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Catching condyle – Endoscopic-assisted transoral open reduction and rigid fixation of condylar process fractures using an auto reposition and fixation osteosynthesis plate

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ABSTRACT

Introduction: Fractures of the mandibular condyle are reported to account for 9 %–45 % of all mandibular fractures. There has been a long lasting controversy on the superiority of different treatment options with endoscopic-assisted transoral approaches gaining increasing attention in recent years. In this article, we report the application of a newly developed osteosynthesis plate for an auto reposition, reconstruction and rigid fixation of condylar process fractures.
Material and methods: We present 6 cases of uni- or bilateral fractures of the condylar process treated with a transoral open reduction and rigid fixation using an auto reposition plate. Via a transoral endoscopic assisted approach the proximal condyle fragment is captured using an anatomical defined clinch of the cranial part of the plate. The reposition of the condyle is facilitated with the distal bridge of the plate ranging around the posterior part of the ascending ramus.
Results: The results show a sufficient reposition, rigid fixation and no facial nerve palsy or postoperative long-term occlusal disturbances. The mean operating time was 86 min.
Conclusion: Transoral endoscopic-assisted surgery with application of an auto reposition, reconstruction and fixation plate offers a quick and convenient way for open reconstruction and rigid fixation of condylar process fractures.

1. Introduction

Fractures of the mandibular condyle are reported to account for 9%–45% of all mandibular fractures (Schön et al., 2001; Shahim et al., 2006). They can occur uni- or bilaterally and be combined with other fractures of the mandible and/or dentoalveolar injuries (Kokemueller et al., 2012).

Different treatment options exist for the management of condylar process fractures. Each of these procedures has its advantages and shortcomings, and there has been a longlasting controversy on the superiority of each treatment option (Danda et al., 2010; Eckelt et al., 2006; Schneider et al., 2008). For decades, conservative treatment approaches with maxillo-mandibular fixation have been considered the treatment option of choice by many authors, even in cases of heavily displaced condylar fractures (Hidding et al., 1992; Konstantinović and Dimitrijević, 1992; Walker, 1994). However, today there is a consensus that correct anatomical repositioning of the condylar process after fracture is an essential element to allow for optimal recovery of function (Baker et al., 1998). This can be difficult to achieve applying a conservative treatment approach and may require surgical treatment with reposition and internal fixation in many cases.

Surgical treatment can be performed via an open approach or as an endoscopic assisted procedure. Conventional extraoral access with submandibular, retromandibular or preauricular incisions can injure the facial nerve and comprise esthetics by creating undesirable scars (Veras et al., 2007). In recent years, endoscopic-assisted transoral approaches have gained increasing attention

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(Kokemueller et al., 2012). Using a transoral endoscopic assisted approach with internal fixation offers the advantages of a non-visible scar, considerably reduced danger to the facial nerve and an anatomic reduction which ensures a physiologic occlusion. After an initial learning curve, the operation time is the same for open reduction via an extraoral or an intraoral endoscopic-assisted approach (Loukota, 2006). Controlling the reposition quality often is reserved for centers using intraoperative CBCT control. Unsolved problems exist in fractures presenting a tangential fracture line from the medial/lingual aspect to the lateral aspect. In these cases, often the vertical dimension is hard to fix due to slippery contact surfaces.

To facilitate the reposition and fixation of the condylar process, we developed a preformed plate using statistical shape models. This plate allows to “catch” the proximal fragment via two small clinches at the top of the plate that can be placed around the mesial and distal part of the condyle. At the posterior part of the ascending ramus a guiding area ranging around the dorsal ramus offers the anatomical orientation for the reposition. In this article we present 6 patients treated with an endoscopic-assisted approach using this auto reposition and fixation plate.

2. Material and methods

This study was approved by the Ethics Commission of the University of Freiburg (Reference 87/18).

2.1. Patients and preoperative evaluation

A total of 6 patients presenting to the Department of Oral and Craniomaxillofacial Surgery, University Medical Center Freiburg, Germany with uni- or bilateral fractures to the condylar process and being treated via a transoral endoscopic assisted approach using an auto reposition and fixation plate were included in this study.

Preoperative evaluation included thorough extra- and intraoral clinical examination and three-dimensional imaging. Fragment length was evaluated preoperatively using three-dimensional radiographs and all condylar fractures were classified according to the current AOCMF classification system (Neff et al. 2014). Classification of the fracture was reevaluated intraoperatively via the endoscope.

