Chapter 1

General introduction
Chapter 1

Incidence and aetiology of mandibular fractures

The incidence of maxillofacial fractures varies widely between different countries. Traffic accidents and interpersonal violence, followed by falls and sport injuries are the main causes for such fractures.\(^1\)\(^-\)\(^5\)

In recent studies the mandible proved to be one of the most frequently fractured anatomical structures.\(^5\)\(^-\)\(^7\) Although the mandible is the largest and strongest of the facial bones, its prominence, position, lack of bony support and its mobility make the bone prone to fracturing.\(^1\)\(^,\)\(^8\) According to the literature, fractures of the mandible account for 25.3% - 65.1% of all maxillofacial fractures.\(^9\)\(^,\)\(^10\) Further, the male female ratio varies between 2:1-4:1 and most of the patients are in their twenties.\(^1\)\(^,\)\(^5\)\(^,\)\(^6\)\(^,\)\(^8\)

The mandibular fractures can be subdivided according to the anatomical localization, into mandibular body (including symphysis and parasymphysis), angle, ramus and condyle fractures. The main causes for a mandibular fracture, -as for maxillofacial fractures in general- are traffic accidents, followed by assault.\(^5\)\(^,\)\(^10\)\(^-\)\(^14\) Such fractures may occur as solitary fractures, or one or more accompanying injuries may be present.

Mandibular fractures have caused significant management problems for maxillofacial surgeons for many years. Restoring a pretraumatic occlusion is mandatory to optimize masticatory function. In the literature different treatment modalities for managing these fractures have been described. The majority of mandibular fractures is repositioned and immobilized by open reduction and internal fixation using screws and plates (ORIF).

The used treatment modality depends on the location of the fracture. Of all mandibular fractures, 25-52% are mandibular condyle fractures.\(^15\)\(^-\)\(^17\) Treatment of the condylar fracture proved to be the most discussible treatment as these type of fractures can be treated successfully with both a conservative or a surgical approach.\(^15\)\(^-\)\(^17\)

The overall complication rate for all mandibular fractures is reported to be 9-36%. Postoperative complications are related to the type of fracture, dislocation or displacement, additional maxillofacial fractures and the chosen (surgical) treatment.\(^8\)\(^,\)\(^18\) The complications described most frequently are mandibular asymmetry, temporomandibular joint pain, dysocclusion, (transient) facial nerve paresis, wound infection, osteosynthesis failure and pseudoarthrosis.\(^8\)\(^,\)\(^19\)\(^-\)\(^25\)
Anatomy of the mandibular condylar process

The mandibular condylar process is the bilateral proximal part of the mandible, consisting of the condylar head, the condylar neck and the condylar base (Figure 1). The condylar process forms the mandibular part of the temporomandibular articulation at the temporomandibular joint (TMJ). It is a bilateral, incongruent joint, with a cartilage disc between the condylar head and the glenoid fossa of the temporal bone. The small bony structure is fragile and thus it fractures relatively easily when a blunt trauma impacts on the mandibular body or ramus.

Figure 1. Condylar process of the mandible, on the left side a condylar fracture is present

The complex anatomical orientation of the joint, with close relation to the parotid gland with the facial nerve as well as with the masseteric muscle and the pterygoid muscles and the small window of view when approximating the mandibular condylar process, pose a challenge in the operative approach to fractures of the condylar process.

Figure 2. The facial nerve and its branches, in relation to the temporomandibular joint. Red and blue branches: motor nerves, to facial and suprahyoidal muscles respectively. Orange branches: parasympathetic, to salivary and lacrimal glands. Purple branches: sensory, taste. (Image by Noor van Ginkel)
Chapter 1

Imaging

When a patient presents at the hospital, surgeons collect clinical data from a patient, anamnestic as well as from physical examination. Furthermore it goes without saying that in both the diagnostic process and the process of treatment decision-making imaging plays a key role.

Until recently, an orthopantomography (OPT) and Towne image were used to diagnose and classify mandibular condyle fractures. Shortening of the height of the mandibular ramus and angulation of the condylar process could be evaluated, to assess displacement and possibly dislocation out of the glenoid fossa.26-28 As these conventional radiographic imaging techniques may result in superimpositions of adjacent anatomical structures as well as possible overlap of the bony structures, interpretation of such images may be difficult. This is especially difficult in high condylar fractures.29, 30 In current times, conebeam computed tomography (CBCT) is increasingly available in hospital settings and provides a both cost- and radiation dose effective diagnostic method for use in patients with suspected pathology concerning the temporomandibular joint.30

Additionally, software programs allow for 3D reconstruction of CBCT scans, creating digital models of the mandible, showing the fracture line from all sides. It is even possible to manufacture these models using rapid prototyping techniques and bend a miniplate on this manufactured model before performing the surgery, thus reducing operation time and costs and improving the fitting of the osteosynthesis material.

Treatment decision making

The subject of mandibular condyle fracture treatment to date remains controversial.

In general there are two treatment options. The nonoperative, conservative treatment consist of an expectative treatment, with dietary advice only, or a period of intermaxillary fixation (IMF) with arch wires or screws.31 The IMF is either rigid or semi-rigid with guiding elastics, for a period varying between one to six weeks. The surgical treatment consists of open reduction with internal fixation (ORIF), where the proximal fragment is repositioned anatomically and fixed with osteosynthesis material (e.g. miniplates, lag screws or wires). Both treatment modalities may benefit from additional physical therapy.15-16

In most studies directly comparing the open versus closed treatment methods, acceptable results are gained with both methods.32-36
Treatment outcomes

As described elsewhere, although the temporomandibular joint may be surgically exposed relatively easily, many important anatomical structures are found in near proximity to the joint. Surgical treatment may therefore be time consuming and asks for experience and skills of the operator as well as extensive knowledge of the complex local anatomy. Several possible complications may occur, facial nerve damage and avascular necrosis of the proximal fragment being the most severe and feared ones.

On the other hand, possible complications like dysocclusion, facial height asymmetry, reduced interincisal opening and reduced protrusion or laterotrusion, according to the literature are seen more often in patients who have been treated nonoperatively as compared to patients who have been treated surgically.

Thusfar, it is not possible to predict which patients are likely to develop long term complications like dysocclusion or hypomobility when treated nonoperatively. As operative techniques and materials are developing constantly, the access to the mandibular condyle as well as the possibilities of internal fixation are becoming better and the risk of complications seems to decrease. In recent years, a trend can be seen towards more operative treatment of especially lower (condylar base and condylar neck) mandibular condyle fractures.

Aim and outline of this thesis

In the current thesis, it is aimed to offer new perspectives on the diagnostics and treatment outcomes of unilateral mandibular condyle fractures.

In Chapter 2 a literature review is presented, in which the subjective outcomes of open versus closed treatment methods for unilateral mandibular condyle fractures was assessed.

During this literatures study, several new questions rised. In the literature, often fracture displacement is quantified measuring shortening of the ascending ramus of the mandible on an orthopantomographic image (OPT). The treatment decision-making in mandibular condyle fracture cases is based on the amount of displacement found on OPT and Towne images. Chapter 3 describes the shortcomings of measurements on OPT images in unilateral mandibular condyle fractures.

The aim of mandibular condyle fracture treatment is to regain both function and aesthetics. As described in the review on the subjective outcomes of mandibular
Chapter 1

condyle fracture treatment, little is known about the long term effects on the Quality of Life of these patients. Posttraumatic dysocclusion is one of the most frequently occurring bony complications after mandibular condyle fracture treatment. It is a complication that may influence both the mandibular function and the aesthetics and thus may have a large impact on the subjective treatment outcome. A secondary correction is sometimes needed. In Chapter 4 a retrospective study concerning these issues is presented. We analysed the patients in our population who needed a secondary correction for their posttraumatic dysocclusion. Both the orthognatic treatment and the treatment outcomes are discussed.

As it is not possible to prevent the development of dysocclusion, or to predict which patients may be at risk for developing such a long term complication, in Chapter 5 a study is presented in which a computer simulation is used to investigate the occurrence of this complication.

After describing several difficulties regarding unilateral mandibular condyle fracture treatment and treatment outcome, in Chapter 6 it was aimed to analyse how surgeons in the clinical setting address these difficulties. An overview is presented of 491 maxillofacial surgeons, giving their classification and treatment decisions on three cases of a unilateral mandibular condyle fracture.

In Chapter 7 the conclusions and future perspectives of the thesis are described.

Chapter 8 and 9 provide an English and a Dutch summary of this thesis.
General introduction

References


Chapter 1


35. Schneider M et al.: Open reduction and internal fixation versus closed treatment and


37. Ellis and Zide, Äl book surgical approaches to the facial skeleton


Chapter 2

Quality of life after open versus closed treatment for mandibular condyle fractures: A review of literature

Kommers, SC
Bergh van den, B
Forouzanfar, T

Chapter 2

Abstract

Introduction: Many studies elaborate on the comparison of treatment outcomes after open reduction and internal fixation (ORIF) versus closed reduction (CR) of mandibular condyle fractures. However, the optimal treatment for these fractures remains a controversy. The purpose of this review was to compare the influence of objective and subjective treatment outcomes after open versus closed treatment of mandibular condyle fractures on quality of life based on current literature.

Methods: A MedLine and Embase search was performed to find relevant titles on treatment outcomes after open versus closed reduction of mandibular condyle fractures.

Results: A total of 36 studies were found. Twenty-eight retrospective studies, in addition to eight prospective studies were assessed. All studies combined, nine treatment outcome variables were evaluated. Three studies reported on subjective discomfort. Although many studies investigated (objective) measurements (e.g. range of motion, masticatory function), no studies evaluated quality of life outcomes. In conclusion, prospective, patient-centered research is needed, in order to provide a guideline in decision making in the treatment of mandibular condyle fractures, reasoning from subjective patient satisfaction.
Introduction

The best treatment for mandibular condyle fractures is an ongoing controversy.\(^1\)\(^-\)\(^4\) Although it is said to be impossible to make a well substantiated outcome comparison between open versus closed treatment based on present literature\(^3\), many studies covering the subject can be found. Practically without an exception, published studies render acceptable results with either of the two treatment options.\(^4\)\(^-\)\(^6\) Some state a preference for closed reduction (CR), owing to significant disadvantages of surgery, like scarring, postoperative pain or facial nerve paralysis.\(^7\) Others, on the contrary, describe a preference for open reduction and internal fixation (ORIF), for better anatomical reduction, range of motion and/or functional outcomes are seen.\(^8\)\(^-\)\(^10\) All these various studies and treatment outcomes still have not led to a clinical guideline for treatment of mandibular condyle fractures.

Several authors judge treatment success by radiographic fracture healing. A review by Assael recites a study by MacLennan on 180 cases of condylar fractures.\(^1\) On radiographic imaging 61% of these condyles had a post-treatment deformity. Only 6% of all patients however had a clinical deformity. This study argues that patients will interpret outcome based on function, appearance and the absence of pain, not on fracture healing on radiographic imaging.\(^11\)

The mandibular function impairment questionnaire (MFIQ) by Stegenga et al. provides a tool, additional to the clinical assessment, evaluating the function impairment based on the patients' own value system.\(^12\)\(^,\)\(^13\) The MFIQ measures the relationship between functional impairment of mandible and maxilla, pain, movement restriction, and psychological distress.\(^12\) Complaints like pain, perceived occlusion and reduced mouth opening are predictors of mandibular function impairment after closed treatment of fractures of the mandibular condyle.\(^14\)

Most studies use significant differences in clinical signs measured by the clinician as relevant to state whether a treatment is superior compared to another treatment. It remains unclear if these objective differences are clinically important to patients. (Slight) derangements, objectively assessed, will not necessarily lead to disability in everyday life. Scores rated by clinicians often differ from patients' perspective. Therefore it is important to include subjective measures to supplement the traditional outcome parameters.\(^15\)
Chapter 2

According to Oliver these patient-centered and subjective outcome measures are still rarely taken into account. Therefore the purpose of this review was to investigate the relation of objective treatment outcomes measured by the clinicians, subjective assessments according to the patients with mandibular condyle fractures undergoing ORIF versus CR and the corresponding effect on quality of life, based on current literature.

Materials and methods

Literature search

Relevant literature was searched in MedLine and Embase, using the terms 'mandibular condyle fracture' and 'treatment outcome', as well as synonyms for these terms as keywords to identify relevant titles. After study selection, the reference list of retrieved relevant articles was reviewed to identify any additional relevant articles.

