Effects of Internal Rigid Fixation on Mandibular Development in Growing Rabbits With Mandibular Fractures

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Purpose: The aim of this research was to determine whether rigid internal fixation interferes with mandibular growth and development in growing New Zealand white rabbits with induced mandibular fractures.

Materials and Methods: Ten 3-month-old New Zealand white rabbits were included in the study. Surgical fractures were performed in the right mandibular bodies of the 10 rabbits. These fractures were reduced with internal rigid fixation by use of a 1.0-mm titanium system, taking the contralateral left mandibular bodies as the control group. We obtained radiographs preoperatively and at 1, 2, and 3 months postoperatively. Predetermined cephalometric points were used to measure and compare jaw growth. The protocol was approved by the Bioethics Committee of Universidad El Bosque, Bogotá, Colombia.

Results: There were no statistically significant differences between the experimental and control groups ($P = .95$). Mandibular growth in the studied rabbits was not affected by the use of internal rigid fixation.

Conclusions: The use of internal rigid fixation for the treatment of induced mandibular fractures in growing rabbits did not alter the normal process of growth and development. The findings of this study should lead to investigations using larger samples and to long-term prospective follow-up studies of children who have undergone open reduction and internal rigid fixation.
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Surgeons and researchers started to pay attention to the utilization of rigid fixation for mandibular fractures in 1943, when Waldron et al[1] published a landmark report in which they summarized several articles regarding the use of rigid fixation for these types of fractures. Two years later, Christiansen[2] introduced the use of bone plates to oral and maxillofacial surgery. He used tantalum plates to provide stability to displaced, unstable mandibular fractures. Although this technique started to gain the attention of surgeons, closed reduction of facial fractures was the standard approach until the early 1970s, when researchers began to understand the principles of internal rigid fixation. In great part this was made possible thanks to the 1968 publication of Luhr,[3] where he reported the use of an innovative Vitallium compression bone plate using the gliding screw principle. Other researchers who contributed notably to the development of internal rigid fixation and its use during the 1960s and 1970s were Michelet et al,[4] Spiessl,[5] and Champy et al.[6]

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Because facial and mandibular fractures are more prevalent in the adult population than in children, early researchers concentrated and based their studies on the former group. The fact that facial fractures in children are infrequent[7-16] did not prevent Waldron et al[17] from writing about this important topic. In an article published in 1943, they discussed the etiology of facial fractures, fracture types, dental development, diagnostic methods, and general principles for the management of facial fractures in children.

Waldron et al[17] recognized the differences between traumatized children and adults, thus recommending a conservative approach for the management of facial and mandibular fractures with closed reduction and immobilization. From that epoch work, this paradigm has dominated the way most oral and maxillofacial surgeons treat injured children, and today, it is the standard treatment in the growing population.[16] Even though stable or greenstick fractures in pediatric patients generally do not require internal fixation and they are actually best treated conservatively, significantly displaced pediatric mandibular fractures may require an aggressive approach with internal rigid fixation as has been already described by numerous authors.[11-13,18-21]

Surgeons who advocate for closed reduction of mandibular fractures in children have strong reasons to believe open reduction will put growing patients at risk. During the 1950s and 1960s, MacLennan,[22] Rowe,[7] and Graham and Peltier,[23] as well as other leaders, reinforced the philosophy of Waldron et al[17] and concluded that conservative management prevented the complications associated with tooth buds and growth centers. Today, the fundamental premise is that internal rigid fixation (ie, plate-and-screw fixation) not only may damage developing teeth but also may interfere with the normal growth and development of pediatric mandibles, although few experimental studies have been performed and their conclusions are ambiguous.[24-26]

The differences between the 2 philosophies, that is, conservative approaches versus the use of internal rigid fixation for fractured pediatric mandibles and its clinical and, perhaps, commercial implications, indicate that the debate needs more experimental and clinical long-term prospective follow-up studies of children who have undergone open reduction and internal rigid fixation. Unless research proves that internal rigid fixation does not actually alter growth, our knowledge will remain limited and we will be confined to using expressions such as "possibly alters normal development" or "may alter normal development". Understanding this unquestionable fact, the objective of this study was to investigate whether rigid internal fixation interferes with mandibular development in growing New Zealand white rabbits (*Oryctolagus cuniculus*) with induced mandibular fractures.

FIGURE 1. Localization of surgical fracture.

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Materials and Methods

A divided-mouth experimental study was used to study mandibular growth in ten 3-month-old New Zealand white rabbits whose right mandibles were surgically fractured and reduced with internal rigid fixation by use of a 1.0-mm titanium system. Their left mandibles were not touched, thus serving as the control group. We obtained radiographs preoperatively and at 1, 2, and 3 months postoperatively. Predetermined cephalometric points were used to measure and compare jaw growth.

