J Mater Sci: Mater Med (2006) 17:945–948
DOI 10.1007/s10856-006-0184-9

Morphometric analysis of the effects of LactoSorb® bioabsorbable plates on the craniofacial growth of rabbits using computed tomography

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Received: 30 March 2005 / Accepted: 23 August 2005

Abstract This study investigated the effect of bioabsorbable plates and titanium microscrews on the growth of the craniofacial skeleton of rabbits (*Oryctolagus cuniculus*) in the neonatal period. All animals underwent surgery at seven weeks of age and were killed at twenty-four weeks. In the study group, LactoSorb® plate and PROMM® titanium microscrews were positioned across the coronal suture. In the control group, only PROMM® titanium microscrews were attached to the cranium. Computed tomography was used to obtain morphometric measurements of volume. Results showed no significant intergroup ($P \leq 0.05$) or intragroup (control group $P \leq 0.01$; study group $P \leq 0.05$) differences in craniofacial volume. Under the experimental conditions of this study, bioabsorbable plates did not affect neonatal growth of craniofacial volume in rabbits.

Introduction

Facial fractures in growing patients have distinctive characteristics [1, 2]. The low incidence of this type of fracture may be assigned to a number of age-related factors, such as low cranial-to-facial volume ratio, [3, 4], bone resilience [5], underdevelopment of paranasal sinus [2] and the protected environment that surrounds children in their first years of life [6].

Controversies in the management of these fractures may be assigned to the anatomic features [4, 7] and the dynamic physiology and morphology of these growing patients. The difficulty in comparing the different studies in the literature also contributes to the lack of a consensus in the treatment of these fractures [3]. The use of metal plates for internal fixation in children may result in complications, such as growth restriction [8] and plate displacement [9]. Several experimental studies investigated the use of rigid fixation materials in growing animals, and their results also suggest that these materials may be a restrictive factor to the normal development of craniofacial bones [10, 11].

These disadvantages led many researchers to investigate alternative techniques for the management of facial fractures in growing patients [12–14]. In 1995, the use of an absorbable material, which had the same resistance as titanium for at least six weeks, predictable absorption, and did not trigger inflammatory or foreign body reactions, was suggested [15]. In 1996, this material, which is a copolymer of poly-L-lactic and polyglycolic acid at an 82:18 ratio (Lactosorb®—Walter Lorenz Surgical®. Jacksonville, Fl, USA), was approved by the *United States Food and Drug Administration* (FDA) [16].

The purpose of this study was to investigate, using computed tomography for morphometric analysis, whether postnatal growth potential of the craniofacial volume of rabbits (*Oryctolagus cuniculus*) is compromised by the use of Lactosorb® bioabsorbable plates and titanium microscrews applied in fast bone growth zones.

Materials and methods

Twenty white male New Zealand rabbits (*Oryctolagus cuniculus*) were divided in two groups of 10 (study and control) and were weighed weekly during the study. The

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animals underwent surgery at seven weeks of age. Preoperative medication was penicillin G benzathine (Benzetacil® 60000 UI, Eurofarma Laboratórios Ltda., São Paulo, Brazil), and anesthetic medication was xylazine, (Kensol®, Laboratório König do Brasil Ltda., São Paulo, Brazil) and tiletamine and zolazepam (Zoletil® Virbac do Brasil Indústria e Comércio Ltda., São Paulo, Brazil).

In the study group a linear incision was made on the head of the animal, and the bone surface of the cranium was visualized. A bioabsorbable LactoSorb® plate with four holes, 25 mm long and 0.75 mm thick in its reinforced portion and 0.25 mm thick in its central portion, was selected and properly adapted to the convex surface of the cranium. The plate was positioned on the right side, parallel to and at a distance of 5 mm from the sagittal suture, traverse to and with two holes on each side of the coronal suture. It was attached with four PROMM® (Indústria de Materiais Cirúrgicos Ltda., Porto Alegre, Brazil) titanium screws 3.5 mm long and 1.5 mm in diameter. In the control group, only 2 PROMM® titanium screws were placed in each animal. The screws were positioned using a titanium plate with 4 holes in the same position as the plate in the study group, and the two outermost holes of the plate were used to position the two screws. At 24 weeks of age, the animals were killed with a potassium chloride intracardiac injection under anesthesia. They were beheaded and volume morphometric measurements of their heads were obtained using CT images.