Study selection

The following inclusion criteria were used: 1) original study, either retrospective or prospective, 2) comparing treatment outcomes of ORIF versus CR of mandibular condylar fractures. Exclusion criteria were: 1) paediatric or animal studies 2) language other than English, German or Dutch 3) studies involving other maxillofacial fractures. All titles and abstracts were assessed to determine if the study met the inclusion and exclusion criteria. All included articles were read in full assessing study design, number of patients and treatment outcome variables that were measured. Aim of the review was to evaluate whether the influence of a treatment outcome on the quality of life of a patient was taken into account.

Results

Article selection

Our initial search found 1500 articles (Figure 3). After filtering doubles (n = 348), titles and abstracts were screened, applying previously mentioned inclusion and exclusion criteria. A total of 36 articles remained. These were all reviewed in full.
Quality of life after open versus closed treatment for mandibular condyle fractures: A review of literature

Figure 3. Flow chart literature search.

Study characteristics

The included articles (Table 1 and 2) had sample sizes ranging from 20 to 234 patients, treated for either unilateral or bilateral fracture of the mandibular condyle, with a mean of 69 patients per study. Each study directly compared outcomes of ORIF with CR and IMF. Some studies provided more thorough comparison of one outcome, whereas other studies evaluated up to seven outcome variables to assess the results of treatment in a broader manner. Twenty-eight retrospective studies were reviewed (Table 2), in addition to 8 prospective studies (Table 1).

Outcomes assessment

Nine objective outcome variables were assessed in 36 reports. The majority of studies reported on radiologic outcomes, defined as anatomical reduction (n = 24), as well as range of motion of the jaw (mouth opening, protrusion, laterotrusion, or a combination thereof) (n = 30) and occlusal results (n = 22). Other variables seen were postoperative pain (n = 14), facial nerve paralysis (n = 14), masticatory function (assessed by the Helkimo-index, n = 14), TMJ complaints (n = 7), scarring (n = 7) and facial (a)symmetry (n = 6).
Three of the articles, two prospective and one retrospective, reported on subjective discomfort, using the MFIQ by Stegenga et al. In this questionnaire, patients are asked to what extend they are limited in their daily activities. A total of 17 activities are scored on a Likert scale from 0 to 4, with a maximum of 68 points. A lower score represents less subjective clinical limitations. Fifteen out of the seventeen questions concern activities such as eating, speaking, laughing, yawning and kissing. The remaining two questions concern the amount of limitations experienced in social activities and in daily activities in general, as a consequence of complaints originating from the mandible and maxilla.

Santler et al. report subjective discomfort in 20.3% of the CR patient group, as opposed to 43.2% of the surgically treated group (p = .006). They conclude ORIF is not the treatment of preference due to its disadvantages. In 2006 Eckelt et al. describe a significantly lesser amount of subjective discomfort in the ORIF group with a score on the MFIQ of 2.4, compared to 10.5 in the CR group (p = .001). These results are in consistency with scores of 2.7 and 8.6 respectively (p = .009) in a study by Schneider et al.

**Table 1. Prospective studies included.**

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**Table 2. Retrospective studies included.**

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Quality of life after open versus closed treatment for mandibular condyle fractures: A review of literature

Discussion

The best treatment for mandibular condyle fractures remains a subject of debate. Although it is stated to be impossible to make a well substantiated outcome comparison based on the present literature, many studies covering the subject can be found.

Patient-centered outcome measures are rarely taken into account, while health-care professionals tend to underestimate the long-term effects of maxillofacial trauma and scores rated by clinicians often differ from patients' perspective.

The purpose of this review was to investigate the influence of objective as well as subjective treatment outcomes on quality of life in patients with mandibular condyle fractures undergoing ORIF versus closed reduction based on the current literature.

Thirty-six articles were reviewed in full, in which a total of nine outcome variables were assessed. It should be noted that a great heterogeneity was found on various aspects. Fracture classification, surgical techniques, examinations during follow-up and follow-up duration all vary widely. Nussbaum et al. stated a review to be only as good as the data in the studies it comprises and due to the great heterogeneity in the studies on this subject it was not possible to perform a reliable meta-analysis.

Throckmorton et al. analyzed the chewing cycle after open versus closed treatment of mandibular condyle fractures. Duration and excursive range did not differ significantly between the two treatment groups. Three-dimensional chewing cycle shape showed a significant difference between the surgically and non-surgically treated groups. The impact of the three-dimensional cycle shape on the subjective experience by patients was not further elaborated.

A study by Vesnaver et al. described better results from surgical treatment as opposed to conservative treatment, based on clinical and radiographic parameters, assessing long-term results as objectively as possible. The degree of subjective burden was not considered.

Discrepancies between objective outcome measures and patients’ perspective are found in other fields of medical science as well. In a report on intermittent claudication by Breek et al., it was concluded that health status and quality of life (QoL) represent different outcomes in their patient group. Objective and subjective outcomes were complementary and not identical, therefore these measures should be combined in treatment selection to best meet patients' needs. Additionally, a study by Kelly et al.
demonstrates adults and children with fibrous dysplasia of bone have Health Related Quality of Life (HRQoL), Mental Component Score and Psychological Summary scores equal to those of the general U.S. population, although they score significantly lower on physical functioning.

Although Santler et al., Eckelt et al. and Schneider et al. did take subjective discomfort into account in their studies by using the MFIQ, it is in lack of depth as to the impact on the psychological, environmental and emotional level. Furthermore the results of the three studies evaluating subjective discomfort were contradictory. However most recent studies indicate significantly less subjective discomfort in surgically treated patients. The influence of both objective and subjective treatment outcome measures on the health related quality of life (HRQoL) was not described. The authors opinion is that general HRQoL in a broader perspective should not be disregarded. Especially while maxillofacial trauma patients are found to be more vulnerable to psychological sequelae like anxiety and depression.

A study by Tjakkes et al. described the evaluation of the influence of TMJ complaints on health related quality of life, using the MFIQ as well as several other QoL questionnaires. This method could be adequate to use in the outcome assessment of mandibular condyle fracture treatment as well.

When considering a HRQoL score assessing as broadly and thoroughly as possible the impact of maxillofacial trauma on a patients experienced general QoL, being a wide concept depending on a multitude of factors, it would be recommended to use a questionnaire which is widely used in QoL research, comprising a great variety of health concepts. Most suited for this purpose might be the SF-36 questionnaire, covering eight domains: physical functioning, bodily pain, role limitations due to physical health problems, role limitations due to personal or emotional problems, general mental health, social functioning, energy/fatigue, and general health perceptions. Furthermore the SF-36 includes a single item that provides an indication of perceived change in health. However, the importance of using not only the SF-36, but also the MFIQ simultaneously is emphasized, to separately assess subjective mandibular function, and to allow comparison of mandibular function impairment and general HRQoL outcomes.

Evaluating outcomes using such subjective questionnaires in patients with condylar fracture(s), matched for ORIF versus CR, would give a patient-centered, well substantiated basis for choosing the best therapeutic option. This may then be of use for providing a guideline in decision making in the treatment of mandibular condyle fractures, reasoning from subjective patient satisfaction.
Conclusions

Over the past decades, numerous studies have been published on the complex matter of how best to treat a fractured mandibular condyle. Only three studies looked at clinically relevant subjective parameters, all using the MFIQ. Not one study had a patient-centered approach in the comparison of treatment outcomes, assessing for example the influence on patients quality of life.
References


16. Oliver R: Condylar fractures: is open or closed reduction best? Evid Based Dent 9: 84-2008
Quality of life after open versus closed treatment for mandibular condyle fractures: A review of literature


Chapter 2


Quality of life after open versus closed treatment for mandibular condyle fractures: A review of literature


Chapter 3

Is radiological shortening of the ramus a reliable guide to operative management of unilateral fractures of the mandibular condyle?

Kommers, SC
Moghimi, M
Ven van de, L
Forouzanfar, T

Chapter 3

Abstract

Several studies have published measurements of the height of the ramus on orthopantomographic (OPT) images of patients with unilateral fractures of the mandibular condyle as a possible quantitative measure for making decisions about treatment. However, we know of no studies that have described the accuracy and validity of such measurements. The aim of the present study was to assess the shortening of the ramus in patients with such fractures, and compare them with differences found in a control group. Seventy-four patients and 74 controls were studied. The height of the ramus on the fractured was less than that on the uninjured side, although this was not statistically significant ($p = 0.25$). In the control group, 50 subjects (68%) had a difference in the ramal height of more than 2 mm. Of 74 patients, 25 (34%) had a shorter, uninjured ramus on the opposite side. A Bland and Altman scatterplot showed 23 outliers (31%) among the patients, which exceeded the mean (SD 1.96) of the control group. The interobserver and intraobserver reliability both showed excellent agreement for all measurements made. Shortening of the ramus can be measured on OPT images. However, in a control group there was a large mean difference in height. Among the patients, 25/74 (34%) also had an uninjured ramus on the opposite side that was shorter than that on the fractured side. Measurement of the difference in height on an OPT image cannot be relied on as an absolute indication for intervention.
Is radiological shortening of the ramus a reliable guide to operative management of unilateral fractures of the mandibular condyle?

Introduction

Measurements of the ramal height made on panoramic radiographs in patients with unilateral fractures of the mandibular condyle have been described elsewhere.1-7 A reduction of 2 mm or more, an angular deviation of 10° or more, or both are sometimes regarded as quantitative indications for the surgical management of such fractures.1,8,9 Other studies have shown different cut-off points to indicate an operative approach to these fractures. For example, Sugiuria et al. described a shortening of the ramus of 7 mm or more, or an angular deviation of 35° or more, or both, and Kleinheinz et al. reported that an angular deviation of more than 37° should be considered as indications for surgical treatment.10 Although many different measurements are used as guidelines for decision-making in the treatment of these patients1,2,5-7,11,12, we know of no publications about the accuracy and validity of the quantitative measurement of ramal shortening. The aim of this study therefore was to find out whether measurement of differences in ramal height is a good model for surgical decision-making. We also assessed the validity and accuracy of such measurements on panoramic views.

Patients and methods

All patients who presented at the VU medical centre with a unilateral fracture of the mandibular condyle between 2003 and March 2013 were assessed. Inclusion criteria were: age over 16 years, and availability of a preoperative orthopantomographic image (OPT). Exclusion criteria were: non-traumatic mandibular deformities or a history of a previous operation of the mandible.

The control group consisted of patients who presented at the VU medical centre department of oral and maxillofacial surgery for elective removal of a third molar in the months of February and March 2013. Inclusion criteria were the same, and exclusion criteria were: any indication for the current referral other than removal of a third molar or a history of previous trauma or surgery of the mandible.

The measurements were done on digital OPT using the hospital imaging database. As described elsewhere,12 a reference line was drawn through both gonial angles, together with a further line perpendicular to this reference line. The distance between the reference line and the highest point of the condylar head indicated the ramal height (Figure 4).1-3,12 Ramal shortening was defined as the height of the ramus on the opposite, uninjured side minus the height on the fractured side.
Chapter 3

Figure 4. Measurement of the ramal height using the method described by Palmieri et al.\textsuperscript{12}
A horizontal reference line is drawn through both gonial angles. A line perpendicular to the reference line through the highest point of the condyle indicates the height of the ramus.

All measurements were made separately by two investigators. Investigator 1 made the measurements a second time with an interval of at least 2 weeks between the 2 measurements. Means were calculated from the 2 measurements made by observer 1 added together and divided by 2. Data were stored and analysed in IBM SPSS software (version 20.0, IBM Corp., Armonk, NY). Details collected comprised age, sex, and treatment. As the outcome of treatment is out of the range of the present study, these data were not recorded.

The means (SD) were calculated separately for men and women. Among the patients the means were calculated for the fractured and uninjured sides separately. Mean ramal shortening was calculated from these measurements. For the control group the mean of each side was calculated. The mean of the left ramal height minus that of the right ramal height was also calculated, and referred to as the difference in ramal height. This was regarded as the gold standard for the present study. We used a paired t test to assess the significance of differences between the means of the fractured side and the other side among the patients, and an independent t test to assess the significance of differences between the following means: among men who fractured the left mandibular condyle, we compared the mean left ramal height with the mean left ramal height of the sex-matched controls. A similar comparison was made on the right side, and for the female patients and controls. Probabilities of less than 0.05 were accepted as significant, and 95% CI were also calculated.
Is radiological shortening of the ramus a reliable guide to operative management of unilateral fractures of the mandibular condyle?

