Outcomes of functional treatment of condylar mandibular fractures with an articular impact: a retrospective study of 108 children

Mathilde Malinge M.D. , Fanny Grimaud M.D. ,
Jean-Philippe Perrin M.D. , Justine Loin M.D. ,
Marine Anquetil M.D. , Jacques Mercier M.D. ,
Pierre Corre M.D., Ph.D. , Hélios Bertin M.D., Ph.D.

PII: S2468-7855(21)00142-7
DOI: https://doi.org/10.1016/j.jormas.2021.06.016
Reference: JORMAS 1039

To appear in: *Journal of Stomatology oral and Maxillofacial Surgery*

Received date: 4 May 2021
Accepted date: 29 June 2021

Please cite this article as: Mathilde Malinge M.D. , Fanny Grimaud M.D. , Jean-Philippe Perrin M.D. , Justine Loin M.D. , Marine Anquetil M.D. , Jacques Mercier M.D. , Pierre Corre M.D., Ph.D. , Hélios Bertin M.D., Ph.D. , Outcomes of functional treatment of condylar mandibular fractures with an articular impact: a retrospective study of 108 children, *Journal of Stomatology oral and Maxillofacial Surgery* (2021), doi: https://doi.org/10.1016/j.jormas.2021.06.016

TITLE

Outcomes of functional treatment of condylar mandibular fractures with an articular impact: a retrospective study of 108 children

AUTHORS NAME AND AFFILIATIONS

Mathilde Malinge[a] (M.D.)
mathilde.malinge@chu-nantes.fr

Fanny Grimaud[b] (M.D.)
drfgrimaud@gmail.com

Jean-Philippe Perrin[a] (M.D.)
jeanphilippe.perrin@chu-nantes.fr

Justine Loin[a] (M.D.)
justine.loin@chu-nantes.fr

Marine Anquetil[a] (M.D.)
marine.anquetil@chu-nantes.fr

Jacques Mercier[a] (M.D.)
jacques.mercier@chu-nantes.fr

Pierre Corre[a,c] (M.D., Ph.D.)
pierre.corre@chu-nantes.fr

Hélios Bertin[a,d*] (M.D., Ph.D.)
helios.bertin@chu-nantes.fr
Tel: +33 (0)2 40 08 36 79

Fax: +33 (0)2 40 08 36 68

* Corresponding author

[a] Service de chirurgie maxillo-faciale et stomatologie, CHU de Nantes, 1 place Alexis Ricordeau, 44093 Nantes, France

[b] Chirurgie maxillo-faciale et stomatologie, Clinique Jules Verne, 2-4 route de Paris, 44300 Nantes, France

[c] Regenerative medicine and skeleton (RMeS), Faculté de Chirurgie Dentaire, 1 Place Alexis Ricordeau, 44042 Nantes, France

[d] Laboratoire des sarcomes osseux et remodelage des tissus calcifiés (Phy.Os UMR1238), faculté de médecine, 1 rue Gaston Veil, 44000 Nantes, France

Abstract

Introduction: The treatment of fractures of the mandibular condylar process remains controversial, especially in children. The aim of this study was to assess the long-term clinical and radiographic outcomes of functional treatments for mandibular condylar fractures with an articular impact.

Materials and Methods: Young patients (< 15 years of age) presenting with either a unilateral or a bilateral mandibular fracture of the condylar process were included in this retrospective study. The clinical analysis focused on investigation of joint amplitudes at 1, 2, 6, 12, and 24 months after the beginning of the treatment, and at the end of their physical growth for the long-term study. Other clinical parameters included temporomandibular joint (TMJ) disorders and facial asymmetry. Photographs of patients and panoramic X-rays were assessed to identify any growth disorders at the end of the follow-up.

Results: One hundred and eight patients were included in this study, and 33 patients who were no longer undergoing mandibular growth at the time of the last follow-up were included in the long-term study. The mean age at the time of the trauma was 9.33 years, and the mean follow-up was 82.2 months. A significant improvement was

observed in the maximal mouth opening (MMO), diduction, and propulsion in the first months after the trauma, reaching 44.31 mm ($p < 0.0001$), 10.50 mm ($p=0.0001$), and 6.33 mm ($p=0.01$), respectively, at 6 months. Three patients experienced a clinical posterior vertical insufficiency, one of which required a surgical procedure, while four patients exhibited a ramus asymmetry of up to 10 mm, albeit with no clinical consequences. One case of TMJ ankylosis was noted.

Conclusion: Our study suggests that functional treatment is appropriate for fractures of the mandibular condyle with an articular impact in children, as it promotes mandibular growth and good functional recovery. Children have to be followed up, however, until completion of growth.

Keywords

Mandibular fracture; mandibular condyle; treatment; growth disorders; temporomandibular joint disorders

Introduction

Mandibular fractures are the most common type of facial fracture in children [1–4], and they involve the condylar process in 72 to 80% of cases [3,5,6]. The temporomandibular joint (TMJ) is often damaged indirectly after an isolated trauma on the chin symphysis. At the time of diagnosis, patients often suffer from TMJ pain and dental occlusion disorders. Long-term consequences consist of functional disturbances, with a risk of developing TMJ ankylosis, and facial asymmetry due to disruption of mandibular growth [7–10].

Management of such fractures has three objectives: 1) maintenance of a normal articular function, 2) restoration of dental occlusion, and 3) preservation of mandibular growth [11,12]. Conservative treatments are often preferable in children, combining blended feeding, maxillomandibular elastic fixation, and physiotherapy [13–15]. There is no universal protocol for surgical rehabilitation of the condylar process [13,16,17]. Some authors argue for restoration of TMJ function by restoration

of its anatomy [13,18]. Such a surgical approach has proven to be widely effective in the adult population, thanks to the development of miniaturized plates and minimally invasive approaches [10,13,19–24]. However, surgical treatment exposes to the risk of facial nerve injuries, joint and teeth bud damage, and healing disorders [25]. Furthermore, it does not take into account the specific remodelling capacities of the TMJ during growth [26,27].

