REVIEW ARTICLE

Pediatric Maxillofacial Trauma: Insights into Diagnosis and Treatment of Mandibular Fractures in Pediatric Patients

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Abstract

Aim: To assess the diagnostic and therapeutic approaches in pediatric mandibular fractures with regards to fracture pattern and localization.

Patients and methods: This retrospective study included patients under the age of 17 years that presented to the Department of Oral and Maxillofacial Surgery at Charité–Universitätsmedizin Berlin with mandibular fractures over an 11-year long period (2010–2020). Medical records were analyzed for age, gender, injury mechanism, clinical presentation, imaging modalities, fracture pattern, and fracture management. Statistical analyses included descriptive statistics, normality testing, and Mann–Whitney *U* tests.

Results: A total of 91 pediatric patients (23 females and 68 males) presented with mandibular fractures. The majority of mandibular fractures occurred in patients aged 13–16 years (67.0%, $n = 61$). The main causes were activities of daily life (34.1%), followed by assault (25.3%). Malocclusion and pain upon mandibular joint compression were documented in 72.5% and 51.7% of patients, respectively. The most frequently applied radiological diagnostic tool was a panoramic X-ray (49.5%). The main fracture patterns were single (42.9%) and double fractures (48.4%). An age-adapted surgical approach using open reduction and internal fixation (ORIF) was the most frequent management (61.5%). A conservative approach was favored in cases of condylar head fractures. Resorbable plates were used in eight cases of ORIF (8.8%).

Conclusion: Treatment regimens should be carefully selected based on the unique anatomy of the pediatric patient with regards to centers of growth and dentition phase, to restore stomatognathic function and to maintain adequate skeletal growth and eruption of teeth.

Clinical significance: This study illustrates the challenges of mandibular fracture management in the pediatric patient.

Keywords: Fracture management, Mandibular fracture, Pediatric maxillofacial trauma, Pediatric patient.

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Introduction

Due to their flexible and elastic bony structure with more cartilaginous tissue and greater protection by vast subcutaneous tissues, pediatric patients are less susceptible to trauma of the facial skeleton than adults.[1,2]

The overall incidence of facial fractures in children amounts to approximately 15% and increases the older the age of the pediatric patient.[3,4] Low numbers of children and adolescents presenting with mandibular fractures limit the experience in the management of pediatric fractures. Furthermore, the noncompliant child and misleading clinical presentation may complicate the successful diagnosis of a mandibular fracture, whereas diagnostic imaging techniques must be selected critically to avoid unnecessary radiation exposure. However, the restoration of stomatognathic function and adequate growth demands the careful consideration of diagnostic tools and treatment options.

The etiology, incidence, and fracture pattern in children may differ when compared to adults, given a different social environment and anatomical factors.[2,5–7] The lower face lengthens during the growth of the skeleton, so the distribution of facial fractures shifts from the upper to the lower aspect of the face.[8,9] Besides nasal fractures, mandibular fractures are the most common facial fractures in pediatric patients with regional differences regarding their incidence.[7,10–12]

Anatomical fracture localizations of the mandible vary across age groups, with younger patients being more susceptible to condylar head and neck fractures, whereas angular fractures are more common at an older age.[9,10] The general treatment principles of mandibular fractures aim to restore and/or maintain form and function, as well as occlusion, by using minimally invasive approaches for fracture reposition and fixation. However, in the pediatric patient, mandibular growth and different phases of dentition are important factors when deciding on the most suitable treatment regimen. Fracture localization, the presence of tooth buds, growth centers and the adaptive capacity need to be considered. For example, condylar head fractures may occur due to direct trauma to the chin that translates the force to the mandibular condyle. Intra-articular fractures are associated with a high risk of growth disturbance that can result in asymmetry of the mandible. Hence, early mobilization is

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essential to avoid ankyloses and facilitate physiological jaw function in the condylar head fracture of a pediatric patient.[3]

The purpose of this study was to investigate age, gender distribution, and etiological factors, to define the cohort of pediatric patients presenting with mandibular fractures. The rationale was to elucidate the diagnostic approach and treatment options of pediatric mandibular fractures, taking into consideration the dentition phases, as well as fracture patterns and localizations.

Patients and Methods

Ethical Agreement

Ethical approval for data collection and publication was provided by the Institutional Review Board of the Charité–Universitätsmedizin Berlin (EA4/098/20).

Study Design

A retrospective single-center study of all children and adolescents 1–16 years of age admitted to the emergency department of a Level I Trauma Center over an 11-year long period between January 2010 and December 2020 was performed. Patients were included who presented with at least one fracture of the mandible based on the codes of the International Classification of Diseases 10 (ICD-10; Version 2018; German Modification I). The main diagnosis was derived from the ICD code (S02.60–S02.69). Isolated dental fractures (S02.5) and dentoalveolar fractures (S02.67) were excluded. Electronic medical records were reviewed regarding patients' characteristics, etiologies, clinical findings, radiological examination techniques, fracture patterns, concomitant injuries, and therapies.

Patients were divided according to the following three age groups and phases of dentition as follows:

- 1–5 years at the primary dentition phase
- 6–12 years at the mixed dentition stage
- 13–16 years at the permanent dentition phase.

Statistical Analysis

Data was collected using Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA, USA), and statistical analysis was performed and graphs were created using GraphPad Prism Software Version 9 (La Jolla, California, USA). A descriptive analysis was performed and results display mean values with standard deviations (SD). Testing of normal distribution was conducted by the Shapiro-Wilk normality test. The Mann–Whitney *U* test was applied to compare the mean values between two groups. A *p*-value below 0.05 was defined as statistically significant.