To assess the agreement between the measurements in the 2 groups, we used the Bland and Altman method to create two scatterplots. First, the differences in ramal height for each control subject was compared with the mean difference in ramal height of the control group as a whole. Secondly, the ramal shortening for each patient in the fracture group was calculated. The ramal shortening of each individual patient was compared with the mean difference in ramal height in the control group. The limit of agreement (95% CI) was defined as the mean difference in the control group (the norm value) plus or minus 1.96 SD. The intraclass correlation coefficient was calculated using the 2 measurements made by observer 1 and the mean of these measurements compared with the measurement made by observer 2 to find the intraobserver and interobserver reliability of the measurement technique.

**Results**

Between January 2003 and March 2013, a total of 120 patients presented at the VU medical centre with a unilateral fracture of a mandibular condyle. Four patients were younger than 16 years old and were therefore excluded. Of the remaining 116, 74 patients had an OPT available from before their treatment. Of these 74 patients, 50 (68%) were male and 24 (32%) were female, with a mean (range) age of 32 (16-74) years (Table 3). For the control group, subjects who attended the outpatient clinic for removal of third molars were matched with the patient groups based on sex. A total of 74 subjects, 50 male and 24 female, were selected, with a mean (range) age was 30 (18-66) years.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control group</th>
<th>Unilateral fracture patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (range)</td>
<td>30.2 (18-88)</td>
<td>31.5 (18-74)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>50 (67.6%)</td>
<td>50 (67.6%)</td>
</tr>
<tr>
<td>Female</td>
<td>24 (32.4%)</td>
<td>24 (32.4%)</td>
</tr>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expectative</td>
<td></td>
<td>19 (25.7%)</td>
</tr>
<tr>
<td>Conservative (IMF)</td>
<td></td>
<td>55 (74.3%)</td>
</tr>
<tr>
<td>ORIF</td>
<td></td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Total</td>
<td>74 (100%)</td>
<td>74 (100%)</td>
</tr>
</tbody>
</table>

IMF = intermaxillary fixation and ORIF = open reduction and internal fixation.

Table 3. Details of patients (n=74 in each group). Data are number(%) except where otherwise stated.
Chapter 3

Fractured side compared with uninjured side

The mean (SD) ramal height on the fractured side was 73 (7) and on the uninjured side 75 (8) (t (146) = 1.15, p = 0.25), so the fractured side was not significantly shorter than the uninjured side. In 25 patients (34%), the ramus on the uninjured side was actually shorter than that on the fractured side.

Fractured side compared with control group

Table 4 shows the results for the male patients and their controls as well as corresponding results of the independent t-tests comparing the means, and Table 5 those for the female patients and their controls. Bland and Altman scatterplots were made to compare measurements in the control group with those among the patients. Figure 5 shows a scatterplot for the control group. The overall mean (SD) was -2 (3) mm. There are 2 outliers (3%), who have a larger difference between left and right ramal height than the standard deviation (1.96SD, 95% confidence interval). Figure 6 shows the scatterplot for the patients. In 23 patients (31%) the difference between the fracture side and the uninjured side was more than the mean (SD) difference (1.96SD, 95% confidence interval).

Table 4. Mean (SD) height of ramus (mm) in men with unilateral fractures of the mandibular condyle (n=25) and the control group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean (± SD)</th>
<th>T-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left fracture (n = 25)</td>
<td>75.79 (6.09)</td>
<td>-0.41</td>
<td>0.684</td>
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<tr>
<td>Left side control group</td>
<td>76.33 (4.95)</td>
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<tr>
<td>Right fracture (n = 25)</td>
<td>76.01 (5.88)</td>
<td>-1.75</td>
<td>0.084</td>
</tr>
<tr>
<td>Right side control group</td>
<td>78.28 (4.97)</td>
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</table>

Table 5. Mean (SD) height of ramus (mm) in women with unilateral fractures of the mandibular condyle (left n=15, right n=9) and the control group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean (± SD)</th>
<th>T-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left fracture (n = 15)</td>
<td>66.83 (5.84)</td>
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<td>0.252</td>
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<td>Left side control group</td>
<td>68.65 (3.88)</td>
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<tr>
<td>Right fracture (n = 9)</td>
<td>66.34 (6.84)</td>
<td>-1.95</td>
<td>0.061</td>
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<tr>
<td>Right side control group</td>
<td>70.27 (4.43)</td>
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Is radiological shortening of the ramus a reliable guide to operative management of unilateral fractures of the mandibular condyle?

Figure 5. Scatterplot showing the difference in height for each individual control subject compared with the mean. Circles indicate men, and squares women. The central horizontal line indicates the mean, and the dotted lines the SD (1.96).
Figure 6. Scatterplot showing the amount of shortening of each individual patient with a fractured mandibular condyle compared with the mean of the control group. Circles indicate men, and squares women. The central horizontal line indicates the mean, and the dotted lines the SD (1.96).
Is radiological shortening of the ramus a reliable guide to operative management of unilateral fractures of the mandibular condyle?

Intraobserver and interobserver reliability

The intraobserver reliability was calculated by comparing the first and second measurements made by observer 1, and this resulted in an intraclass correlation coefficient (ICC). All measurements among both patients and control groups scored an ICC of over 0.95. The reproducibility of the measurements by the same observer was therefore almost perfect. The inter-observer reliability was assessed by comparing the measurements of the 2 observers. In the group of patients the ICC all varied between 0.89 and 0.93. In the control group they varied between 0.89 and 0.91. This was slightly less than the intraobserver outcome, but still showed excellent agreement.

Discussion

There is an ongoing debate about the treatment of fractures of the mandibular condyle. In recent years, numerous studies have been published about how best to treat them. Some concluded with a preference for open reduction and internal fixation (ORIF), whereas others stated that conservative treatment with closed reduction also provide acceptable results, but with less potential hazard than an operative approach.15

Several studies have sought to create a quantitative treatment protocol, to identify those fractures that required ORIF and those that could be adequately treated conservatively. Loss of height of the mandibular ramus is one of the quantitative measures often mentioned. Different cut-off points have been used as critical values for whether or not to operate.15,8,9

The aim of the present study was to evaluate whether measurements of the height of the mandibular ramus on OPT were accurate enough to use to support clinicians in deciding about treatment in patients with fractures of the mandibular condyle. The mean ramal heights of a group of patients with unilateral fractures was therefore compared with those of a sex-matched control group. Measurements were made on OPT taken before treatment.

The results of this study showed that the mean ramal height was less among the patients than the controls for all measurements made. However, the differences in height did not differ significantly from those in the control group. It is questionable whether measurements of mean height give enough information to draw firm conclusions.
Chapter 3

Using the Bland and Altman agreement analyses the individual differences in height were calculated and compared with the mean differences in the group. The SD of 1.96 is the 95% CI in these calculations. The results show that the individual differences in mean height between the patients and the control group did not differ significantly, and the calculations showed that in the control group only 2 patients exceeded the SD of 1.96, whereas in the group of patients 23 patients (31%) exceeded it (4.2 mm). The value of the mean of the control group (SD1.96) at 4.2 mm can probably be used as a cut-off point for clinical decision-making, as patients with a greater difference in ramal height lie outside the 95% CI of the control group.

Notably in 25 patients (34%) the ramus on the opposite uninjured side was actually shorter than the ramus on the side on which the mandibular condyle was fractured. This may have influenced the results, as the actual mean ramal shortening might have been more distinct if these had not been included.

To put the outcomes into perspective, it is important to provide additional information on the degree of displacement of the fractured bony segments, so we measured the overlap of the bony segment on OPT. The definition of minimal displacement was used for overlap of bony segments of less than 2 mm.16 Among the group of patients, most had a displaced condyle (n = 52, 70%). In 22 patients (30%), there was minimal displacement, consisting of a fracture line with overlap of the bony segment of less than 2 mm. Even though these minimally-displaced condyles undeniably influenced the mean ramal shortening among the patients, they did not change the outcome of the study. The inclusion of these patients contributes to a more representative group of patients with unilateral fractures of the mandibular condyle.

Several studies have shown OPT to be fairly reliable for measurements in the vertical dimension.17-20 Although only one measurement technique was used in this study, others might approximate the actual values more or less accurately. The intraclass correlation coefficient for intraobserver and interobserver reliability was high, so the repeatability of the measurement technique cannot be cited as an argument for the unexpected difference between the left and right ramal height. Such a difference on OPT should be defined as shortening of the ramus as the result of a fracture if the difference is more than 4.2 mm.
Is radiological shortening of the ramus a reliable guide to operative management of unilateral fractures of the mandibular condyle?

References


Is radiological shortening of the ramus a reliable guide to operative management of unilateral fractures of the mandibular condyle?
Chapter 4

Dysocclusion after maxillofacial trauma: a 42 year analysis

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Boffano, P
Verweij, KP
Forouzanfar, T

Abstract

Background: The aim of the present study was to evaluate the surgical management of posttraumatic dysocclusion in the department for oral and maxillofacial surgery in the VU medical center in Amsterdam.

Patients and methods: All patients who underwent surgical correction of a posttraumatic dysocclusion between 1970 and 2012 were reviewed. Patient charts were reviewed retrospectively.

Results: A total of 42 patients were included. Twenty-seven patients had a mandibular condyle fracture (64.3%). The initial fracture-treatment was either expectative, consisted of only intermaxillary fixation (IMF) or open reconstruction and internal fixation (ORIF). Different orthognathic treatment options were used to regain normal occlusion, the most frequently used surgical techniques were a uni- or bilateral sagittal split osteotomy of the mandible in 21 patients (50.0%), followed by a Le Fort I osteotomy of the maxilla in 17 patients (40.5%).

Conclusions: Most dysocclusions occur after mandibular condyle fractures, however fractures of other maxillofacial structures also account for a considerable part. Good results are achieved with orthognathic surgery for posttraumatic dysocclusion.
Dysocclusion is one of the most common hard tissue complications after treating patients with maxillofacial trauma. The incidence of posttraumatic dysocclusion is reported between 5-20% in the literature. It is the main indication for secondary operative intervention after maxillofacial trauma. Previous studies have shown orthognathic surgery to be a stable and predictable treatment of severe posttraumatic dysocclusion due to mandibular condyle fractures. In the literature, condyle fractures account for 15.6% - 22.6% of all maxillofacial fractures. Posttraumatic dysocclusion however is not always a complication of mandibular condyle fractures.

According to a study by Haralabakis et al, posttraumatic dysocclusion has a complex aetiology. Patients treated with maxillomandibular fixation, without surgical fracture reduction, are reported to have a higher chance of developing severe dysocclusions. A statistically significant difference in the development of postoperative complications after mandibular fracture repair between early and late treatment groups has been reported. The best time to treat a facial fracture is the period immediately following the trauma. Delayed, inadequate or absent treatment of displaced facial fractures and even previous attempts at treatment may result in deformities causing aesthetic or functional impairment.

Although since the 1960's several case reports and a few case series of patients treated with orthognathic surgery for a posttraumatic dysocclusion have been published, there is still a lack in the literature concerning surgical treatment of posttraumatic dysocclusion. The aim of the present study was to evaluate the surgical management of posttraumatic dysocclusion in our department. A retrospective study was performed on patients who underwent surgical correction of a posttraumatic dysocclusion between 1970 and 2012.

Patients and methods

A database consisting of all patients who underwent orthognathic surgery between 1970 and 2012 was reviewed. The following inclusion criteria were used: 1) dysocclusion indicating osteotomy 2) maxillofacial trauma in medical history. Exclusion criteria were: 1) treatment abroad 2) missing data on fracture type, type of dysocclusion or type of surgical dysocclusion treatment. The aim of the present study was to evaluate the surgical management of posttraumatic dysocclusion in our department. A retrospective study was performed. Data collected included age, gender, cause of injury, type of fracture, type of dysocclusion, operative techniques, time between trauma and surgical treatment of the dysocclusion and any complications of the orthognathic surgery performed if present. Data was stored and analysed using SPSS.
Chapter 4

Results

In total, 64 patients underwent orthognathic surgery for a posttraumatic dysocclusion between 1970 and 2012. After applying exclusion criteria 42 patients remained. Twenty-six were male (61.9%) and 16 were female (38.1%). The mean age was 34 years (range 16-70 years). In 9 patients the cause of trauma was unknown. For the remaining 33 patients, the two main causes of injuries were traffic accidents (n = 15, 35.7%) followed by falls (n = 9; 21.4%). Four patients (9.5%) had sports-related accidents, two fractures (4.8%) were work related and two patients had interpersonal violence as a cause (4.8%). One patient had a condyle fracture as a complication of an osteotomy (2.4%).