Following the principles and standards of the Bioethics Committee of Universidad El Bosque, Bogotá, Colombia, and with its approval, we studied a sample of ten 90-day-old New Zealand white rabbits. With the rabbit under intravenous sedation with fentanyl, 0.2 mL/kg, and ketamine, 25 mg/kg, its head was positioned on a cephalostat designed by us and a cephalocaudal radiograph of the mandible was taken (FE Speed; Kodak, Rochester, NY) to expose the whole mandible. Prophylactic cephalexin, 10 to 20 mg/kg intravenously, was administered, and the rabbits were positioned in the right lateral position. The mandible and its surrounding soft tissues were infiltrated with 3% prilocaine without epinephrine (Pricanest 3% [Ropsohn Laboratorios, Bogotá, Cundinamarca, Colombia]). A 25-mm submandibular incision over the right mandibular body was performed, followed by plane dissection until the body of the mandible was reached.

Surgical fractures or longitudinal osteotomies (Fig 1) were made between the right mental foramen and the first lower right molar with a No. 701 bur (SS White, Lakewood, NJ) with a low-speed motor and

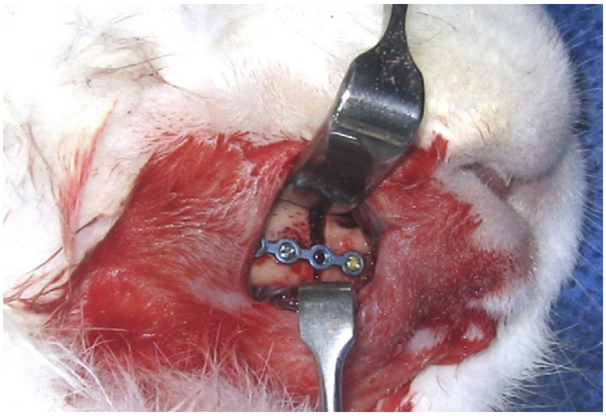

FIGURE 2. Position of 1.0-mm titanium miniplate system on right mandibular body.

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profuse irrigation with 0.9% saline solution. Once the fractures were induced, the segments were stabilized and fixed by use of 1.0-mm internal rigid fixation miniplates and 3-mm titanium screws (Leibinger [Stryker, Kalamazoo, Michigan]). Once the fractures were reduced, the surgical site was irrigated with saline solution, hemostasis was controlled, and the surgical wound was sutured with No. 3-0 nylon (Fig 2). Postoperative pain was controlled with buprenorphine, 0.05 to 0.1 mg/kg, and antibiotic coverage with cephalexin, 10 to 20 mg/kg per day for 7 days. A soft diet was given for 3 days.

We obtained preoperative radiographs, as well as follow-up radiographs, at 1, 2, and 3 months after surgery, following the maximum mandibular development known for these type of rabbits. Predetermined cephalometric points were used to measure and compare jaw growth. A calibrated examiner (κ, 0.8) external to the study performed the cephalometric measures. We used 3 cephalometric points: interincisal (In), confluence of the left internal and external oblique line (LD), and confluence of the right internal and external oblique line (LI). The length of the left mandibular body was established by measuring the distance from In to LI. The length of the right mandibular body was established by measuring the distance from In to LD (Figs 3, 4).

STATISTIC ANALYSIS

The collected data were stored and analyzed with SPSS statistical software, version 14.0 (SPSS, Chicago, IL), by use of descriptive statistics. We also used analysis of variance to compare lineal measurements between the 2 groups at 1, 2, and 3 months with 95% reliability.

Results

All 10 mandibles were measured from In to LD and from In to LI (Fig 4) and grouped according to timing as follows: preoperatively; immediately after surgery; and 1, 2, and 3 months postoperatively. Using a 2-way analysis of variance, we found no statistically significant differences between the control and experimental groups ($P = .95$) when comparing the mandibular length preoperatively; immediately after surgery; and 1, 2, and 3 months later (Figs 5, 6).

When we compared the length of the mandible using measures of central tendency preoperatively and immediately after surgery, there were no statistically significant differences between the evaluated groups (Fig 7). In the same manner, we found no statistically significant differences when comparing postsurgical growth at 1, 2, and 3 months.

Discussion

Facial fractures while patients are growing are rare, and they are determined by factors such as bone resistance, development of paranasal sinuses, and facial volume.[27,28] In the management of the traumatized patient, it is important to consider the fact that

FIGURE 3. Cephalocaudal projection.