Results

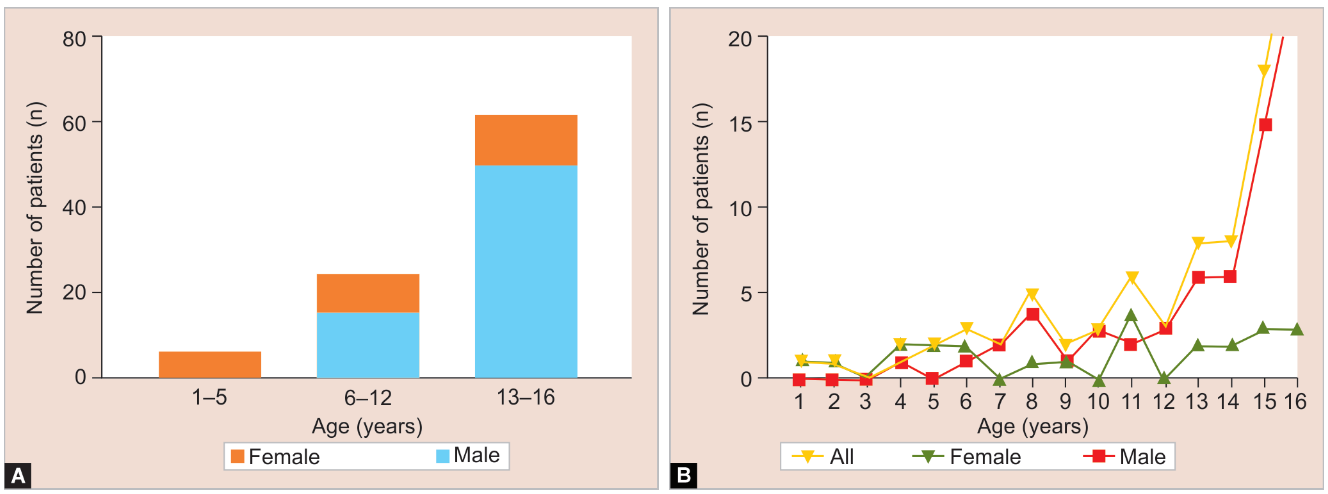
Age and Gender Distribution

During an 11-year long period (2010–2020), a total of 91 children and adolescents (23 females and 68 males) under the age of 17 years presented to our department with mandibular fractures. The majority of all mandibular fractures were documented in male patients (74.7%, $n = 68$). The mean age at presentation was 12.8 years (SD 3.81; 1–16 years). Mean age in the female cohort was 10.3 years (SD 4.78), while the mean age in male patients was 13.6 years (SD 3.03). The age difference between male and female pediatric patients presenting with mandibular fractures was statistically significant ($p = 0.0013$).

Most mandibular fractures occurred in pediatric patients 13–16 years of age (67.0%, $n = 61$; Figs 1A and B). Female patients under the age of 6 years presented with mandibular fractures more frequently than young male patients (female $n = 5$; male $n = 1$). However, in the age group 6–12 years, male patients were predominantly affected (female $n = 8$, male $n = 16$). In patients older than 12 years, the number of males presenting with a mandibular fracture was five-fold greater than the number of females (female $n = 10$, male $n = 51$).

Etiology

The main causes of mandibular fractures were activities of daily life (34.1%, $n = 31$), assault (25.3%, $n = 23$) and bike accidents (14.3%, $n = 13$) (Fig. 2). The injury mechanism was further evaluated with regards to gender and age group (Table 1). Assaults were the second most common reason for fractures in male patients (30.9%, $n = 21$), while only two fractures related to assaults were documented in female patients (8.7%). Half of the mandibular fractures in patients 1–5 years of age were caused by falls from a great height (50.0%, $n = 3$). In patients aged 6–12 years, the main reasons for mandibular fractures were activities of daily life, such as slips, trips and falls, and injuries during sports or play (50.0%,



Figs 1A and B: Pediatric mandibular fractures in relation to age and gender. (A) The numbers of female and male patients (*n*) are illustrated per age group. Age groups were based on the dentition phases. Patients in the age group 1–5 years were in the primary dentition phase, 6–12 years at the mixed dentition stage and 13–16 years at the permanent dentition phase. (B) The total number of patients with mandibular fractures per age (years) is displayed according to gender ($n = 91$)

n = 12). In the age group 13–16 years, the most common injury mechanisms were activities of daily life (27.9%, *n* = 17) and assaults (23.1%, *n* = 21).

Next, the etiology was reviewed with regards to fracture pattern. The main cause for single mandibular fractures were activities of daily life (41%, *n* = 16), followed by assaults (17.9%, *n* = 7) and bike accidents (15.4%, *n* = 6). Double mandibular fractures were predominantly reported following assaults (36.3%, *n* = 16) and activities of daily life (29.5%, *n* = 13). The majority of triple mandibular fractures were associated with bicycle accidents (57.1%, *n* = 4). One fracture with multiple fracture localizations (four sites) was caused by a fall on the chin during playful climbing.

Clinical Findings

Overall, malocclusion (72.5%, *n* = 66) and pain upon mandibular joint compression (51.6%, *n* = 47) were the most frequent clinical findings. Dental fractures (5.5%, *n* = 5) or tooth loss (2.2%, *n* = 2) were only reported in a small proportion of patients. Paresthesia of the inferior alveolar nerve was also rarely documented (2.2%, *n* = 2).

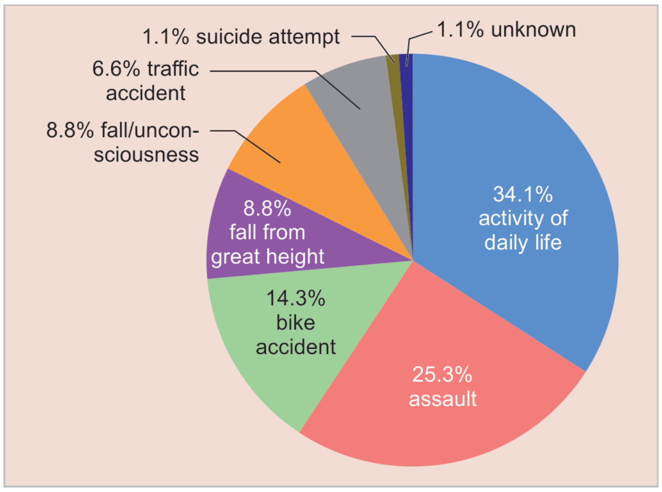


Fig. 2: Etiology of pediatric mandibular fractures. The proportion of injury mechanisms relative to the total number of patients 1–16 years of age with mandibular fractures is displayed (*n* = 91)

Diagnostic Approach

Radiological diagnostic methods for fracture identification and localization included panoramic X-ray (49.5, *n* = 45), computed tomography (CT)/ cone beam-CT (CBCT) (30.7, *n* = 28), or the combination of a panoramic view and a CT/CBCT scan in inconclusive cases (18.7%, *n* = 17). In suspected high-energy or polytrauma injury patterns, three-dimensional imaging using CT or CBCT was initially performed. In one case, the diagnosis of a single fracture located at the symphysis was based on the clinical presentation with gross dislocation and immediate intraoperative exploration was performed in a two-year old with a fall from a great height. This was the only case, where no preoperative radiological imaging was performed.

