D. Burlini*, G. Conti**, F. Amadori***, E.Bardellini***, C. De Giuli*

*Department of Paediatric Maxillofacial Surgery, Spedali Civili di Brescia, Brescia, Italy
**UOC Maxillofacial Surgery and Dentistry, IRCCS Fondazione "Ca Granda" Ospedale Maggiore, University of Milan, Milan, Italy
***Department of Paediatric Dentistry, Dental School, University of Brescia, Brescia, Italy

e-mail: giuliocontiphd@gmail.com

Management of paediatric maxillofacial fractures: conventional methods and resorbable materials

ABSTRACT

Aim *To compare the outcomes between the use of resorbable plates and screws and the conventional methods in children with paediatric maxillofacial fractures.*
Materials and methods *Study design: a retrospective observational study was designed reviewing the clinical records from June 2007 and June 2011. Data collected included aepidemiological data, type of treatment, outcome and satisfaction questionnaire. Descriptive statistics and bivariate analysis were performed.*
Results *A total of 1122 children (0-17 years old) were studied. Children treated by conventional methods were 912, while children treated by resorbable materials were 210. The frequency of complications during recovery was similar and no statistically significant difference was noted. The satisfaction questionnaire revealed similar percentages of satisfaction, with a high degree of satisfaction.*
Conclusion *Our experience suggests that resorbable devices should be considered as a treatment option, which avoids the need of further surgery to remove metallic fixation, limits hospital spending and increases children's quality of life.*

Keywords *Biodegradable ostheosynthesis materials, Children, Paediatric maxillofacial fracture.*

Introduction

Paediatric maxillofacial fractures (PMF) are uncommon if compared with those in the adult population and with other bone fractures of the body. In children, because of the age-related features, such as the peculiar anatomy, dentition, the small-sized face, the extent of the paranasal sinus pneumatisation, the bone growth and the greater cranio-maxillofacial mass to body ratio [Scariot et al., 2009], the management requires a treatment ranging from soft diet to open reduction and internal fixation [Goth et al., 2012]. In addition, long-term sequelae can affect the type of treatment in order to reduce facial asymmetry and malocclusion [Burlini et al., 2013].

Over the past decades, in order to treat craniofacial fractures, several techniques and materials for fixation have been proposed, such as interosseous and suspension wiring, plating and microplating system, miniplate system.

In the last 30 years, the most common treatment consisted in the application of metal plates and screws, both for adults and for children.

Although controversial, the reported problems about metal fixation included: prolonged recovery, intracranial translocation of plates and screws, increased inflammatory responses, interference with craniofacial growth of the peadiatric skull and interference with diagnostic techniques. Furthermore, ankylosis at the temporomandibular joint after prolonged immobilisation requires protracted rehabilitation. Bioresorbable devices have revolutionised the treatment of PMF, with the development and use of polylactic (PLA), polyglycolic (PGA) and polydioxanone acid plates. They are totally biocompatible, and they do not need to be removed since they completely degrade after bone healing by hydrolysis within 12 to 14 months and do not cause restriction and reduction of bone growth [Eppley BL, 2005; Campbell and Lin, 2009]; this allows to employ new techniques for the use of resorbable materials especially in paediatric maxillofacial surgery [Imola et al., 2001; Gosain et al., 1998; Habal and Pietrazak, 1999; Krsarai et al., 1999; Pietrazak et al., 1997].

The aim of the present study is to report the experience of the Paediatric Maxillofacial Surgery Department of Brescia (Italy) about the maxillofacial fractures in paediatric patients, comparing the features and outcomes of patients treated by bioresorbable plates and those treated by conventional methods, such as metal fixation.

Materials and methods

Selection of the sample

A retrospective observational study was designed using clinical records from the Pediatric Maxillofacial Surgery Department of Brescia, Italy, from June 2007 to June 2011. All cases of PMF were selected. The collected data included demographic characteristics, location and type of fractures, treatment provided, intraoperative data, follow-

up, outcome and a satisfaction questionnaire (for patients' parents or caregivers) including symptoms during recovery, outcome and personal opinion (bad, adequate, good or excellent result).