In 42 patients, 79 fractures were diagnosed. The mandibular condyle was the most frequently involved structure. In twenty-seven (64.3%) patients one or both condyles were fractured. A total of 19 patients (45.2%) had a solitary fracture of either mandible or maxilla, the remaining 23 patients (54.8%) had two or more fractures combined. Table 6 shows fracture localisation with corresponding percentages. Five concurrent fractures of the zygomatic complex were left out in this counting, as these fractures do not involve the occlusal plane.

The initial fracture-treatment was expectative in 13 (31.0%) cases, in 10 cases (23.8%) intermaxillary fixation (IMF) was given, open reduction and internal fixation (ORIF) was performed in 17 cases (40.5%). Of 2 cases (4.8%) no data on initial fracture-treatment was documented. During follow-up, all developed dysocclusions were severe enough to be treated by secondary correction in order to regain normal occlusion. This was either on functional or on aesthetic grounds. Table 7 shows the different types of dysocclusions. Twelve patients had developed an anterior open bite (28.6%). Nine patients presented with lateral open bites (21.4%) and 9 with laterognathia. Six patients developed a maxillary retrognathia (14.3%), 3 patients mandibular retrognathia (7.1%) and 3 patients had a crossbite.

In table 8 the surgical treatment used to regain normal occlusion are displayed. Fourteen patients (33.3%) underwent a Le Fort 1 osteotomy, equal to the number of patients that underwent a unilateral sagittal split osteotomy. Four patients (9.5%) underwent bilateral sagittal split osteotomies, two patients (4.8%) were treated with a segmental osteotomy of the mandible and three times (7.1%) a vertical ramus osteotomy was the treatment of choice. The remaining 5 patients (11.9%) underwent multiple osteotomies simultaneously.
The average interval from trauma to treatment of the dysocclusion was 17.7 months (range 2-152). Seven patients (16.7%) were treated within 6 months after the injury, 14 patients (33.3%) were treated between 6 and 12 months, 8 patients (19.0%) between 12-24 months and 13 patients (31.0%) more than 24 months after trauma.

In table 9 the different types of dysocclusion are listed according to the fracture side. Table 10 gives an overview of which type of dysocclusion was treated with what surgical technique. Of 27 patients with either uni- or bilateral fracture of the mandibular condyle, 17 (63.0%) underwent a (bilateral) sagittal split osteotomy, twice combined with a Le Fort I osteotomy and once with a segmental osteotomy of the mandible. Seven patients (25.9%) underwent only a Le Fort I osteotomy, 2 patients (7.4%) a vertical ramus and 1 patient (3.7%) a segmental osteotomy of the mandible. Of 9 patients with mandibular fractures, without condylar fracture, 4 (44.4%) underwent a sagittal split osteotomy, 2 (22.2%) had a Le Fort I osteotomy, one (11.1%) a vertical ramus osteotomy, one (11.1%) a segmental osteotomy of the mandible and one vertical ramus combined with a segmental osteotomy of the mandible was performed. All seven patients with midfacial fracture underwent a Le Fort I osteotomy, in one case combined with a vertical ramus osteotomy.

All except one of the unilateral sagittal split osteotomies was performed on the fractured side. One patient thus underwent a sagittal split osteotomy on the contralateral side. Furthermore in 3 cases a bilateral condylar fracture was treated with a unilateral sagittal split osteotomy, as these patients presented with either laterognathia or lateral open bite. In 1 patient a bilateral sagittal split osteotomy was used after a unilateral condylar fracture. This patient had developed a crossbite. In total, five times genioplasty was performed simultaneously. In four cases (9.5%), after initial treatment of the posttraumatic dysocclusion, an additional second osteotomy was necessary. All four had an open bite, 3 anterior and 1 lateral. The reosteotomy consisted of either a Le Fort osteotomy (n = 2, 50%) or a sagittal split osteotomy (n = 2, 50%). The mean interval between injury and first dysocclusion treatment in these four patients, was 11 months.

Complications were reported in five patients (11.9%). Two patients suffered persistent dysocclusion, however they did not undergo re-osteotomy. One patient experienced both TMJ-complaints and persistent dysocclusion, despite re-osteotomy. One patients had TMJ-complaints. One patient had complaints about the osteosyntheses material, but this was not removed.
## Table 6. Fracture localisation.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral condyle</td>
<td>9</td>
<td>21.4</td>
</tr>
<tr>
<td>Unilateral condyle + corpus/angle/ramus</td>
<td>4</td>
<td>9.5</td>
</tr>
<tr>
<td>Unilateral condyle + midface</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Bilateral condyle</td>
<td>3</td>
<td>7.1</td>
</tr>
<tr>
<td>Bilateral condyle + corpus/angle/ramus</td>
<td>9</td>
<td>21.4</td>
</tr>
<tr>
<td>Bilateral condyle + midface</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Corpus/angle/ramus/combination</td>
<td>9</td>
<td>21.4</td>
</tr>
<tr>
<td>Midface</td>
<td>5</td>
<td>11.9</td>
</tr>
<tr>
<td>Midface + corpus</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

## Table 7. Types of dysocclusion

<table>
<thead>
<tr>
<th>Condition</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior open bite</td>
<td>12</td>
<td>28.6</td>
</tr>
<tr>
<td>Lateral open bite</td>
<td>9</td>
<td>21.4</td>
</tr>
<tr>
<td>Cross-bite</td>
<td>3</td>
<td>7.1</td>
</tr>
<tr>
<td>Mandibular retrognathia</td>
<td>3</td>
<td>7.1</td>
</tr>
<tr>
<td>Maxillary retrognathia</td>
<td>6</td>
<td>14.3</td>
</tr>
<tr>
<td>Laterognathia</td>
<td>9</td>
<td>21.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

## Table 8. Orthognathic surgical techniques used.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagittal split</td>
<td>14</td>
<td>33.3</td>
</tr>
<tr>
<td>BSSO</td>
<td>4</td>
<td>9.5</td>
</tr>
<tr>
<td>BSSO + Le Fort 1</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>BSSO + segmental</td>
<td>2</td>
<td>4.7</td>
</tr>
<tr>
<td>Le Fort 1</td>
<td>14</td>
<td>33.3</td>
</tr>
<tr>
<td>Le Fort 1 + vertical ramus</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Vertical ramus</td>
<td>3</td>
<td>7.1</td>
</tr>
<tr>
<td>Vertical ramus + segmental</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Segmental</td>
<td>2</td>
<td>4.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Abbreviation: BSSO: Bilateral sagittal split osteotomy
Dysocclusion after maxillofacial trauma: a 42 year analysis

Table 9. Types of dysocclusion according to fracture type.

<table>
<thead>
<tr>
<th>Type of malocclusion</th>
<th>AOB</th>
<th>LOB</th>
<th>CB</th>
<th>ManR</th>
<th>MaxR</th>
<th>LG</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of fracture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unilateral condyle</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Unilateral condyle + c/a/r</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Unilateral condyle + midface</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Bilateral condyle</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Bilateral condyle + c/a/r</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Bilateral condyle + midface</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Corpus/angle/ramus*</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Midface</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Midface+ corpus</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>42</td>
</tr>
</tbody>
</table>

Abbreviations: AOB: Anterior open bite; LOB: lateral open bite; CB: crossbite; ManR: mandibular retrognathia; MaxR: maxillary retrognathia; LG: laterognathia; c/a/r: corpus/angle/ramus.
*Patients in this group may have had a single fracture or multiple fractures of the mandibular corpus/angle/ramus.

Table 10. Orthognathic surgical treatment according to dysocclusion.

<table>
<thead>
<tr>
<th>Type of surgery</th>
<th>SS split</th>
<th>BSSO</th>
<th>BSSO + LF</th>
<th>BSSO + Segm</th>
<th>LF + VR</th>
<th>VR</th>
<th>VR + Segm</th>
<th>Segm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dysocclusion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AOB</td>
<td>1</td>
<td>2*</td>
<td>-</td>
<td>1</td>
<td>7*</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>LOB</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>1*</td>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>CB</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>ManR</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>MaxR</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>LG</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>14</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>42</td>
</tr>
</tbody>
</table>

Abbreviations: SS split: sagittal split osteotomy; BSSO: bilateral sagittal split osteotomy; LF: Le Fort I osteotomy; Segm: segments; osteotomy of the mandible; VR: vertical ramus osteotomy; AOB: anterior open bite; LOB: lateral open bite; CB: crossbite; ManR: mandibular retrognathia; MaxR: maxillary retrognathia; LG: laterognathia. In this patient group one patient underwent re-oslect

Discussion

The best time to treat a facial fracture is the period immediately following the trauma. Delayed, inadequate or absent treatment of displaced facial fractures may result in deformities causing aesthetic and/or functional impairment. Unsuccessful outcomes may occur even with a good treatment course, as not all patients might have the biological ability to adapt to their injury harmoniously.

The treatment of dysocclusion after maxillofacial trauma is still a challenge for the surgeons. The most common treatment modality consists of orthognathic surgery.
When deciding whether to perform orthognathic surgery, aesthetic and functional disturbances are the leading arguments in favour of operating. After having decided for a surgical treatment, several types of osteotomies are available to regain normal occlusion and thereby functional and aesthetic results. Segmental osteotomies can be used to treat segmental dysocclusions, whereas when correcting more extensive deformities reopening the fracture lines and nonsegmental osteotomies may be necessary. A thorough evaluation of patient characteristics is necessary in order to make a funded treatment choice.

The present study describes the treatment of 42 patients treated with orthognathic surgery for a posttraumatic dysocclusion. Fractures of the mandibular condyle accounted for the most dysocclusions. Twenty-seven (64.3%) of all patients had either a unilateral or bilateral mandibular condyle fracture, with or without accompanying fractures of the mandibular body or midface. In contrast to several studies in the literature our population did not consist only of mandibular condyle fractures. The initial trauma treatment consisted of an expectative, a conservative or surgical approach. The patients developed several types of dysocclusions, e.g. anterior open bite, lateral open bite, crossbite, mandibular retrognathia, maxillary retrognathia or laterognathia.

In literature, several reports state dysocclusions resulting from unilateral mandibular condyle fractures are best treated with a sagittal split osteotomy on the affected side. Ellis et al added if the mandible does not move into occlusion easily, a sagittal or vertical ramus osteotomy should be performed on the other side as well. In this study, all but one of the unilateral sagittal osteotomies were performed at the fracture side. One bilateral osteotomy was performed. This is thus in consistency with the literature as described above.

According to the literature, if a patient presents with an anterior open bite after bilateral mandibular condyle fracture, either a BSSO or a Le Fort I osteotomy can be the treatment of choice. More recent studies note Le Fort I osteotomy to be preferable as no manipulation of the malunited mandibular rami is required. Further Le Fort I osteotomy proved to be more versatile. In this study, 6 patients with dysocclusion after bilateral mandibular condyle fractures underwent a Le Fort I osteotomy. Three patients underwent BSSO. In 1 patient a Le Fort I osteotomy was combined with a BSSO and in 1 patient a bilateral vertical ramus osteotomy was performed. The treatment of these dysocclusions is therefore also in line with the current literature.

Three patients were treated with a unilateral sagittal split osteotomy after bilateral fracture of the mandibular condyles. The reason for this decision was two of these
patients had developed laterognathia and one a lateral open bite.

In the present study, all patients with dysocclusion after a fracture of the middle third of the face were treated with a Le Fort I osteotomy. One time a vertical ramus osteotomy was performed simultaneously. This is in consistency with what is described and recommended in the literature.1, 18, 22

Ellis et al suggest the time interval between trauma and dysocclusion treatment to be one of the most important variables in treatment decision-making.17 Dysocclusion present less than three months after the injury can be treated as if concerning a fresh fracture. Dysocclusions developed more than three months after trauma in a patient with full range of mandibular motion, can be approached as a standard orthognathic patient.17 Vega also describes in patients with dysocclusions recognized early the mandible should be approached as the original fracture repair.18 Zachariades et al reported on 34 patients needing surgical correction of a posttraumatic dysocclusion. In their study, an interval of six months between trauma and osteotomy was considered to be reasonable when performing the operation at the original fracture site. A time-span of two months was held as sufficient when operation was performed on a different site.22 In the present study, the mean time interval between injury and dysocclusion treatment was 17.7 months. When evaluating the four patients in which a re-osteotomy was deemed necessary, the primary orthognathic surgery was performed 6, 6, 7 and 25 months after the trauma (mean 11.0 months). However, as 7 patients were treated successfully with a time-interval of less than 6 months between trauma and osteotomy, orthognathic surgery seems a stable treatment for post-traumatic dysocclusion in an early stage as well.