Fracture Pattern

The most common fracture types were double mandibular fractures (48.4%, *n* = 44) and single fractures (42.9%, *n* = 39). Gender distribution related to fracture pattern is displayed in Table 2. The male to female ratio in single (female *n* = 8, male *n* = 31) and double mandibular fractures (female n = 11, male *n* = 33) was approximately 3:1. Triple and complex mandibular fractures were documented in a small proportion of pediatric patients without a gender difference.

Table 3 illustrates the distribution of fracture pattern and localization in relation to age group and gender. In the age group 1–5 years, the majority of mandibular fractures observed were single fractures and occurred predominantly at the symphysis (*n* = 3). Within the age group 6–12 years, the main fracture pattern was the single fracture type (*n* = 13), followed by double (*n* = 9) and triple fractures (*n* = 2). Single fractures in this age group occurred most frequently at the parasymphysis. Amongst the patients in the age group 13–16 years, the most common fracture patterns were double fractures (*n* = 34), followed by single (*n* = 22), triple (*n* = 4), and multiple fractures (*n* = 1).

The distribution of fracture localization was analyzed with regards to fracture type (Supplement 1). Condylar head (*n* = 11), parasymphysis (*n* = 9), and condylar neck (*n* = 8) were the most common localizations in single mandibular fractures, followed by fractures localized at the angle (*n* = 6), symphysis (*n* = 3), and corpus (*n* = 2). The most frequent fracture pattern in double mandibular fractures was the combined localization at the angle

Table 1: Etiology of pediatric mandibular fractures in relation to gender, age, and fracture pattern. The numbers of female (f) and male (m) patients are reported *(n)*, and the percentage of the total number of patients admitted with mandibular fractures is given in parentheses (*n* = 91)

	Gender			*Age group*			*Fracture pattern*			
	All	*F*	*M*	*1–5 years*	*6–12 years*	*13–16 years*	*Single*	*Double*	*Triple*	*Multiple*
Etiology	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Activity of daily life	31 (34.1)	7 (30.4)	24 (35.3)	2 (33.3)	12 (50.0)	17 (27.9)	16 (41.0)	13 (29.5)	1 (14.3)	1 (100)
Assault	23 (25.3)	2 (8.7)	21 (30.9)	0	2 (8.3)	21 (23.1)	7 (17.9)	16 (36.3)	0	0
Bike accident	13 (14.3)	4 (17.4)	9 (13.2)	1 (16.7)	3 (12.5)	9 (9.9)	6 (15.4)	3 (6.8)	4 (57.1)	0
Fall from great height	8 (8.8)	4 (17.4)	4 (5.9)	3 (50.0)	3 (12.5)	2 (2.2)	4 (10.3)	2 (4.5)	2 (28.6)	0
Fall/unconsciousness	8 (8.8)	3 (13)	5 (7.4)	0	1 (4.2)	7 (7.7)	4 (10.3)	4 (9.1)	0	0
Traffic accident	6 (6.6)	2 (8.7)	4 (5.9)	0	3 (12.5)	3 (3.3)	2 (5.1)	4 (9.1)	0	0
Suicide attempt	1 (1.1)	1 (4.3)	0	0	0	1 (1.1)	0	1 (2.3)	0	0
Unknown	1 (1.1)	0	1 (1.5)	0	0	1 (1.1)	0	1 (2.3)	0	0
Total	91	23	68	6	24	61	39	44	7	1

Table 2: Mandibular fracture pattern in female and male pediatric patients. The number of patients is reported (*n*), and the percentage of the total number of patients admitted with mandibular fractures is given in parentheses

		Gender	
	All	*Female*	*Male*
Fracture pattern	*n (%)*	*n*	*n*
Single	39 (42.9)	8	31
Double	44 (48.4)	11	33
Triple	7 (7.7)	3	4
Multiple (≥4)	1 (1.1)	1	0
Total	91	23	68

Table 3: Fracture patterns and detailed fracture localization in relation to age and gender in pediatric patients presenting with a mandibular fracture. The number of female (F) and male (M) patients per age group is reported *(n)*

	Gender					*Fracture localization*					
Age group	*All*	*F*	*M*			*Symphysis*	*Parasymphysis*	*Corpus*	*Angle*	*Condylar neck*	*Condylar head*
Years	*n*	*n*	*n*	*Fracture pattern*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
1–5	6	5	1	Single	4	3					1
				Double	1				1	1	
				Triple	1			1			2
6–12	24	6	16	Single	13		7	2		2	2
				Double	9	1	3	4	5	3	2
				Triple	2			2		1	3
13–16	61	10	51	Single	22		2		6	6	8
				Double	34	1	20	3	24	14	6
				Triple	4		4		1	7	
				Complex	1	1		1			2

and parasymphysis (*n* = 14), followed by the combination of the condylar neck and parasymphysis (*n* = 8) (Supplement 2). In triple fractures, fracture localizations included the symphysis (*n* = 4), corpus (*n* = 3), angle (*n* = 1), condylar neck (*n* = 8), and head (*n* = 5). The reported case of multiple fracture localizations demonstrated fracture sites at the symphysis, at the corpus, at the left and right condylar heads, and at the coronoid processes.

Fracture Management

We further examined fracture management with regards to fracture pattern and localization (Supplement 3). Overall, the most common treatment regimen was open reduction and internal fixation (ORIF; 61.5%, *n* = 56). Intraoperative techniques of intermaxillary fixation (IMF) included the use of IMF screws (*n* = 27), Schuchardt's splints (*n* = 5) or Ernst ligatures (*n* = 1). In five cases, an orthodontic appliance was used for intraoperative IMF, whereas in 18 cases, the intraoperative use of IMF was not documented. A conservative or functional approach (soft diet, regular follow-up or the use of orthodontic appliances) was favored in 12.1% of all patients (*n* = 11). The use of an orthodontic appliance, such as an activator appliance, was reported in 18.1% of all conservatively treated patients (*n* = 2). IMF was selected in 15.4% of cases (*n* = 14) for a mean of 3 weeks (SD 1.01), with the majority of patients receiving IMF screws (*n* = 10) or Schuchardt's splints (*n* = 4). Due to a lack of secure occlusion at the mixed dentition stage or following dental trauma, 11% of all fractures (*n* = 10) were treated with the combination of ORIF and postoperative IMF using IMF screws (*n* = 9), or Schuchardt's splints (*n* = 1). Postoperative IMF was applied at a mean time of 2 weeks (SD 0.75). Plate removal was documented in 59.1% of patients (*n* = 39) that received ORIF. Osteosynthesis material removal was performed at a mean time of 6 months (SD 5.1) after the initial surgery. Moreover, resorbable fixation systems were used in eight cases of ORIF (8.8%) in pediatric patients 4–13 years of age.