A total of 1,793 paediatric patients with a diagnosis of maxillofacial fracture (age range 0 -17 years), were studied; 512 patients were excluded because they underwent a non-surgical approach and 159 patients because of an uncompleted documentation or a too short follow-up. The final sample of 1,122 patients was composed of two groups: 210 children treated by resorbable screws and plates (study group), and 912 children treated by conventional methods such as metal fixation (control group).

Data analysis

All data were entered into a Microsoft Excel 2007 database for Macintosh. Analysis was performed using statistical software Stata 9.0. Descriptive statistics and bivariate analysis through chi-squared test were performed. Results were considered to be statistically significant when $p<0.05$.

Results

A total of 1,122 children (mean age 8.57 ± 0.3 years) were studied: 662 male (69%) and 460 female (41%). The study group consisted of 210 children treated by resorbable materials. The age range was 0-17 years (mean age of 7.74 ± 0.2 years), with a male-to-female ratio of approximately 2:1 (126 boys and 84 girls). The control group consisted of 912 children treated by conventional methods, such as metal fixation. The age range was 0-17 years (mean age of 8.63 ± 0.3 years), with a male-to-female ratio approximately 1.5:1 (536 boys and 382 girls).

Most of the fractures were caused by sport accidents and falls (n=583, 52%), followed by road accidents such as by bicycle, motorcycle or car (n=395, 35.2%), and other causes (personal violence and birth trauma) (n=144, 12.8%) (Table 1). About the location of the fractures, the maxilla was the most frequently involved bone (n=126, 60%) in the study group: in particular, 29 (23%) fractures were associated to other types of fracture (nasal or dentoalveolar bone), 52 (41.3%) fractures were of Le Fort I type, 34 (27%) Le Fort II type, and 11 (8.7%) fractures Le Fort III type. The orbital bone was affected in 49 (23%) cases followed by the mandible, fractured in 35 (17%) patients. In particular, 22 fractures (62.8%) involved the parasymphysis, 10 (28.6%) the condylar neck, and 3 (8.6%) the symphysis. No patients reported fracture of the coronoid process.

In the control group, the fractures mainly involved the mandible (n=581, 63.7%), followed by the orbital bone (n=165, 18.1%), and the maxilla (n=163, 17.9%). Soft tissues damages, such as lacerations and contusions resulted common in both the study group (172 patients, 82%) and the control group (803 patients, 88.04%).

Preoperative diagnosis methods were the same for both the study and the control group. Panoramic radiographs were taken for mandibular fractures while patients underwent skull X-ray and/or CT scans for orbital and maxillary fractures.. The same radiographic criteria were chosen during the follow-up in order to evaluate the reduction and fixation of the fractures. Children belonging to control group were treated by conventional methods, such as rigid fixation by means of titanium screws and plates. The surgical approach was intraoral for the mandibular fractures, intraoral and subciliary for maxillary fractures and transconjunctival for orbital fractures (Fig. 1, 2, 3). A second surgery to remove all non-resorbable appliances 6-8 months after the first surgery was needed in all treated patients.

Children treated by resorbable plates were 0-17 years old with maxillary or orbital fractures, not polytraumatised, with greenstick non-displaced fractures or patients aged 0-3 (as plates and screw are not allowed for mandible in children over 3 years) with mandibular fractures, not polytraumatised, with greenstick non-displaced fractures.

Children belonging to the study group underwent surgery under general anaesthesia within 3 days from the trauma. The reduction of the fractures was manual and the retention was performed through a rigid fixation with bioresorbable plates. In maxillary LeFort fractures and

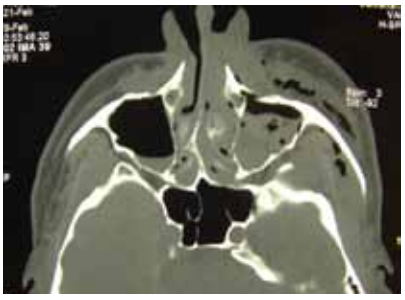

FIG. 1 CT of a fractured right orbital roof in a 12-year-old girl.

