 0,033). Betere kauwprestaties werden gemeten voor mannelijke patiënten, die fysiotherapie kregen, die geen andere mandibulafracturen hadden en/of een goede subjectieve occlusie hadden. Er werd geen significant verschil gevonden voor de MAI tussen de open en de gesloten behandeling.

Ook bleek er geen significant volumeverschil van de caput te bestaan tussen de open en gesloten behandeling. Wel was een grotere caput geassocieerd met een betere kauwprestatie en bleek geslacht en MMO de gemeten volumes van de caput na trauma te beïnvloeden. Over het algemeen werden goede resultaten behaald met zowel open als gesloten behandelingen.

In **hoofdstuk 4.4** wordt een alternatief voor het gerandomiseerd klinisch onderzoek (RCT), de gouden standaard, gepresenteerd voor het evalueren van de effecten van medische interventies. Aangezien een RCT, in het geval van het open versus gesloten vraagstuk, een uitdaging is in termen van logistiek, planning en kosten, is een veelbelovend alternatief voor de conventionele pragmatische RCT, de multipele cohort gerandomiseerd klinisch onderzoek (cm-RCT) benadering. De cm-RCT is ontworpen om gerandomiseerde studies voor de evaluatie van interventies te vergemakkelijken.

Voor nu lijkt gesloten behandeling een veilige en juiste behandelingsmethode te zijn voor de meeste unilaterale collum mandibulae fracturen. Hoewel de open groep in het algemeen vergelijkbare resultaten liet zien, moet deze behandelmethode worden gereserveerd voor beperkte indicaties. Adequate klinische besluitvorming is de spil in het voorkomen van ongewenste chirurgisch gerelateerde complicaties.

6.3

Dankwoord

Toen ik in 2011, tijdens de najaarsvergadering, professor Jan de Lange aan zijn jasje trok, was dat het begin van een vruchtbare samenwerking. Tijdens de eerste gesprekken ging het al snel over onderzoek, een passie van ons beiden. Een door mij uit te voeren onderzoek werd geopperd; dit moest klinisch zijn en vooral een onderzoek waarin patiëntencontact voorop stond. Jan kwam met een tot op heden onoplosbaar dilemma in de wetenschap van de MKA chirurgie en daar gingen we vol enthousiasme mee aan de slag! Dank Jan, voor de mogelijkheden die je mij hebt gegeven!

Allereerst werd er een protocol ontwikkeld en, samen met Annelies Rotte, een professionele database. Door Maurits Selms werden digitale vragenlijsten samengesteld. Voor het verder opzetten van dit multicenter onderzoek deed ik een beroep op een groot aantal specialisten binnen het vakgebied, die ik niet genoeg kan bedanken voor hun inzet en coöperatie; Baucke van Minnen, Bart van den Bergh, Erik Baas, Johan van Ingen en professor Eppo Wolvius. Verder bedank ik de staf en AIOS-groep in het AMC voor hun oplettendheid bij het includeren van patiënten.
Ik ben verheugd dat Loreine Helmer dit prachtige project zal voortzetten.

Intussen werd er gestart met een case serie, waarbij Leander Dubois het idee opperde de 'hypomochlion' nieuw leven in te blazen. Met hulp van Dan Milstein en Ruud Schreurs is hieruit een prachtig artikel ontstaan. En het begin was gemaakt.

Leander leerde mij al snel iets heel belangrijks: onderzoek is een teamsport; een sterke groep om op te bouwen is 'key'. Leander is tijdens het gehele traject dan ook een groot voorman in mijn team geweest, waarvoor veel dank! We konden er geen genoeg van krijgen. Stuurde ik om 23.00 uur een nieuwe versie van een artikel naar hem op, dan zond Leander het me diezelfde nacht, gecorrigeerd, nog retour, go go go!

En wat is onderzoek naar een specifiek onderwerp doen, zonder dat je eerst volledig up-to-date bent ten aanzien van de bestaande literatuur. Een tweetal systematic reviews moest er komen en zonder René Spijker was dit me niet gelukt. We stelden uitgebreide searches op en de twee systematic reviews werden samen met hem en professor Ruud Bos geschreven.

Ruud Bos, vader van het onderzoek, altijd betrokken en vol enthousiasme. Ik vergeet nooit dat ik in Hong Kong zat tijdens de TOVA opleiding, i.e., geconcentreerde Tandarts Opleiding Voor Artsen, en dat ik voor het onderzoek Skype contact had met Ruud; er was bezorgdheid om ondergetekende alom. Ruud wat ben je een warme man!, en ik kan je niet genoeg bedanken voor alle uren die je in het onderzoek hebt gestoken.
P.S. de sleutelhanger met het 'collum-osteosynthese-plaatje' draag ik nog altijd bij me!