The treatment regimen was analyzed according to age group, gender, and fracture pattern (Supplement 4). Single fractures were treated either by ORIF (43.6%, *n* = 17), IMF (23.1%, *n* = 9) or a conservative approach (25.6%, *n* = 10). The combination of ORIF and postoperative IMF was applied in 7.7% (*n* = 3) of single fractures. A conservative approach was favored in the treatment of condylar head fractures (*n* = 8). The majority of double mandibular fractures (77.3%, *n* = 34) and triple mandibular fractures (57.1%, *n* = 4) were treated using ORIF.

Discussion

Epidemiology and Etiology

Mandibular fractures occur less frequently in pediatric patients when compared to adults, which is attributed to anatomical differences and etiological factors.[2,5–7] Yet, with older age of the child, the incidence of mandibular fractures increases.[13] Gassner et al. reported that the risk for the growing child to sustain a facial bone fracture increases by 14% every year.[7] The greater risk was related to the change in behavior, which becomes more adventurous and playful, and the increasing ratio of facial to cranial volume.

Current literature reported a 2:1 male to female ratio in the pediatric patient presenting with facial bone fractures.[9,14] Fracture pattern and etiology are influenced by the patient's age and gender.[13] The majority of mandibular fractures in this study were documented in male patients. Furthermore, male patients affected by mandibular fractures were significantly older than female patients. These findings were in concordance with previous studies on pediatric facial trauma that found that boys older than 12 years of age were predominantly affected by fractures.[13,15]

This study identified activities of daily life, assault, and traffic accidents as the most frequent injury mechanisms in pediatric mandibular fractures. Previous studies documented assault as the primary cause of maxillofacial fractures in young male adolescents, pointing towards an effect of age and gender on the injury mechanism.[13,15]

Clinical Presentation and Diagnostic Approach

While clinical findings in children and adolescents may be limited by compliance, a thorough physical examination serves as the basis for further radiological investigation. The vast majority of children and adolescents affected by mandibular fractures reported malocclusion and pain upon mandibular joint compression. Previous studies found a high diagnostic accuracy of mouth opening restriction, auditory canal bleeding, intra-oral assessment-related findings, palpable step-off, inferior alveolar nerve paresthesia, angular compression test, and chin axial pressure test in mandibular fractures.[16] Two of the patients in this study presented with hypoesthesia or anesthesia of the inferior alveolar nerve. The absence of paresthesia may be explained by age-related noncompliance. Especially in the younger age group, a clinical presentation with minor symptoms may be misleading.

If a fracture was suspected after taking a medical history, reviewing the injury mechanism and performing a clinical examination, conventional radiological imaging using a two-dimensional panoramic view was considered sufficient in the majority of pediatric patients. However, fractures at certain anatomical regions, such as the condylar head and neck, the coronoid processes, and the symphysis and parasymphysis (blurring effects), are more difficult to detect by panoramic radiography.[17] Furthermore, incomplete fracture patterns that may result from the elastic bony structure of the pediatric patient may not be ascertained using a panoramic X-ray. In inconclusive cases or a suspected fracture of the condylar neck or head, CBCT or low- dose CT was performed, in addition to a panoramic view. Three-dimensional imaging using CT or CBCT was initially selected in high-energy or polytrauma injury patterns and in the unconscious patient. We suggest the more frequent use of three-dimensional low-dose CT or CBCT to reduce the high proportion of pediatric patients that are exposed to greater radiation exposure during two imaging modalities (panoramic view and CT/CBCT) due to insufficient imaging by conventional panoramic X-ray.

Diagnostic and Treatment Considerations using Illustrative Examples

In order to provide a coherent approach to the diagnosis and treatment of mandibular fractures, examples of pediatric mandibular fractures are presented. The decision-making process considers multiple patient-specific factors as follows:

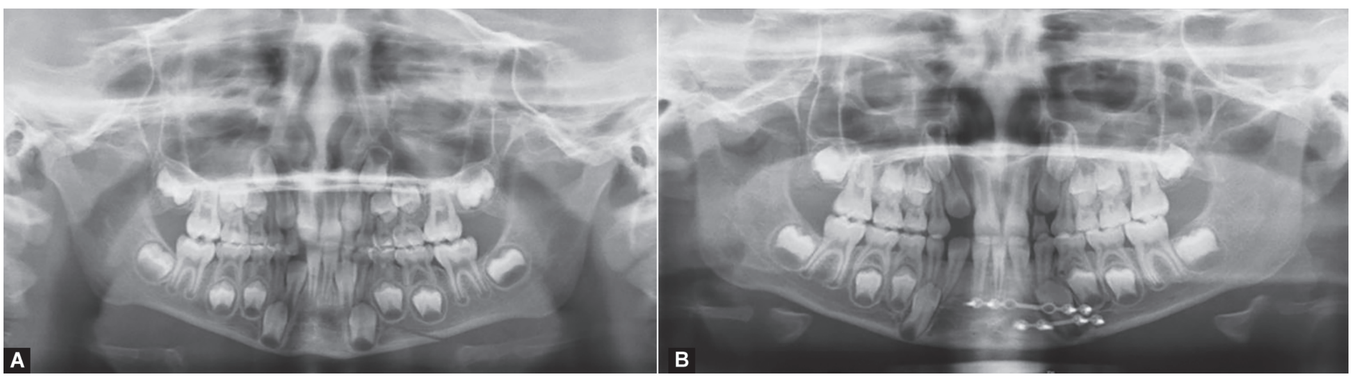
- age
- dentition phase
- compliance
- symptoms
- fracture pattern and localization (with regards to dislocation, angulation, and position of deciduous and primary teeth)
- concomitant injuries.

Based on these factors, different questions need to be addressed regarding the final treatment, including surgical or conservative treatment, number of plates and localization, plate thickness, osteosynthesis material (resorbable or nonresorbable), duration and type of IMF, necessity of an orthodontic appliance, and follow-up intervals, as well as the need and time point for plate removal.