2.2. Design of the plate

After segmentation of 127 mandibles from clinical CT-scans (62 males and 65 females), three-dimensional triangular surface meshes were generated. To ensure (pseudo-)homology (Fig. 1) throughout the sample, an elastic registration procedure (for further details on registration see (Schlager and Rüdell, 2017) was employed (Fig. 2). All statistical analyses were done using the statistical software R (R Core Team, 2015) and specifically the R-packages Morpho, Rvcg and RvtkStatismo (Schlager, 2015, 2017).

The region of interest was defined on the sample's mean (Fig. 3) and successively extracted automatically from all registered meshes, exploiting the identical mesh topologies (i.e. corresponding vertex indices). The vertices belonging to this region were then rigidly aligned using a Procrustes registration (Goodall, 1991) and a Principal Component Analysis (PCA) was computed on these aligned data. The first PC represents the major axes of variation (accounts for 47.17% of the total variation in this sample). As the data were not standardized regarding size, the first PC is associated with allometric effects as well as sexual dimorphism. In order to model these effects, we regressed the shape of this region onto the first PC, calculating a surface model for the 20%, 50% and 80% quintile of the 1st PC-Scores. That way the resulting surfaces are not only varying isotropically but also incorporate the shape change associated with size. The final design of the plate is depicted in Fig. 4.

2.3. Surgical procedure

The surgical technique was adapted from Schoen et al. who previously described the transoral endoscopic assisted approach (Schön et al., 2002). After securing mandibulo-maxillary fixation, the intraoral incision was placed similar to a surgical approach to the sagittal split osteotomies. The periosteum of the ascending ramus is elevated down to the angle of the mandible. The lower inserting fibers of the temporal muscle are stripped off the mandible and the endoscope is inserted and advanced towards the fracture. The temporomandibular joint (TMJ) is distracted by putting pressure onto the teeth of the mandible to bring the proximal condylar fragment to the lateral aspect. At this moment, the caudal surface of the fracture line appears and will be visible beside the bony surface of the ascending ramus. A reposition to the anatomical position is not yet the target. The sideward dislocation helps to present the “entrance” to impose the plate (Fig. 5). The periosteum and soft tissue in the vicinity of the condyle are carefully removed to allow for the placement of the plate (Schön et al.,

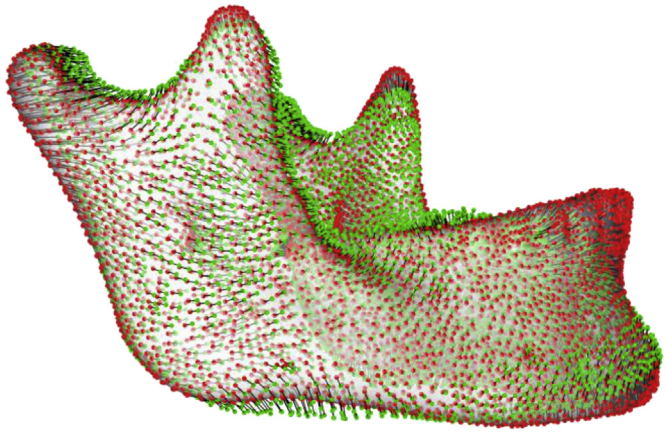

Fig. 1. Pseudo-homologous vertices after registration.

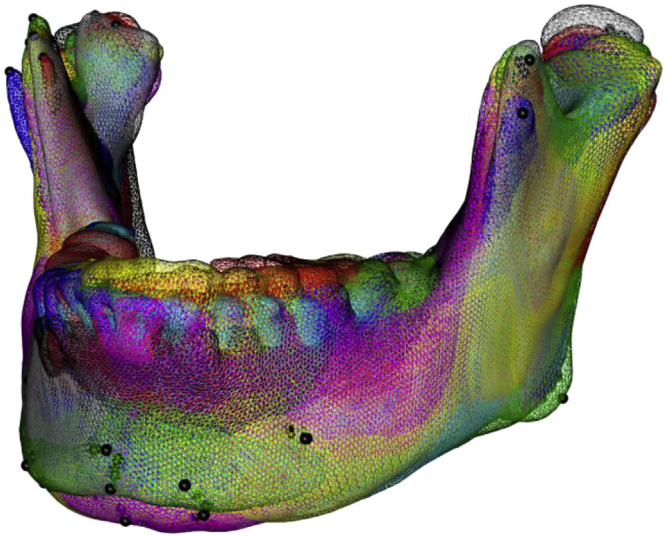

Fig. 2. Meshes superimposed by their corresponding vertices.

