Is the Mandibular Growth Affected by Internal Rigid Fixation?: A Systematic Review

Humberto Fernández-Olarte^{1,2} · Andrés Gómez-Delgado^{3,4,9} · Dayan López-Dávila⁵ · Rodolfo Rangel-Perdomo⁵ · Gloria Inés Lafaurie^{6,7} · Leandro Chambrone^{6,8}

Received: 24 November 2015 / Accepted: 16 September 2016 / Published online: 29 September 2016
© The Association of Oral and Maxillofacial Surgeons of India 2016

Abstract

Purpose The purpose of this systematic review was to evaluate, in animal model-based studies, whether there are mandibular growth alterations, after open reduction and internal rigid fixation with titanium plates and screws.

Methods A literature search was conducted using the MEDLINE, EMBASE, and LILACS databases, up to and including August 2015. Surgical reduction and internal rigid fixation (IRF) of induced fractures were compared to non-invasive procedures, in order to investigate if there were alterations in the mandibular growth patterns.

Results Of a total of 624 potentially relevant papers identified through the searching process, five were eligible for inclusion. Three studies using 3-month old New

Zealand white rabbits induced fractures of mandibular body or symphysis and internal fixation with titanium microplates and screws, whereas two were based on 6-month old goats with condylar fracture. None of the studies showed statistically significant difference between experimental and control groups.

Conclusion As literature regarding this subject is scarce, and the included studies show low level of evidence, it is not possible to conclude that open reduction and internal rigid fixation with titanium plates and screws cause significant growing alteration of the mandible.

Keywords Open reduction · Internal fixation · Mandibular growth · Animal model

✉ Andrés Gómez-Delgado
andresgd78@gmail.com

¹ Oral and Maxillofacial Surgery Residency Program, Universidad El Bosque, Bogotá, Colombia

² Department of Oral and Maxillofacial Surgery, Clínica El Bosque and Hospital Simón Bolívar, Bogotá, Colombia

³ Universidad El Bosque, Bogotá, Colombia

⁴ Private Practice, San José, Costa Rica

⁵ Department of Oral and Maxillofacial Surgery, Universidad El Bosque, Bogotá, Colombia

⁶ Unit of Basic Oral Investigations (UIBO), School of Dentistry, Universidad El Bosque, Bogotá, Colombia

⁷ Department of Periodontics, School of Dentistry, Universidad El Bosque, Bogotá, Colombia

⁸ Department of Periodontics, College of Dentistry, The University of Iowa, Iowa City, IA, USA

⁹ Departamento de Cirugía Oral y Maxilofacial, Universidad El Bosque, Carrera 7 B Bis No. 132-11, Bogotá Código Postal 110121, Colombia

Introduction

Despite pediatric fractures occurring to craniomaxillofacial structures are rare, mandibular fractures are the most common of them [1, 2]. They can involve all the mandibular structures, as the condyles, that are fragile, but they can also be present in the body, ramus and parasymphysis as well.

The incidence of pediatric facial fractures is relatively low compared to adult patterns due to the flexibility of the immature bone, and high energy trauma is the main reason [2]. Some undisplaced mandibular fractures can be treated with the traditional closed reduction methods, and followed by strict controls, but severe displaced fractures are indicated for open surgical reduction and fixation with internal rigid devices, generally using metallic plates and screws [3].

In 1943, Waldron et al. [4] stated that internal rigid fixation represent a risk not only for dental germs but for mandibular growth as well. Later, experimental studies

debated about this theory, reporting contradictory conclusions [5, 6].

At the present, debate is still open, and the introduction of absorbable plates has been considered as the solution, despite their higher cost and their minor resistance to functional forces. This is an important reason why, detailed revision of the scarce literature about this particular theme is necessary.

The lack of randomized clinical trials (RCTs) in human pediatric population regarding this issue, mainly due to ethical reasons, is probably the reason why only a few of experimental studies are available in literature, and all of them are based in animal models.

To date, no systematic evaluations of the base of evidence are available, thus the purpose of this study is to perform a systematic review (SR) of literature in order to determine if the mandibular growth (MG) is affected by internal rigid fixation (IRF) with titanium plates and screws after fractures, using animal models. The following focused question was addressed: “Is the MG affected by IRF with titanium plates and screws after fractures?”