Single Mandibular Fractures

Corpus Fractures

The corpus is a frequent localization of a single mandibular fracture (Figs 3A and B). IMF may be considered in a compliant pediatric patient with a nondisplaced corpus fracture at the mixed dentition phase (Fig. 3A). However, fracture displacement, instability or noncompliance requires a surgical approach using ORIF. Plates are usually positioned at the superior and inferior border of the mandible. In case of ORIF in the mixed dentition phase, special attention must be drawn to correct screw positioning to avoid tooth injuries (Fig. 3B). The additional use of postoperative IMF may improve stability, ameliorate occlusion, and support healing



Figs 3A and B: X-rays demonstrating exemplary mandibular fractures in pediatric patients. (A) Panoramic view displaying a parasymphysis fracture of the left mandible at the mixed dentition stage. (B) Postoperative panoramic X-ray following ORIF in a single parasymphysis mandibular fracture in a patient at the mixed dentition phase of the fracture site. However, it is not mandatory in every pediatric patient. Limited compliance, especially in the younger age groups of 1–5 years and 6–12 years, must be considered.

Resorbable and nonresorbable osteosynthesis materials may be selected in the pediatric patient. However, the use of nonresorbable fixation systems frequently requires the early removal of osteosynthesis material after 3–4 months to avoid growth disturbances or secondary material failure. Specialists should inform parents about the long-term risks of mandibular fractures and treatment strategies, as well as the need for material removal.

Condylar Neck Fractures

Low and high condylar fractures with or without displacement or dislocation (types I–V) and condylar head fractures (type VI) are classified according to Spiessl and Schroll.[18] The management of fractures located at the neck of the condylar process depends on the fracture pattern and displacement, as well as the patient's occlusion and compliance. In cases presenting with axial deviation or complete condylar head displacement (Figs 4A to C), surgical treatment should be performed to reposition the fragments and relocate the condylar head under the intraoperative temporary use of IMF (Figs 4D to F). For higher condylar fractures, an extraoral approach using a preauricular approach is considered, whereas an intraoral approach is typically applied in lower condylar fractures. Given a stable reposition and occlusion in a young noncompliant patient, postoperative IMF is not required. To avoid any growth disturbances or failure of osteosynthesis material, removal of osteosynthesis material is recommended after complete bone healing.

Condylar Head Fractures

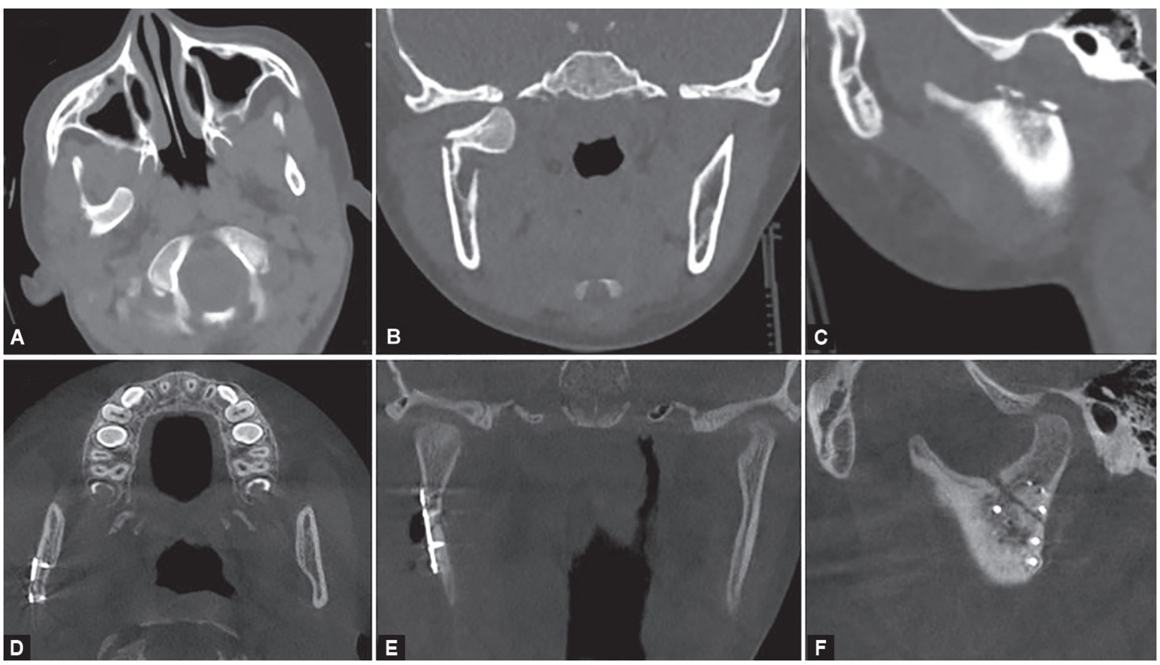
Fractures of the condylar head (Spiessl and Schroll type VI)[18] require early mobilization to prevent ankyloses or mandibular asymmetry due to growth disturbances.[3] Single mandibular fractures located at the condylar head in patients aged 1–16 years should be considered for conservative treatment, including the use of orthodontic appliances and early mobilization. While short immobilization followed by early mobilization is recommended in nondisplaced or minimally displaced fractures, orthodontic appliances, such as an activator appliance, can be used in patients with nonocclusion under frequent orthodontic follow-up visits during the growth period (Figs 5A and B).