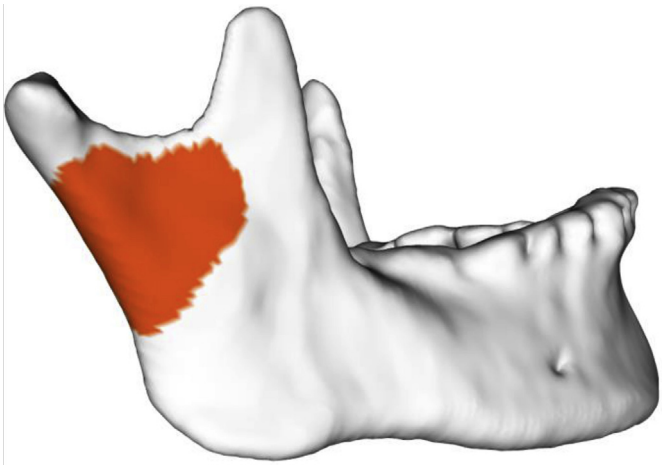

Fig. 3. Definition of the ROI (orange) on the sample mean.

2002). The tips of the plate are used as a hook to grab the proximal condylar fragment. Therefore the plate is inserted and placed lateral to the condyle segment. By pushing the plate cranially and medially, the tips are imposed over the bony edge of the condyle fragment. Now the reposition is performed. The rounded distal bridge of the plate is placed around the back side of the posterior ascending ramus, allowing a straight reposition of the ascending ramus (Fig. 6b and c). The indicator for the correct vertical height and therefore the correct reposition of the fracture fragments is the alignment of the posterior ascending ramus. After getting hold of the proximal fragment, the fracture can be repositioned using the guiding implant around the ascending ramus (Fig. 6d). After correct repositioning is achieved and confirmed endoscopically, screws are placed in the proximal fragment, using an angulated drill and screwdriver. After another control of the correct reposition via the endoscope, screws are placed in the distal fragment respectively (Fig. 7). This is followed by a multilayered wound closure.

2.4. Postoperative procedure and evaluation

All patients were examined for postoperative complications. A final follow-up examination with evaluation of the mandibular function by measurement of maximal incisor opening, degree of deviation on mouth opening, and lateral and protrusive extrusion as well as examination for the presence of TMJ clicking and/or pain was scheduled 6 months post-surgery. All patients were recommended to have their plates removed 6–9 months post-surgery.

3. Results

3.1. Patients and preoperative evaluation

Of the 6 patients, 3 were male and 3 were female, the mean age was 48.5 years (SD ± 21.3 years; range: 21–74 years). Preoperative clinical examination revealed malocclusion in all patients.

The right condylar process was fractured in one case, the left condylar process in 4 cases, and in one case, both sides were affected. 3 patients presented with an additional mandibular fracture, one patient presented with an additional fracture of the ramus and one patient had suffered a panfacial fracture. The mean length of the proximal fragment was 27 mm with a range of 22.1–32.7 mm. Characteristics of the patients are given in Table 1, classification of the condylar fractures according to the current AOCMF classification system and length of the proximal fragment are given in Table 2.