It is well known that maxillofacial fractures go accompanied by dento-alveolar trauma in a significant number of patients. In the literature the incidence of dental trauma in maxillofacial fracture patients varies between 13.1%23 and 41.8%.24 However, there is a paucity in the literature concerning the treatment of dental trauma in maxillofacial fracture patients. Several studies emphasize the importance of thorough intra-oral examination in every patient presenting with maxillofacial injury, bone fractures as well as soft tissue injuries.23-25 At the VU medical center, maxillofacial surgeons treat dento-alveolar injuries, if necessary, with temporary fixation using arch bars or in few cases extract elements to be able to provide the best possible fracture treatment. This is in line with a study by Roccia et al from 2012.23 Patients are then referred to their dentists for further treatment as soon as possible after dismissal from the hospital. For the type of treatment for the dento-alveolar injuries lies with the patients dentist, this was not assessed in this study. However, treatment of dento-alveolar trauma in this specific
patient group would be interesting for future research.

Like other retrospective studies, in the present study there possibly is some form of information bias. Further only 42 out of 64 patients were included in the study. Consequently 34.4% of patients treated surgically for posttraumatic dysocclusion were not assessed due to missing data. Despite these shortcomings the present study provides insight in the diversity of posttraumatic dysocclusions and treatment thereof.

**Conclusion**

After treatment of maxillofacial trauma different types of dysocclusion can occur, including anterior open bite, lateral open bite, crossbite, mandibular retrognathia, maxillary retrognathia or laterognathia. Several orthognathic surgical modalities are available to treat these dysocclusion. In the present study these modalities proved to be unilateral sagittal split osteotomy, BSSO, Le Fort I, vertical ramus and segmental osteotomies or combinations of the before mentioned. Further according to the literature the time frame between the initial treatment of the trauma and the occurrence of the dysocclusion is important for the treatment of the dysocclusion. In the present study we were not able to draw firm conclusions on the importance of this time frame.
Dysocclusion after maxillofacial trauma: a 42 year analysis

References


Dysocclusion after maxillofacial trauma: a 42 year analysis
Chapter 5

Biomechanical analysis of fractures in the mandibular neck (collum mandibulae)

Koolstra, JH
Kommers, SC
Forouzanfar, T

Chapter 5

Abstract

After treatment of fractures in the neck of the mandible by means of immobilization of the dentition, often more or less severe manifestations of dysocclusion remain. It was hypothesized that this is caused by an altered articulation in the jaw joint on the affected side. Furthermore, it was hypothesized that an anteriorly displaced condyle, as observed frequently as a side effect of the treatment, is caused by pull of the lateral pterygoid muscle, despite maxillomandibular fixation. Intervention experiments were performed in silico to test these hypotheses. With a biomechanical model of the human masticatory system alterations were applied mimicking a fractured mandibular neck and configurations that had been observed after healing. It was predicted that the altered articulation in the jaw joint caused asymmetrical jaw movements despite symmetrical muscle activation. The jaw was predicted to close with an open bite similar to clinical observations. The predicted laterodeviations, however, were not in accordance with clinical observations. Despite maxillo-mandibular fixation the lateral pterygoid muscle was able to pull the mandibular condyle out of its fossa in anterior direction. Consequently, despite some methodological limitations, in general the predictions corroborated the hypotheses.
Biomechanical analysis of fractures in the mandibular neck (collum mandibulae)

Introduction

Fractures in the mandibular neck (collum mandibulae) are generally caused by accidents or fights. There is some discussion and controversy in treatment of these traumas. Although many studies have been published on the subject of how to best treat a collum mandibulae fracture, based on the present literature no well substantiated conclusion can be made. Some authors conclude closed reduction to be the treatment of preference, due to the risk of scarring, postoperative pain and facial nerve paralysis with performing surgical reduction. Other studies found that surgical reduction and internal fixation should be the treatment of choice, for better anatomical reduction and range of motion. Recently, the possibilities for adequate surgical treatment have been improved. However, practically every published study has described acceptable results for both surgical and conservative treatment methods. One of the most frequently occurring hard tissue complications after treatment for maxillofacial fracture is a dysocclusion. Sometimes these dysocclusions are severe enough to indicate secondary surgical treatment. In a recent study regarding patients surgically treated for a posttraumatic dysocclusion, the majority had a fracture in one or both condyles (64.3%). The remaining patients thus had another type of maxillofacial fracture resulting in dysocclusion. Posttraumatic dysocclusion has a complex etiology, however patients undergoing closed reduction as primary fracture treatment are reported to have a higher risk of developing dysocclusion than those treated surgically. Observation with X-rays of a mandible after treatment often reveals that the condyle on the treated side is dislocated inferiorly or anteriorly. This dislocation has occurred despite precautions like immobilization of the lower jaw. A possible consequence is that the articulation in the temporomandibular joint (TMJ) has been altered. It is not unlikely that this alteration contributes to the observed dysocclusions. Since the lateral pterygoid muscle is attached to the mandibular condyle and neck this muscle has the potency to pull the condyle anteriorly with respect of the mandibular ramus. The articular eminence, however, may act as an obstacle. Since access to the lateral pterygoid muscle is not possible without invasive measures, this consideration can hardly be verified experimentally. The aim of the present study was to analyze the mechanical consequences of a fractured mandibular neck using mathematical modeling. The consequences of either the fracture itself or the altered morphology after repair was considered. It was hypothesized that the often observed open bite as a complication after treatment of a fracture of the mandibular neck is a mechanical consequence of an altered articulation in the TMJ. Furthermore, it was hypothesized that immobilization of the mandible by mutual fixation of the dental arches does not prevent a disconnected mandibular condyle to be dislocated anteriorly.
Chapter 5

Material and methods

The model

A biomechanical model of the human masticatory system was constructed using MADYMO 7.4.2 (TASS International, Helmond, The Netherlands). It contained the skull and the mandible, articulating at two six degree-of-freedom temporomandibular joints. 12 pairs of Hill-type muscles were able to move the mandible with respect to the skull (Fig. 7). Their attachments, maximum force, fiber length and sarcomere length (for a complete overview see: Koolstra and van Eijden (2005)\(^\text{15}\)) had been obtained from eight human cadavers.\(^\text{16-18}\) The contractile characteristics had been shaped according to van Ruijven and Weijs.\(^\text{19}\) Both temporomandibular joints contained deformable articular cartilage layers connected to the (rigid) temporal bone and the mandibular condyle, respectively. Between them a deformable cartilaginous articular disc was situated. The geometry of these structures had been obtained from the right temporomandibular joint of a normal cadaver.\(^\text{20,21}\) The cartilaginous structures were divided into about 14,500, 12,500 and 12,200 tetrahedral finite elements with edges of maximally 0.25 mm (HyperMesh 12.0, Altair Engineering GmbH, Boeblingen, Germany) for the temporal cartilage, articular disc and condylar cartilage, respectively. The left side joint was constructed as a mirror image. The mandibular condyle was guided free of friction along the articular surface of the temporal bone by the reaction forces from the contacts between the finite element models. For a complete overview of the applied parameters is referred to Koolstra and van Eijden.\(^\text{22}\)

Extraordinary articulations

Articulation in the TMJ is defined by the contacts between the cartilaginous structures in the joint. After the rigid connection between the condyle of the right joint and its ramus was removed or displaced, the condyle might contact the base of the skull beyond the articular surface. Therefore, a horizontal plane was defined at the level of the anterior rim of the cartilaginous layer of the mandibular fossa to represent this structure. Contacts were defined between this plane and the mandibular condyle and the articular disc, preventing them to penetrate the skull. This contact was implemented without additional friction.

Simulations

From a closed jaw position jaw open-close cycles were simulated. Jaw-opening started with activation of the jaw-opening muscles simultaneously. Next, they were
Biomechanical analysis of fractures in the mandibular neck (collum mandibulae)

deactivated with a simultaneous activation of the jaw-closing muscles. Activation and deactivation of the muscles included ramps of 45 ms and 75 ms, respectively, to incorporate activation dynamics. To obtain a maximum possible jaw opening (30 mm inter-incisal distance, 23° jaw angle) the jawopeners were activated to 100% of their capacity. A jaw-closer activation of 10%, was sufficient to close the jaw about as fast as it had been opened. All activation patterns were symmetrical.

The effect of a collum fracture was simulated by detaching the right sided mandibular condyle from the mandibular body. With relatively slack Kelvin-type (spring-like) restraints it was reattached in its normal situation. The effect of a healed fracture was simulated by applying more rigid restraints. Then the condylar position was altered according to the one obtained from CT scans of patients where the fractured mandibular neck had been treated using a nonsurgical approach (Fig. 8). The results were analyzed and visualized using HyperView 12.0 (Altair Engineering GmbH, Boeblingen, Germany).

Biomechanical analysis of fractures in the mandibular neck (collum mandibulae)

Results

The predicted jaw movements had similar characteristics as observed habitually when the right condyle was still connected in its original position to the mandible. The computations to simulate one open-close cycle were completed in about 35 h on a dual-core personal computer. When the mandibular condyle was connected to the mandible with relatively compliant restraints, upon jaw opening it dislocated inferiorly. This affected the articulation in the TMJ. As a result the condyle and its articular disc moved about 14.4 mm in anterior direction along the articular eminence. This is about 5 mm more than originally. The mandibular ramus followed this anterior displacement. Since the left condyle remained in the mandibular fossa this caused a deviation of the lower incisors to the left. Upon jaw closing the right condyle returned to the mandibular fossa. Subsequently, the left condyle moved about 1.8 mm posteriorly. The shortened mandibular process on the right caused the mandible to be displaced about 4 mm posteriorly, while it tilted over 5° about the sagittal axis to the left (Fig. 9A). Supplementary video related to this article can be found at http://dx.doi.org/10.1016/j.jcms.2014.06.016.

When the lateral pterygoid muscle was attached to the disconnected fragment and activated to 50% of its maximum, it pulled the condyle forward with respect to mandible when the jaw opened. During the following jaw open-close cycles the condyle remained in that position. The predicted jaw movements were nonsymmetrical. Since the connection between condyle and mandible was not able to restrict upwardly directed movement of the right mandibular ramus anymore, articulation in the right joint became limited. Simultaneously, the left condyle remained in its mandibular fossa to provide articular support. Herewith, at final jaw closure, the rotation about a sagittal axis (roll) increased to about 10 degrees. This is reflected by an extreme open bite (Fig. 9B). After an anteriorly dislocated mandibular condyle had been reconnected to its mandibular ramus (representing the situation after repair), articulation on the right side was restored to a certain extent. This mainly occurred against the base of the skull, in front of the articular eminence (Fig. 9C). It helped to close the jaw more evenly than without this support. However, still a deviation of about 5.5 mm to the right and a roll of 3.3° was predicted when the jaw was closed finally. In a configuration where the dentition had been tied together with inextensible wires, the muscles were recruited according to a normal open-close movement. The activity of the lateral pterygoid muscles was limited to 50% of their maximum. This appeared sufficient to dislocate the right condyle, which was attached with compliant restraints to its mandibular ramus, anteriorly (Fig. 10). Due to the maxillo-mandibular fixation the predicted mandibular movements were negligible. When the activity of the lateral pterygoid muscles was reduced to 10% of their maximum the predicted anterior dislocation remained absent (data not shown).
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Figure 10. Predicted effect of activity of the lateral pterygoid muscle during maxillo-mandibular fixation (cyan lines). A: sagittal view of the normal situation. The mandibular condyle is connected to the mandibular ramus with compliant restraints (magenta lines) and the lateral pterygoid muscle is attached to the condylar fraction. B: sagittal view of the situation after the lateral pterygoid muscle has started to contract at 50% of its maximum.
Discussion

Biomechanical consequences of a healed fracture

When the mandibular condyle was disconnected (representing fracture) or attached in a displaced position non-symmetrical opening and closing movements were predicted. Despite symmetrical muscle activation, the mandible deviated to the contralateral (left) side. Furthermore, the jaw closed while the mandible maintained a rotation of 3°-10° about the sagittal axis (roll), creating an open bite at the contralateral side. These results are in agreement with the observation that normally an open bite occurs at the non-fractured side. However, they disagree with the observation that generally the jaw deviates to the fractured side when opening the jaw. The latter can be attributed to the predicted relatively large anteriorly directed travel of the right mandibular ramus. This is normally limited by the soft tissue surrounding this structure (not present in the model). Furthermore, excessive movements of the fractured side could lead to pain, which the patient might try to avoid by adapting muscle control. Finally, feedback from the muscles themselves might alter the neuro-muscular control.