Multisegmented Mandibular Fractures

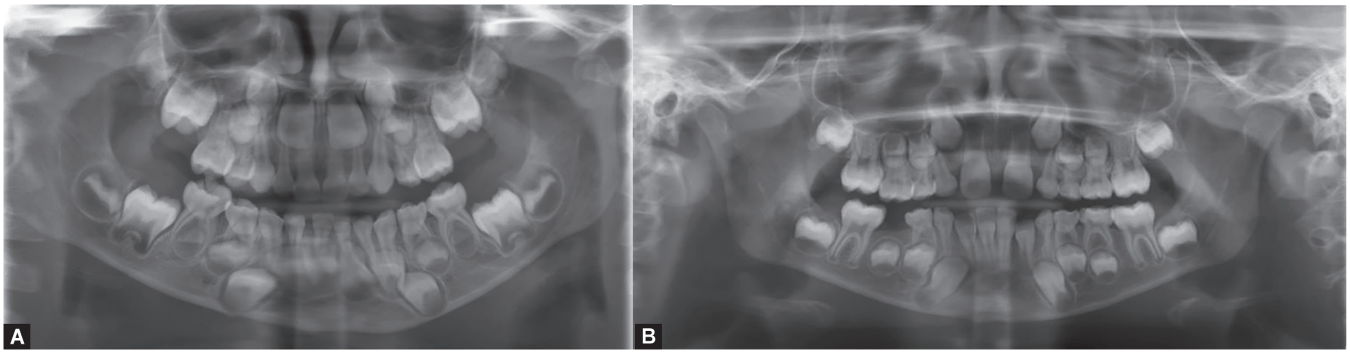
The same principles should be applied for multisegmented mandibular fractures when compared to single mandibular fractures. Depending on the fracture displacement and location, resorbable and nonresorbable osteosynthesis materials can be used, and individualized treatment regimens should be applied. The use of biodegradable osteosynthesis materials eliminates the need for postoperative material removal (Figs 6A to H). When applicable, the combination of a conservative and surgical approach with regards to different fracture localizations and fracture displacement may be applied in the same patient (Figs 7A to E).

Posttraumatic and Postinterventional Concerns

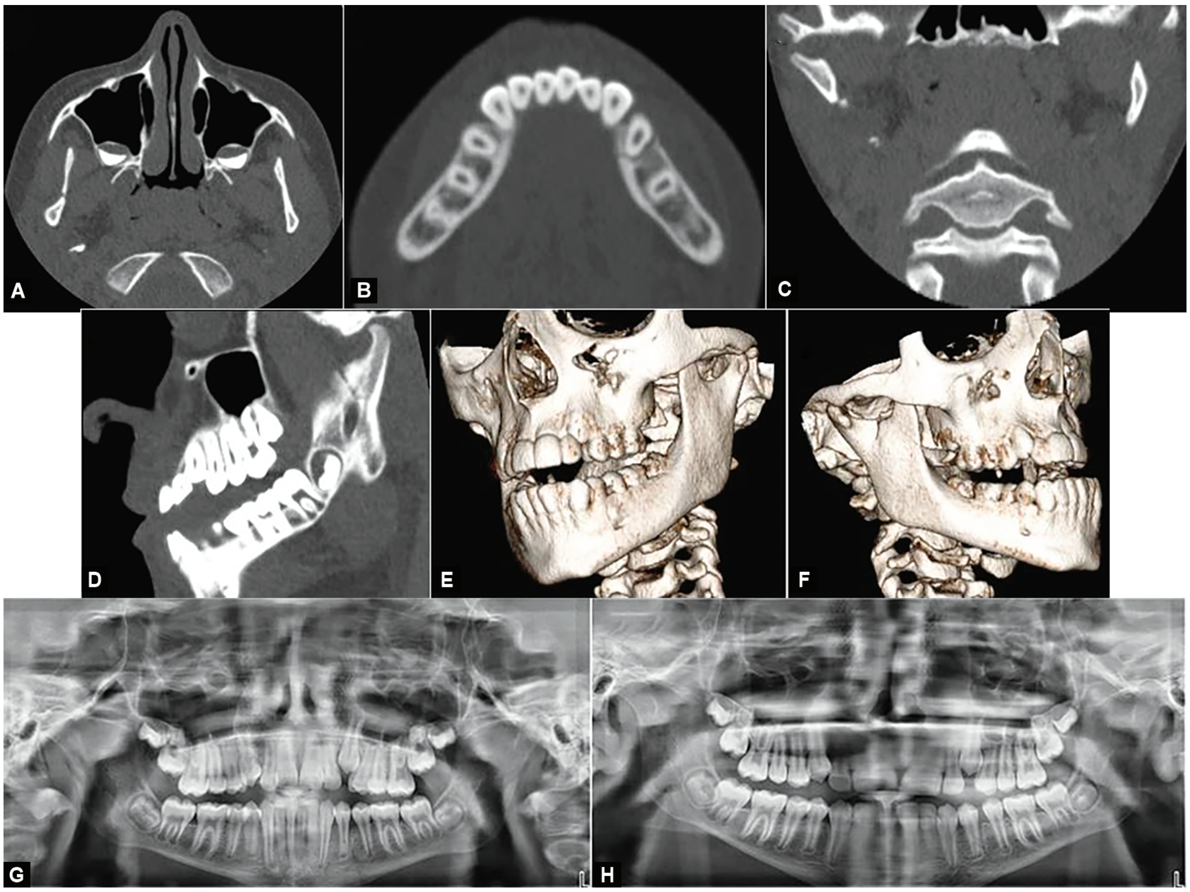
The main concern related to facial fractures in the pediatric patient, especially mandibular fractures, are growth disturbances. Hence, the management of mandibular fractures in children and adolescents remains challenging and requires the careful consideration of the unique needs of the growing patient. Two main growth periods with rapid mandibular height growth take place at 1–2 and 3–4 years of age.[19] In line with the current literature,[13,15] this study demonstrated that only a minority of mandibular fractures occur in children younger than 6 years of age. Mandibular body growth is influenced by the existence of tooth buds and their stage of maturation, as well as the time points of eruption in general. The mandibular condyle is functionally and anatomically linked to the temporomandibular joint. However,



Figs 4A to F: Case presentation of a dislocated condylar neck fracture (Spiessl and Schroll, in an 8-year-old female patient. (A–C) Preoperative DVT scans demonstrating the angulated fracture of the right condylar neck (Spiessl and Schroll type IV).[18] (D–F) Postoperative CT scans following ORIF using a preauricular extraoral surgical approach to the condylar region. Using short-acting muscle relaxants, a nerve stimulator is used to identify and preserve the facial nerve