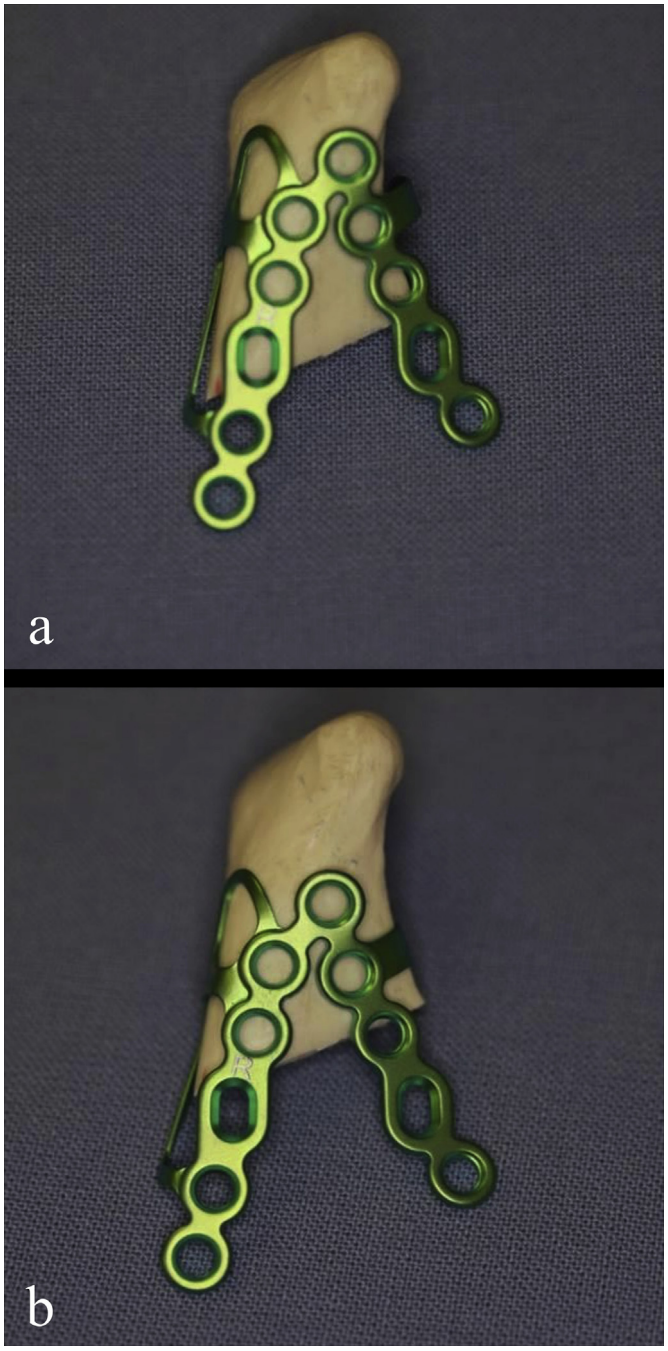

Fig. 4. Design of the plate with (a) showing the status directly after placement of the plate and (b) showing the status after pulling down the plate for fixation of the proximal fragment.

3.2. Surgical procedure

The anatomical correct reposition was confirmed intraoperatively via the endoscope and performing intraoperative C-arm cone beam computer tomography. In all patients a sufficient reposition and rigid fixation was facilitated, with 4–5 screws needed for rigid fixation of the fracture using the preformed plate. In none of the patients an intraoperative switch from transoral to extraoral approach had to be performed.

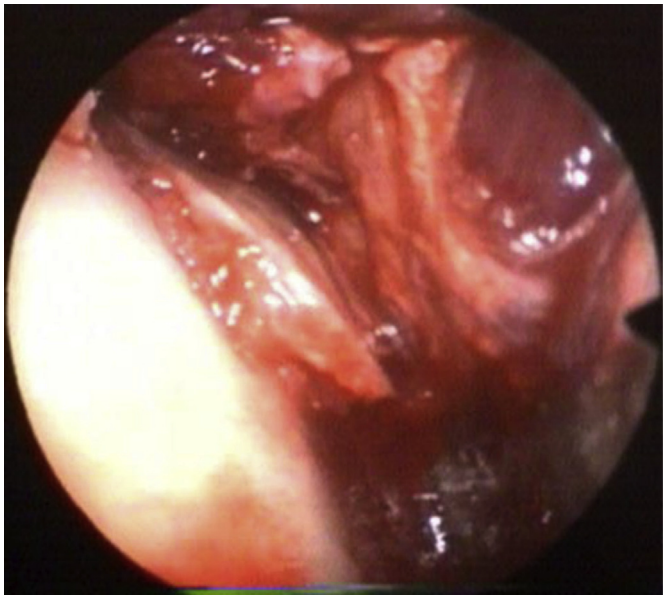

Fig. 5. Intraoperative endoscopic image (sideward displacement of proximal fracture fragment).

The mean duration of surgery for the condylar fractures was 86 min (range 52–120 min). In case of additional fractures, the time required to treat these fractures was subtracted from the overall duration of surgery. Evaluating all 6 cases in a chronologic order, we found a steady decrease in the time required for the surgical treatment of the condylar fractures (Fig. 8).

3.3. Postoperative procedure and evaluation

In all patients immediate postoperative movement of the mandible was allowed. Patients received a liquid diet for 7–10 days and were recommended to have a soft diet the following 2–4 weeks. One patient reported postoperative TMJ pain; however this symptom was only transient. In none of the 6 patients reported in this article did postoperative facial nerve palsy occur. We did not observe any intraoral wound healing disturbances or complications related to intraoral scars.