	Maxilla	Maxilla associated to other bones	Orbital bone	Mandible	
Sport	184	41	156	202	
Transport	66	16	31	282	
Others	19	11	90	24	
	269	68	277	508	n= 1122

TABLE 1 PMF (n patients) divided on the base of location and cause of the traumatic event.

in condylar mandibular fractures, a soft elastic maxillo-mandibular fixation was applied for 7-10 days as an occlusal guide. All patients were discharged 3 or 4 days after surgery, following a radiological check-up; within 10 days, patients returned to a normal diet. No additional surgery was needed to remove plates and screws, which appeared completely resorbed in two years. A single type of resorbable plating and screwing system was used (KLS Martin, Tuttlingen Germany), in particular biodegradable straight plates with 3, 4, 5 holes and 1 mm thickness, with thickness mesh 27 x 27 mm and screws 1.6 x 6 mm and 2.1 x 7 mm long (Fig. 4, 5, 6).

Only one intraoperative complication (i.e. the breaking of a screw head) was recorded.

The radiological follow-up was performed the day after surgery and at 1, 6, 12 and 24 months for both groups. Panoramic radiographs were taken of the mandibular fractures, skull x-ray of the orbital-maxillary fractures, and orbital radiographs for the orbital fractures. In all cases, the radiological follow-up revealed a complete restitutio ad integrum (Fig. 7). Clinical examinations at 1, 6, 12 and 24 months were also performed.

Out of the 1,122 patients, 42 post-operative complications were recorded, including 28 infections, treated and healed with antibiotic therapy and 14 exposure of the plate, treated by means of gingivoplasty with locoregional anaesthesia.

The frequency of complications was similar in the two groups and no statistically significant difference was noted (χ^2= 0.48; OR 0.88). In the study group (n=210) no complications were reported in 161 patients (76.7%) while 24 patients (11,4%) complained paraesthesia or malocclusion in maxillary fractures, 14 (6.7%) patients diplopia in the case of orbital fractures and 11 patients (5.2%) malocclusion or mucosal scars in the case of mandible fractures.

In the control group (n=912), 719 patient reported no complications; 90 (9.9%) patients complained malocclusion in mandibular and condylar fractures, 58 (6.4%) patients paraesthesia in the case of maxillary bone fractures, and 45 (4.9%) patients diplopia in the case of orbital fractures. There were no surgical sequelae except for a slight malocclusion in a condylar fracture and a moderate paraesthesia in a patient with maxillary fracture Le Fort Type II.

In the study group, postsurgical patient evaluation was positive in 203 cases (96.7%). In particular, 133 patients (65.5%) rated treatment and outcome as "good", 28 (13.8%) "adequate" and 42 (20.7%) "excellent". Only 7 patients (3.3%) rated both treatment and outcome as "bad"; they complained a slight malocclusion after the reduction of Le Fort Type II fracture and the mandibular fracture. Also in the control group, satisfaction was high (n=867; 95.1%). In detail, 130 patients (15%) considered excellent the treatment received, 555 children (64%) rated it "good" and 182 (21%) "adequate". Forty-five patients

FIG. 2 Intraoperative view, blow-out fracture of right orbital floor.

FIG. 3 Intraoperative view, reconstruction with 27 x 27 mm mesh.

FIG. 4 Resorbable plate.

FIG. 5 Fixation screws set.

FIG. 6 27 x 27 mm resorbable mesh.

FIG. 7 Rx 20 months after operation: restitutio ad integrum of orbital roof.

(4.9%) were not satisfied of the treatment because of the scars, the malocclusion or the persistent diplopia (Table 2).