Tijdens het retrospectieve onderzoek kreeg ik hulp van bovenaf, uit Groningen wel te verstaan. 'Mijn' vroegere co-assistent in Zwolle en inmiddels tandarts Léon Klumpert, bood me een helpende hand. Hele weekenden en avonden werden in het AMC doorgebracht, want wat was het een klus om alle patiënten voor dit deel van het onderzoek terug te zien. Dank Léon, dank.

Ondersteuning en onderricht bij onder andere het klinische onderzoek naar de kaakgewrichten kreeg ik van Michalis Koutris en professor Frank Lobbezoo. Voor de technische ondersteuning tijdens onder andere de CBCT-analyses kon ik rekenen op de hulp van het 3D lab, met als directe aanspreekpunten Ruud Schreurs en Thomas Maal.

Een grote steun en toeverlaat tijdens het promotietraject is Caroline Speksnijder geweest. Kon er geen plek in de agenda worden gevonden tussen 08.00 uur en 18.00 uur, dan Skypeten we daarbuiten toch gewoon! Caroline draagt een warm hart toe aan onderzoek en wat was het een genoegen om al die keren opnieuw met je te sparren en te werken naar een prachtig eindresultaat. Dank voor al je input!

Vervolgens zijn er de krachten die ervoor zorgden dat alle woorden ook echt tot een boek werden. Hiervoor dank ik Ferdinand van Nispen tot Pannerden en zijn team voor het meer dan meesterlijke eindresultaat, de details zijn uitzonderlijk!

En uiteraard dank ik de leden van de beoordelingscommissie, die dit proefschrift hebben willen lezen en beoordelen op de wetenschappelijke waarde. Het is een eer dit proefschrift tegenover u te mogen verdedigen.

Verder grote dank aan degene die de dag van de promotie-plechtigheid een origineel en goed georganiseerd feestelijk tintje heeft gegeven, dank je wel lieve Madelein Cramer (Plus Belle Weddingplanner)!
En natuurlijk de sponsoren voor de financiële bijdrage.

Maar ook andere personen die tijdens deze gehele periode van onderzoek en tijdens de opleiding tot MKA chirurg belangrijk voor mij zijn geweest, mogen in dit dankwoord niet ontbreken.

Graag begin ik hiermee bij Eddy Becking. Tijdens mijn geneeskundestudie kwam ik in het laatste jaar 'per toeval' voor een keuzestage terecht bij de afdeling MKA chirurgie in het toenmalig Kennemer Gasthuis in Haarlem. Na twee weken meegelopen te hebben met Eddy was ik overtuigd: dit was mijn voorland, dit wilde ik doen. Vanaf dat moment heeft Eddy altijd in mij geloofd, mij altijd gesteund. Eddy, je bent heel bijzonder voor mij en ik ben heel dankbaar dat ik je destijds heb mogen ontmoeten.

En dan het steunende thuisfront. Mijn ouders hebben hierin een bijzondere plek, want wat hebben ze een studiebol op de wereld gezet. Mijn vader heeft vaak genoeg tijdens mijn schooltijd thuis gezeten met de televisie op minimale geluidsterkte of met een koptelefoon op, zodat er rustig door dochterlief gestudeerd kon worden. En altijd was daar mijn moeder om me te steunen of nog even een stuk door te lezen en dit met haar kritische en analytische oog te corrigeren waar nodig. Geen toeval dat de voorkant van dit boekje door haar ontworpen en gemaakt is. Mam, dank voor je geweldige creativiteit! En pap en mam wat dank ik jullie voor alle mogelijkheden die jullie mij al deze jaren hebben gegeven en de steun die ik altijd van jullie heb gekregen en nog steeds krijg.

En dan uiteraard, last but not least, mijn vriend Rogier, want oh oh oh, je zult zo een vriendin maar hebben, die altijd in de avonduren achter dat beeldscherm duikt en weekenden in het ziekenhuis doorbrengt. Maar schat, nooit maar dan ook nooit heb jij daar een probleem van gemaakt. En altijd, ja altijd heb ik je volledige steun mogen ontvangen, dank lief!

6.4

Author contributions

Authors and their initials

R.R.M. Bos, DDS, PhD	RB
L. Dubois, DDS, MD, PhD	LD
L.M.L. Helmer, MSc	LH
L.T. Klumpert, MSc	LK
M. Koutris, DDS, MSc, PhD	MK
J. de Lange, DDS, MD, PhD	JdL
F. Lobbezoo, DDS, PhD	FL
T.J.J. Maal, PhD	TM
D.M.J. Milstein, MSc, PhD	DM
A.V.J. Rozeboom, MD, DDS	AR
R. Schreurs, MSc	RSch
C.M. Speksnijder, PT, MSc, MPT, PhD	CS
R. Spijker, BAS, MSc	RSp