Materials and Methods

This SR was structured in accordance with guidelines from PRISMA [7], the *Cochrane Handbook of Systematic Reviews of Interventions* [8], and Check Review checklist [9, 10]. The IRB considered that no review of this investigation was needed.

Type of Studies and Participants (Inclusion Criteria)

Because of the nature of the intervention of interest considered by this review and the impossibility of testing its hypothesis prospectively in humans for ethical reasons, we considered exclusively animal trials (ATs), in which the animals were exposed to induced mandibular fractures followed by internal rigid fixation with miniplates and screws, followed by postoperative care and radiographic assessment (after 3 months at least).

Exclusion Criteria

Studies in which absorbable fixation devices were used to reduce the fractures were excluded from this review.

Outcome Measures

The clinical outcome measure was the growth pattern in the mandible, after the performance of unilateral or bilateral mandibular induced fractures, followed by the placement of titanium plates and screws to reduce the fractures.

Search Strategy

Detailed search strategies were developed for each database search individually, in order to identify studies to be included or considered for this review. Databases were searched to include articles and abstracts published in all the languages. The MEDLINE (via PubMed), Excerpta Medica Database (EMBASE), and Latin American and Caribbean Health Sciences Literature (LILACS) databases were searched for articles published up to and including August 2015. Terms, key words, and other free terms from the Medical Subject Headings (MeSH) or Emtree terms were used for searching, and Boolean operators (OR, AND) were used to combine searches. Detailed search strategies were developed for each database searched based on the search strategy used for searching MEDLINE:

- #1 (mandibular) AND growth OR ((mandibular) AND growth)) AND internal fixation
- #2 (((mandibular) AND growth)) AND children OR
- #3 (((mandibular) AND growth)) AND animal) AND model
- #4 (#2) OR #3
- #5 (#1) AND #4
- #6 (titanium plate) NOT resorbable plate
- #7 (#5) AND #6

Unpublished data was sought by searching a database that lists unpublished studies (System for Information on Gray Literature in Europe [OpenSIGLE]), and reference lists of any experimental studies were examined in an attempt to identify any other studies.

Assessment of Validity and Data Extraction

Two independent reviewers screened the titles, abstracts, and full texts of the articles identified by searching. Disagreement between the reviewers was resolved by discussion and consensus. If data was missing, the authors of the original reports were contacted and asked to provide further details. Data was extracted using standardized evaluation forms. The extraction of data includes study design, sample characteristics, concomitant intervention and outcome measures.

Quality Assessment and Risk of Bias in Included Studies

The methodological quality of the included studies was assessed according to the points proposed by Higgins and Green in 2011, as adapted by Chambrone et al. in 2010 and 2013 [7–10].

- Method of randomization: (1) adequate if a random number of tables, a coin toss, or shuffled cards were used to assign treatments, (2) inadequate if any other method was used to assign treatments, (3) unclear if a method of randomization was not reported or explained, or (4) not applicable (i.e., for trials without randomization).
- Allocation concealment: (1) adequate if examiners maintain unaware of randomization sequence, (2) inadequate if allocation was not concealed, (3) unclear if the method of allocation concealment was not reported or explained, or (4) not applicable (i.e., for trials without randomization).
- Blindness of examiners with regard to the procedures used in the study period (yes/no response): Were the examiners masked?
- Completeness of the follow-up period (yes/no responses): (1) Were the number of subjects at baseline and at the completion of the follow-up period interval reported? (2) All animals completed the follow up period? (3) Reasons for drop-outs.

The risk of bias was categorized according to the following classification: (1) Low risk of bias (i.e., plausible bias that was unlikely to seriously alter the results) if all criteria were met (i.e., adequate methods of randomization and allocation concealment and a yes answer to all questions about completeness of follow-up questions and masking of examiners); (2) Unclear/moderate risk of bias (i.e., a plausible bias that raised some doubt about the results) if one or more criteria were partly met; or (3) High risk of bias (i.e., a plausible bias that seriously weakened confidence in the results) if one or more criteria were not met.

Data Synthesis

The data were pooled into an evidence table, and a descriptive summary was created to determine the quantity of data and study variations (characteristics of interventions/samples and results).

Results

Results of the Search

The total number of studies yielded by search is 624, of which 613 were excluded on the basis of title and abstract review. Eleven studies were excluded posteriorly after full-text screening, and the reasons for their exclusion are described in Fig. 1.