In our current practice, we apply the principles described by Delaire in regard to facial and mandibular growth [28,29]. Young patients with condylar fractures with a particularly high risk of damage to joint structures are provided a functional treatment based on immediate mobilization of the injured TMJ. Due to the lack of studies evaluating this functional treatment at the end of growth [3,11,13,16,30], we aimed to retrospectively assess the long-term clinical and radiological results obtained with this protocol in growing children.

Materials and Methods:

Young patients (< 15 years of age) presenting with either a unilateral or a bilateral mandibular fracture of the condylar process at the Nantes University Hospital (France) between 2002 and 2018 were included in this retrospective study. To assess the long-term efficacy of functional treatment, we secondary excluded from this study the patients with non-articular fractures of the condyle unit, patients with a follow-up of less than 24 months and/or that ended before the end of the facial growth, and patients with no functional treatment. Due to the retrospective nature of the study, it was formally granted exemption approval from the ethics committee of the Nantes University Hospital in accordance with French legislation article L. 1121-1 paragraph 1 and R1121-2 of the Public Health Code.

1. Clinical data

Data were collected from the patients' medical charts. These data comprised the date of birth, unilateral or bilateral involvement, and the mechanism of the fracture. The clinical findings regarding the maximal mouth opening (MMO), the lateral excursion,

and the mandibular projection were also recorded at 1, 2, and 6 months, as well as at 1 and 2 years after the trauma. For the analysis of diduction, only unilateral fractures were considered. We focused on identification of TMJ dysfunction and pain. Photographs of the patients (when available) were analysed to evaluate the facial and mandibular symmetry (chin position, occlusal plane) at different times during the follow-up.

2. Functional treatment

Functional treatment was provided in case of fracture of the condylar process with an articular impact, according to Delaire's technique [31]. Briefly, the treatment consisted of immediate active mobilization of the mandible with projection and lateral excursion movements. Some patients were fitted with customized maxillomandibular vestibular arches that allowed daily active and passive physiotherapy using elastics and intermaxillary fixation during the night.

3. Radiographic evaluation

All of the fractures were characterized according to the Mercier and Perrin classification [32,33]. This classification differentiates:

- Fractures with a joint impact in which the condyle is no longer in the glenoid fossa (capital fractures, condyle dislocation).

- Fractures without a joint impact (overlapping fragments, angulation of the condyle but remaining in the glenoid fossa).

The panoramic X-rays were reviewed by two investigators at the end of the follow-up. The means of the values obtained by the two investigators were considered for the statistical analysis. The ramus height was measured between the top of the condylar process and the distal part of the angular notch (Figure 1). For unilateral fractures, measurement of the ascending ramus allowed the percentage of the initial and the final height loss to be established. Bilateral fractures were not considered for height evaluation.

4. Condylar remodelling

Remodelling of the condylar process was analysed by a single investigator and classified according to three levels as previously defined by Gilhuus-Moe [34]:

- Complete remodelling (+++): no condylar deformity radiologically, symmetrical condylar processes, and symmetrical mandible.
- Moderate remodelling (++): irregular condylar process not grossly malformed, with the condyle clearly outlined in both lateral and frontal projections.
- Poor remodelling (+): condyle clearly deformed and irregular in the lateral view.

5. Statistical analysis

The statistical analysis was performed using GraphPad Prism 5.0 software for Mac (GraphPad Software, La Jolla, CA, USA). The quantitative data were analysed using a paired *t*-test when there were more than 30 replicate values, and with a Wilcoxon test when there were fewer than 30 paired observations. A p-value of less than 0.05 ($p < 0.05$) was taken to indicate statistical significance.

Results

1. Epidemiological data

One hundred and eight patients were retrospectively included in this study. There was a female predominance (54.6%). The mean age of the patients at the time of the trauma was 9.33 years (6 months - 15 years). The mean follow-up was 39.2 months (0 - 168 months). The most common aetiologies of the fractures were falls in 74 patients, followed by traffic accidents and sporting accidents. The associated injuries included chin wounds, dental injuries, and associated fractures. The initial symptoms included limitation of maximal mouth opening (MMO) and pain in the preauricular area.

All of the epidemiological data are summarized in Table 1.

Characteristics of the patients	
Gender: females/males, n (%)	59 (54.6)/49 (45.4)
Unilateral/bilateral fracture, n (%)	76 (70)/33 (30)
Mean age (years), range (years)	9.33 (0.5 - 15)
Follow-up duration (months), range (months)	39.2 (0 - 168)
Aetiologies, n (%)	
Falls	74 (68.5)
Traffic accidents	21 (19.4)
Sporting accidents	9 (8.3)
Other	4 (3.7)
Associated injuries, n (%)	
Chin wound	70 (76.4)
Dental injuries	45 (41.7)
Associated mandibular fracture	34 (31.5)
Upper maxillary fracture	4 (3.7)

Table 1. General characteristics of the patients; n, number of patients.

Seventy-seven patients were secondarily excluded from the long-term study, based on the following exclusion criteria: 12 patients presented with a condylar fracture with no articular impact and were treated surgically or with intermaxillary fixation, 2 patients were not treated (one was too young, another had an undetected fracture). Sixty-one patients were excluded due to a follow-up that stopped before the end of growth. The long-term study involved 33 patients who had completed their growth at the last follow-up (mean follow-up duration of 82.2 months). These patients presented with a unilateral fracture of the condylar unit in 21 cases, and a bilateral fracture in 12 cases. All of these patients were treated with functional physiotherapy with or without vestibular arches.

2. Clinical data

A significant improvement was observed regarding the recovery of the MMO between one month after the fracture and the various follow-up times. The MMO was significantly improved in the first six months after the trauma, and it reached 48.91 mm at the end of growth in 33 patients (38 - 56 mm) (Table 2). In these patients, the

mouth opening was centred in 16 patients. The other patients exhibited a 3 to 5 mm deviation to the fractured side.

