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Matthieu Olivetto, Jérémie Bettoni, Jebrane Bouaoud, Sylvie Testelin, Stéphanie Dakpé, Michel Lefranc, Bernard Devauchelle

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Original article

Matthieu Olivetto[a] (MD.), matthieuolivetto@live.fr
Jérémie Bettoni[a] (MD.), jeremiebettonie@gmail.com
Jebrane Bouaoud[b] (MD.), jebrane.bouaoud@gmail.com
Sylvie Testelin[a] (MD.-PhD.), testelin.sylvie@chu-amiens.fr
Stéphanie Dakpé[a] (MD.-PhD.), dakpe.stéphanie@chu-amiens.fr
Michel Lefranc[c] (MD.-PhD.), lefranc.michel@chu-amiens.fr
Bernard Devauchelle[a] (MD.-PhD.), devauchelle.bernard@chu-amiens.fr

[a]Department of Maxillofacial surgery, University Hospital of Amiens-Picardy, Amiens, France
[b]Department of Maxillofacial Surgery and Stomatology, Pitié-Salpétrière Hospital, Pierre et Marie Curie University Paris 6, Sorbonne Paris Cite University, AP-HP, Paris,75013, France
[c]Department of Neurosurgery, University Hospital of Amiens-Picardy, Amiens, France

Corresponding author:
Matthieu Olivetto
Department of Maxillofacial surgery,
University Hospital of Amiens-Picardy, Amiens, France
Avenue René Laennec, 80000 Amiens
Email: matthieuolivetto@live.fr
Phone number: +33 01 22 08 90 50

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Abstract

Introduction

To evaluate the feasibility of safely managing subcondylar fractures using an original surgical procedure combining an intraoral approach, the use of a custom-made occlusal overlay splint, and intraoperative imaging.

Materials and Methods

Condylar fragment was freed from surrounding soft tissues, was laterally exposed to the ramus, and a miniplate was fixed in place for osteosynthesis. An overlay splint maintaining the dental occlusion was used to facilitate reduction and stabilization during fixation. Intraoperative monitoring by cone-beam computed tomography (CBCT) was performed before completing the fixation.

Results

Between November 2018 and June 2019, 10 patients were treated using this procedure. The median length of the proximal condylar fragment was 29 mm (range 24-39 min). Five patients had an associated mandibular fracture. The median duration of the condylar fracture surgery was 54.5 minutes (range38-79 min). All patients had satisfactory reduction and osteosynthesis with no complications.

Conclusion

It is feasible to safely manage subcondylar fractures with this surgical procedure that could facilitate open reduction using intraoral approaches. Occlusal splints maintain downward pressure on the rami bilaterally and symmetrically, helping to anatomically reposition condylar process fractures. Intraoperative imaging is used to monitor this step.

Keywords

Mandibular subcondylar fracture; Condylar process fracture; Open treatment; Intraoral approach; Intraoperative cone-beam CT; Bite splint

Text

1. Introduction

Different treatment options for the management of mandibular subcondylar fractures can be considered with no consensus on optimal treatment. There are two different approaches: functional therapy (closed treatment) and surgical management by open reduction and internal fixation (ORIF). For fractures, it has been demonstrated that anatomical repositioning of the condylar process is critical for optimal functional recovery *(Baker et al., 1998)*. To achieve this, functional treatment is effective in some conditions (in children, slightly displaced or greenstick fractures). In other cases, the surgical option allows anatomical repositioning of the fractured fragment by releasing the displaced fragment, often entrapped in the soft tissue *(Weinberg et al., 2019)*. Several open approaches have been described that allow direct access to the fracture site. Their main disadvantages are skin scars, risk of salivary fistulas, and facial nerve injury *(Al-Moraissi et al., 2018; Rozeboom et al., 2018).* An intraoral approach is an alternative that avoids these drawbacks, but it is challenging given the limited surgical field and the quantity of instruments needed *(Vajgel et al., 2015)*. Although endoscopic assistance is offered for better intraoperative control, it demands extensive experience, a longer operating time, and precise monitoring of reduction, especially for high and medially tilted fractures *(Blumer et al., 2019)*.