Included Studies

Five ATs were considered eligible for inclusion: Uckan et al. [11]; Bayram et al. [12]; Fernández et al. [13]; Feng et al. [14]; Li et al. [15]. The first 3 studies [11–13] were performed using 3-month old New Zealand white rabbits, in which bilateral or unilateral induced fractures were executed, through the mandibular body or symphysis. Then, the fractures were fixed with titanium microplates and screws. The last 2 articles [14, 15] were based on 6-month old goats, in which condylar fractures were performed, uni or bilaterally. Detailed information about the characteristics of included studies is shown in Table 1.

Vertical growth was evaluated in the studies of Bayram et al. [12], Feng et al. [14], and Li et al. [15]; symmetry was assessed in the study performed by Uckan et al. [11]; and mandibular length was evaluated in the study executed by Fernández et al. [13]. All of the studies reported that the MG was not affected by IRF with titanium plates and screws after induced fractures were performed in different mandibular anatomic landmarks.

Methodological Quality of Included Studies

All of the studies were considered to have an unclear risk of bias because the methods of randomization, allocation concealment, and blinding were not described or could not be identified. In the case of the study of Li et al. [15], the use of randomization is mentioned, but the exact method is not described.

Occurrence of Adverse Effects/Complications

No adverse effects or complications were reported in the studies.

Discussion

Summary of Main Results

All the animal trials included in this revision showed no alteration of mandibular growth, specifically in the symphysis, body or condyle/ramus, after reduction of induced fractures by means of titanium plates and screws (Table 1). Also, no complications or adverse effects associated to the interventions were identified.

Quality of the Evidence

None of the 5 animal trials included were considered to have a low but unknown risk of bias, because none of them mentioned the method of randomization, allocation

Fig. 1 Flow chart of studies screened through the review process

concealment or if examiners were blinded. The study of Li et al. [15] mentioned that there was randomization, but didn't clarify the method. Despite the fact that all the studies were properly evaluated and approved by ethical committees for experimental research on animals, and the intervention was clearly described within the materials and methods section, there was no information regarding the number of subjects initially submitted to the experiment versus the number of subjects that completed the follow-up.

As the authors wanted to gather data from primary sources using experimental models, no human studies were included, although some case series are available in literature. For ethical reasons, there are no experimental studies of this kind using human sample.

It is important to mention that the three studies based on rabbits, used cephalometric measures to evaluate the impact of the intervention, based on two-dimensional X-rays. Despite the fact that this kind of imaging tools have a wide range of distortion, the rate of change was always evaluated using the same X-ray in each individual case, so the proportional distortion affected the measures equally. In the case of the studies executed in goats, three-dimensional CT scanning was used to assess the changes, which gives more accuracy to the measures.

Limitations and Potential Biases in the Review Process

It was not possible to perform a meta-analysis because the interventions were too heterogeneous, and there were two subgroups of samples. For example, despite the fact that induced fractures were executed over the mandibular condyle in the goat group, Li et al. [15] evaluated the changes in growth of mandibular ramus comparing open (using IRF) and closed reduction of the fractures, meanwhile Feng et al. [14] assessed the mandibular growth pattern considering 3 types of intervention after the condylar fracture: isolated IRF, IRF plus removal of the condylar cartilage, and no intervention at all. Concerning the rabbit subgroup, unilateral osteotomies and IRF were executed over the mandibular body in the studies of Uckan et al. [11] and Fernández et al. [13]. On the first study, titanium screws were placed contralaterally, but no intervention over the contralateral side was performed in the latter study. Regarding the study of Bayram et al. [12], only one induced midline symphyseal fracture was executed in the experimental group, and the pattern of mandibular growth was compared with a control group in which no