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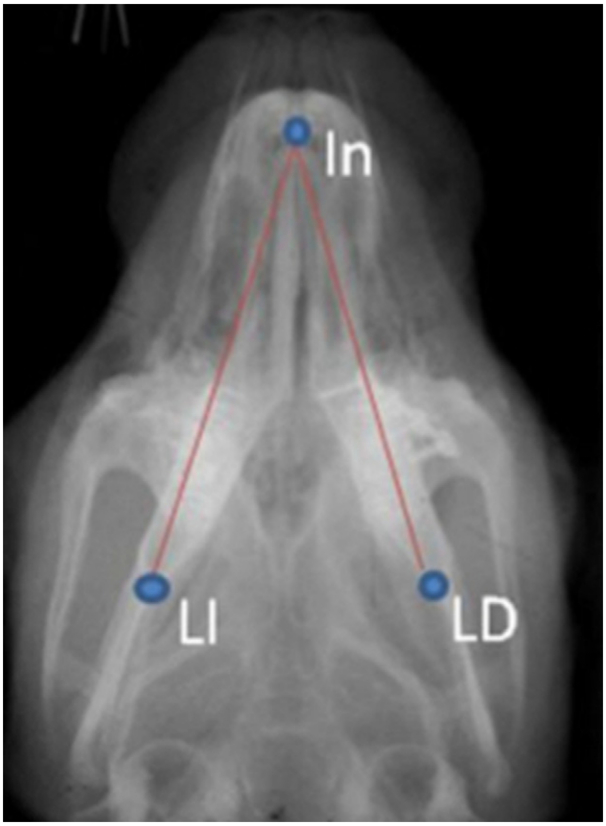

FIGURE 4. Cephalometric points: interincisal (In), left confluence (LI), and right confluence (LD).

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the rates of osseous remodeling and bone healing in the pediatric population are higher and faster when compared with adults; this minimizes immobilization times when reducing fractures by conservative means.[21,29,30] Mandibular fractures in children can be treated by many methods, ranging from mere observation and pain medication to open reduction with titanium miniplates and screws,[11-13,18-21] a method that is widely used in adults but is not so popular in children mainly because of the risk of damaging the tooth buds and the potential negative effects on growth and development. Whether internal rigid fixation interferes with normal growth or not has not been completely elucidated.[31] To solve this concern, bioabsorbable miniplates and screws were developed during the early 1990s; however, today, we still do not know whether they have a true advantage over their titanium counterparts because of the lack of evidence-based literature.

Various authors have suggested that internal rigid fixation with titanium miniplates, as well as plates and screws, may alter the growth pattern when used in patients whose osseous development is not complete.[21,27,28,31,32] This premise, however, is not supported by current evidence because the results of available studies are equivocal.[11] Nevertheless, authors such as Posnick et al,[11] Infante Cossio et al,[12] Haugh and Foss,[13] and Iida and Matsuya[14] have either used or reported the placement of internal rigid fixation in pediatric mandibular fractures. In the midst of this controversial topic, 1 old medical principle stands out: the importance of individualizing each patient[33] with an exhaustive medical history that takes into account all factors that may affect the treatment plan and its course. Another key decisive factor when approaching such cases is open discussion with the child's family regarding the pros and cons of each method. According to Myall,[34] there are 4 objectives of treatment during management of mandibular fractures in children: *1)* to obtain osseous union; *2)* to stabilize the occlusion; *3)* to restore normal form and function; and *4)* to avoid impediments to normal growth.

Clinical factors such as age, degree of tooth bud development, type and site of fracture, and nonclinical variants (ie, socioeconomic status, ethnicity, availability of appropriate hospitals or medical personnel, and religion) play a role in determining the best approach.

The great majority of condylar and subcondylar fractures can be treated adequately in a nonsurgical way, because open reduction with internal rigid fixation rarely is indicated. For displaced fractures of the body or symphysis, closed reduction and immobilization are usually performed. The exact method of immobilization is determined by the child's chronologic age and the stage of dental development.[19,20]

Closed or open reduction with either circummandibular wires or monocortical microplates at the inferior border of the mandible to avoid the tooth buds can be performed. Usually, this offers a more efficient

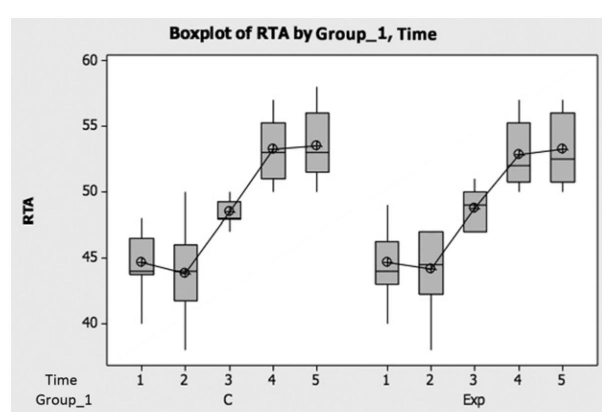

FIGURE 5. Analysis of variance. (C, control group; Exp, experimental group.)