Regardless of the chosen approach, it is necessary to anatomically replace the fragment to restore dental occlusion. Open reduction requires pulling the mandibular ramus down to create a sufficient gap for fragment repositioning. Maintaining the fragment in an optimal reduction position for rigid fixation is a recurrent problem, particularly when the fracture is unstable and/or the fragment is medially tilted.

To facilitate anatomical repositioning and fixation of the condylar process while maintaining dental occlusion, the authors have developed an original surgical procedure. The aim of this study was to evaluate the feasibility of a surgical technique that combines the use of an occlusal overlay splint for reduction and intraoperative cone-beam computed tomography (CBCT) monitoring.

2. Materials and Methods

2.1 Patients, fracture classification, and outcomes

Between November 2018 and June 2019, all patients with a mandibular subcondylar fracture with or without a dentate portion fracture were included in a prospective single center study. All participants signed an informed consent before their inclusion, and the study was conducted in accordance with the Declaration of Helsinki. The exclusion criteria were: comminuted fractures and fractures occurring in completely edentulous patients.

All patients had a preoperative clinical examination and a CT scan evaluation. Based on the preoperative CT-scan, the longest portion of the fragment was measured on sagittal reconstruction slices, and fractures were classified according to Spiessl and Schroll classification criteria *(Spiessl and Schroll et al., 1972)*. The surgical indication was based on both the clinical (disturbance of dental occlusion) and the ramus shortening measured on the CT scan (> 2 mm). Other data such as sex, age, and affected side were collected. Outcomes were:

- The duration of subcondylar ORIF, measured in minutes, from the incision in an intraoral approach to closure;

- The number of intraoperative CBCT checks needed;

- The quality of the final subcondylar fracture repositioning: considered as anatomically acceptable or not acceptable by an independent surgeon in an intraoperative assessment by CBCT scan;

- Postoperative complications in the perioperative period (7 days): facial nerve injury (facial paresis), visible scars, salivary fistulas, hematoma, infection

2.2 Fabrication of the splint

Maxillary and mandibular dental casts were made. Then, the mounted models were adjusted to the maximum intercuspation position by adding a maxillo-mandibular space of 7 mm. The occlusal splint was made of silicone for direct application (polyvinyl siloxane, Memosil® 2) (Supplementary data 1, Video). Asepsis was achieved by treating the splint with an aqueous sodium hypochlorite solution (5.25%) for 10 minutes. If there was an additional displaced mandibular fracture, a reduction in the molding was done to realign the dental arch. In cases of a partially edentulous dentition, the silicone application filled the toothless spaces.

2.3 Surgical procedure

For each patient, an intraoral approach and intraoperative CBCT monitoring were performed. To facilitate immobilization, the patient's head was placed on a radiolucent Mayfield skull clamp. An O-arm® CBCT (Medtronic, Minneapolis, USA) was centered by 2D front and profile shots, then parked near the patient's feet to prevent obstruction during the operation.

The intervention starts with the placement of preformed rigid arch bars. If there are additional mandibular fractures, they are first reduced and fixed using osteosynthesis. Then, ORIF of the subcondylar fragment is performed. After the intraoral incision, similar to a sagittal split osteotomy, a periosteal elevation along the mandibular ramus to the fracture site is carried out.

Then, the pericondylar soft tissues and the periosteum of the condylar fragment are moved apart (Figure 2). At this point in the procedure, a dose of muscle relaxant is administered before the reduction to facilitate manoeuvres, and hemorrhage management is optimized with a hypotensive agent. If the condylar fragment is medially displaced by the pull from the lateral pterygoid muscle, the surgeon should manipulate it, moving it into a lateral override position (laterally to the ramus) and a luxation could be reduced if necessary. The fragment is thus more accessible for the placement of the osteosynthesis miniplate (Modus 2.0, Medartis®, Basel, Switzerland). A first screw is inserted into the condyle fragment with a 90° screwdriver (Modus Optofix 2.0, Medartis®, Basel, Switzerland), then tightened, but not fully, allowing plate rotation. The bite splint is then fixed in placed with an intermaxillary steel wire (Figure 3A). To complete the procedure, the plate is positioned before the ramus is pulled down by the splint to prevent possible medial displacement of the condyle fragment.

