Optimization of mandibular fracture treatment
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Document Version
Publisher's PDF, also known as Version of record

Publication date:
2019

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):
CHAPTER 2

NON-IMF MANDIBULAR FRACTURE REDUCTION TECHNIQUES:
A REVIEW OF THE LITERATURE

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https://doi.org/10.1016/j.jcms.2017.05.017
ABSTRACT

Background. Intermaxillary fixation (IMF) techniques are commonly used in mandibular fracture treatment to reduce bone fragments and re-establish normal occlusion. However, non-IMF reduction techniques such as repositioning forceps may be preferable due to their quick yet adequate reduction. The purpose of this paper is to assess which non-IMF reduction techniques and reduction forceps are available for fracture reduction in the mandible.

Methods. A systematic search was performed in the databases of Pubmed and EMBASE. The search was updated until February 2016 and no initial date and language preference was set.

Results. 14 articles were selected for this review, among them ten articles related to reduction forceps and four articles describing other techniques. Thus, modification and design of reduction forceps and other reduction techniques are qualitatively described.

Conclusion. Few designs of repositioning forceps have been proposed in the literature. Quick and adequate reduction of fractures seems possible with non-IMF techniques resulting in anatomic repositioning and shorter operation time, especially in cases with good interfragmentary stability. Further development and clinical testing of reduction forceps is necessary to establish their future role in maxillofacial fracture treatment.
INTRODUCTION

Mandibular fractures are the most common injuries of the maxillo-facial area. Reduction of the fractured bone segments is an important phase of fracture treatment of any bone, as precise reduction facilitates the bone healing process and reduces infections. Direct bone contact between the fracture segments supports primary bone healing, which leads to earlier bone regrowth and stability across the fracture site. However, reduction gaps of more than 1 mm across fractured bone segments result in secondary healing, which causes callus formation and increases the risk of a malunion.

Reduction of mandibular fractures is achieved by using intermaxillary fixation (either with IMF screws or splints), reduction forceps, manual reduction, or a combination of these methods. The choice of method depends on the location and severity of the trauma, preference of the surgeon, and the dislocation or comminution. The application of IMF with arch bars is time-consuming, and has several disadvantages, such as patient discomfort, gingivitis and infection. Recently, IMF screws have become more popular in mandibular trauma surgery due to their easy and quick application. However, screw failure, gingival and mucosal tissue damage and root injury may occur. In order to overcome the possible disadvantages of IMF techniques, some surgeons prefer to use manual repositioning or reduction forceps. Several studies have shown that reduction forceps could significantly reduce operation time, and their use results in adequate bone fragment reduction and causes few postoperative complications such as infection and occlusal disturbance. However, surgeons must pay attention to lingual site gapping when using reduction forceps, because it could cause separation of lingual borders of the mandible.

According to the literature, only a few types of repositioning forceps are available for application in OMF surgery. Frequently, modified larger towel clamps are used, but some surgeons and biomedical engineers have reported on the development of more efficient ones. The aim of this paper is to review all studies related to reduction forceps and other non-IMF reduction techniques in order to assess which forceps are available and which developments are needed.
MATERIALS AND METHODS

In order to identify studies on reduction forceps for mandibular fractures, a systematic search was performed in the database of PUBMED and EMBASE. The search was updated until February, 2016 and no initial date and language preferences were set. Furthermore, citations of the retrieved articles were screened to identify additional relevant articles. Case reports, studies on small populations, technical notes and laboratory studies were all included in this review.


Embase search: ‘mandible fracture’/exp AND ‘fracture reduction’/exp OR ‘reduction forceps’ OR ‘reduction clamps’

RESULTS

The systematic search strategy resulted in 1285 hits from the Pubmed and Embase, of which 295 duplicates were removed. The titles of the remaining 990 articles were screened, after which another 925 hits were ejected due to irrelevancy. The abstracts of the remaining 65 articles were screened, and another 52 publications were excluded as they were not relevant or animal studies. Screening of the references resulted in one additional publication. Finally, 14 articles were chosen for this review (Fig 1). The selected articles were categorized as either clinical or experimental studies.

1. Clinical studies

Accuracy of fracture reduction

Eight of the 14 articles mentioned that stable pre-compression and reduction were achieved with help of a reduction forceps. Four articles described other techniques which will be described below.

Reduction forceps. In one study\(^6\), two modified reduction forceps were used for the symphyseal and parasymphyseal fractures. One was applied at the
Fig 1. Algorithm of study selection procedure.
inferior border and another one in the subapical zone of the anterior mandible, in order to reduce lingual cortical bone sufficiently. In the other clinical studies, the reduction was achieved by using one clamp or forceps in the anterior and posterior region of the mandible.