Discussion

We carried out a retrospective observational study about PMF using the clinical records of the Pediatric Maxillofacial Surgery Department of Brescia (Italy) from June 2007 till June 2011, to evaluate the difference in outcome between resorbable materials and conventional rigid fixations. The main strengths of this study are the high number of paediatric patients included and the high number of resorbable materials used.

In our experience, PMF represent a high percentage (about 45%) of all admissions to the emergency paediatric ward, with seasonal variations and peaks during summer, when outdoor activity increases [Cole et al., 2009]. This divergence could be explained because our paediatric emergency service is the main hospital centre of the entire district.

As reported in the literature [Cole et al,. 2009], in our study we found a preponderance of boys to girls; this can be easily justified because of the frequent involvement in sports and dangerous behaviour and activities.

About the aetiology of the traumatic event, in agreement with other reports [Iida et Matsuya, 2002], the majority of PMF resulted caused by sports injuries and accidental falls, due to children's underdeveloped motor skills and poor coordination. Increasing the age, in particular over 6 years of age, road accidents were the main cause of facial fractures, followed by violence and birth trauma, in agreement with previous studies [Kaban, 1993]. Some authors report a higher percentage of interpersonal violence as cause of PMF [Gassner et al. 2004, Prigozen et al. 2006], but this was not confirmed in our study; this discrepancy could be explained by the fact that Northern Italy (and especially the city of Brescia) has a low violence rate compared to other countries.

Although in literature [Qudah and Bataineh, 2002] nasal and dentoalveolar fractures account for more than 50% of PMF, they are usually treated in the outpatient setting and they are not considered maxillofacial fractures requiring hospitalisation. In agreement with the literature [Qudah and Bataineh, 2002], in our control group, PMF involved mainly the mandible, followed by the maxilla and the orbital bone. Otherwise, in the study group, treated by resorbable materials, maxillary fractures were the most common ones, followed by orbital and mandibular ones. This discrepancy depends on the fact that patients under 3 years of age should be necessarily treated by resorbable materials as the use of metallic fixation is not allowed at this age. Regarding maxillary and orbital fractures, as reported by other authors [Cole et al., 2009], we found the prominent frontal bone to be the most commonly involved site. In fact, the progressive pubertal pneumatisation of the frontal sinus leads to an increase of the incidence of frontal bone fractures.

		Satisfied	Not satisfied
Control group (n)	867	45	912
adequate	182		
good	555		
excellent	130		
Study group (n)	203	7	210
adequate	28		
good	133		
excellent	42	52	1122
tot	1070		

TABLE 2 Satisfaction questionnaire in the control and study group.

As regards pre-operative and follow-up imaging evaluation, no differences were found between the methods used in this study and those reported by other authors [Cole et al., 2009]; in particular, panoramic radiography was adopted in addiction to computed tomography, considered the gold standard for evaluation of craniofacial fractures.

The conventional treatments provided to our patients with PMF was similar to those described in the literature [Cole et al., 2009; Saikrishna and Gupta, 2010; Haug and Foss, 2000; Baumann et al., 2004]. The maxillary injuries were treated with maxillomandibular fixation (MMF) and elastic traction if the teeth were adequately erupted; if not, open reduction and fixation were used. Displaced mandibular fractures were managed through intermaxillary fixation and wire stabilisation according to the protocol reported in the literature [Cole et al., 2009; Saikrishna and Gupta, 2010; Haug and Foss, 2000; Baumann et al., 2004]. The orbital fractures, usually greater than 1 cm^2, were treated with an autologous or alloplastic graft placed in the orbital cone to cover the defect, after defect exposure through transconjunctival incision; in some cases rigid fixation was necessary.

All patients underwent a second surgery to remove the non-resorbable materials 6-8 months after the first surgery to prevent long-term growth disturbance.