Table 1 Characteristics of the included studies

Study	Type and follow-up	Sample	Methods	Results	Conclusions
Uckan et al. [11]	Experimental study, 6 mos follow-up with cephalometric analysis	Thirteen 90-day-old New Zealand white rabbits weighing 2–2.6 kg	Induced unilateral left mandibular fractures were fixed with titanium microplates and screws. Only screws were placed in the right (control) side	There was no statistically significant difference between right and left mandibular growth	“Metallic fixation of a mandibular body fracture did not cause mandibular asymmetry or restricted mandibular growth in growing rabbits in this relatively small sample”
Bayram et al. [12]	Animal trial, 6 mos follow-up with cephalometric analysis	Eighteen 90-day-old growing white New Zealand rabbits weighing 1.6–2.5 kg	In the experimental group, midline mandibular osteotomies simulating symphyseal fractures were performed and then fixed with titanium microplates and microscrews (1.6 mm). Same procedure for the control group, but only two screws were inserted on each side of the midline	There was no statistically significant difference between the 2 groups for growth amount of both sides of the mandible	“Metallic fixation of mandibular symphyseal fracture does not affect the vertical and sagittal mandibular growth in growing rabbits”
Fernández et al. [13]	Animal trial, 1, 2 and 3 mos follow-up with cephalometric analysis	Ten 3-month-old New Zealand white rabbits	Surgical fractures were performed in the right bodies of the mandible, and posteriorly reduced with internal titanium rigid fixation (1.0-mm). No procedure were executed in the contralateral side	There were no statistically significant differences between the experimental and control groups	“The use of internal rigid fixation didn’t alter the normal process of growth and development in growing rabbits”
Feng et al. [14]	Animal trial, 3 and 6 mos follow-up with CT scanning	Twelve 6-month-old goats	Intracapsular condylar fractures were induced bilaterally and treated with internal rigid fixation. On the group 1 (n = 4) the condylar cartilage was removed unilaterally, on the group 2 (n = 4) it was retained. Condyles in the control group 3 (n = 4) were untouched	There were significant reductions in the height of rami in the group 1 compared with groups 2 and 3, but no significant differences were observed between groups 2 and 3	“Removal of condylar cartilage can limit vertical growth of the mandible, but internal fixation itself doesn’t affect it”
Li et al. [15]	Animal trial, 6 mos follow-up with 3-dimensional computed tomographic analysis	Twelve 6-month-old goats	Unilateral right intracapsular condyle fractures were performed and treated with open reduction and internal fixation in group 1, and with closed treatment in group 2. No operation was taken in group 3	Heights of mandibular ramus in groups 1 and 3 were significantly longer than that in the group 2, after 3 months	“Internal fixation with titanium plates and screws is an efficient method to treat ICF of growing goats, with better results on maintaining mandibular ramus growth than closed treatment”

osteotomies were performed and only one screw was inserted on each side of the symphyseal midline.

In addition, it should be accounted that animal-model research has long been used to test issues related to efficacy/effectiveness and safety/adverse effects of dental/maxillofacial interventions in order to understand the mechanisms of action of such events in human beings [9]. Although the strength of translating outcomes from animal

research to humans seems questionable because of the inherent wound healing dynamics of the different species, findings from animal models are certainly important when clinical/radiographic/histologic outcomes need to be assessed in conditions that cannot be reproduced in humans. As a result, this issue should be considered the main limitation of this review.

Agreements and Disagreements with Other Studies or Reviews

Even though the authors of this study did not find others systematic reviews related to this particular subject, there are ATs related to internal fixation and growing alterations of other facial bones. We also found, some case reports and retrospective studies in pediatric population, regarding internal fixation with titanium plates and screws and its relation to facial growth. Persing et al. [5] executed an AT, in which they immobilized unilaterally the coronal suture in 9-day-old rabbits, using methylcyanoacrylate adhesive, and found subsequent growing effects, decreasing it in the anterior cranial base and orbit on the immobilized side. Marshall et al. [6] reported the long-term effects of IRF on the growing craniomaxillofacial skeleton of eight 2-month-old beagle dogs, placing plates and screws across the coronal and nasofrontal sutures. They concluded that there were significant craniomaxillofacial growth pattern alterations. The difference between the results documented by Persing et al. [5] and Marshall et al. [6], and the clinical trials presented in this revision, may be due to the difference between growth patterns showed by the facial thirds. The growing of the upper and middle facial thirds is related directly to the endochondral ossification of the cranial base and the suture growing, unlike the mixed ossification pattern of the mandible.

In relation to human studies, Bos [16] stated in 2005 that the main reason to remove titanium plates in growing patients isn't the growing alteration but a drift phenomenon, in which there is a chance that the growth can lead to inclusion of plates and screws that could risk important structures later on. At the same time, this author considered that there is insufficient knowledge about long-term effects of nonfunctional plates and screws after bone healing in the long-term [16]. Other authors reviewed several papers about the general management considerations in pediatric facial fractures. All of them considered that there's not enough evidence to prove that titanium hardware causes growth restriction when it is placed on the facial skeleton [17–19]. Facing the impossibility of perform randomized clinical trials in pediatric human population, and the difficulty to obtain reliable evidence in this regard, animal trials must be considered as useful tools for analysis.