The success of the reduction is described in terms of postoperative clinical observation and complications in all eight articles. Two studies described additional post-reduction radiography to confirm healing. Mandibular angle fracture cases were followed up prospectively via orthopantomograms (OPG) and reverse Towne views or both.\textsuperscript{3,7} The study of Choi et al.\textsuperscript{3} included two treatment groups (reduction forceps and IMF group) and used a scale of 1 to 3 to assess the accuracy of anatomic reduction in the radiographic image. A score of 1 indicated a poorly reduced fracture which required a second operation, while a score of 2 indicated a slight displacement but an acceptable occlusion. A score of 3 indicated a precise reduction. The reduction forceps group had a higher number of accurate anatomic alignments of the fractures than the IMF group.

Three studies provided information about the distance between the drill holes in which the teeth of the forceps find their grip. One study\textsuperscript{11} describes two monocortical holes were drilled, each 10 mm from the fracture line. A second study\textsuperscript{12} describes monocortical holes at approximately 12 mm from the fracture line at midway down the vertical height of the mandible. The third study describes either monocortical or bicortical holes depending on difficulties. These difficulties are not described in detail. In this study\textsuperscript{8}, the distance of 5-8 mm from the fracture was chosen at the inferior margin of the mandible (Table 1).

\textit{Other techniques.} Scafati et al.\textsuperscript{13} used elastic rubber bands stretched between screws placed across both sides of the fractured parts in order to reduce mandibular and orbito-maxillary fractures. Orthodontic rubber bands and two self-tapping monocortical titanium screws with 2 mm diameter and 9-13 mm length were used. The heads of the screws protruded about 5 mm and the axis had to be perpendicular to the fracture line. Degala et al.\textsuperscript{14} used comparable techniques for symphyseal, parasymphyseal and body fractures. Titanium screws with 2 mm diameter and 8 mm length were tightened at a distance of 10-20 mm from the line of fracture, and around 2 mm screw length remained above the bone to engage a 24 G wire loop. However, before applying this technique, they used IMF.
<table>
<thead>
<tr>
<th>Study</th>
<th>Study type</th>
<th>No. of patients</th>
<th>Fracture location</th>
<th>Type of reduction method</th>
<th>Drill holes distance (from the fracture line)</th>
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<tr>
<td>Kallela et al. 17</td>
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<td>Modified large towel clamp</td>
<td>5-8 mm at inferior margin of mandible</td>
</tr>
<tr>
<td>Choi et al. 8</td>
<td>Clinical/technical note</td>
<td></td>
<td>Angle</td>
<td>Specifically designed forceps of the angle fractures</td>
<td>-</td>
</tr>
<tr>
<td>Choi et al. 3</td>
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<td>Shinohara et al. 6</td>
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<td>2</td>
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<tr>
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<td>Clinical/Case report</td>
<td>7</td>
<td>Transverse angle</td>
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</tr>
<tr>
<td>Scafati et al. 13</td>
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<td>Degala et al. 14</td>
<td>Clinical/technical note</td>
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<td>24</td>
<td>Body</td>
<td>Computer guided fracture reduction with custom-fabricated surgical stent</td>
<td>-</td>
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<td>Beech et al. 15</td>
<td>Clinical/technical note</td>
<td>1</td>
<td>Bilateral (Right angle, left parasympyseal)</td>
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<td>-</td>
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<td>Choi et al. 18</td>
<td>Experimental</td>
<td>36*</td>
<td>Body, Symphyseal, Parasympyseal</td>
<td>Stress patterns generated by Synthes</td>
<td>10-16 mm in the different level</td>
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<tr>
<td>Kontio 10</td>
<td>Experimental</td>
<td></td>
<td></td>
<td>Only virtual reduction in a computer model with computer aided designed forceps</td>
<td>-</td>
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* Photoelastic mandibular models
Two publications describe reduction methods that use custom made splints. A vacuum-formed splint was used by Beech et al.\textsuperscript{15} in the reduction of one bilateral mandibular fracture case. In this case, the patient underwent two operations. Final precise reduction and fixation was done seven days after immediate stabilization with miniplates and screws followed by alginate impressions for manufacturing the splint. El-Gengehi et al.\textsuperscript{16} virtually reduced mandibular fracture segments based on three-dimensional reconstruction of a CBCT scan. Based on the reconstruction, custom made surgical guides were fabricated. At the start of the surgical treatment, the mandibular fracture segments were aligned with help of the custom made a surgical guide, which was placed in the subapical zone using monocortical mini screws. Above and below this guide the osteosynthesis material was placed to fixate the fracture. Finally the guide was removed.