Patients were followed up for a postoperative period of 6–11 months (see Table 1). No long-term occlusal disturbance/malocclusion, asymmetry or TMJ pain/clicking was observed in any of the patients at the follow-up examinations. No plate breaking or loss of osteosythesis screws was witnessed, and plates have been removed without complications in 2 patients (patient 2 and 3) so far. In 3 patients (patients 4, 5 and 6) the removal of plates has been scheduled and, in a shared decision-making process, the decision to not remove the plate was made in one patient (patient 1) due to her age and general conditions.

Three-dimensional pre- and postoperative radiographs of patient N° 3 as well as a panoramic radiograph showing the conditions after the removal of plates are shown in Fig. 9.

4. Discussion

The purpose of this study was to evaluate an endoscopic-assisted surgical treatment approach using a preformed auto repositioning plate.

The choice of treatment for condylar process fractures has been debated extensively and still constitutes a controversial issue. Closed treatment is considered the treatment of choice for a large proportion of condylar process fractures by many clinicians, reporting no advantages of surgical treatment (Hidding et al., 1992; Konstantinović and Dimitrijević, 1992; Zachariades et al., 2006). However, a growing number of publications clearly emphasizes the advantages of surgical treatment. The aim of surgical treatment of condylar process fractures is the anatomic repositioning and restoration of occlusion at minimal damage to surrounding structures. Performing reliable meta-analysis on closed versus open reduction procedures is impeded due to a lack of patient randomization, a large variability within the surgical protocols, heterogeneous classification of condylar fractures and inconsistencies in the variables examined in the literature (Nussbaum et al., 2008). However, there are investigations directly comparing closed to open treatment and reporting superior results of open treatment approaches. In a randomized multi-center study Eckelt et al. (2006) and Schneider et al. (2008), comparing closed reduction and mandibular-maxillary fixation to open reduction and internal fixation, found surgical treatment to be superior in all objective and subjective functional parameters. Correspondingly, Kokemueller et al. (2012) in a prospective study directly comparing closed treatment to open reduction confirmed the surgical treatment approach to be significantly superior regarding post-operative long-term occlusal disturbances.

The main issues of open procedures are facial scars and the risk of facial nerve injury. The risk of injuring the facial nerve can be considered a factor depending on the surgeon's experience in performing extraoral surgical treatment of condylar process fractures and would be very low in an experienced surgeon. Transoral endoscopic-assisted approaches facilitate a good fracture alignment and functional restoration and in addition reduce the risk of facial nerve damage, leave no facial scar and have no risk of saliva fistulas (Schmelzeisen et al., 2009). However, both approaches are technically demanding and the risk of complications depends on the surgeon's experience in performing either procedure.

Current surgical protocols for transoral open reduction of condylar process fractures use miniplates for the repositioning and fixation of the fracture fragments (Blumer et al., 2018; Veras et al., 2007). Applying this approach, it can be challenging to reposition the proximal condyle fragment. After careful removal of the periosteum and soft tissue, an osteosynthesis plate is placed at the posterior part of the fragment and fixed with screws. With the help of the posterior plate and the use of specialized nerve hooks to align the fragments, the proximal fragment can be repositioned and fixed to the distal fragment. In many cases, this is followed by the placement of a second osteosynthesis plate anterior to the distal plate for stable fixation of the fracture.

Advancing technological options with the possibility of statistical shape modeling have allowed for the creation of size information that can provide a profound base for the production of standardized reconstruction plates (Metzger et al., 2011). Such plates can be applied to the treatment of common fractures of the maxillofacial region like the orbit or mandible and have been found to be advantageous in terms of the time required for the surgical procedure, ease of use, contour accuracy or plate breaking (Probst et al., 2012; Strong et al., 2013).

Designing our plate, we combined the technological possibilities of statistical shape modeling with a technical concept to facilitate open reduction of condylar process fractures. The idea behind the design of our plate was to find a quick and convenient way to “catch” the proximal fragment. This can be facilitated by the two small tips at the top of the plate that can be placed around the mesial and distal part of the neck of the condyle. Advantages of this plate are the one step design that allows reposition and fixation via the same plate and provides a guiding splint to anatomically reconstruct the vertical height of the ascending ramus.