	Number of patients (n)	Mean MMO (mm) ± SD (mm)	Mean difference (mm)	p
1 month	83	32.93 ± 7.06	-	-
2 months	82	40.12 ± 7.43	7.19	*< 0.0001*
6 months	58	44.31 ± 5.48	4.19	*< 0.0001*
12 months	51	45.72 ± 6.09	1.41	*0.001*
24 months	38	46.53 ± 6.32	0.81	*0.09*
End of growth	33	48.91 ± 5.66	2.38	*0.36*

Table 2. Comparison of the maximal mouth opening at the various follow-up times; n, number of patients; SD, standard deviation.

Regarding the other joint amplitudes, the diduction contralateral to the fracture increased from 7.85 ± 2.75 mm at one month to 9.10 ± 2.80 mm at two months ($p < 0.0001$) and 10.50 ± 3.26 mm at six months ($p=0.0002$) after the fracture. There was not a statistical difference in the homolateral diduction (Figure 2). The mean mandibular protrusion increased from 4.23 ± 2.12 mm at one month to 5.62 ± 2.42 mm at two months ($p=0.0001$) and 6.33 ± 2.39 mm at six months ($p=0.01$), reaching 7.74 ± 1.79 mm at the end of growth. The protrusion was centred for 11 patients, and it deviated to the fractured side with a mean of 1 to 2 mm for 8 patients and by 3 mm for one patient. There was no difference in the joint amplitudes between the unilateral and the bilateral fractures.

In terms of TMJ disorders, 23 patients did not experience any pain or clicking of the TMJ at the last follow-up. Nine patients suffered from a TMJ dysfunction, with unilateral or bilateral clicking in five cases and chronic pain in 4 patients. No disc dislocation was observed in our series.

Late dental occlusion was assessed for all of the patients, and it revealed malocclusion in 11 patients, primarily Class II malocclusions. Three patients experienced a clinical posterior vertical insufficiency (PVI) with maxillary occlusal

canting on the side of the unilateral fracture (Figure 3). One patient who was followed up for a bilateral condylar fracture at 6 years of age developed TMJ ankylosis with limitation of the MMO (20 mm) at the age of 18 that required surgical resection. The results for the TMJ disorders and the occlusal anomalies are presented in Table 3.

	Unilateral fractures (n=21)	Bilateral fractures (n=12)
Normal TMJ function	14	9
TMJ disorders		
Clicking	3	2
Chronic pain	4	0
Normal Angle Class I occlusion	15	8
Occlusion abnormalities		
Class II	3	1
Class III	1	1
Maxillary occlusal tilting	3	0
Anterior open bite	0	2
TMJ ankylosis	0	1

Table 3. Results for the TMJ disorders and the dental malocclusions after completion of facial growth for 33 patients with unilateral and bilateral condylar fractures.

3. Radiological data

The ramus height was compared between the broken and the healthy side at the last follow-up for the unilateral fractures (n=21). A difference of less than 2 mm between the two sides was considered to be normal, and this was found to be the case for 16 patients. Four patients exhibited a significant reduction in the height of the mandibular ramus on the side of the fracture, with a mean difference of 10.25 ± 1.96 mm. Only one patient with unilateral PVI required a surgical procedure for mandibular ramus lengthening (Figure 3). The other patients did not exhibit any facial asymmetry. One patient had condyle hyperplasia on the fracture site during growth. The mean ramus heights are presented in Table 4.

Difference in ramus height	Number	Min – Max (mm)	Mean (mm)
< 2 mm	16	0 - 2	0.42
> 2 mm (fractured side elongated)	1	4.67	4.67
> 2 mm (fractured side shortened)	4	4 - 12.33	10.25

Table 4. The mean difference in the ramus heights between the fractured side and the normal side at the end of growth for unilateral fractures (non-significant).

4. Condylar remodelling

Remodelling of the condylar process was assessed on the most recent panoramic X-rays. Twenty-seven images were available for this analysis (15 for unilateral fractures, 12 for bilateral fractures). We observed a greater degree of bone remodelling of the mandibular condyle and the glenoid fossa when the location of the fracture was high. By contrast, the bone remodelling was poor in low subcondylar fractures, irrespective of whether the fracture was unilateral or bilateral. The results of the bone remodelling are presented in Table 5.

Location of the fracture	Unilateral fractures			Bilateral fractures		
	+++	++	+	+++	++	+
Head	2	5	0	3	1	0
High neck	2	2	3	2	4	1
Low neck	0	1	0	0	2	0

Table 5. Results of the condylar bone remodelling examination on panoramic X-rays for unilateral and bilateral fractures of the condyle unit.

Discussion

The treatment of fractures of the mandibular condylar process remains controversial, particularly for the paediatric population [25]. The rationale for conservative

management is based on the capacity of the paediatric condyle and glenoid fossa to remodel (4,26). Moreover, due to the presence of a growth centre, condylar fractures and their surgical treatment may lead to growth disturbances and facial asymmetry (7). However, some authors have applied surgical procedures involving open reduction and internal fixation (ORIF) with good results [35,36]. In our current practice, we systematically apply a functional treatment based on immediate mobilization of the fractured condyle in propulsion and diduction. These movements are close to the physiology of the TMJ and allow traction to be placed on the injured joint structures. This rehabilitation can be enhanced by the use of maxillomandibular arches that allow neutral fixation during the night, which promotes bone healing, and the use of a diduction elastic during the day to ensure passive rehabilitation (Figure 4). In some cases, children are referred to an orofacial physiotherapist, and sometimes customized splints or orthodontic brackets are made for the teeth to facilitate the physiotherapy, especially in young patients (Figure 4). While early TMJ mobilization is highly recommended by most authors, our protocol of functional treatment is nevertheless used by a number of surgical teams [35,37,38]. Moreover, the term functional treatment includes very different techniques depending on the team, ranging from simple mobilization in mouth opening to elastic traction [11,30]. We previously reported the results obtained with the functional treatment in terms of joint amplitude recovery compared to osteosynthesis for condylar fractures in the adult population [39]. We aimed to assess the long-term functional and architectural results of such treatment in children with an evaluation at the end of growth.