Conclusions

Despite the fact that all the studies included in this SR support that internal rigid fixation do not alter the mandibular growth, the high risk of bias detected within included trials precludes definitive assumptions at this

moment in time. This issue should be accounted when interpreting the findings of the present review.

Implications for Practice

This SR suggests the feasibility of IRF using titanium plates and screws, for the treatment of pediatric mandibular fractures. This option has considerable advantages for public health systems, due the lower cost of this therapy if compared with absorbable plates. Better stability and quick recovering of normal function are additional advantages of this system.

Implications for Future Research

Technology applied to tissue engineering and virtual modeling can be the basis for future research, considering that ethical considerations on human research will always limit the possibility to obtain information based on clinical experimentation regarding traumatic events. In addition, because of the critical issues relating to the design of studies included in this SR, further research is required to confirm the effect of internal rigid fixation on mandibular growth. For future studies, we recommend that critical components as method of randomization, allocation concealment, blinding and the drop-out rate must be included.

Acknowledgments We want to thank Sabrina Castillo for her support and collaboration during the preparation of this article.

Funding This study wasn't funded by any person, institution or company.

Compliance with Ethical Standards

Ethical Approval Statement This article contains just one study with animals performed by one of the authors. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed on it. This article does not contain any other studies with animals performed by any of the authors.

Conflict of interest Authors Humberto Fernández Olarte, Andrés Gómez-Delgado, Dayán López-Dávila, Rodolfo Rangel-Perdomo, Gloria Inés Lafaurie, Leandro Chambrone declares that they have no conflict of interest.

References

1. Demianczuk AN, Verchere C, Phillips JH (1999) The effect on facial growth of pediatric mandibular fractures. *J Craniofac Surg* 10:323
2. Imahara SD, Hopper RA, Wang J et al (2008) Patterns and outcomes of pediatric facial fractures in the United States: a survey of the national trauma data bank. *J Am Coll Surg* 207:710
3. Epplé BL, Prevel CD (1997) Nonmetallic fixation in traumatic midfacial fractures. *J Craniofac Surg* 8:103
4. Waldron CW, Kazanjian VH, Parker DB (1943) Skeletal fixation in the treatment of fractures of the mandible: a review. *J Oral Surg* 1:59