Chapter 2

Closed treatment of unilateral mandibular condyle fractures in adults: a systematic review
A.V.J. Rozeboom, L. Dubois, R.R.M. Bos, R. Spijker, J. de Lange
International Journal of Oral and Maxillofacial Surgery. 2017; 46: 456 - 464
Author contributions:

Conceived and designed the study	AR, LD
Performed the study	AR, LD, RB, RSp
Analysed the data	AR, LD, RB
Critically revised the manuscript	LD, RB, JdL

Management of post-traumatic malocclusion: an alternative treatment
A.V.J. Rozeboom, L. Dubois, F. Lobbezoo, R. Schreurs, D.M.J. Milstein, J. de Lange
Oral Surgery. 11 (2018) 241 - 246
Author contributions:

Conceived and designed the study	AR, LD
Performed the study	AR
Analysed the data	AR, RSch
Critically revised the manuscript	LD, FL, DM, JdL

Chapter 3

Open treatment of unilateral mandibular condyle fractures in adults:
a systematic review
A.V.J. Rozeboom, L. Dubois, R.R.M. Bos, R. Spijker, J. de Lange
International Journal of Oral and Maxillofacial Surgery. 2017; 46: 1257 - 1266
Author contributions:

Conceived and designed the study	AR, LD
Performed the study	AR, LD, RB, RSp
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Open treatment of condylar fractures via extraoral approaches:
a review of complications
A.V.J. Rozeboom, L. Dubois, R.R.M. Bos, R. Spijker, J. de Lange
Journal of Cranio-Maxillo-Facial Surgery. 46 (2018) 1232 - 1240
Author contributions:

Conceived and designed the study	AR, LD
Performed the study	AR, LD, RB, RSp
Analysed the data	AR, LD, RB
Critically revised the manuscript	LD, RB, JdL

Chapter 4

Clinical outcome in treatment of unilateral condylar fractures:
a cross-sectional study
A.V.J. Rozeboom, L.T. Klumpert, M. Koutris, L. Dubois, C.M. Speksnijder,
F. Lobbezoo, J. de Lange
International Journal of Oral and Maxillofacial Surgery. 2018; 47: 1132 - 1137
Author contributions:

Conceived and designed the study	AR, LD
Performed the study	AR, LK, MK, LD
Analysed the data	AR, LK, CS
Critically revised the manuscript	MK, LD, CS, FL, JdL

Is masticatory performance affected after a unilateral condylar fracture?
A cross sectional study
A.V.J. Rozeboom, C.M. Speksnijder, L. Dubois, F. Lobbezoo, M. Koutris, J. de Lange
Journal of Oral Rehabilitation. 2018 Oct.; 45(10): 777 - 782
Author contributions:

Conceived and designed the study	AR, CS, LD
Performed the study	AR, CS, MK
Analysed the data	AR, CS
Critically revised the manuscript	CS, LD, FL, MK, JdL

Volumetric outcomes of treatment for unilateral condylar fractures:
a pilot study
A.V.J. Rozeboom, R. Schreurs, L.M.L. Helmer, L. Dubois, T.J.J. Maal, F. Lobbezoo,
J. de Lange
Submitted
Author contributions:

Conceived and designed the study	AR, RSch, LD
Performed the study	AR, RSch
Analysed the data	AR, RSch, TM
Critically revised the manuscript	RSch, LH, LD, TM, FL, JdL

Letter to the editor: Randomized clinical trial on condylar fractures: 'open or closed'
A.V.J. Rozeboom, L. Dubois, J. de Lange
International Journal of Oral and Maxillofacial Surgery. 2018; 47: 683 - 684
Author contributions:

Conceived and designed the study	AR, LD, JdL
Performed the study	AR
Critically revised the manuscript	LD, JdL

6.5

Curriculum vitae

Antoinette Véronique Josephine Rozeboom was born in Doetinchem on August 8, 1987. She finished her secondary school education (gymnasium) cum laude in 2005 at the Sint Ludger College in Doetinchem. That same year, she began her medical studies at the VU Medical Center in Amsterdam, during which she undertook an extra-curricular Clerkship in General Surgery at the Steve Biko Hospital in Pretoria, South Africa. In 2011, she graduated with an A degree and went on to study dentistry at the St. Radboud University in Nijmegen. After an internship in maxillofacial surgery at the Prince Philip Dental Hospital/ Hong Kong University in Hong Kong, she started her residency in oral and maxillofacial surgery at the Academic Medical Center in Amsterdam (head: prof. dr. J. de Lange) in July 2013. During this time, she was working at the Isala Clinics in Zwolle for 9 months to practice oral and maxillofacial surgery. In 2017, she received additional training in cleft surgery as an honorary doctor in the Cleft Team under the supervision of prof. dr. P. Haers at St. Thomas Hospital in London, UK. Antoinette finished her residency in July 2017. Currently, she works as an oral and maxillofacial surgeon at the Erasmus Medical Center in Rotterdam and the Reinier de Graaf Hospital in Delft.