We included 108 patients in our study, 33 of whom were followed until the end of growth, which represents one of the largest series published in the literature to date, and with a long follow-up time (mean 82.2 months) [3,11,16,30]. All of the patients included in the long-term follow-up study exhibited condylar fractures with an articular impact and they were treated by functional therapy. We observed fast recovery of the joint amplitudes, particularly during the first six months after the fracture, and normal amplitudes at the end of growth, with no difference between unilateral and bilateral fractures. The MMO values at the end of the follow-up reached 48.9 mm, which is comparable to the values reported in the literature. The diduction reached 10.5 mm, which is higher than what has been reported in most of the publications to date [30,40,41]. Functional treatment would allow recovery of the articular amplitudes. An

important finding of our study is the high rate (27.3%) of TMD observed in adulthood in patients with a previous history of mandibular fracture. This association was observed particularly in patients with unilateral condylar fracture. This result is higher than what has been observed in previous studies, where it varied from 5 to 20% [40,41]. The prevalence of TMJ dysfunction remains high in the general population but is lower in children, and its relation to previous condylar fractures is difficult to prove [42,43]. Merlet *et al.* did not observe any difference in TMD occurrence in adult patients with condylar fractures treated by functional therapy or ORIF [39]. Condylar fracture in children results in a high risk of developing a growth disorder, and this is due to the presence of the growth plate within the condylar unit and its potential damage after a fracture [28,33]. This can lead to a posterior vertical insufficiency (PVI) characterized by a shortening of the mandibular ramus, an elevation of the commissural line and occlusal cant, a Class II malocclusion, and a chin deviation [44,45]. We investigated the occurrence of PVI by means of a retrospective analysis of the most recent panoramic X-rays and photographs in patients after they had stopped growing. We found a radiographic PVI in four patients treated for a unilateral fracture, with a mean difference of 10 mm between the fractured and the healthy mandibular ramus, although none of these patients had clinical asymmetry. A clinical PVI was found in three patients, mostly as elevation of the occlusal cant and a slight deviation of the chin, although most of these patients were bothered by this asymmetry and only one patient required a surgical correction. This dissociation between the clinical and the radiological parameters has already been described [15], and it can be attributed to the remodelling capacity of the condyle and the glenoid cavity in response to the trauma and to the shortening of the mandible [11,46,47]. The capacity of the condyle to undergo remodelling after a condylar fracture appears to be high in young children and it appears to decrease over time [47]. We noted high remodelling capacities after the fractures, with no obvious difference according to the height of the fracture or according to its unilateral or bilateral location. Mobilization of the mandibular condyle in propulsion is based on the adaptive condyle growth pattern described by Delaire [28]. Growth of the mandibular condyle occurs in part in response to the mechanical forces that are transmitted. Contraction of the lateral pterygoid muscle during propulsive movements stimulates mitosis of the prechondroblasts and compensatory ossification of the growth plate. We observed a case of TMJ ankylosis that occurred 12 years after the

mandibular trauma. This risk is estimated to be 0.3% after a condyle fracture at any age, and it appears to be higher in young children [35]. This complication highlights the need to follow children until the end of their growth with an annual clinical examination.

There are many classifications to describe condylar process fractures. Loukota *et al.* proposed an anatomic classification of high- and low-condylar fractures, but this does not reflect the degree of displacement and dislocation of the condylar process [48,49]. The Spiessl and Schroll classification provides more anatomic information regarding the fracture as well as useful information for the surgical treatment [50]. An advantage of the anatomical-functional classification proposed by Mercier and Perrin is that it provides an indication of whether a specific functional treatment is needed [32,33]. It differentiates the fractures with a joint impact in which the condyle is no longer in the glenoid fossa (capital fractures, condyle dislocation) and that require early mobilization from fractures without a joint impact (overlapping fragments, angulation of the condyle but remaining in the glenoid fossa) (Figure 5).

Our study suffers from several limitations. First and foremost is its retrospective nature, with an analysis of the clinical parameters based on medical records. Moreover, our method of measurement of the height of the ascending ramus on the panoramic X-rays is open to criticism, given their poor reproducibility. However, the interobserver variability was reduced by the use of a double measurement. Nevertheless, this study remains a longitudinal study, with a long-term follow-up at the end of the growth period to establish the effectiveness of our functional treatment. A prospective study using 3-dimensional radiological criteria would allow for a more comprehensive study of the architectural parameters of traumatized mandibles as well as comparison of different treatments.

Conclusion

As previously reported in the literature, functional treatment of mandibular condylar process fractures in children generally leads to satisfactory long-term functional and architectural outcomes. Early mobilization of the injured joint and long-term follow-up

of children until they have completed their growth are key to obtaining optimal outcomes.