A Picker PQ5000® helical CT scanner (Marconi Medical Systems of Brasil Ltda., Brazil) was used for image acquisition. Polystyrene blocks and adhesive tape were used to position the heads of the animals so that an imaginary line from tragus to auricle was perpendicular to the ground, and a collimated light beam from the scanner was used to confirm positioning. The head was scanned, and axial images were acquired in multislice mode, at 120 kV, 100 MA, and using a bone window. Scanning settings were: 1.5 s exposure time, 1.0 mm slice thickness and 1.0 mm increment. Mean number of slices was 65.2 ± 3.69.

A Voxel-Q workstation was used for image processing, and image densities were standardized by setting window at zero and level at 210. All craniofacial bone images were defined as interest areas and were reformatted for the three-dimensional mode (Fig. 1). Using the *Measurements* tool of the software, the option *Statistics* was selected for calculation of total three-dimensional volume (Vt). Partial volume, on each side of the craniofacial skeleton, was also analyzed. The axial image where the foramen magnum was best visualized was selected for analysis. The craniofacial midline was determined by tracing a straight line from the posterior to the anterior points of larger convexity of the magnum foramen. A new area of interest was determined from the midline to the lateral-most point to the midline. The right side of the craniofacial area was selected and the *Measurements* and *Statistics* tools were again used for the analysis of right side volume (Vr). Partial left side volume (Vl) was calculated by the subtraction of right side volume from total volume (Vl = Vt-Vr).

The SPSS® software (version 10.0 for Windows, Inc., Chicago, USA.) was used for statistical analysis. Repeated measures Analysis of Variance (ANOVA) was used for comparison of weight between groups ($P \leq 0.05$); one-way ANOVA at a significance level of $P \leq 0.05$ was used for total volume analysis. A paired *t* test and significance level of $P \leq 0.01$ for the control group and of $P \leq 0.05$ for the study group were used for partial volume analysis.

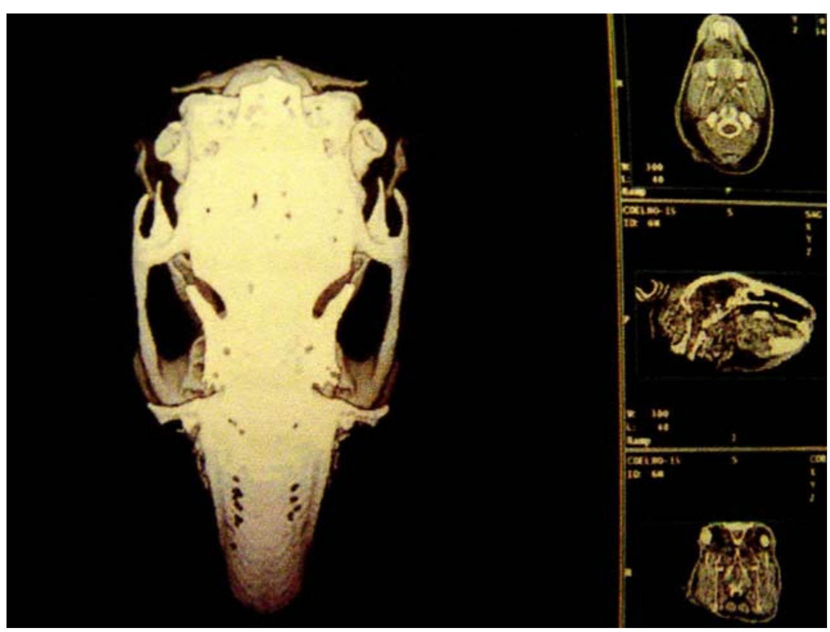

Fig. 1 Three-dimensional CT image of craniofacial skeleton.

Table 1 Total cranial volume (cm^3) according to intergroup morphometric analysis$^+$

Specimen	Control Group	Study Group
1	24.30	26.13
2	25.73	28.52
3	28.08	27.31
4	27.15	29.61
5	24.71	26.41
6	28.85	25.47
7	24.14	23.70
8	27.64	27.32
9	31.10	28.81
10	27.11	25.66

$^+$No statistically significant difference between groups ($P \leq 0.05$).

Table 2 Partial cranial volume (cm^3) according to intragroup morphometric analysis

	Control Group$^+$		Study Group^{++}	
Specimen	Left	Right	Left	Right
1	11.46	12.84	12.21	13.45
2	12.53	13.20	12.71	13.42
3	13.53	14.55	16.30	12.22
4	13.69	13.46	13.10	14.21
5	13.39	13.72	14.29	15.32
6	11.43	12.35	12.61	13.80
7	13.64	15.21	13.07	12.40
8	12.55	11.59	12.27	11.43
9	13.58	13.94	13.08	14.24
10	15.70	15.4	16.55	12.26

$^+$ No statistically significant differences ($P \leq 0.01$).
$^{++}$ No statistically significant differences ($P \leq 0.05$).