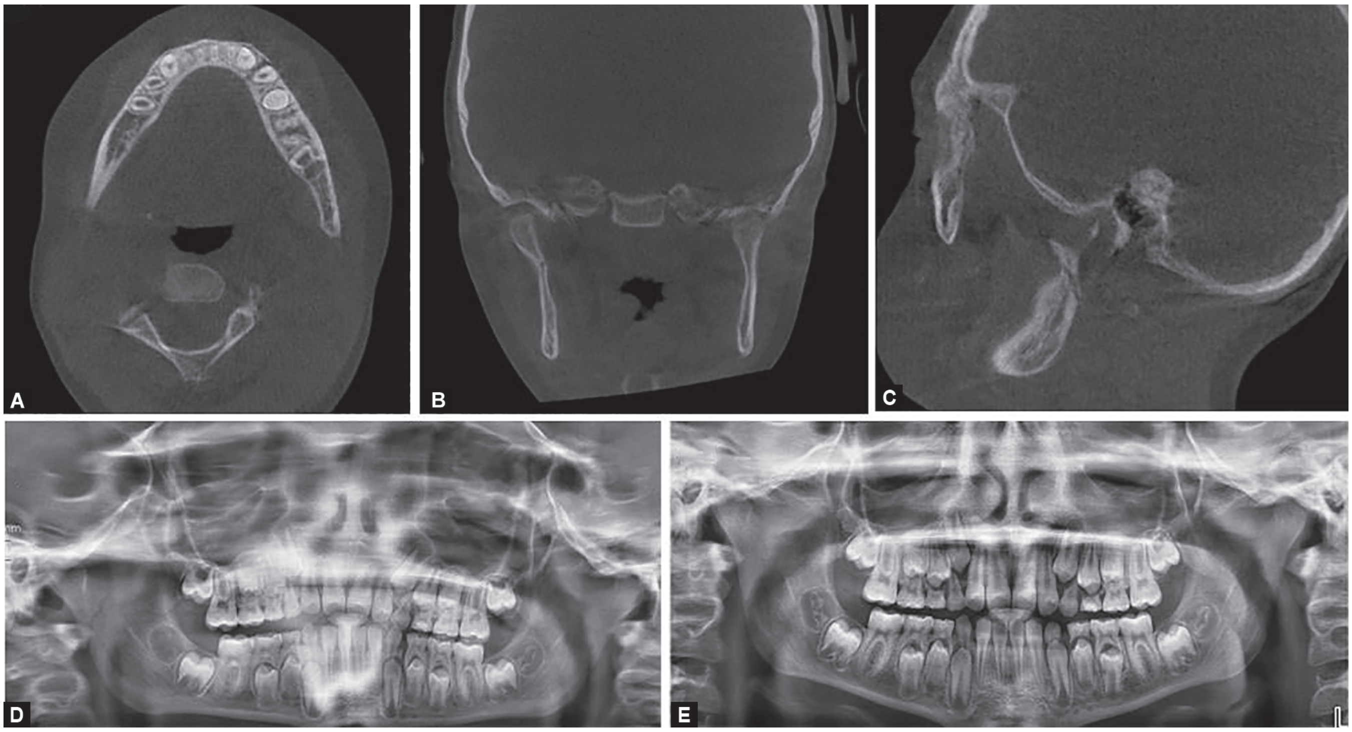
Figs 5A and B: Case presentation of a 5-year-old female patient with a single mandibular fracture of the left condylar head. (A) Panoramic view displaying a left condylar head fracture before orthodontic treatment using an activator appliance; (B) Postinterventional panoramic view 3 years after the trauma demonstrating sufficient reposition of the left condylar head



Figs 6A–H: Case presentation of an 11-year-old male patient with a double mandibular fracture. Preoperative (A–D) CT scans and (E,F) Three-dimensional reconstruction images demonstrating the fractures localized at the left parasymphysis and the right condylar neck (Spiessl and Schroll type II).[18] ORIF was performed to address the two fracture sites using resorbable osteosynthesis plates and screws. Postoperative panoramic view (G) 1-week and (H) 6 weeks after surgery

the condyles react to growth and should not be considered the primary center of growth. Here, growth might be disturbed secondary to trauma or surgical intervention, in particular due to the effects of scar tissue.[20] With the majority of mandibular fractures reported in children and adolescents within the third dentition phase, the choice of fracture management must consider any effects on the eruption of teeth and the continuing growth of facial bones.

While injury mechanism and fracture pattern must be recognized, the treatment and its effect on mandibular growth and stomatognathic function are highly relevant.[3] Overall, the majority of mandibular fractures in the pediatric patient were managed surgically by the implantation of osteosynthesis material and the temporary intraoperative use of IMF. Long-term monitoring and orthodontic evaluation are mandatory, especially in cases of condylar neck and head fractures. Dentition changes during growth may equilibrate minor malocclusions. Similarly, ongoing growth in children and adolescents may allow for the restoration of anatomical architecture following a fracture, thus avoiding functional impairment. In this study, the implantation of



Figs 7A–E: Case presentation of a 10-year-old male patient with a double mandibular fracture. Preoperative (A–C) CT scans display the fractures localized at the left parasymphysis site and the right condylar neck. ORIF was performed to address the parasymphysis fracture using resorbable osteosynthesis plates. Postoperative panoramic view (D) 1 day and (E) 5 months after surgery

osteosynthesis plates in the age groups 1–5 years and 6–12 years was the more frequently elected surgical approach in comparison to the use of IMF or conservative treatment. This was attributed to the reduced compliance with Schuchardt's splints or screws used for IMF in younger children.

The risk of tooth injuries following the surgical management of pediatric fractures has been discussed in previous literature.[21] In a cohort of 366 patients, nine tooth root injuries (56.3%) were recorded following IMF and seven injuries (43.8%) following ORIF. The consecutive risk of root canal treatment due to loss of vitality or tooth extraction must be considered when evaluating surgical treatment options, especially in children and adolescents. Previous studies have reported a risk of up to 20% for dental maleruption due to root injury or tooth resorption of deciduous teeth following ORIF of mandibular fractures.[22] Besides the insertion of IMF screws, the use of Ernst ligatures, and temporary Schuchardt's splints is considered a reasonable and save option to avoid root damage in the compliant patient.

Resorbable plates have been used as an alternative for metallic osteosynthesis devices with comparable outcomes.[23,24] Resorbable plates potentially eliminate the need for osteosynthesis material removal, which is performed in the majority of pediatric mandibular fractures. Yet, resorbable plates are associated with the adverse events of nonunion, wound infection, and dehiscence, hardware failure, and revision surgery.[25]

Conservative fracture management was favored in the treatment of condylar head fractures in this study. The nonsurgical approach for condylar fractures in pediatric patients has found wide acceptance. It has been demonstrated that the conservative management of condylar fractures in pediatric patients permits the restitutional remodeling of a novel condylar process with normal morphology.[26] While orthodontic management with functional appliances may be used in the treatment of pediatric mandibular fractures, more evidence for the efficacy of functional appliances is required.[27,28] Follow-up visits during the early (1–2 weeks after trauma) and late phases (at 6–12 months) after treatment are important to intervene in case of growth or functional disturbances. Extended periods of follow-up visits are recommended if orthodontic appliances are used.