Subjects and scenarios

The present study analysed two different scenarios for repair of a fractured mandibular neck. They were interpreted from CT scans obtained from patients approximately 4.5 years after the accident. In the first patient the condyle was reattached to the ramus oriented about normally, but with a shortened neck. In the second patient the condyle was reattached to the ramus in a forwardly tilted position. Also in this patient the vertical dimension of the affected side of the mandible was reduced. It must be noted that CT scanning is not yet a standard procedure in the clinical setting regarding condylar neck fractures. They were available because these patients had complaints that required additional examination. In both cases the configuration of the masticatory system had been changed which resulted ultimately of an altered articulation in the TMJ. Whether the integrity of the joint itself was affected cannot be distinguished from the CT scans. For both cases the predicted jaw open-close movements were non-symmetrical. The dentition could not obtain a centric occlusion. It was predicted that the second case may come into existence after the jaw has been immobilized due to contractions of the lateral pterygoid muscle. Although in the present simulations the consequences for masticatory function were not extremely severe, it is to be expected that a considerable anterior displacement of the condyle will challenge the integrity of the TMJ. And that might have consequences for movability and possibly discomfort in the long run.
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Methodological limitations

Fracture of the mandibular neck was modelled by applying a flexible mounting of the mandibular condyle to the ramus by means of Kelvin-type restraints. Their configuration and stiffness control how much the condyle is able to move with respect to the mandible, determining the amount of deviation from symmetry during movement and occlusion. This also applies for the position of the dislocated (and reattached) condyle and the plane representing the base of the skull. Herewith, the severity of the movement disorder could be influenced. Since the present analysis is qualitative this limitation was considered of minor importance. Bone fractures generally generate pain. Patients, therefore, may adapt their movements to avoid this pain. They may change the way they recruit their muscles. In the present study this aspect has been disregarded, since firstly every subject may react differently, and secondly relevant detailed data is not present. In the present model the dentition is relatively simple. The cusps that normally guide dental occlusion are not present. Therefore, the normally observed premature contacts at the fractured side which can be considered a major factor in occlusion and herewith for the final position of the lower jaw, remained beyond consideration. Consequently, the predicted amount of laterodeviation of the mandible in the closed position could both be over- or underestimated.

The lateral pterygoid muscles were able to pull the mandibular condyle in the anterior direction despite maxillo-mandibular fixation. Such displacements are most probably resisted by the articular capsule. The amount of resistance is not known. To account for this uncertainty the forces of the lateral pterygoid muscle was limited to 50% of its maximum. Although the amount of forward distraction could be subject to debate, it was demonstrated that in principle this unwanted movement cannot be prevented by maxillomandibular fixation.

Contralateral joint

The simulations predicted that the antero-posterior movements in the joint at the unaffected side became limited. The condyle remained in the mandibular fossa, and moved posteriorly when the jaw closed. Herewith, the articular disc was squeezed out in anterior direction. This could be interpreted a mechanism to initiate an anterior disc displacement disorder.

However it must be noticed that in the present model an articular capsule was not properly modeled. Since this capsule can be considered as one of the structures that keeps the disc in place, this observation should be interpreted with care.
Biomechanical analysis of fractures in the mandibular neck (collum mandibulae)

Considerations regarding surgical and nonsurgical treatment

In this journal there is still a debate on the advantages and disadvantages for nonsurgical or surgical treatment for fractures of the mandibular neck with a moderately displaced mandibular condyle. Various authors argue that a surgical approach leads to better function and reduction of pain. Others found no significant clinical differences. Since surgery can lead to complications, including facial nerve injury, salivary fistula and visible scars, general and unambiguous guidelines are still not available. Nonsurgical treatment is generally very straightforward. It can be interpreted a one-method-suits-all therapy. The mandible is immobilized by fixation of the dentition with splints and wires. After a few weeks the wires are slackened to enable some movement in the jaw joint, preventing it to become immobile. In contrast, a surgical treatment is very patient specific. Since fractions must be repositioned and reconnected with screws and plates the surgery is dependent on the way the mandibular neck is fractured. This discrepancy might be considered to bias the comparison of successes and failures of both methods. If it were possible to predict the chance of success, not only based upon bone healing but also on restoration of function, this could be considered to make a better evidence based decision about the therapy. The present study suggests that the position of the condyle with respect of the mandible, or the risk of an anterior displacement of that structure might make part of the decision procedure. It was predicted that maxillomandibular fixation not necessarily prevents the mandibular condyle to dislocate further to an anterior position, during the healing process. Such a dislocation could have serious consequences for the integrity of the TMJ. Provided that it has not been dislocated yet when the patient arrives at the clinic for treatment, temporary paralysis of the lateral pterygoid muscle could be considered to prevent dislocation later on. Although such has been applied successfully in related types of maxillofacial trauma, success for this special case is not obvious.

Conclusion

The present biomechanical analysis demonstrated that after a unilateral fracture of the mandibular neck, jaw movements became non-symmetrical, despite symmetrical muscle activation patterns. The jaw was predicted to close with an open bite similar to clinical observations. However, upon jaw opening the orientation of the predicted laterodeviations was not in accordance with clinical observations. The differences could be attributed among others to the absence of volumes of soft tissue in the applied biomechanical model. In general, the non-symmetrical movements could be attributed to an altered articulation in the temporomandibular joint on the affected side. Maxillomandibular fixation is often applied to restore masticatory function. It is considered to
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stabilize the mandibular condyle with respect to the mandibular body. The present analysis, however, predicted that it may not prevent a disconnected mandibular condyle to be dislocated anteriorly due to contractions of the lateral pterygoid muscle.

Acknowledgments The authors gratefully thank Dr. G.E.J. Langenbach for his constructive comments on the manuscript. This research was institutionally supported by Academic Centre for Dentistry Amsterdam (ACTA).
Biomechanical analysis of fractures in the mandibular neck (collum mandibulae)

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Biomechanical analysis of fractures in the mandibular neck (collum mandibulae)
Chapter 6

Consensus or controversy? The classification and treatment decision-making by 491 maxillofacial surgeons from around the world in three cases of a unilateral mandibular condyle fracture

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Accepted for publication in the Journal of Cranio-Maxillo-Facial Surgery
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Abstract

Introduction: Many studies are available in the literature on both classification and treatment of unilateral mandibular condyle fractures. To date however, controversy regarding the best treatment for unilateral mandibular condyle fractures remains.

Methods: In this study an attempt was made to quantify the level of agreement between a sample of maxillofacial surgeons worldwide, on the classification and treatment decisions in three different unilateral mandibular condyle fracture cases.

Results: In total, 491 out of 3044 participants responded. In all three mandibular condyle fracture cases, a fairly high level of disagreement was found. Only in the case of a subcondylar fracture, assuming dysocclusion was present, over 81% of surgeons agreed the best treatment would be open reduction and internal fixation. 3D imaging in higher fractures leads to more invasive treatment-decisions than 2D imaging.
Introduction

In the past five decades, a multitude of studies has been published concerning the best treatment methods in mandibular condyle fracture cases. Confusingly, a number of different fracture classifications are used in common clinical practice for mandibular condyle fractures1-3. A conventional way to classify these fractures has been a subcondylar fracture, a condylar neck fracture or a condylar head fracture according to Lindahl et al.1 In recent years, the Strassbourg Osteosynthesis Research Group (SORG) specified this tripartite classification according to reproducible anatomical landmarks, subdividing the condylar process into the condylar base (i.e. replacing the inconsistent term subcondylar), the condylar neck and diacapitular fractures.2 The latter term was later replaced by condylar head fractures according to a consensus supported by the SORG, the IBRA (International Bone Research Association) and the Arbeitsgemeinschaft für Osteosynthesefragen (AO).4 Only very recently based on this tripartite classification, the AO updated the AO Comprehensive Injury Automatic Classifier (AOCOIAC), which allows for a precise anatomical description of condylar base, neck and head fractures.5 Many different treatment modes have been described and suggested to be the preferable one. Roughly, two treatment groups can be distinguished: Non-surgical treatment on the one hand and surgical treatment on the other. Generally, according to the literature, acceptable results are reported following both nonsurgical, conservative treatment as well as following surgical reduction.6-11 In a recent meta-analysis by Chrcanovic et al, it was described that the surgical treatment of mandibular condyle fractures results in a better clinical outcome regarding dysocclusion after treatment, protrusion, laterotrusion, and lateral deviation during maximal interincisal opening, when compared with non-surgical treatment.12 Infections however more frequently affected patients who had been treated surgically. In post-treatment TMJ pain, noise or maximal interincisal opening, there were no statistically significant differences between the two compares treatment techniques.12 However, there is still no consensus in treatment decision-making in clinical practice.

Many variations on basic treatment techniques have been described. When open reduction and internal fixation (ORIF) is chosen, a surgeon has to decide via which anatomical route the fracture is best approached.13,14 Also, the option to perform the operation endoscopically-assisted is available.9,15,16 When chosen for conservative treatment, intermaxillary fixation (IMF) can be performed using for example arch wires,17,18 bone screws18-20 or orthodontic brackets.21-23 When an expectative policy is the treatment of choice, a soft diet will suffice. Physiotherapy may speed the rehabilitation.24 Expert opinion has a major role in how a patient will most likely be treated.25
Outcome variables, based on which successfulness of treatment has been measured, vary enormously in the literature. Quantitative as well as qualitative, objective as well as subjective and clinical as well as radiological outcome variables have been assessed. Some studies conclude open reduction and internal fixation should be preferred, for better anatomical reduction is achieved. Whereas other authors suggest a more conservative approach to be preferable, because acceptable results are gained and the risk of complications like facial nerve damage, infection or scarring is avoided. It seems reasonable to presume that these controversial results do not make it easier to make clinical treatment decisions.

However, almost without an exception, studies available in the literature on this subject do seem to agree upon one statement. There is an ongoing lack of consensus amongst maxillofacial surgeons worldwide, as to what the best treatment method for mandibular condyle fractures is. In 2012 the IBRA symposium was held on the subject of mandibular condyle fracture treatment. Neff et al published the results of this meeting of experts and participating surgeons. A number of 77 participants, mainly from Europe (n = 63, 81.8%) assessed 12 cases and 27 statements on the subject of mandibular condyle fractures. In this publication, especially in the condylar neck and base fractures, ORIF was judged to be the preferable treatment.

The mandibular condyle is an anatomically complex structure to interpret on two-dimensional radiographs. Imaging plays an important role in the process of classification and decision-making in mandibular condyle fractures. In recent years, the use of 3D imaging using (conebeam) computed tomography (CBCT) has become more and more widespread in the field of maxillofacial surgery. It is relatively easy to make a 3D digital model based on a CBCT scan. This may help in the assessment of fractures of the mandibular condyle.

Baker et al., have described a valuable method by questionnaire dating from 1998, in which they assessed the consensus amongst maxillofacial surgeons from around the world, on a number of difficulties concerning mandibular condyle fractures. In 1999 an international conference was held on mandibular condyle trauma in Groningen the Netherlands. Bos et al reported the outcomes of this meeting, based on presentations by experts and a Consensus Panel debate afterwards. In more recent years, as previously mentioned, in 2007 and 2012 the IBRA symposium was held on the subject of mandibular condyle fractures. Experts were engaged in evaluating up to date trends and potential changes in treatment strategies. As expert opinion seems to be a major determining factor in treatment decision-making, we thought it valuable and illustrative.
Consensus or controversy?

to assess agreement in current times, in a large population of experts and/as well as practicing maxillofacial surgeons worldwide. Moreover, since new imaging techniques are finding their way into daily practice, this study has also focussed on the difference between 2D and 3D imaging in such cases.

Thus the aim of the present study was to assess the agreement of maxillofacial surgeons worldwide, on three cases of a unilateral mandibular condyle fracture, via a digital questionnaire.

**Materials and methods**

**Case selection**

Unilateral mandibular condyle fracture cases were selected from the hospital database from the VU medical centre in Amsterdam, representing varying types of mandibular condyle fractures. Two maxillofacial surgeons separately classified each case as a subcondylar, a condylar neck or a condylar head fracture according to Lindahl and conform the nomenclature by Loukota et al.\(^1\),\(^2\) It was made sure that both assessors agreed upon each of the cases, in order to have a baseline classification of the fractures to compare received data with.

**Participation requests**

A web-based survey was created and it was made available online. Email addresses were obtained from published studies on maxillofacial trauma in the last 10 years. PubMed databases were used to search for the publications. The following keywords were used: facial trauma, maxillofacial injury, facial fracture, trauma. In addition to these addresses, a search of maxillofacial surgery national societies websites was performed. The available addresses were included for our purpose. A hyperlink to the website of the survey along with an explanation of the study was sent to all the email addresses that were found. No incentives were provided. A reminder email was send once, 4 weeks after the initial request.