Figure captions

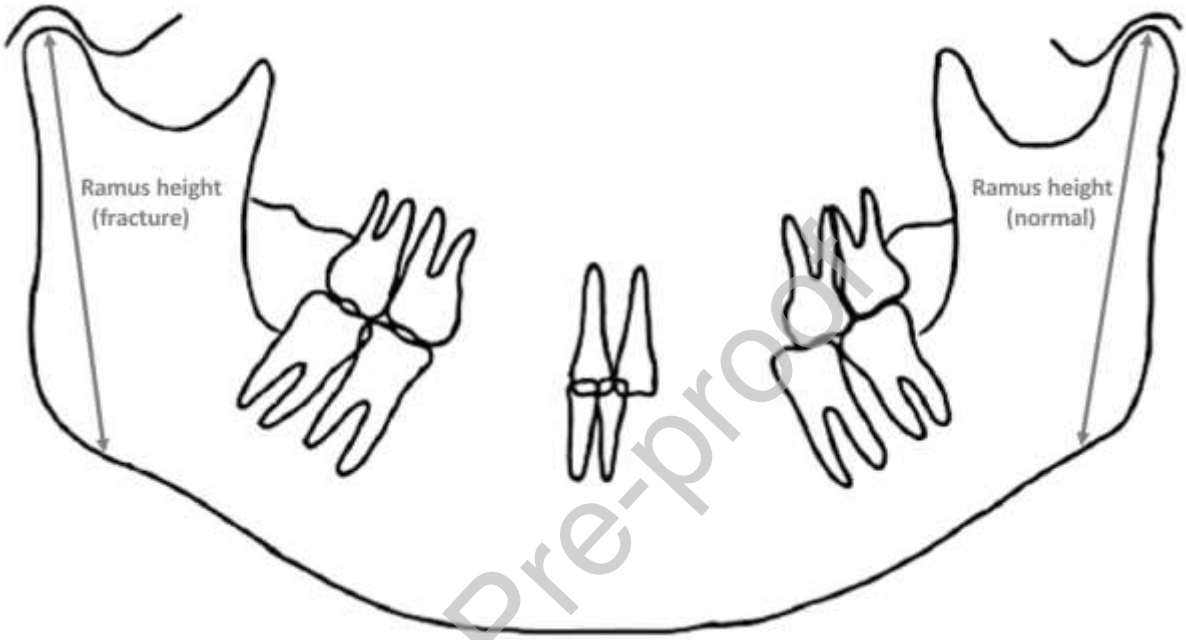

Figure 1. Measurement of the height of the ascending ramus on panoramic X-rays.

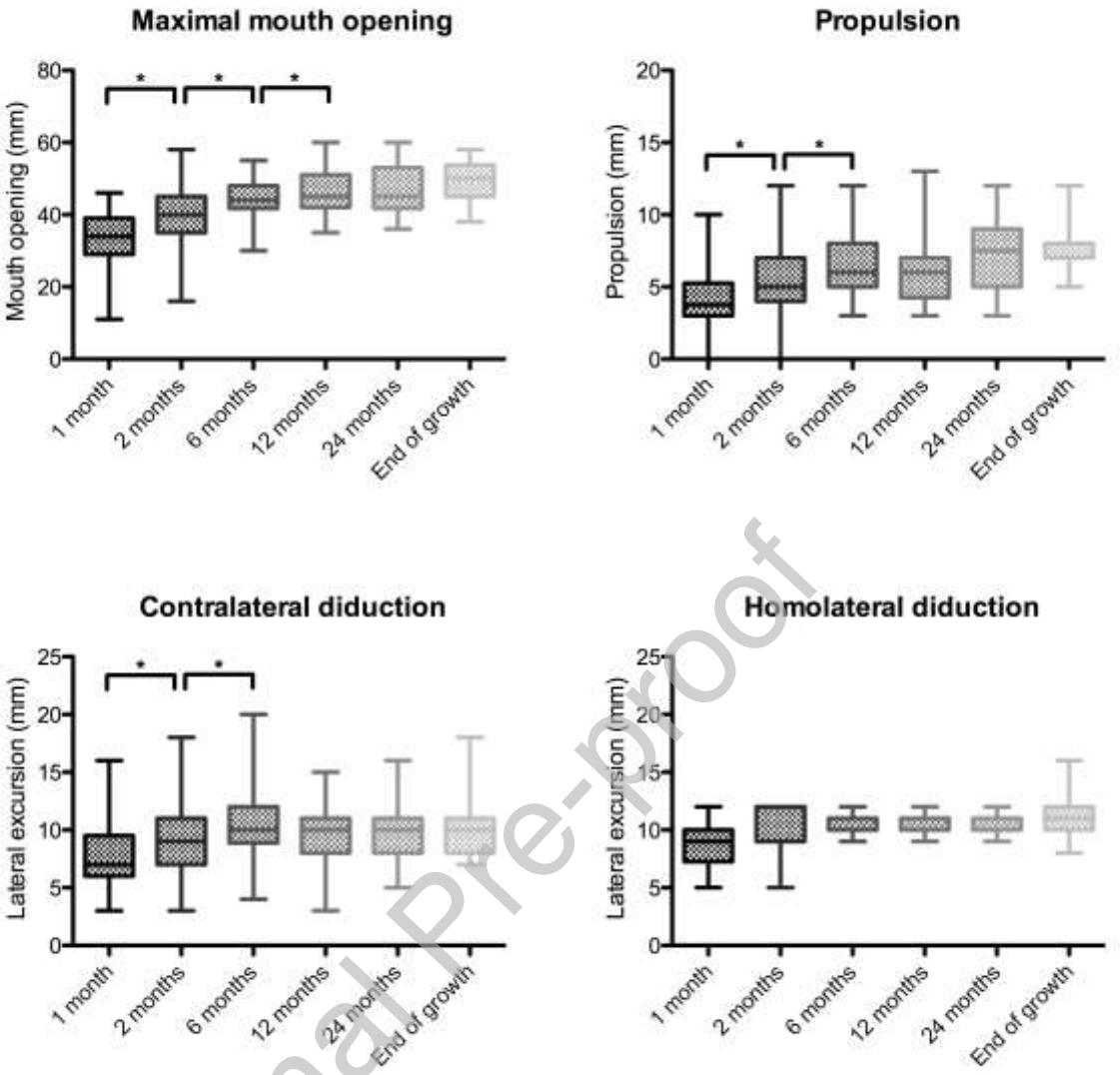

Figure 2. TMJ amplitudes over time in patients with unilateral and bilateral fractures. * $p < 0.05$.