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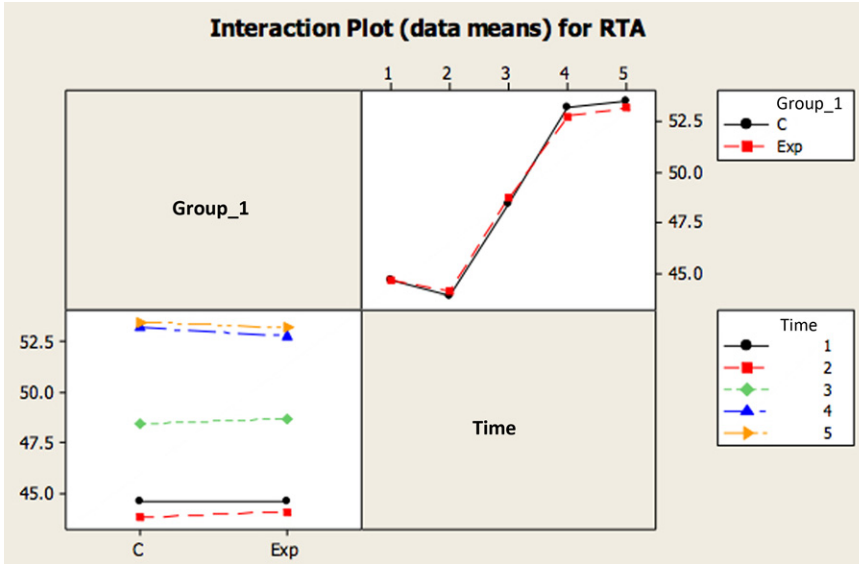

FIGURE 6. Measures of central tendency. (C, control group; Exp, experimental group.)

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and stable method of reduction.[35] Kaban[16] recognizes that with the current availability of miniplates and microplates, it is now possible to achieve open reduction and internal rigid fixation without damaging the tooth buds in fractures of the symphysis or the parasymphysis in mixed-dentition patients, once the incisors and/or canines have erupted beyond the posterior border. Open reduction and direct fixation also may be used in the ramus, body, and angle. Posnick et al[11] advocate for the use of titanium miniplates along the inferior border of the mandible, avoiding complications such as tooth bud injury.

It is well understood that fractures at the mandibular angle are not properly immobilized by a mandibular splint alone. Therefore closed reduction and intermaxillary fixation for 3 weeks are required. In their authoritative book, Kaban and Troulis[20] concluded that meaningfully displaced mandibular fractures are reduced and immobilized using rigid internal fixation in concordance to the same principles used in adults. Despite the fact that many authors have reported the successful use of internal rigid fixation in growing patients, closed reduction and immobilization comprise the standard during the period of deciduous dentition. The unquestionable risk of damaging the tooth buds, the low modulus of elasticity of bone in children, and the possible changes in growth are the foundation on which this paradigm rests.

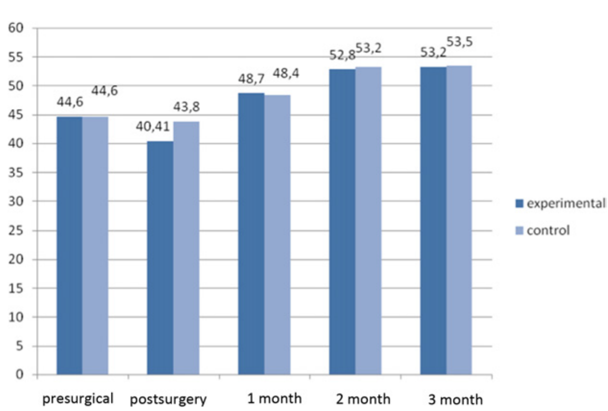

FIGURE 7. Comparison between experimental and control groups using measures of central tendency.

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The purpose of our study was to determine whether rigid internal fixation interferes with mandibular development in growing rabbits with induced mandibular fractures. New Zealand white rabbits have a bulbous condyle, being responsible for growth of the vertical ramus by a process of endochondral ossification. While the condyle expands, the adjacent neck takes its place, allowing development. The ramus moves posteriorly to permit further elongation of the mandibular body. Studies have shown that the periosteal outward along the gonial angle is depository, which allows for growth increase in a downward direction. The upper surface of the angular process is essentially resorptive. Not only the lingual but also the labial sides are depository. Periosteal bone deposits in these areas help increase the size of the body in proportion to the overall size of the entire growing mandible. The maximum mandibular development known for these types of rabbits is achieved before the third month.[36-38]

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