**Questionnaire content**

Each participant received a link to either a questionnaire with two-dimensional (OPT and Towne) imaging or with three-dimensional imaging of the three unilateral mandibular condyle fracture cases (Figure 11). The 3D images were created from a conebeam computed tomography scan (CBCT) using Mimics 14.0.22 software. The entire database
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was randomly divided in two groups. One group receiving the 2D imaging and the other group receiving the 3D imaging of the mandibular condyle fracture cases.

Participants were asked to fill in the following demographics: 1) age 2) sex 3) number of years of experience 4) country of residence and practice.

They were then asked to fill in information concerning three given cases of unilateral mandibular condyle fractures (Table 11). First, a classification as fracture type A subcondylar, fracture type B condylar neck or type C condylar head fracture according to Lindahl was asked. Then, it was asked if the surgeon would treat the patient that
was presented expectatively, conservatively with intermaxillary fixation (IMF), or if the surgeon would prefer open reduction and internal fixation (ORIF). If chosen for conservative treatment a following question concerned what type of intermaxillary fixation would be used. If chosen for ORIF, a following question regarding surgical approach was filled in. Each question was asked twice for each of the three cases; once assuming there was no dysocclusion present, the second time assuming the patient did have an altered occlusion.

Table 11. Questionnaire content

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer options given</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How would you classify this fracture?</td>
<td>Class A. Subcondylar fracture</td>
</tr>
<tr>
<td></td>
<td>Class B. Condylar neck fracture</td>
</tr>
<tr>
<td></td>
<td>Class C. Capitulum fracture</td>
</tr>
<tr>
<td></td>
<td>Other...</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>2. A. How would you treat this patient, given there is NO dysocclusion?</td>
<td>Expectative</td>
</tr>
<tr>
<td></td>
<td>Conservative (IMF)</td>
</tr>
<tr>
<td></td>
<td>Open reduction, internal fixation</td>
</tr>
<tr>
<td></td>
<td>Other...</td>
</tr>
<tr>
<td>B. If chosen for IMF, what technique would you use?</td>
<td>Bone screws</td>
</tr>
<tr>
<td></td>
<td>Arch wires</td>
</tr>
<tr>
<td></td>
<td>Other...</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>3. A. How would you treat this patient, given there IS dysocclusion?</td>
<td>Preauricular</td>
</tr>
<tr>
<td></td>
<td>Retromandibular</td>
</tr>
<tr>
<td></td>
<td>Other...</td>
</tr>
<tr>
<td>B. and C. as in question 2.</td>
<td></td>
</tr>
</tbody>
</table>
Statistical analysis

First, demographics of all the participants were assessed and analysed. Next, the percentages of participants agreeing on the classification for each of the three cases were calculated. Then the percentages of participants agreeing on treatment decision per clinical case were calculated, representing the so-called raw-agreement between the observers. Chi square tests were performed to compare the outcomes of treatment decisions for each of the three cases. It was analysed whether the variables years of experience, continent of residence and practice or 2D- vs 3D imaging influenced the distribution between expectative or conservative treatment or ORIF.

Furthermore, the treatment decisions were analysed based on the classification by the participants themselves. The three cases were put together and sorted into type A, B or C fractures as judged by the participants. The raw agreement within these classification groups was calculated.

Results

Unilateral mandibular condyle fracture cases Three cases of different types of mandibular condyle fractures were selected from the hospital database. Case 1 comprised a condylar neck fracture on the right side. Case 2 was assessed to be a condylar head fracture on the left side. Case 3 was classified as a subcondylar fracture on the left side (i.e. a condylar base fracture according to Loukota et al. 2005). This classification was made separately by two maxillofacial surgeons.

Figure 11 shows the two-and three-dimensional images that represented case number 1. Figure 12 and 13 show the three-dimensional images of cases 2 and 3 respectively.
Figure 12. 3D images representing the unilateral mandibular condyle fracture from case 2.

Figure 13. 3D images representing the unilateral mandibular condyle fracture from case 3.
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Participants

From the total number of 3044 times the hyperlink was sent out, a total of 491 responses were received, 245 from the 2D-questionnaire and 246 from the 3D-questionnaire. The vast majority of the participants were male, 443 (90.2%) as opposed to 48 (9.8%) females. The mean age was 47.0 ± 10.9 years. Demographics of the responding participants are shown in table 12. The numbers of years of working experience were categorized in 3 groups, from 0-10, 10-20 or 20 or more years. The 0-10 years group consisted of 143 participants (29.1%), the 10-20 years of experience group consisted of 145 (29.5%) people and the 20 or more years of experience group was slightly larger with 203 (41.3%) participants.

The participants came from 6 different continents and a total of 46 different countries. Most participants came from Europe, South America and North America, with 232 (47.3%), 178 (36.3%) and 62 (12.6%) respectively. From Asia 15 (3.1%) questionnaires were received, and only 2 (0.4%) from Oceania and Africa were submitted.

Statistical analysis

Table 13 shows the classification of the fractures by all 491 participants who submitted their questionnaire. Table 14 shows the treatment decisions for case 1 to 3 as filled in by the participants.
## Table 12. Patient characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>2D questionnaire n = 245</th>
<th>3D questionnaire n = 246</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (yrs ± SD)</td>
<td>48 ± 11.3</td>
<td>46 ± 10.4</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>221 90.2</td>
<td>222 90.3</td>
</tr>
<tr>
<td>Years of experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In residency</td>
<td>1 0.4</td>
<td>10 4.1</td>
</tr>
<tr>
<td>0-2</td>
<td>5 2.0</td>
<td>7 2.8</td>
</tr>
<tr>
<td>2-5</td>
<td>21 8.6</td>
<td>20 8.1</td>
</tr>
<tr>
<td>5-10</td>
<td>38 15.5</td>
<td>40 16.2</td>
</tr>
<tr>
<td>10-20</td>
<td>74 30.2</td>
<td>71 28.9</td>
</tr>
<tr>
<td>More than 20</td>
<td>106 43.3</td>
<td>98 39.9</td>
</tr>
<tr>
<td>Continent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>27 11.0</td>
<td>35 14.2</td>
</tr>
<tr>
<td>South America</td>
<td>91 37.1</td>
<td>88 35.8</td>
</tr>
<tr>
<td>Europe</td>
<td>115 46.9</td>
<td>116 47.2</td>
</tr>
<tr>
<td>Africa</td>
<td>2 0.8</td>
<td></td>
</tr>
<tr>
<td>Asia</td>
<td>10 4.1</td>
<td>5 2.0</td>
</tr>
<tr>
<td>Australia</td>
<td>2 0.8</td>
<td>-</td>
</tr>
</tbody>
</table>

## Table 13. Fracture classifications

<table>
<thead>
<tr>
<th>Outcome variable</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 491</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Classification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class A</td>
<td>158</td>
<td>32.2</td>
<td>123</td>
</tr>
<tr>
<td>Class B</td>
<td>319</td>
<td>65.0</td>
<td>153</td>
</tr>
<tr>
<td>Class C</td>
<td>12</td>
<td>2.4</td>
<td>205</td>
</tr>
<tr>
<td>Needs more imaging</td>
<td>2</td>
<td>0.4</td>
<td>10</td>
</tr>
<tr>
<td>Ramus mandibularis</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

## Table 14. Treatment decisions for case 1 to 3

<table>
<thead>
<tr>
<th>Outcome variable</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 491</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Therapy if WITHOUT dysocclusion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expectative</td>
<td>110</td>
<td>22.4</td>
<td>170</td>
</tr>
<tr>
<td>Conservative</td>
<td>273</td>
<td>55.6</td>
<td>230</td>
</tr>
<tr>
<td>Open reduction and internal fixation</td>
<td>96</td>
<td>19.6</td>
<td>72</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Needs more imaging</td>
<td>11</td>
<td>2.2</td>
<td>12</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>0.2</td>
<td>7</td>
</tr>
<tr>
<td>Therapy if WITH dysocclusion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expectative</td>
<td>15</td>
<td>3.1</td>
<td>28</td>
</tr>
<tr>
<td>Conservative</td>
<td>242</td>
<td>49.3</td>
<td>281</td>
</tr>
<tr>
<td>Open reduction and internal fixation</td>
<td>229</td>
<td>46.6</td>
<td>167</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Needs more imaging</td>
<td>3</td>
<td>0.6</td>
<td>6</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>0.4</td>
<td>9</td>
</tr>
</tbody>
</table>
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Table 15. Treatment decisions specified per case

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without dysocclusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n = 273</td>
<td>n = 230</td>
<td>n = 148</td>
</tr>
<tr>
<td><strong>Conservative</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arch bars</td>
<td>161</td>
<td>20</td>
</tr>
<tr>
<td>Bone screws</td>
<td>87</td>
<td>76</td>
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Case 1 - Condylar neck fracture

Our classification of case 1 as a condylar neck fracture was agreed upon by a total of 319 (65.0%) of the participants. The remaining participants classified this fracture as either a subcondylar fracture (158, 32.2%) or a condylar head fracture (12, 2.4%). Two (0.4%) participants found they needed further imaging in order to make a funded choice.

When assuming there was no altered occlusion in this case, 110 (22.4%) would have chosen for an expectative treatment, 273 (55.6%) would have performed intermaxillary fixation (IMF) and 96 (19.5%) would have performed open reduction and internal fixation (ORIF).

If the patient would have a dysocclusion, the treatment decision shifted towards the operative approach. Only 15 (3.1%) of the surgeons would have treated expectatively, 242 (49.3%) chose to perform IMF and 229 (46.6%) preferred ORIF.

Case 2 - Condylar head fracture

Only 205 (41.8%) of the participants agreed with our case 2 classification. A condylar neck fracture was diagnosed 153 (31.2%) times, and the fracture was judged to be subcondylar in 123 (25.1%) of the received questionnaires. More imaging was needed according to 10 (2.0%) participants.
Consensus or controversy?

Without dysocclusion, 170 (34.6%) surgeons chose an expectative policy. Conservative treatment with IMF was chosen by 230 (46.8%) and ORIF by 72 (14.7%) of the participants. When dysocclusion was assumed, 28 (5.7%) chose an expectative approach, 281 (57.2%) a conservative approach and 167 (34.0%) would have performed ORIF.

Case 3 - Subcondylar fracture (viz. condylar base fracture)

344 (70.1%) participants agreed upon our case 3 classification as a subcondylar fracture. A condylar neck fracture was diagnosed 122 (24.8%) times and 24 (4.9%) surgeons judged this fracture to be a condylar head fracture. One (0.2%) participant requested further imaging.

When no dysocclusion was assumed, 60 (12.2%) expectative treatments were chosen. Conservative treatment was chosen 148 (30.1%) and ORIF 277 (56.4%) times.

If case three was combined with the assumption of an altered occlusion, only 6 (1.2%) surgeons would have treated this case expectatively. A conservative treatment was chosen by 85 (17.3%) of the participants. The vast majority, 399 (81.3%) of the participants would have repositioned and fixated surgically.

Specification of treatment techniques

Table 15 shows the results of the received answers on the questions specifying the treatment choices. If chosen for a conservative approach, surgeons where asked what type of IMF would have been used. If chosen for ORIF, the surgical approach of preference was asked for.

In all cases, with or without dysocclusion present, the majority of the surgeons preferring a conservative treatment would have performed IMF using arch wires (arch bars with guiding elastics) (mean 68.5%), followed by bone screws (mean 22.5%).

In case 1 and 3, representing the condylar neck and subcondylar fracture, regardless of the presence of dysocclusion, most surgeons chose for ORIF via a retromandibular approach (mean 59.8%). Second most, the preauricular approach was chosen (mean 20.8%).

In case 2 the approach preferred by most surgeons choosing for ORIF, was via preauricular (58.0%) followed by the retromandibular approach (28.9%).
Chapter 6

Treatment decisions based on participants classification

In total a type A fracture was diagnosed 623 times (42.8%), followed by a type B fracture 594 times (40.8%) and a type C fracture 239 times (16.4%).

Figure 14 and 15 show bar charts from the treatment decisions in type A, B or C fractures, in the absence or presence of dysocclusion respectively. As can be seen, in case of a dysocclusion, expectative treatment is chosen less frequently and more often ORIF is performed in each of the cases.