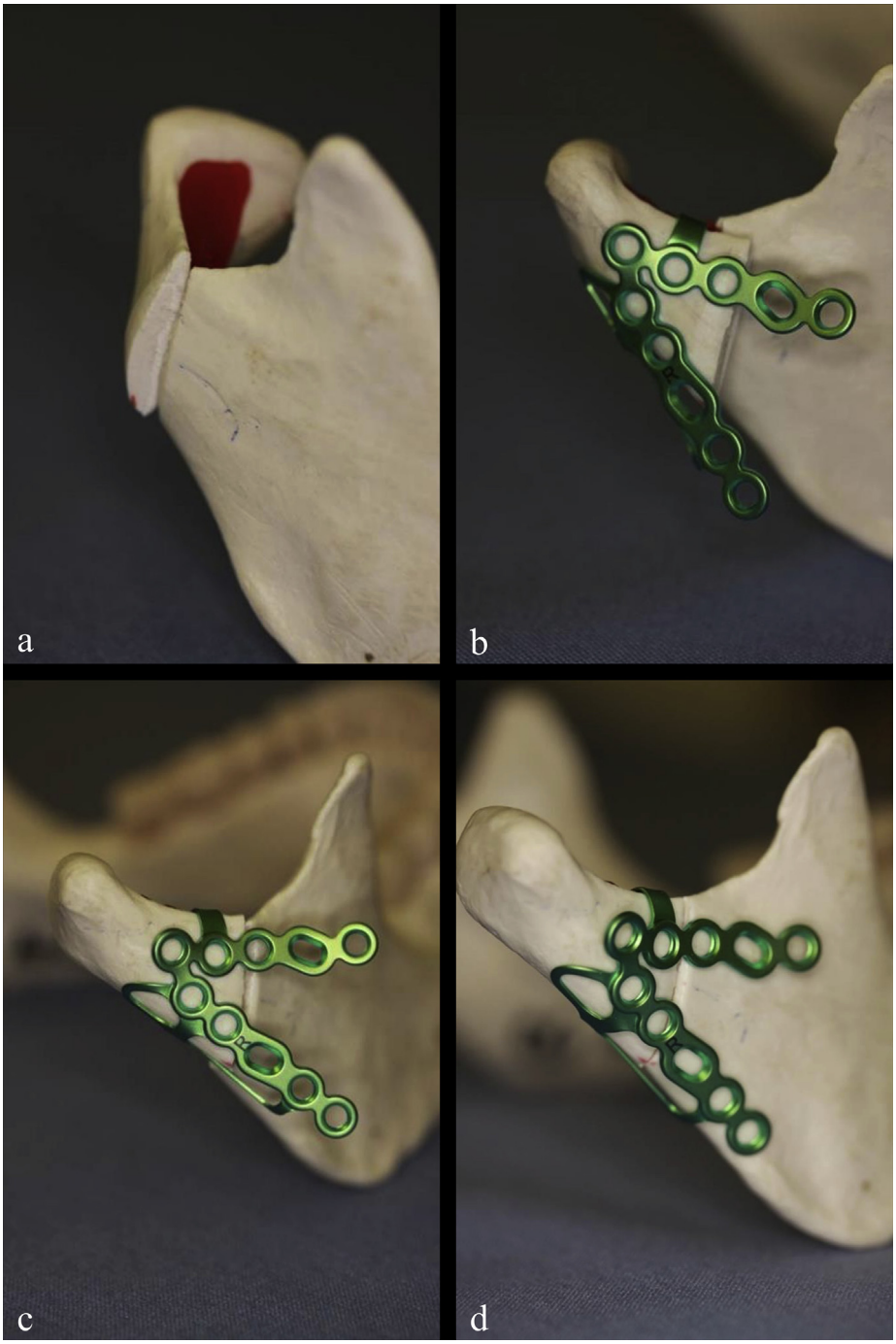

Fig. 6. Surgical procedure depicted in mandible model.

Our system has some shortcomings as well. It is limited to condylar process fractures in which the proximal fragment in the region of the condyle neck is broad enough to be cached by the two tips of the plate. In our experience a minimal distance of 12 mm between the posterior and the anterior edge of the condylar process is required to apply our plate. The plate is also quite extensive although we did not encounter any problems regarding this aspect in our patients. However, we recommend the removal of the osteosynthesis plate 6–9 months after surgery as we do for all osteosynthesis material with the exception of titanium meshes for orbital reconstruction. The removal of the plate has been performed without complications in 2 patients so far.

The mean duration of surgery in the 6 patients presented in this article was 86 min. This is lower than the duration reported in other articles (Blumer et al., 2018; Kang et al., 2012) and supports our aim of facilitating the surgical procedure applying a one-step plate design. Comparing the duration of surgery in each of the patients considering the chronologic order in which these patients presented to our department, we found the duration to decrease with time. This suggests that the time required might decrease with increasing experience of the surgeon in handling the endoscopic equipment. A steep learning curve for endoscopic-assisted transoral treatment of condylar process fractures has been reported by other investigators as well (Loukota, 2006; Schoen et al., 2008).