Results

At the beginning of the study, all animals were 5 weeks of age and weighed 551 ± 63.57 g in the control group and 488.89 ± 81.31 g in the study group. Animals underwent surgery at 7 weeks of age and were killed at 24 weeks, when their mean weight was 3156.11 ± 315.04 g in the control group and 2951.82 ± 322.86 g in the study group. Repeated measures ANOVA was used to evaluate weight differences between groups during the study, and results showed no significant statistic differences at $P \leq 0.05$.

Mean total volume was 26.89 ± 0.85 cm^3 in the study group and 26.89 ± 0.83 cm^3 in the control group. Results of one-way ANOVA showed no significant statistic differences in mean total volume between groups at $P \leq 0.05$, where $P = 1.0$ (Table 1).

The paired t test was used to compare partial left and right volumes for each animal in the control and in the study group. In the control group, mean left volume was 13.15 ± 1.25 cm^3 and mean right volume was 13.63 ± 1.25 cm^3, and these results were not statistically different for $P \leq 0.01$, where $P = 0.092$. In the study group, mean left volume was 13.62 ± 1.59 cm^3, and mean right volume was 13.28 ± 1.18 cm^3, and these results were not statistically significant either for $P \leq 0.05$, where $P = 0.092$ (Table 2).

Discussion

Studies have demonstrated that internal metal fixation may be a factor of craniofacial growth restriction. Therefore, internal fixation systems that retain the benefits of metal devices but do not offer the risks of growth restriction have been investigated. Bioabsorbable plates made of homopolymers, such as polyglycolic acid (PGA), poly-L-lactic acid (PLLA), polydioxanone (PDS) and their copolymers, seem to be the most promising materials [17, 18]. The bioabsorbable properties of these materials may affect bone growth less than any other fixation material [19].

The effects of internal metal and bioabsorbable fixation materials on craniofacial skeleton can be evaluated using different methods, such as: (1) direct measurement using a caliper [20]; (2) direct measurement using teleradiography [8, 10, 21]; (3) computed cephalometry [22]; and (4) computed tomography [23].

Rabbits have been used as an animal model in several studies about the use of internal bioabsorbable fixation materials to avoid the problems associated with internal metal fixation in growing patients [15, 18, 24]. However, results from animal and human studies are not directly related—craniofacial growth patterns, for example, are different for each species—and special care should be taken when comparing results of these studies [20].

The use of bioabsorbable plates on the human craniofacial skeleton has been reported by many authors. Most results did not show changes or complications associated with the use of these plates, which have been considered a safe material for pediatric use [19, 25–27].

In this study, morphometric measurements of volume using computed tomography were obtained for the craniofacial skeleton of rabbits. The comparison between mean total volume in study and control groups and between mean partial (left and right) volumes between specimens in the same group did not reveal any statistically significant differences. This suggests that the side that received an absorbable plate (right side) and the side that did not (left side) had similar growth, with no difference in total volume.

However, bone growth may have been restricted around the plate, but total craniofacial volume may have been the same due to compensatory changes in other areas of the skeleton. Such possible changes may not be detected by the type of morphometric analysis conducted in this study because the basis for craniofacial volume calculation was the entire image. Under the experimental conditions of this study, the use of LactoSorb® bioabsorbable plates did not affect normal neonatal growth of the craniofacial skeleton of rabbits.