**Postoperative complications**

Several authors\textsuperscript{6,8,11} did not mention post-operative complications, whereas other authors\textsuperscript{7,12} did not experience any complications when they used reduction forceps. Kallela et al.\textsuperscript{17} described some cases with infection and non-stable fixation. However, in this study, they used a lag screw technique for fixation instead of plates and screws. Choi et al.\textsuperscript{3} noted one case of infection in the reduction forceps group versus four cases in the IMF group. The IMF group had two cases with occlusal disturbance, while no occlusal disturbance was observed in the reduction forceps group. Furthermore, one case of dental root perforation due to the IMF screw and two cases of infections with malunion were observed in the elastic internal traction technique group.\textsuperscript{13} In a study on the tension band wiring technique\textsuperscript{14} three cases developed an infection and eight cases had a minor occlusal discrepancy.

**Duration of surgery**

Two studies reported on the duration of the operation when using reduction forceps. Shinohara et al.\textsuperscript{6} mentioned that using reduction forceps without IMF for mandibular fractures reduced the time of surgery, but they did not provide exact information on operation times. Choi et al.\textsuperscript{3} described operation times as being significantly reduced in the reduction forceps group; the average operation time was 41 minutes in the forceps group compared to 87 minutes in IMF group. With respect to other techniques, operative time was shortened in several studies\textsuperscript{13,14} but the authors did not provide exact information either.
2. **Design of the repositioning forceps**

Eight articles described a new design for reposition forceps.\(^3,6-9,11,12,17\) These designs can be divided into two groups.

**A. Modified towel clamps**

A standard towel clamp was modified by Rogers et al.\(^8\) bending two ends of a clamp approximately 10 degrees outward. This was done to prevent disengagement from the bone (Fig 2-A). Kellela et al.\(^17\) modified a standard AO reduction forceps through shortening the teeth and made notches at the ends to grasp tightly in the drill holes (Fig 2B). Shinohara et al.\(^6\) used two modified reduction forceps: one was positioned at the inferior border and the other in the neutral subapical zone. However, the authors did not describe the modification technique (Fig 2C).

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**Fig 2.** Schematic drawing of existing reduction forceps. A, Modified towel-clamp (Rogers et al.) B, Modified AO forceps (Kellela et al.) C, Modified reduction forceps (Shinohara et al.) D, Reduction forceps for mandibular angle fracture (Choi et al.), E, Commercially available reduction forceps (Synthes).
B. Specific or new design

New reduction forceps were developed by Choi et al.\textsuperscript{3,9} for mandibular angle fractures based on the unique anatomy of the oblique line and body; one end of the forceps was designed for positioning in the fragment medial to the oblique line and another end was positioned in the distal fragment below the oblique line. The prongs are asymmetrically designed, with the medial prong being longer than the distal one (Fig 2D).

The reduction-compression forceps of Scolozzi et al.\textsuperscript{7} was designed similar to standard orthopedic atraumatic grasping forceps (Fig 3A).

Kluszynski et al.\textsuperscript{12} designed a prototype of a right-angled reduction forceps to prevent bone chipping of the drill holes during the reduction (Fig 3B).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{forceps.png}
\caption{Schematic drawing of existing reduction forceps (continues) A, Specific ad hoc, the prongs of the forceps made a 90-degree angle sagittally and a 70-degree angle coronally relative to the midline of the forceps (Scolozzi et al.) B, Right-angle, prongs are designed an approximately 90-degree angle coronally (Kluszynski et al.) C, Combination of self-cutting screws and a repositioning forceps (Zerdoner et al.).}
\end{figure}
Žerdoner et al.\textsuperscript{11} used a combination of self-cutting screws and a repositioning forceps which has butterfly-like shaped prongs. First, two screws are fastened on each side of the fracture line and then the reposition forceps is placed over the heads of the screws (Fig 3C).

3. Experimental studies

Choi et al.\textsuperscript{18} evaluated the stress pattern generated by reduction forceps (Fig 2E; Model 398.98 Synthes, Waldenberg, Switzerland) with a photoelastic mandibular model in order to determine the ideal position of the reduction forceps. They osteotomized 36 mandibular models into three groups of fractures: symphyseal, parasymphyseal and body fractures. According to this study, symphyseal and parasymphyseal fractures have similar stress distributions, and a distance between the two engagement holes of more than 12 mm is ideal in both lingual and labial areas. Furthermore, reduction forceps should be placed between the midway level of the mandible or 5 mm below the midway level. In the case of body fractures, optimum stress distribution was achieved when both tips of a reduction forceps were placed more than 16 mm away from the fracture line at midway level.