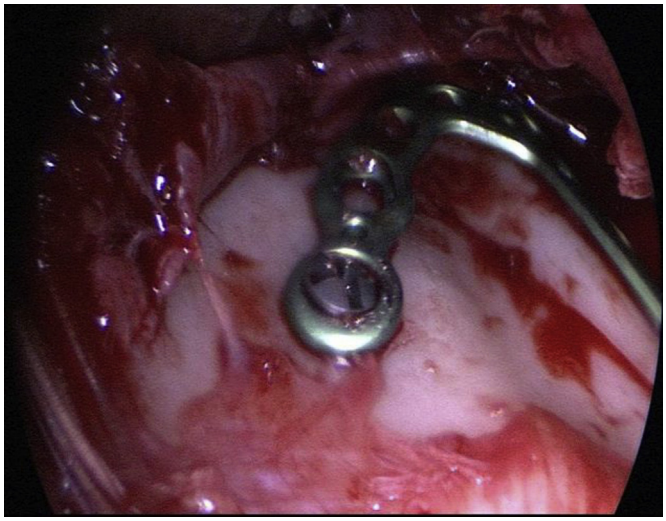

Fig. 7. Intraoperative endoscopic image (placement of the screws).

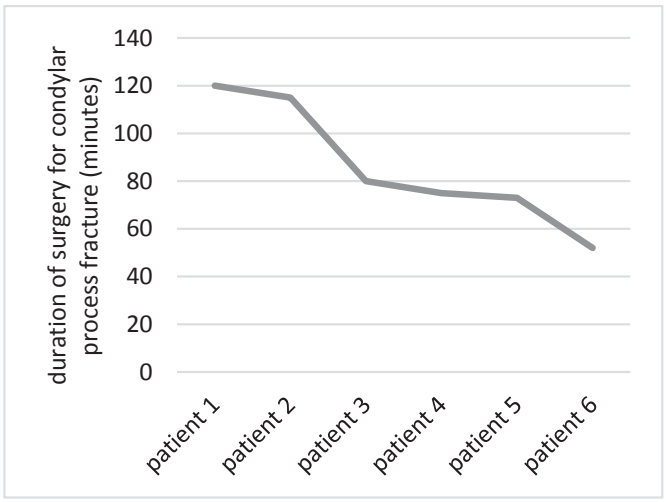

Fig. 8. Duration of surgery (minutes).

The alignment of the posterior border of the ascending ramus is of utmost importance in fracture repair and can sometimes be difficult to visualize through a transoral endoscopic assisted approach (Hwang et al., 2016). With the use of the one step reduction and repositioning plate, the posterior bridge of the plate aligns the ascending ramus and serves as guidance for the repositioning. Determining the right type of fracture for a transoral endoscopic assisted approach can be difficult. Therefore, a careful case selection is essential to avoid intraoperative complications. Due to the anatomy of the mandible, the visibility of the posterior aspect of the ascending ramus and control of the reduction of the fracture the transoral approach is sometimes compromised (Undt et al., 1999). In our study no intraoperative switch to an extraoral approach was necessary.

In terms of complications, asymmetry, muscular/articular pain and residual discomfort as well as malocclusion have been found to be more frequent following conservative treatment than following open reduction and internal fixation of fractures of the mandibular condyle. Potential complications following open reduction and internal fixation include facial nerve damage, with a relative frequency of 8.6% reported in current literature, saliva fistula and plate breaking/loss of osteosythesis screws (García-Guerrero et al., 2018). In this context, endoscopic-assisted transoral approaches possess the advantage of no visible facial scars and significant lower risk of facial nerve damage (Schmelzeisen et al., 2009).

In none of the 6 patients reported in this article facial nerve palsy or occlusal disturbances were diagnosed following surgery and no long-term occlusal disturbance/malocclusion,

Table 1
Patient characteristics.

Patient No.	Age (years)	Sex	Affected side (condylar process)	Additional fractures	Postoperative follow-up (months)	Removal of plates
1	74	f	left	left ramus	6	no
2	27	m	both[a]	paramedian right	9	yes
3	21	m	left	paramedian left	8	yes
4	59	f	right		11	scheduled
5	65	f	left	panfacial fracture	7	scheduled
6	45	m	left	paramedian right	7	scheduled

[a] Fracture of left condylar process treated with miniplates.