Anatomically correct repositioning of the fractured condylar process is achieved with a periosteal elevator under direct vision control (incisura notch alignment without fragment rotation) and by palpating the basilar edge with an angled periosteal elevator. After clinical reduction verification, one of the two standard cortical screws is placed into the proximal mandibular fragment.

Intraoperative O-arm® CBCT (Figure 3B) allows verification of the following in a few seconds:

-Reduction, which must be anatomical: alignment of the basilar border on the sagittal slides and the vertical axis on the coronal slices, no rotation on the axial slides, and maximum interfragmentary contact

- Correct positioning of the plate (3D reconstruction) and the screws (90° angle with the cortical plane, on coronal slices)

If the assessment is satisfactory, the fourth and last cortical screw is put in place. If the assessment is not satisfactory, the re-execution of the reduction-osteosynthesis sequence is necessary. At the end of the intervention, the intermaxillary fixation and the splint are removed. Mouth opening-closing movements are done to check the restored occlusion, check for the absence of temporomandibular clicking, and verify the stability of the osteosynthesis plate. In the absence of complications, the arches are removed at the one-week follow-up consultation.

3. Results

3.1 Patients and fracture classification

Ten patients (9 males, 1 female), with a median age of 32 years (range 18 to 40), having a unilateral mandibular condyle fracture, were included in the study (Table 1). Patients and surgical characteristics are summarized in Table 1. All patients had occlusion disorders with a condylar fragment entrapped in muscle tissue, as noted in a surgical approach. No case of condyle fragmentation was found. For 5 patients, an additional mandibular fracture was associated with the studied fracture. The median length of the proximal fragment was 29 mm (range 24 to 39 mm), with an average of 30.3 mm.

3.2 Splint fabrication

After mounting the casts on the articulator, the silicone application time was 30 seconds, with a 3-minute drying time (Supplementary data 1, video).

3.3 Surgical procedure

For all patients, the anatomically correct repositioning of the condylar fragment was intraoperatively assessed with O-arm® CBCT. Repositioning of the fracture fragment and miniplate osteosynthesis were required in patients #3 and #5, which involved two intraoperative 3D CBCT checks. Converting to an extraoral approach was never required. Patient #10 had a partial edentulous posterior region that posed no problem when using the splint. The median duration of surgery for the condylar fractures was 54.5 minutes (range 38 to 79 min) after subtracting the time needed for arch bar placement and management of additional fractures). All the procedures were performed by the same surgeon, a junior collaborator, with one assistant and one operating-room nurse. There were no postoperative complications in the perioperative period.

4. Discussion

This study reports the management of 10 condylar fractures with a new surgical procedure using an occlusal splint, an intraoral approach, and intraoperative CBCT monitoring. According to the literature, ORIF seems to be more effective than closed reduction for displaced condyle fractures resulting in dental malocclusion *(Li et al., 2019; Neff et al., 2014)*. In many cases, the entrapment of the fragment in the masseter muscle fibers makes anatomical closed reduction impossible. Therefore, a surgical approach is required to release it from the muscle fibers. Many approaches have been described for surgical management. An extraoral approach allows better control of reduction but exposes the patient to a risk of facial nerve injury and aesthetic sequelae. By contrast, an intraoral approach avoids neurological sequelae, but monitoring reduction presents its main challenge. Nevertheless, the main priority is to ensure stable osteosynthesis after the anatomical repositioning of the fractured fragment. Some reductions are not easy, particularly for an unstable fracture that requires pulling down the ramus to open the space required for reduction.

Open reduction techniques have been described using an Eckelt retractor, angular screws, or manual traction *(Sugamata et al., 2011; Rao et al., 2017; Thakur et al., 2019)*. All of these present various disadvantages: i) unilateral traction leads to rotation of the ramus in the sagittal axis, not ensuring optimal preservation of dental occlusion after rigid fixation of the fracture, ii) the procedure requires an operating-room assistant and/or additional instruments in a restricted surgical field, and iii) these methods do not guarantee stable maintenance of the reduction and the dental occlusion before the rigid fixation, or might require an intraoperative CBCT.