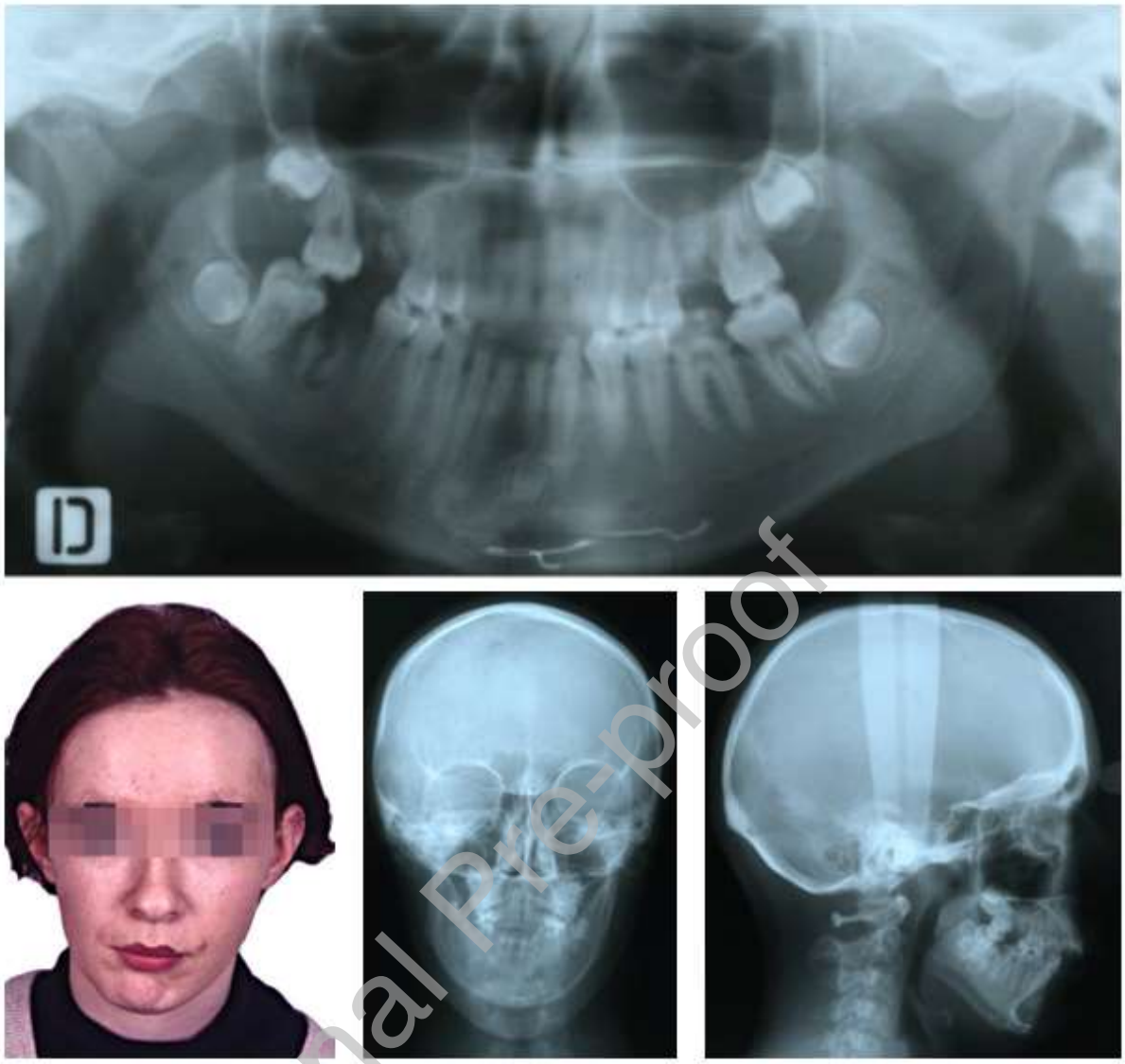

Figure 3. A 15-year-old patient with posterior vertical insufficiency of the right mandible after an untreated bilateral fracture of the condylar processes at one year of age. The panoramic X-rays reveal a degree of asymmetry of the mandibular ramus. The frontal photograph shows the deviation of the inferior jaw and the chin to the right side. The frontal and lateral cephalograms confirm the asymmetry of the inferior borders and the ramus of the mandible.

Figure 4. Schematic representation of elastic positioning in a neutral position during the night (left), and in a diduction position on the fractured side during the day (right) (a). Use of orthodontic brackets on the incisors to facilitate physiotherapy in children (b). The child should try to align the elastics with the same colour and perform diduction movements. Use of thermoformed splints with sticks to improve rehabilitation in children (c). The child should try to move the sticks away from each other, thereby accomplishing the requested diduction movements.

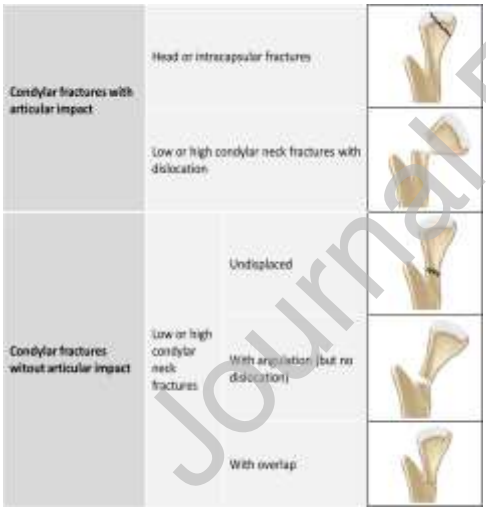

Figure 5. Anatomical-functional classification of condylar fractures.

References

[1] Iatrou I, Theologie-Lygidakis N, Tzerbos F. Surgical protocols and outcome for the treatment of maxillofacial fractures in children: 9 years' experience. J Cranio-Maxillofac Surg 2010;38:511–6. https://doi.org/10.1016/j.jcms.2010.02.008.

[2] Iida S, Matsuya T. Paediatric maxillofacial fractures: their aetiological characters and fracture patterns. J Cranio-Maxillofac Surg 2002;30:237–41. https://doi.org/10.1054/jcms.2002.0295.

[3] Smith DM, Bykowski MR, Cray JJ, Naran S, Rottgers SA, Shakir S, et al. 215 Mandible Fractures in 120 Children: Demographics, Treatment, Outcomes, and Early Growth Data. Plast Reconstr Surg 2013;131:1348–58. https://doi.org/10.1097/PRS.0b013e31828bd503.