The consistency in treatment decisions based on the participants’ classification is similar to the consistency in treatment decisions when analysed per clinical case.
Influence of participant characteristics on treatment decisions

Chi square tests were performed to analyse whether several variables have an influence on the outcomes of the treatment decisions in the three cases of unilateral mandibular condyle fractures. Table 16 shows the results of the $x^2$ tests. The number of years of experience seems not to have a significant influence on the treatment that was chosen. There was a trend towards the 10-20 years of experience group less often choosing the expectative treatment.

Interestingly, what continent a surgeon came from did play a significant role in the treatment decision that was made. In all three cases, with or without dysocclusion assumed, surgeons from North America chose to perform ORIF significantly less often. European surgeons seem to prefer an expectative treatment significantly more often than a conservative treatment as compared to their colleagues in other continents.

Furthermore, in both case 1 and case 2, participants who submitted the questionnaire with the 2D imaging of the mandibular condyle fracture, would significantly choose a conservative treatment more often than ORIF, compared to the surgeons who filled out the questionnaire based on the 3D images.

Table 16. Chi square test

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<tr>
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<td>Dysocclusion</td>
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Chapter 6

Discussion

The purpose of the current study was to analyse the level of agreement amongst maxillofacial surgeons worldwide, when it comes to classifying and treating unilateral mandibular condyle fractures.

A hyperlink to an online questionnaire was sent to 3044 maxillofacial surgeons via email. A number of 491 participants responded, from 46 different countries. All had reviewed the same 3 cases of unilateral mandibular condyle fractures, based on either 2D imaging or 3D imaging of the fracture. The cases were classified as a condylar head, condylar neck or subcondylar fracture according to Lindahl.1 Subsequently a treatment decision was requested.

Both classification and treatment decision showed a great variance amongst participants. In the case of a condylar head fracture without dysocclusion, the largest degree of discrepancy was seen, whereas in case of a subcondylar fracture with dysocclusion the level of agreement was relatively high.

The outcomes of this study are largely in accordance with what is known from the available literature. Although it is not possible to compare our results directly to the results from previous studies, it seems that open reduction and internal fixation is performed more often in current times. This is in consistency with what is expected and written in the literature.12,37

In our study, the open treatment was chosen most when an altered occlusion is present. In these three cases of mandibular condyle fractures, the lower the fracture line was, the more often ORIF would have been performed. A remark needs to be made concerning the simplification of the presented three cases. As in clinical settings a surgeon would need more information regarding the patient than merely imaging and if there is dysocclusion. In the cases presented, a dysocclusion can be expected, because all cases show displacement. Therefore an information bias is to be taken into account, potentially leading to misinterpretation of the cases.

The surgical approach that was chosen the most often was the retromandibular approach, followed by the preauricular approach. In the study by Baker et al., the preauricular approach was used by 70% of the surgeon, the submandibular approach by 47% and the retromandibular approach by 36%.42 Bos et al in 1999 describd the preauricular and retromandibular approaches were used most frequently.43 Chrcanovic in a meta-analysis from 2015 found 36 reviews, of which in seven studies the retromandibular
approach was used, in four the submandibular approach, the preauricular approach was used in three studies, two studies an endoscopically assisted intraoral approach, and the auricular approach, the intraoral approach and the anteroparotid transmasseteric approach were all used in one study. Twelve studies used more than one type of approach, six studies did not mention what approach had been used. Our results suggest the submandibular approach has been replaced by the retromandibular approach in popularity, confirming the expectations based on the current literature.

Interestingly, the participants who received the cases represented by the 3D images of the fracture chose an operative approach significantly more often than the participants who received the 2D imaging of the mandibular condyle fractures in two out of three cases (the higher fractures, in the condylar head and condylar neck). This leads to the assumption that the imaging of fractures has an influence on the treatment decisions, and possibly the severity of a mandibular condyle fracture can be judged better on 3D images. Another explanation may be that more operative possibilities are seen on 3D images compared to on 2D images. Three dimensional imaging in condylar head and neck fractures thus leads to more invasive indications based on the results of this study. It seems important to investigate these results in a future research, assessing inter and intrarater reliability.

As mentioned previously in the discussion, the three cases were presented in a rather simplified manner (with no data on for example, the patients age, further injuries, pre-existent occlusion etc), it is difficult for participating surgeons to form a well-funded definitive treatment decision. However, keeping the questionnaire brief and basic was a deliberate choice, to increase the number of replies and to avoid answers becoming too widespread to be compared.

Regarding the classification method according to Lindahl in the present study, it should be noted that this may have increased the controversy between the participants. As this classification method is not landmark based and the definition of especially subcondylar fractures may be different between participants, it hence may have caused a bias. If the classification method by Loukota et al had been used, possibly less controversy concerning the classification of the fractures would have been found.

Furthermore a geographic bias is caused by the fact that participants from Europe and South America form a vast majority. They may not be representative of the entire population of maxillofacial surgeons worldwide. The search terms that have been used to identify potential participants are broad, aiming on maxillofacial fractures in general. Therefore, not only experts in the field of mandibular condyle fractures, but a rather
random sample of maxillofacial surgeons has been addressed for participation. This is an important drawback in this study. However, due to the large number of participants and the fact that this study does have intercontinental participation, the authors believe it offers some new interesting perspectives in the complex matter of mandibular condyle fractures treatment decision-making. However, as the study comprises several risks of bias, all results should be interpreted with caution.

A higher level of agreement amongst participants might have been reached if the classification of each fracture as determined by the investigators had been provided in the questionnaire. However, we chose to let the classification happen as it would in clinical practice. Therefore it is likely that different participants may have used different classification methods or definitions. We think this in fact underlines how knowledge on the classification of mandibular condyle fractures is insufficient in the clinical setting. Recently publishes results from the IBRA symposium by Neff et al, underlines the importance of clarity amongst specialists when it comes to the classification and nomenclature.37 In the present study, three cases of unilateral mandibular condyle fractures were classified as either a subcondylar, a condylar neck or a condylar head fracture according to Lindahl.1 An updated classification method and nomenclature by Loukota et al from 2010 has been adopted by the SORG and the AO foundation.2,4 Quite recently, according to a consensus now supported by the SORG, the IBRA and also the Arbeitsgemeinschaft für Osteosynthesefragen (AO) the AO Comprehensive Injury Automatic Classifier (AOCOIAc) has been updated, which allows for a precise anatomical description of condylar base, neck and head fractures.5 It must be emphasised that consistency amongst surgeons when making treatment decisions and reporting fracture characteristics in patient charts, is important. It enables future research to compare data more easily.

Conform the available literature, the current study illustrates the high level of controversy when it comes to making treatment decisions in cases of unilateral mandibular condyle fractures.33–36 Strikingly, this study demonstrates that controversy in treatment decisions remained, even when fractures previously classified as subcondylar, condylar neck or condylar head fractures by the participants themselves, were analysed as separate groups. In the report from the IBRA symposium by Neff et al, much more consistency amongst the participants was reached when it comes to treatment decisions, when compared to this current study. ORIF was described as the new gold standard for condylar base and condylar neck fractures. Furthermore, there was a tendency to treat condylar head fractures operatively as well.37 The remarkable difference to the results in the present study may be at least partially explained by two facts. First, at the IBRA symposium, there was a panel of experts on osteosyntheses that participated
the survey. Whereas in the current study, maxillofacial surgeons were approached, regardless if they were specialized in condylar trauma. Secondly, at the IBRA meeting, 63 of 77 participants (81.8%) were from European countries. In our study, a large group of participants came from South America (36.3%) and North America (12.6%). Especially in North America a more conservative approach is seen.

In the future, large, preferably randomized clinical trials investigating long-term outcomes of unilateral mandibular condyle fracture treatment are necessary. The authors believe that also subjective outcome measurements regarding patient Quality of Life should be focussed on.
Chapter 6

Conclusion

Consistent with what is known from the current literature, it seems there is a large degree of controversy when it comes to unilateral mandibular condyle fractures. Treatment decision-making is largely done based on expert opinion, and varies notably amongst maxillofacial surgeons worldwide, as well as knowledge about actual classification methods. The number of years of experience of a surgeon does not seem to influence treatment decision-making. However, the continent of residence and practice do significantly influence the choice of treatment. In Northern-America, maxillofacial surgeons will less frequently choose an operative treatment, compared to colleagues from other continents. European surgeons showed a preference for expectative treatment relative to conservative treatment with IMF, when compared with surgeons from other continents.

In the two higher fractures (in the condylar head and condylar neck) in this study, assessment of the fracture based on 3D imaging resulted in significantly more operative treatments compared to assessment based on 2D imaging.

Research aiming to create a widely used and accepted evidence based treatment protocol for unilateral mandibular condyle fracture treatment is needed. The current study illustrates the difficulties in these clinical cases.
Consensus or controversy?

References


Chapter 6


33. Assael LA: Open versus closed reduction of adult mandibular condyle fractures: an alternative
Consensus or controversy?


Chapter 7

Conclusions and future perspective
Chapter 7

This chapter will shortly address the main conclusions of the presented thesis. Furthermore future research aims are briefly discussed.

1. Over the past decades, numerous studies have been published addressing the complex matter of how to best treat a fractured mandibular condyle. Only three studies looked into clinically relevant subjective parameters as experienced by the patient, all using the mandibular function impairment questionnaire (MFIQ). None of the studied publications, had a patient-centered approach in the comparison of open versus closed treatment outcomes.

2. Several studies have shown OPT to be fairly reliable to perform measurements on in the vertical dimension. As only one measurement technique was used in the study presented in this thesis, others might approximate the actual values more or less accurately. The intraclass correlation coefficient for intraobserver and interobserver reliability however was high, so the repeatability of the used measurement technique cannot be cited as an argument for the unexpected difference of more than 2 mm between the left and right ramal height that was present in 50 subjects (68%) in the control group. Such a difference on OPT should be defined as shortening of the ramus caused by a fracture of the mandibular condyle if the difference measured is more than 4.2 mm, based on the results of chapter 3 of this thesis.

3. After treatment of maxillofacial trauma different types of dysocclusion may occur, including an anterior open bite, lateral open bite, crossbite, mandibular retrognathia, maxillary retrognathia or laterognathia. Several orthognathic surgical modalities are available to treat these dysocclusions. In the study presented in chapter 4 these modalities proved to be unilateral sagittal split osteotomy, BSSO, Le Fort I, vertical ramus and segmental osteotomies or combinations of the before mentioned.

4. Further, according to the literature, the time frame between the initial treatment of the trauma and the occurrence of the dysocclusion is important for the secondary treatment of the dysocclusion. In the present study we were not able to draw firm conclusions on the importance of this time frame.

5. The biomechanical analysis presented in chapter 5 demonstrated that after a unilateral fracture of the mandibular neck, jaw movements became non-symmetrical, despite symmetrical muscle activation patterns. The jaw was predicted to close with an open bite similar to clinical observations. However, upon jaw opening the orientation of the predicted laterodeviations was not in accordance with clinical observations. The differences could be attributed among others to the absence
Conclusions and future perspective

of volumes of soft tissue in the applied biomechanical model. In general, the non-symmetrical movements could be attributed to an altered articulation in the temporomandibular joint on the affected side. Intermaxillary fixation is often applied to restore masticatory function. It is considered to stabilize the mandibular condyle with respect to the mandibular body. The present analysis however predicted that it may not prevent a disconnected mandibular condyle to be dislocated further anteriorly due to contractions of the lateral pterygoid muscle.

6. Currently ongoing research aims for the biomechanical analysis of the alterations that have occurred in the temporomandibular joint during healing of a mandibular condyle fracture. Conebeam CT scans will be used to compare joint morphology as well as mandibular movement when simulating the activation of the masticatory muscles before and after healing of the fracture.

7. Consistent with what is known from the current literature, chapter 6 describes a large degree of controversy when it comes to unilateral mandibular condyle fractures. Treatment decision-making is largely based on expert opinion, and varies notably amongst maxillofacial surgeons worldwide, as does the knowledge about actual classification methods. The number of years of experience of a surgeon does not seem to influence treatment decision-making.

8. However, the continent of residence and practice do significantly influence the choice of treatment. In Northern-America, maxillofacial surgeons will less frequently choose an operative treatment, compared to colleagues from other continents. European surgeons showed a preference for expectative treatment relative to conservative treatment with IMF, when compared with surgeons from other continents.

9. Assessment of the condylar head and condylar neck fracture based on 3D imaging resulted in significantly more operative treatments compared to assessment of these fractures based on 2D imaging. Research aiming to create a widely used and accepted evidence based treatment protocol for unilateral mandibular condyle fracture treatment is needed. The current study illustrates the difficulties in these clinical cases.

10. As imaging plays an important role in both classification and treatment decision-making a study further comparing 2D and 3D imaging techniques is currently ongoing.