On the contrary, patients treated with resorbable materials did not need any additional surgery [Cole et al., 2009; Saikrishna and Gupta, 2010; Haug and Foss, 2000; Bos et al., 1997]. The advantage of using resorbable materials is hospital spending reduction; in fact, in terms of cost, the price of resorbable plates and screws is comparable to metallic fixation in most cases. In addition, the use of large mesh panels helps to contain costs with resorbable systems because several smaller pieces can be cost-effectively fashioned from a single large panel [Imola et al., 2001]. The cost-effectiveness and the need for a single surgery reduces hospital spending and improved the paediatric patient quality of life.

Both in patients treated by conventional methods and resorbable systems, the follow-up showed a complete restitution ad integrum.

The frequency of complications during recovery was similar in the two groups without statistical significative difference. Some authors [Cole et al., 2009; Cutright and Hunsuck, 1972] report that resorbable plate fixation of tooth-bearing bony segments can be problematic for the increased risk of injury to the teeth roots and dental buds when using larger resorbable plates; this is the reason why their use in patients with mixed dentition should be carefully selected. Some authors [Cole et al., 2009; Cutright and Hunsuck, 1972], challenged the use of resorbable fixation on the basis of a presumed reduced ability to provide adequate biomechanical strength of fixation. In our patients, as documented in other literature reports [Ballon et al., 2011; Landes and Ballon, 2006], the resorbable plates and screws provided adequate rigidity and immobilisation for routine osteosynthesis within the upper and middle facial skeleton. Considering that the internal fixation in craniofacial surgery encompasses a wide range of forces due to masticatory musculature, the degree of segmentation and the elastic recoil from the overlying soft tissue, each case should be evaluated individually when choosing the type of fixation to use. In particular, in the case of mandibular fractures, the resorbable systems do not yet provide an adequate stability to oppose the masticatory forces, which is the reason why they were used only in patients under 3 years of age.

The satisfaction questionnaire showed similar percentages of satisfaction (with a high degree of satisfaction) for both surgical approaches. The major complaint, in agreement with the literature [Cole et al., 2009; Ballon et al., 2011] was the postoperative visible or palpable scars.

Conclusion and limitations

Management of PMF evolves at a rapid pace and the use of resorbable polymer systems has revolutionised paediatric craniofacial surgery, minimising the risk of growth-restriction and transcranial migration of devices. While this study does provides helpful information, it has some weaknesses. The use of a single type of resorbable material (the only one provided by the hospital) and the young age of the patients (0-3 years) treated by resorbable devices for mandibular fractures are certainly limits. On the other hand, a strength of this study is the length of the follow-up (24 months), long enough to evaluate any long-term complication.

Despite the limitations, our study showed that resorbable devices have sufficient stability and rigidity, not being subject to any complication or growth disturbances, and resulting in favourable outcomes. The use of resorbable materials in PMF represents a valid option, especially when open reduction and internal fixation is the treatment of choice. Furthermore, it is important to highlight that resorbable plates and screws avoid the need of a second surgery; this represents a reduction in hospital spending and an improvement of the children's quality of life.