[4] Cooney M, O'Connell JE, Vesey JA, Van Eeden S. Non-surgical management of paediatric and adolescent mandibular condyles: A retrospective review of 49 consecutive cases treated at a tertiary referral centre. J Cranio-Maxillofac Surg 2020;48:666–71. https://doi.org/10.1016/j.jcms.2020.05.006.

[5] Zerfowski M, Bremerich A. Facial trauma in children and adolescents n.d.:5.

[6] H Thorèn, Iizuka T, Hallikainen D, Nurminen M, Lindqvist C. An epidemiologicalstudyof patterns of condylar fractures in children n.d.:6.

[7] Demianczuk AN, Verchere C, Phillips JH. The effect on facial growth of pediatric mandibular fractures. J Craniofac Surg 1999;10:323–8. https://doi.org/10.1097/00001665-199907000-00007.

[8] Proffit D. Early fracture of the mandibular condyles: Frequent1 y an unsuspected n.d.:24.

[9] Ellis E, Throckmorton G. Facial symmetry after closed and open treatment of fractures of the mandibular condylar process. J Oral Maxillofac Surg 2000;58:719–28. https://doi.org/10.1053/joms.2000.7253.

[10] Ellis III E. Condylar Process Fractures of the Mandible. Facial Plast Surg 2000;16:193–206. https://doi.org/10.1055/s-2000-12579.

[11] Choi J, Oh N, Kim I-K. A follow-up study of condyle fracture in children. Int J Oral Maxillofac Surg 2005;34:851–8. https://doi.org/10.1016/j.ijom.2005.04.005.

[12] Dimitroulis G. Condylar injuries in growing patients. Aust Dent J 1997;42:367–71. https://doi.org/10.1111/j.1834-7819.1997.tb06079.x.

[13] Landes CA, Day K, Glasl B, Ludwig B, Sader R, Kovács AF. Prospective Evaluation of Closed Treatment of Nondisplaced and Nondislocated Mandibular Condyle Fractures Versus Open Reposition and Rigid Fixation of Displaced and Dislocated Fractures in Children. J Oral Maxillofac Surg 2008;66:1184–93. https://doi.org/10.1016/j.joms.2007.06.667.

[14] Eckelt U, Schneider M, Erasmus F, Gerlach KL, Kuhlisch E, Loukota R, et al. Open versus closed treatment of fractures of the mandibular condylar process–a prospective randomized multi-centre study. J Cranio-Maxillofac Surg 2006;34:306–14. https://doi.org/10.1016/j.jcms.2006.03.003.

[15] Nørholt SE, Krishnan V, Sindet-Pedersen S, Jensen I. Pediatric condylar fractures: A long-term follow-up study of 55 patients. J Oral Maxillofac Surg 1993;51:1302–10. https://doi.org/10.1016/S0278-2391(10)80132-6.

[16] Lekven N, Neppelberg E, Tornes K. Long-Term Follow-Up of Mandibular Condylar Fractures in Children. J Oral Maxillofac Surg 2011;69:2853–9. https://doi.org/10.1016/j.joms.2011.03.019.

[17] Bos RR, Ward Booth RP, de Bont LG. Mandibular condyle fractures: a consensus. Br J Oral Maxillofac Surg 1999;37:87–9. https://doi.org/10.1054/bjom.1998.0014.
[18] Meyer C. La voie d'abord sous-angulo-mandibulaire haute (voie de Risdon modifiée) pour le traitement des fractures sous-condyliennes de la mandibule. Rev Stomatol Chir Maxillofac n.d.:6.
[19] Kadlub N, Trost O, Duvernay A, Parmentier J, Wirth C, Malka G. Traitement orthopédique des fractures extra-articulaires de la région condylienne de la mandibule : étude rétrospective de 39 fractures unifocales. Rev Stomatol Chir Maxillofac 2008;109:301–5. https://doi.org/10.1016/j.stomax.2008.05.005.
[20] Rocton S, Chaine A, Ernenwein D, Bertolus C, Rigolet A, Bertrand J-C, et al. Fractures de la mandibule: épidémiologie, prise en charge thérapeutique et complications d'une série de 563 cas. Rev Stomatol Chir Maxillofac 2007;108:3–10. https://doi.org/10.1016/j.stomax.2006.11.001.
[21] Ellis E, Dean J. Rigid fixation of mandibular condyle fractures. Oral Surg Oral Med Oral Pathol 1993;76:6–15. https://doi.org/10.1016/0030-4220(93)90285-c.
[22] Ellis E. Method to Determine When Open Treatment of Condylar Process Fractures Is Not Necessary. J Oral Maxillofac Surg 2009;67:1685–90. https://doi.org/10.1016/j.joms.2009.03.062.
[23] Landes CA, Lipphardt R. Prospective evaluation of a pragmatic treatment rationale: open reduction and internal fixation of displaced and dislocated condyle and condylar head fractures and closed reduction of non-displaced, non-dislocated fractures. Int J Oral Maxillofac Surg 2005;34:859–70. https://doi.org/10.1016/j.ijom.2005.04.021.
[24] Brandt MT, Haug RH. Open versus closed reduction of adult mandibular condyle fractures: a review of the literature regarding the evolution of current thoughts on management. J Oral Maxillofac Surg 2003;61:1324–32. https://doi.org/10.1016/S0278-2391(03)00735-3.
[25] Bertin H, Grimaud F, Corre P. Reply to "Open reduction and internal fixation obtains favorable clinical and radiographic outcomes for pediatric mandibular condylar fractures." J Stomatol Oral Maxillofac Surg 2021;122:121–2. https://doi.org/10.1016/j.jormas.2020.06.009.
[26] Dahlström L, Kahnberg K-E, Lindahl L. 15 years follow-up on condylar fractures. Int J Oral Maxillofac Surg 1989;18:18–23. https://doi.org/10.1016/S0901-5027(89)80009-8.
[27] Chang S, Yang Y, Liu Y, Wang J, Zhang W, Ma Q. How Does the Remodeling Capacity of Children Affect the Morphologic Changes of Fractured Mandibular Condylar Processes After Conservative Treatment? J Oral Maxillofac Surg 2018;76:1279.e1-1279.e7. https://doi.org/10.1016/j.joms.2018.01.029.
[28] Delaire J. [The role of the condyle in the growth of the mandible and in facial balance]. Rev Stomatol Chir Maxillofac 1990;91:179–92.
[29] Delaire J, Ferré JC, Faucher O. [Clinical observations and reflections on condylar growth]. Actual Odontostomatol (Paris) 1970;90:199–215.
[30] Güven O, Keskin A. Remodelling following condylar fractures in children. J Cranio-Maxillofac Surg 2001;29:232–7. https://doi.org/10.1054/jcms.2001.0228.
[31] Delaire J, Le Roux J, Tulasne JF. [Functional treatment of fractures of the mandibular condyle and its neck]. Rev Stomatol Chir Maxillofac 1975;76:331–50.