This work highlights the advantages of using a new device (bite splint) to facilitate fragment repositioning. The splint is easily and quickly fabricated after taking dental impressions and applying silicone directly to the articulator-mounted casts starting from an optimal intercuspidation position and adding 7 mm of mouth opening. This space of 7 mm has been empirically determined and was found to be the most appropriate in several attempts previous to this study. Less than 7 mm is not sufficient for the downward traction needed for repositioning the fragment. More than 7 mm distends the condyle head too far from its glenoid fossa.

This system can be used with all surgical approaches. It allows the two mandibular rami to be pulled down in a stable and symmetrical direction, in contrast to other reduction methods. The general principles are: i) the plate positioned on the proximal fragment before splint traction prevents the medial tilting favored by the lateral pterygoid muscle (mechanical obstacle), ii) the surgeon can take advantage of the elasticity of the curarized muscle strap, creating a vertical condylar space, and can laterally and medially guide the anatomical positioning of the condylar process, iii) dental occlusion is maintained and oral mouth opening kinetics are achieved, and iv) the procedure facilitates surgery by reducing the number of instruments or hands in the restricted surgical field.

The use of intraoperative CBCT monitoring in this procedure solves the main problem of the intraoral approach, which is checking reduction. This includes the realignment of the posterior edge that is difficult to assess visually. Intraoperative imaging also avoids a radiological check-up at postoperative day 1, which could impose a new surgical procedure in the event of an unsatisfactory reduction. An O-arm confirmation with a low dose protocol is equivalent to less than 50% of the effective dose of a CT of the head (https://www.medtronic.com/us-en/healthcare-professionals/products/neurological/surgical-imaging-systems/o-arm/dose-considerations.html). Moreover, this procedure facilitates outpatient management of subcondylar fractures, supported by the intraoral approach in which no drainage is used. In this regard, the use of intraoperative CBCT will become widespread in facial bone surgery and will become part of the maxillofacial surgery technical platform.

In conclusion, the use of an occlusal splint overlay is a feasible and convenient method for ORIF condylar fracture management. It allows for an open anatomical repositioning of a fracture by continuously pulling down the rami bilaterally and symmetrically, creating a space for maneuvering the fragment. Additionally, intermaxillary fixation ensures the correct position of the dental occlusion. It is appropriate to use intraoperative CBCT monitoring that may contribute to easier techniques for open reduction using intraoral approaches.

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Tables

Table 1. Patient characteristics and surgical data

Patient	Sex	Age[a]	Affected side	Type of condylar fracture[b]	Fragment size[c]	Associated fracture	ORIF duration[d]	Number of CBCT[e]
1	M	40	L	II	30	Symphysis	67	1
2	M	19	R	II	28	no	44	1
3	F	40	L	V	25	no	79	2
4	M	33	L	IV	39	no	48	1
5	M	31	R	IV	31	no	74	2
6	M	18	R	II	32	Left parasymphysis	38	1
7	M	31	R	II	28	Left parasymphysis	55	1
8	M	19	R	IV	24	Symphysis	79	1
9	M	52	L	II	38	Opposite angle Coronoid process	54	1
10	M	47	L	II	28	no	51	1

M: male; F: female; L: left; R: right

a: Age at surgery (years)

b: According to the Spiessl and Schroll classification *(Spiessl and Schroll et al., 1972)*

Type I: fracture without displacement; Type II: low fracture with displacement; Type III: high fracture with displacement; Type IV: low fracture with dislocation; Type V: high fracture with dislocation; Type VI: intracapsular fracture (diacapitular)

c: Measured on the preoperative CT scan (millimeters) d: Operating time of open reduction internal fixation (ORIF) of the condyle fragment disregarding other fractures, measured from incision to closure (minutes)

e: Number of intraoperative O-arm® CBCT (cone-beam computer tomography)

Captions to illustrations

Figure 1: Final appearance of the splint fabricated on articulator-mounted casts with a 7 mm mouth opening added

Figure 2: Intraoral approaches showing the restricted surgical field requiring minimal use of instruments or surgical assistance

Figure 3: Open reduction and internal fixation of a right condylar fracture associated with a left parasymphysical fracture in a 31-year-old male

A: Intraoperative use of the 7 mm elevated splint with intermaxillary fixation;

B: Intraoperative CBCT assessment illustrating the anatomical repositioning of the condylar fragment with the use of the elevation splint

Supplementary Materials

Supplementary material 1 (Video): Video illustrating all the steps of the bite splint construction process