References

- Ballon A, Laudemann K, Sader R, Landes CA. Patients' preoperative expectations and postoperative satisfaction of dysgnathic patients operated on with resorbable osteosyntheses. J Craniofac Surg 2011 Mar;22(2):730-4.
- Baumann A, Troulis MJ, Kaban LB. Facial trauma I: midfacial fractures in Kaban LB, Troulis MJ, eds. Pediatric Oral and Maxillofacial. Philadelphia, PA: Saunders 2004:425-440.
- Bos RR, Boering G, Rozema FR, Leenslag JW. Resorbable poly(L-lactide) plates and screws for the fixation of zygomatic fractures. J Oral Maxillofac Surg 1987;45751- 753.
- Burlini D, Conti G, Bardellini E, Amadori F. Rare case of desmoid-type fibromatosis of the mandibular region in a child: diagnosis and surgical management. Eur J Paediatr Dent 2013;14(4):333-4.
- Campbell CA, Lin KY. Complications of rigid internal fixation. Craniomaxillofacial trauma and reconstruct 2009; 2:41-47.
- Cole P, Kaufman Yoav, Holllier LH. Managing the pediatric facial fracture, Craniomaxillofac Trauma Reconstruction 2009;2:77-84.
- Cutright DE, Hunsuck EE. The repair of orbital fractures of the orbital floor using biodegradable polylactic acid. Oral Surg Oral Med Oral Pathol 1972;3328- 34
- Eppley BL. Use of resorbable plates and screws in pediatric facial fractures. J Oral Maxillofac Surgery 2005; 63(3):385-391.
- Gassner R, Tuli T, Hachl O, Moreira R, Ulmer H. Craniomaxillofacial trauma in children: a review of 3385 cases with 6060 injuries in 10 years. J Oral Maxillofac Surg 2004;62:399-407.
- Gerlach KL. Treatment of zygomatic fractures with biodegradable poly(L-lactide) plates and screws: clinical implant materials. Advances in Biomaterials 1990;573- 578
- Gosain AK, Somg L, Corrao MA, Pintar FA. Biomechanical evaluation of titaniumbiodegradable plate and screw, and cyanoacrylateglue fixation systems in craniofacial surgery. Plast Reconstr Surg 1998;101:582-591.
- Goth S, Sawatari Y, Peleg M. Management of pediatric mandible fractures. J Craniofac Surg 2012 Jan; 23(1):47-56.
- Habal MB, Pietrzak WS. Key points in the fixation of the craniofacial skeleton with absorbable biomaterial. J Craniofac Surg 1999;10:491-499.
- Haug RH, Foss J. Maxillofacial injuries in the pediatric patient. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000; 90:126-134.
- Iida S, Matsuya T. Paediatric maxillofacial fractures: their aetiological characters and fractures patterns. J Cranio-Maxillofcial Surg 202;30:237-41.
- Imola MJ, Hamlar DD, Shao W, Chowdhury K, Tatum S. Resorbable Plate fixation in pediatric craniofacial surgery. Arch facial Plast Surg 2001;3:79-90.
- Kaban LB. Diagnosis and treatment of fractures of the facial bones in children. J Oral Maxillofac Surg 1993;51:722-729.
- Krsarai L, Hearn T, Gur E, Forrest CR, Manson P. A biomechanical analysis of the orbital zygomatic complex in human cadavers: examination of load sharing and failurepatterns after fixation with titanium and bioresorbable systems. JCraniofac Surg 1999;10:273-243.
- Landes CA, Ballon A. Five-year experience comparing resorbable to titanium miniplate osteosynthesis in cleft lip and palate orthognathic surgery. Cleft Palate Craniofac J 2006 Jan;43(1):67-74.
- Landes CA, Ballon A. Indications and limitations in resorbable plates osteosyntheses of displaced mandibular fractures in 4.5-year follow-up. Plast Reconstr Surg 2006 Feb;117(2):577-87.
- Pietrzak WS, Sarer DR, Verstynen ML. Bioabsorbable polymer science for the practicing surgeon. JCraniofac Surg 1997:8:87-91.
- Prigozen JM, Horswell BB, Flaberty SK, Henderson JM, Graham DA, Armistead LM et al. All-terrain vehicle-related maxillofacial trauma in the pediatric population. J Oral maxillofac Surg 2006;64:1333-7.
- Qudah MA, Bataineh AB. A retrospective study of selected oral and maxillofacial fractures in a group of Jordanian children. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;94:310-4.
- Saikrishna D, Gupta N. Comparaison of circumandibular wiring with resorbable bone plates in pediatricmandibular fractures. J Maxillofac Oral Surg 2010;9(2):116-118.
- Scariot R, de Oliveira IA, Passeri LA, Rebellato NLB, Muller PR. Maxillofacial injuries in a goup of Brezilian subjects under 18years of age. J of applied oral science 2009; 17(3):195-8.