Virtually designed reduction forceps were developed using a parametric computer aided design (CAD) and additive manufacturing (AM) for the prototype.\textsuperscript{10} In this study, the instruments consist of three separate units: handle, jaw and bar. The prongs of this forceps hold the bone fragments rigidly and the oval axial line of the handles was designed to retract the buccal soft tissues and muscles. However, due to several design-related complications they were unable to make a prototype.

**DISCUSSION**

The use of reduction forceps has been known for many years in general trauma surgery, orthopedic surgery and plastic surgery. In OMF surgery traditionally the dental occlusion was used to perform and check reduction of mandibular fractures. Notwithstanding this historical background, reduction forceps can be used in mandibular fractures as in any other fracture as long as there is sufficient space and as long as the fracture surface permits stable placement and withstands the forces created by such a forceps. Although there have been a number of publications presenting various designs of reduction forceps for use in OMF surgery, a review never has been published.
This article describes the advantages and weak points of the various reduction forceps and their clinical use and designs.

Each author almost exclusively uses his own type of forceps, although there are similarities in the designs. Generally, the curvature in the design of the prongs of any kind of grasping instruments such as bone forceps or towel clamps were kept in all models described in this review, except for a right-angle forceps (Fig.3B). Most of the authors\textsuperscript{6,8,17} simply bent the prongs of the forceps into different angles in order to improve their grip and the pre-compression during the reduction. Mandibular symphyseal and parasymphyseal fractures were rather easy to reduce with reduction forceps due to their curved shape. However, mandibular angle fractures are more challenging to reduce due to the difficulty of positioning the forceps intraorally. Therefore, a specific reduction forceps was designed\textsuperscript{3,9} for fractures of this area. However, this forceps was not able to reduce oblique fractures of the mandible. The modified towel clamp by Rogers et al.\textsuperscript{8} could be used in angle fracture via an extraoral incision, but this clamp is less effective in oblique fractures as well. Therefore, it would be desirable to develop a universal forceps design for all types of mandibular angle fractures.

The positioning of the forceps and location of drill holes are important for adequate reduction and compression. Clinical studies have suggested that a distance of the holes of at least 8-12mm (average 10mm) from the fracture line allows better reduction and pre-compression. Therefore, new designs for the reduction forceps need a certain freedom of movement to allow them to function when holes are at 8-16 mm from the fracture line, and also it should be able to lock fully. Applying reduction forceps can make IMF unnecessary and so reduces operation time. Additionally, with respect to the patient, IMF-related complications such as gingivitis, pain, discomfort or difficulties in maintaining oral hygiene and root injury by IMF screws are diminished by avoiding IMF. Treating patients without IMF could reduce the risk of injury or infection of the surgeons and nursing staff and decreases the number of assistants as well.

Other fracture reduction methods such as traction wire or elastic tension on screws are simple to use in the area of anterior mandibular fractures, but not in the posterior part of the mandible. In addition, this method may cause a gap at the lingual side of the fracture as an effect of the resultant of the force exerted on the protruding screws. This lingual gap should be prevented with reduction forceps as they grab inside the bone and are positioned at a distance of the
fractures site of at least 8-10 mm this should prevented.\textsuperscript{8,11,12} Choi et al.\textsuperscript{18} even suggested that tips of repositioning forceps should place at least 12mm from each site of the fracture line in case of symphyseal and parasymphseal fractures. In the mandibular body fractures, adequate stress pattern at the lingual site was found at least 16 mm from fracture line.

**CONCLUSION**

Based on this review it can be concluded that only a few designs of repositioning forceps have been proposed in the literature. Quick and adequate reduction of fractures seems possible with this technique resulting in anatomic repositioning and shorter operation time, especially in cases with good interfragmentary stability. A satisfying solution for the posterior part of the mandible is not yet available. Further development and clinical testing of reduction forceps is necessary to establish their future role in maxillofacial fracture treatment. Better reduction and decreasing of operation time are incentives to explore the possibilities.

**ACKNOWLEDGEMENTS**

The authors would like to thank Otgongerel Nyamsambuu, for drawing the forceps.
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Pallas’s cat (Otocolobus manul), Credit: Otgonbayar Baatargal