References

1. S. P. BARTLETT and J. P. DE LOZIER, Controversies in the management of pediatric facial fractures. *Clin. Plast. Surg.* **19** (1992) 245–58.
2. J. C. POSNICK, Management of facial fractures in children and adolescents. *Ann. Plast. Surg*. **33** (1994) 442–57.
3. J. C. POSNICK, M. WELLS and G. E. PRON, Pediatric facial fractures: evolving patterns of treatment. *J. Oral Maxillofac. Surg*. **51** (1993) 836–44.
4. P. J. KOLTAI and D. RABKIN, Management of facial trauma in children. *Pediatr. Clin. North. Am*. **43** (1996) 1253–75.
5. N. TANAKA et al., Maxillofacial fractures in children. *J. Craniomaxillofac. Surg.* **21** (1993) 289–93.
6. J. M. SCHWEINFURTH and P. J. KOLTAI, Pediatric mandibular fractures. *Facial Plast. Surg*. **14** (1998) 31–44.
7. L. B. KABAN, J. B. MULLIKEN and J. E. MURRAY, Facial fractures in children: an analysis of 122 fractures in 109 patients, *Plast. Recontr. Surg*. **59** (1977) 15–20.
8. B. L. EPPLEY, J. M. PLATIS and M. D. SADOVE, Experimental effects of bone plating in infancy on craniomaxillofacial skeletal growth. *Cleft Palate Craniofac. J.* **30** (1993) 164–9.
9. J. A. FEARON, I. R. MUNRO and D. A. BRUCE, Observations on the use of rigid fixation for craniofacial deformities in infants and young children. *Plast. Reconstr. Surg*. **95** (1995) 634–7.
10. J. W. POLLEY et al., Effect of rigid microfixation on the craniomaxillofacial skeleton. *J. Craniofac. Surg*. **6** (1995) 132–8.
11. S. M. CONNELLY and R. J. H. SMITH, Effects of rigid plate fixation and subsequent removal on craniofacial growth in rabbits. *Otolaryngol. Head Neck Surg.* **124** (1998) 444–8.
12. L. GETTER et al., A biodegradable intraosseous appliance in the treatment of mandibular fractures. *Oral Surg*. **30** (1972) 344–8.
13. J. P. B. BOUWMAN, D. B. TUINZING and P. J. KOSTENSE, A comparative in vitro study on fixation of sagittal split osteotomies with Würzburg® screws, Champy® miniplates and Biofix® (biodegradable) rods. *Int. J. Oral Maxillofac. Surg.* **23** (1994) 46–8.
14. P. TÖRMÄLÄ, T. POHJONEN and P. ROKKANEN, Bioabsorbable polymers: materials technology and surgical applications. *Proc. Inst. Mech. Eng.* **212** (1998) 101–11.
15. B. L. EPPLEY and M. D. SADOVE, A comparison of reabsorbable and metallic fixation in healing of calvarial bone grafts. *Plast. Reconstr. Surg*. **96** (1995) 316–22.
16. W. S. PIETRZAK, M. L. VERSTYNEN and D. R. SARVER, Bioabsorbable fixation devices: status for the craniomaxillofacial surgeon. *J. Craniofac. Surg*. **8** (1997) 92–96.
17. J. W. LEENSLAG et al., Resorbable materials of poly (L-lactide). VI. Plates and screws for internal fracture fixation. *Biomaterials* **8** (1987) 70–3.
18. S. R. THALLER, V. HUANG and H. TESLUK, Use of biodegradable plates and screws in a rabbit model. *J. Craniofac. Surg*. **2** (1992) 168–73.
19. J. A. GOLDSTEIN, F. A. QUERESHY and A. R. COHEN, Early experience with biodegradable fixation for congenital pediatric craniofacial surgery. *J. Craniofac. Surg*. **8** (1997) 110–5.
20. J. I. RESNICK, B. M. KINNEY and H. K. KAWAMOTO JR, The effect of rigid internal fixation on cranial growth. *Ann. Plast. Surg*. **25** (1990) 372–4.
21. F. CARINCE et al., Histomorphological analysis of the effect of the rigid fixation on growing sutures in the rabbit. *J. Craniomaxillofac. Surg*. **22** (1994) 109–13.
22. M. P. MOONEY et al., Plate fixatio of the premaxillary suture and compensatory midfacial growth changes in the rabbit. *J. Craniofac. Surg*. **3** (1992) 197–202.
23. N. K. SINSEL, P. J. GUELINCKX and H. OPDEBEECK, Effect of nerve repair after unilateral partial facial paralysis on craniofacial growth and development. *Plast. Reconstr. Surg*. **104** (1999) 445–63.
24. A. TSCHAKALOFF et al., Degradation kinetics of biodegradable DL-polylactic acid biodegradable implants depending on the site of implantation. *Int. J. Oral Maxillofac. Surg.* **23** (1994) 443–5.
25. A. V. KUMAR et al., Bioabsorbable plates and srews in pediatric craniofacial surgery: a review of 22 cases. *J. Craniofac. Surg.* **8** (1997) 97–9.
26. B. L. EPPLEY, M. D. SADOVE and R. J. HAVLIK, Resorbable plate fixation in pediatric craniofacial surgery. *Plast. Reconstr. Surg*. **1** (1997) 1–7.
27. W. THARANON et al., Surgical outcomes using bioabsorbable plating systems in pediatric craniofacial surgery. *J. Craniofac. Surg.* **9** (1998) 441–44.