[32] Mercier J, Lemoine V, Gaillard A, Delaire J. [Results of treatment of mandibular fractures in 27 children (author's transl)]. Rev Stomatol Chir Maxillofac 1980;81:296–300.
[33] Mercier J, Huet P, Perrin JP. [Functional management of fractures of the mandibular condyle]. Rev Stomatol Chir Maxillofac 2000;101:203–6.
[34] Gilhuus-Moe O. Fractures of the mandibular condyle in the growth period. Histologic and autoradiographic observations in the contralateral, nontraumatized condyle. Acta Odontol Scand 1971;29:53–63. https://doi.org/10.3109/00016357109026322.
[35] Zachariades N, Mezitis M, Mourouzis C, Papadakis D, Spanou A. Fractures of the mandibular condyle: a review of 466 cases. Literature review, reflections on treatment and proposals. J Cranio-Maxillo-Fac Surg Off Publ Eur Assoc Cranio-Maxillo-Fac Surg 2006;34:421–32. https://doi.org/10.1016/j.jcms.2006.07.854.
[36] Zhang L, Wang Y, Shao X, Chen J. Open reduction and internal fixation obtains favorable clinical and radiographic outcomes for pediatric mandibular condylar fractures. J Stomatol Oral Maxillofac Surg 2021;122:18–23. https://doi.org/10.1016/j.jormas.2020.05.008.
[37] Trost O, Péron J-M. [Latest trends in the surgical management of mandibular condyle fractures in France, 2005-2012]. Rev Stomatol Chir Maxillo-Faciale Chir Orale 2013;114:341–8. https://doi.org/10.1016/j.revsto.2013.05.004.
[38] Meyer C. [Fractures of the condylar region: functional treatment or surgery?]. Rev Stomatol Chir Maxillofac 2006;107:133–5. https://doi.org/10.1016/s0035-1768(06)77005-x.
[39] Merlet F-L, Grimaud F, Pace R, Mercier J-M, Poisson M, Pare A, et al. Outcomes of functional treatment versus open reduction and internal fixation of condylar mandibular fracture with articular impact: A retrospective study of 83 adults. J Stomatol Oral Maxillofac Surg 2018;119:8–15. https://doi.org/10.1016/j.jormas.2017.10.007.
[40] Hovinga J, Boering G, Stegenga B. Long-term results of nonsurg cal management of condylar fractures in children n.d.:12.
[41] Feifel H, Albert-Deumlich J, Riediger D. Long-term follow-up of subcondylar fractures in children by electronic computer-assisted recording of condylar movements. Int J Oral Maxillofac Surg 1992;21:70–6. https://doi.org/10.1016/S0901-5027(05)80534-X.
[42] American Academy of orofacial pain. Temporomandibular disorders. Orofac. Pain Guidel. Assess. Diagn. Manag. Fourth Ed. Quintessence, Chicago: : de Leeuw, Reny and Klasser, Gary D.; 2008, p. 131–3, 161.
[43] Velly AM, Schiffman EL, Rindal DB, Cunha-Cruz J, Gilbert GH, Lehmann M, et al. The feasibility of a clinical trial of pain related to temporomandibular muscle and joint disorders: the results of a survey from the Collaboration on Networked Dental and Oral Research dental practice-based research networks. J Am Dent Assoc 1939 2013;144:e1-10.
[44] Bertin H, Merlet F-L, Khonsari R-H, Delaire J, Corre P, Mercier J. Dental and maxillofacial features of condylo-mandibular dysplasia: A case series of 21 patients. J Cranio-Maxillo-Fac Surg Off Publ Eur Assoc Cranio-Maxillo-Fac Surg 2020;48:956–61. https://doi.org/10.1016/j.jcms.2020.07.007.
[45] Anquetil M, Mercier J, Leveau S, Mrabet S, Durand T, Salagnac J-M, et al. Evaluation of vertical ramus osteotomy for the surgical correction of unilateral mandibular posterior vertical insufficiency: Long-term follow-up results. J Cranio-

Maxillo-Fac Surg Off Publ Eur Assoc Cranio-Maxillo-Fac Surg 2020. https://doi.org/10.1016/j.jcms.2020.02.013.
[46] Sahm G, Witt E. Long-term results after childhood condylar fractures. A computer-tomographic study. Eur J Orthod 1989;11:154–60. https://doi.org/10.1093/oxfordjournals.ejo.a035978.
[47] Lindahl L, Hollender L. Condylar fractures of the mandible. II. a radiographic study of remodeling processes in the temporomandibular joint. Int J Oral Surg 1977;6:153–65. https://doi.org/10.1016/s0300-9785(77)80048-3.
[48] Loukota RA, Eckelt U, De Bont L, Rasse M. Subclassification of fractures of the condylar process of the mandible. Br J Oral Maxillofac Surg 2005;43:72–3. https://doi.org/10.1016/j.bjoms.2004.08.018.
[49] Loukota RA, Neff A, Rasse M. Nomenclature/classification of fractures of the mandibular condylar head. Br J Oral Maxillofac Surg 2010;48:477–8. https://doi.org/10.1016/j.bjoms.2009.08.036.
[50] Schneider M, Eckelt U. Classification of condylar process fractures, n.d.