5. Persing JA, Babler WJ, Jane JA et al (1986) Experimental unilateral coronal synostosis in rabbits. *Plast Reconstr Surg* 77:369
6. Marshall MA, Chidylo SA, Figueroa AA et al (1991) Long-term effects of rigid fixation on the growing craniomaxillofacial skeleton. *J Craniofac Surg* 2:63
7. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group (2009) Methods of systematic reviews and meta-analysis preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *J Clin Epidemiol* 62:1006
<http://www.cochrane.org/training/cochranehandbook>. Updated Sep 2011. Accessed 13 Jul 2015
8. Higgins JP, Green S (eds) (2011) *Cochrane handbook for systematic reviews of interventions*. Version 5.0.1. Cochrane Collab. <http://www.cochrane.org/training/cochranehandbook>. Updated Sep 2011. Accessed 13 Jul 2015
9. Chambrone L, Chambrone LA, Lima LA (2010) Effects of occlusal overload on peri-implant tissue health: a systematic review of animal model studies. *J Periodontol* 81:1367
10. Chambrone L, Mandia J Jr, Shibli JA et al (2013) Dental implants installed in irradiated jaws: a systematic review. *J Dent Res* 92:119S
11. Uckan S, Bayram B, Kecik D et al (2009) Effects of titanium plate fixation on mandibular growth in a rabbit model. *J Oral Maxillofac Surg* 67:318
12. Bayram B, Yilmaz AC, Ersoz E et al (2012) Does the titanium plate fixation of symphyseal fracture affect mandibular growth? *J Craniofac Surg* 23:e601
13. Fernandez H, Osorio J, Russi MT et al (2012) Effects of internal rigid fixation on mandibular development in growing rabbits with mandibular fractures. *J Oral Maxillofac Surg* 70:2368
14. Feng Z, Li L, He D et al (2012) Role of retention of the condylar cartilage in open treatment of intracapsular condylar fractures in growing goats: three-dimensional computed tomographic analysis. *Brit J Oral Maxillofac Surg* 50:523
15. Li L, Feng Z, Ma R et al (2013) The comparative study of mandibular ramus growth with different treatment methods for intracapsular condylar fracture. *J Craniofac Surg* 24:657
16. Bos RR (2005) Treatment of pediatric facial fractures: the case for metallic fixation. *J Oral Maxillofac Surg* 63:382
17. Myall RW (2009) Management of mandibular fractures in children. *Oral Maxillofac Surg Clin N Am* 21:197
18. Baby J, Reena RJ, Stalin A, Elango I (2010) Management of mandibular body fractures in pediatric patients: a case report with review of literature. *Contemp Clin Dent* 1:291
19. Siy RW, Brown RH, Koshy JC et al (2011) General management considerations in pediatric facial fractures. *J Craniofac Surg* 22:1190
20. DeConde AS, Sidell DR, Aghaloo T et al (2012) The segmental mandibular critical size defect in the rat. *Otolaryng Head Neck Surg* 147:43
21. Deconde AS, Lee MK, Sidell D et al (2014) Defining the critical-sized defect in a rat segmental mandibulectomy model. *JAMA Otolaryngol Head Neck Surg* 140:58
22. Chiodo AA, Gur E, Pang CY et al (2000) The vascularized pig fibula bone flap model: effect of segmental osteotomies and internal fixation on blood flow. *Plast Reconstr Surg* 105:1004
23. Ellis E III (1988) Mobility of the mandible following advancement and maxillomandibular or rigid internal fixation: an experimental investigation in *Macaca mulatta*. *J Oral Maxillofac Surg* 46:118
24. Neff A, Chossegros C, Blanc JL (2014) Position paper from the IBRA symposium on surgery of the head: the 2nd international symposium for condylar fracture osteosynthesis, Marseille, France 2012. *J Cranio Maxillofac Surg* 42:1234
25. Kushner GM, Tiwana PS (2009) Fractures of the growing mandible. *Atlas Oral Maxillofac Surg Clin N Am* 17:81

Additional References

26. Amaratunga NA (1988) Mandibular fractures in children: a study of clinical aspects, treatment needs, and complications. *J Oral Maxillofac Surg* 46:637
27. Crean ST, Sivarajasingam V, Fardy MJ (2000) Conservative approach in the management of mandibular fractures in the early dentition phase. A case report and review of the literature. *Int J Paediatr Dent* 10:229
28. Gawelin PJ, Thor AL (2005) Conservative treatment of paediatric mandibular fracture by the use of orthodontic appliance and rubber elastics: report of a case. *Dent Traumatol* 21:57
29. Holland AJ, Broome C, Steinberg A et al (2001) Facial fractures in children. *Pediatr Emerg Care* 17:157
30. Kaban LB (1993) Diagnosis and treatment of fractures of the facial bones in children 1943–1993. *J Oral Maxillofac Surg* 51:722
31. Laster Z, Muska EA, Nagler R (2008) Pediatric mandibular fractures: introduction of a novel therapeutic modality. *J Trauma* 64:225
32. Posnick J, Wells M, Pron GE (1993) Pediatric facial fractures: evolving patterns of treatment. *J Oral Maxillofac Surg* 51:836
33. Rowe NL (1969) Fractures of the jaws in children. *J Oral Surg* 27:497
34. Senel FC, Tekin US, Imamoglu M (2006) Treatment of a mandibular fracture with biodegradable plate in an infant: report of a case. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 101:448
35. Simon BR, Woo SL, McCarty M et al (1978) Parametric study of bone remodeling beneath internal fixation plates of varying stiffness. *J Bioeng* 2:543
36. Torgersen S, Gilhuus-Moe OT, Gjerdet NR (1993) Immune response to nickel and some clinical observations after stainless Steel miniplate osteosynthesis. *Int J Oral Maxillofac Surg* 22:246
37. Turvey TA, Ruiz RL, Blakey GH III, Biron RT, Levin LM (2004) Management of facial fracture in growing patient. In: Fonseca RJ, Walker VR, Betts NJ (eds) *Oral and maxillofacial trauma*, 3rd edn. Elsevier Saunders, St Louis, pp 967–1000
38. Zimmermann CE, Troulis MJ, Kaban LB (2006) Pediatric facial fractures: recent advances in prevention, diagnosis and management. *Int J Oral Maxillofac Surg* 35:2