Conclusion

When deciding on the diagnostic approach and treatment regimen of pediatric mandibular fractures, the fracture pattern and localization, as well as the patient's age with regards to compliance and the dentition phase, must be carefully considered. The challenges of fracture management in children and adolescents include posttraumatic and postsurgical growth disturbances, tooth injury and maleruption of permanent teeth, as well as impaired stomatognathic function. In case of ORIF and/or IMF, fixation techniques and duration have to be adapted to suit the individual situation.

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Supplementary

Supplement 1: Fracture localization in mandibular fractures. n is the total number of patients presenting with a mandibular fracture at the respective localization

		Fracture localization					
		Symphysis	*Parasymphysis*	*Corpus*	*Angle*	*Condylar neck*	*Condylar head*
Fracture pattern	*n*	*n*	*n*	*n*	*n*	*n*	*n*
Single	39	3	9	2	6	8	11
Double	44	2	23	7	30	18	8
Triple	7	0	4	3	1	8	5
Complex	1	1		1			2
Total	91	6	36	13	37	34	26

Supplement 2: Fracture localization in double mandibular fractures. *n* is the total number of patients presenting with a double mandibular fracture pattern, and % represents the percentage of the total number of patients with double mandibular fractures (*n* = 44)

Fracture localization	*n (%)*
Angle + parasymphysis	14 (31.8)
Condylar neck + parasymphysis	8 (18.2)
Angle + condylar neck	7 (15.9)
Angle + corpus	4 (9.1)
Angle + angle	2 (4.5)
Condylar head + symphysis	2 (4.5)
Condylar head + parasymphysis	2 (4.5)
Condylar head + angle	1 (2.3)
Condylar head + condylar head	1 (2.3)
Condylar head + condylar neck	1 (2.3)
Condylar neck + condylar neck	1 (2.3)
Condylar neck + corpus	1 (2.3)

Supplement 3: Mandibular fracture pattern and treatment of pediatric patients 1–16 years of age. The number of patients is reported (*n*), and the percentage of the total number of patients admitted with mandibular fractures is given in parentheses. The number of cases with removal of osteosynthesis material is reported, and the percentage of the total number of patients that received osteosynthesis material is given in parentheses. IMF = intermaxillary fixation, ORIF = open reduction and internal fixation

Fracture pattern and localization		*Conservative*	*IMF*	*ORIF*	*ORIF + IMF*	*ORIF material removed*
		n (%)	*n (%)*	*n (%)*	*n (%)*	*n (%)*
Single	*n* = 39	10 (25.6)	9 (23.1)	17 (43.6)	3 (7.7)	12 (60.0)
Symphysis		0	0	3	0	2
Parasymphysis		0	1	7	1	5
Corpus		0	1	1	0	0
Angle		1	0	4	1	4
Condylar neck		1	5	1	1	1
Condylar head		8	2	1	0	0
Double	*n* = 44	1 (2.3)	4 (9.1)	34 (77.3)	5 (11.4)	22 (56.4)
Angle + parasymphysis		0	1	12	1	8
Condylar neck + parasymphysis		0	0	7	1	1
Angle + condylar neck		0	0	5	2	5
Angle + corpus		0	2	2	0	2
Angle + angle		0	0	2	0	1
Condylar head + condylar neck		0	1	0	0	0
Condylar head + symphysis		0	0	1	1	1
Condylar head + parasymphysis		0	0	2	0	2
Condylar head + angle		0	0	1	0	0

Contd...

Contd...

Fracture pattern and localization		*Conservative* *n (%)*	*IMF* *n (%)*	*ORIF* *n (%)*	*ORIF + IMF* *n (%)*	*ORIF material removed* *n (%)*
Condylar head + condylar head		1	0	0	0	0
Condylar neck + condylar neck		0	0	1	0	1
Condylar neck + corpus		0	0	1	0	1
Triple	*n* = 7	0	1 (14.3)	4 (57.1)	2 (28.6)	4 (66.7)
Condylar head + corpus + condylar head		0	0	1	1	2
Condylar neck + corpus + condylar head		0	0	1	0	1
Condylar neck + parasymphysis + condylar neck		0	1	1	1	0
Corpus + corpus + angle		0	0	1	0	**1**
Multiple	*n* = 1	0	0	1 (100)	0	1 (100)
Left and right condylar head + symphysis + corpus + coronoid		0	0	1	0	**1**
Total	*n* = 91	11 (12.1)	14 (15.4)	56 (61.5)	10 (11.0)	39 (59.1)

Supplement 4: Treatment regimen according to age group, gender and fracture pattern in pediatric patients with mandibular fractures. The number of patients is reported *(n)*, and the percentage of the total number of female (F) and male (M) patients admitted with mandibular fractures is given in parentheses. The number of cases in which removal of osteosynthesis material occurred is displayed, and the percentage of the total number of patients that received osteosynthesis material is given in parentheses. IMF = intermaxillary fixation, ORIF = open reduction and internal fixation

	Gender			*Treatment*						
Age group	*All*	*F*	*M*			*Conservative*	*IMF*	*ORIF*	*ORIF + IMF*	*ORIF material removed*
Years	*n*	*n*	*n*	*Fracture pattern*	*n*	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
1–5	6	5	1	Single	4	1 (25.0)	0	3 (75.0)	0	2 (66.7)
				Double	1	0	0	1 (100)	0	1 (100)
				Triple	1	0	0	1 (100)	0	0
6–12	24	6	16	Single	13	2 (15.4)	3 (23.1)	7 (53.8)	1 (7.7)	5 (62.5)
				Double	9	0	2 (22.2)	7 (77.8)	0	5 (71.4)
				Triple	2	0	0	1 (50.0)	1 (50.0)	2 (100)
13–16	61	10	51	Single	22	7 (31.8)	6 (27.3)	7 (31.8)	2 (9.1)	5 (55.6)
				Double	34	1 (2.9)	2 (5.9)	26 (76.5)	5 (14.7)	16 (51.6)
				Triple	4	0	1 (25.0)	2 (50.0)	1 (25.0)	2 (66.7)
				Multiple	1	0	0	1 (100)	0	1 (100)

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