Table 2
AOCMF classification of the condylar process fractures, length of condylar fragment and duration of surgery.

Patient No.	AOCMF classification of condylar process fracture				Length of condylar fragment (mm)	Duration of surgery (condylar process fracture)
	Fragmentation	Sideward displacement	Angulation	Head and fossa displacement		
1	none	full lateral/posterior	5–45° medial/posterior	displacement	22.1	120 min.
2	none	partial lateral/posterior	>45° medial	displacement	32.1	115 min.
3	none	partial lateral	<5° medial	none	32.7	80 min.
4	none	full lateral	5–45° medial	displacement	29.1	75 min.
5	none	partial medial	<5° medial	none	23.2	73 min.
6	none	full lateral	>45° medial/posterior	displacement	22.7	52 min.

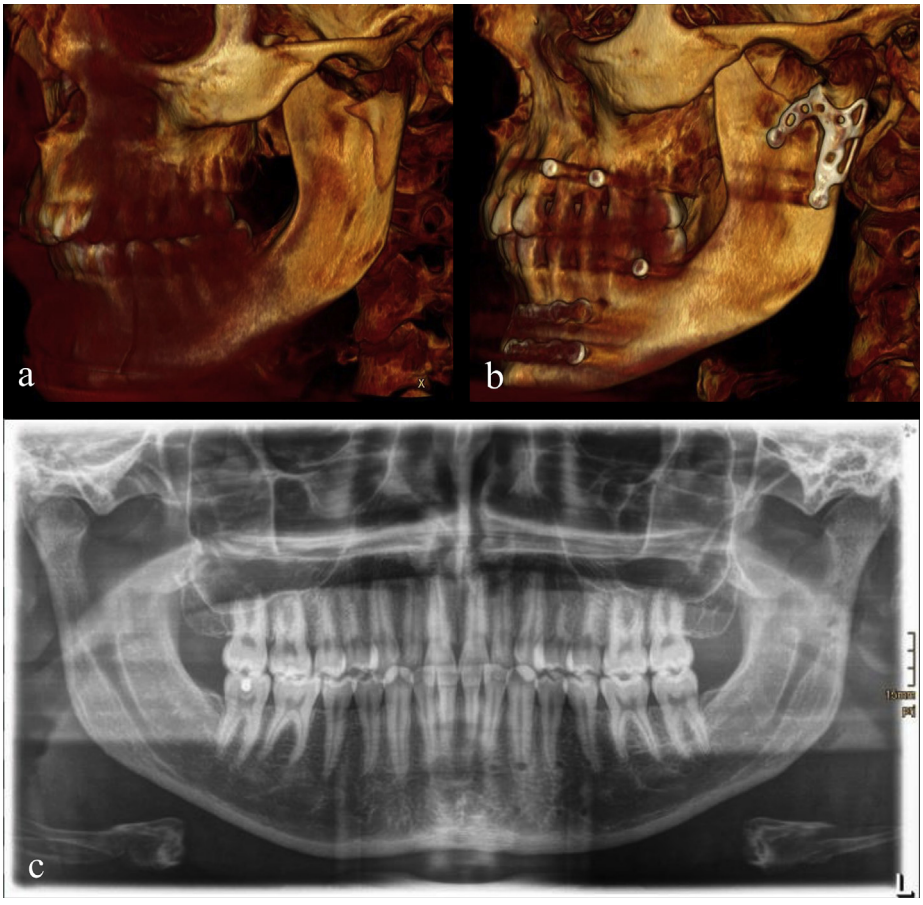

Fig. 9. Pre- and postoperative tree-dimensional imaging as well as panoramic radiograph showing conditions after removal of plates 6 months post-surgery in patient No. 3.

asymmetry or TMJ pain was observed at the follow-up examination. No plate breaking or loss of osteosythesis screws was witnessed.

5. Conclusion

In conclusion, the application of an auto reduction and repositioning plate is a convenient method for the treatment of condylar process fractures. It allows a transoral endoscopic-assisted fracture reduction by handling the displaced proximal fragment with special tips and aligning the posterior border of the ascending ramus due to the novel design. Once surgeons are familiar with this technique, it might contribute to a reduction in the time required for endoscopic-assisted transoral reduction of condylar process fractures.

Informed consent

Informed consent was obtained from all individual participants included in this study.

Conflicts of interest

The authors declare that they have no conflict of interest.

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