In vitro resistance of titanium and resorbable (poly L-co-DL lactic acid) osteosynthesis in mandibular body fracture

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Abstract. This study was a comparative evaluation of the bending resistance of metallic and resorbable plates and screws in a mandibular body fracture model. Forty polyurethane synthetic hemimandibles were used; a vertical linear cut was made between the second and first premolars. These 40 hemimandibles were divided into four groups of 10 and were fixed with titanium plates and screws or resorbable plates and screws, with monocortical screws in the upper sector and bicortical screws in the lower sector. Bending resistance tests were done on a universal testing machine with a linear displacement speed of 1 mm/min, a cell load of 500 N, and a load cell on the lower central incisor or on the lower second premolar. Results were analyzed using the Student’s t-test, with the significance level set at 5%. No statistically significant differences were observed between the groups studied, either in the analysis of the osteosynthesis materials or related to the load-bearing points. The variables of displacement and peak load did not present any significant differences. In this in vitro model of a mandibular body fracture, the mechanical behaviour of a resorbable osteosynthesis was similar to that of a titanium osteosynthesis.

Key words: osteosynthesis; mandible fracture; resorbable material; titanium.

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Surgical treatment of a mandibular body fracture is done with maxillomandibular fixation or surgically with plates and screws. The latter has advantages, such as the possibility of primary bone repair, the rapid re-establishment of function, and the elimination of postoperative intermaxillary fixation.

Surgical treatment has been the choice in many cases, with good results. One of the options for osteosynthesis in the area of tension and compression has been employed with great success and has demonstrated great versatility when different types of systems are used with monocortical or bicortical screws, depending on the area of approach.

Different technologies, including resorbable internal fixation systems, have been used in different cases of maxillofacial surgery with good results. In terms of bone repair, the observations in animal models treated with resorbable materials have been positive. Suuronen treated rabbit models of condylar fracture using resorbable and metallic screws, demonstrating adequate bone repair with the different treatments applied. Suuronen et al., in a sheep model of mandibular body fractures treated with metallic and...
resorbable systems, concluded that there was adequate bone repair in both groups. Quereshy et al.\textsuperscript{10} also treated models of mandibular fractures in dogs using resorbable and metallic systems, concluding that the bone repair was similar in the two groups when the X-ray and histological studies of the animals were analyzed.

Resorbable materials have been applied in patients for more than 20 years. Bergsm et al.\textsuperscript{11} used resorbable systems in zygomatic bone fractures, where after 3 years only four subjects presented episodes of increased facial volume, opting for removal of the elements installed; the authors concluded that the chemical and biological characteristics of the materials could be the cause of this complication. Ylikontiola et al.\textsuperscript{12} treated patients with mandibular fracture by means of resorbable systems, confirming the efficacy of these systems in this type of clinical situation. A more critical stance was taken by Wittwer et al.\textsuperscript{13} who showed that in 24.5% of zygomatic bone fractures it was necessary to stabilize the fractures with metallic plates since the resorbable plates were not able to stabilize the fractures.

The mechanical stability of resorbable plates have also been considered in some areas of maxillofacial surgery,\textsuperscript{14–16} where mandibular body osteotomies or the simulation of a mandibular body fracture have not been sufficiently studied. Mandibular body fractures suggest complex mechanical conditions whenever there is a high demand for the attached muscles, as well as a high demand for the postoperative functional stress.\textsuperscript{17}

The aim of this investigation was to compare the bending resistance of resorbable and metallic systems in a mandibular body fracture model.

Materials and methods

Forty rigid polyurethane replica hemimandibles with teeth, with a density of 200 g/l, were used (Nacional, Jau, SP, Brazil). A linear cut was made in each hemimandible starting between the second premolar and the first premolar of each sample, advancing perpendicularly to the surface and axially to the root of the first premolar; the cut was made with a Stryker reciprocating saw blade.

Analysis group

The osteosynthesis systems used in this study were 4-hole straight plates with screws made from an amorphous poly l-co-dl lactic acid 70:30 copolymer developed by the Department of Materials Engineering at the State University of Campinas, Brazil. In order to determine the width of the lower sector of the mandible, a measurement was taken with a digital Vernier calliper, determining a width of 11 mm in this sector; it was decided that 12-mm screws should be used in the basal region of the mandible, as exemplified by the use of bicortical fixation.

The analysis groups are described in Table 1. In order to establish the exact position of the metallic and resorbable plates and screws, surgical guides made of chemically actuated colourless acrylic resin were used (Dental Vipi Ltda, Pirassununga, SP, Brazil). These were generated from the manufacturer’s hemimandible in both metallic and resorbable fixations (Fig. 1). Each hemimandible was fixed as per the manufacturer’s instructions, using screws in the metallic system and screws with a self-drilling tap in the resorbable system. The plates did not need manipulation or adjustment because the installation area was flat, with the screws being installed perpendicularly to the surface of the analysis substrate.

Finally, the hemimandibles were mounted in a fixed acrylic system in the posterior sector of the mandibular ramus to standardize the 40 hemimandibles; stabilization was standardized in the mandibular ramus and condyle, and subsequently installed for the mechanical test (Fig. 2).

Mechanical test

The mechanical test was undertaken using a pressure device with a rounded working part, applying pressure at the central point of the lower central incisor (Fig. 3) or the central fossa of the lower second premolar (Fig. 4). A universal test machine was used (Instron, Norwood, MA, USA: mod. 4411), programmed with a linear displacement speed of 1 mm/min with a load cell of 500 N.

Application of the progressive load system obtained load resistance values (peak load) measured in kilogram-force (kgf); displacement values were measured in millimetres (mm) and the total displacement analyzed was 10 mm.

Statistical analysis

The data collected were subjected to analysis of variance (ANOVA) and then a Student’s t-test was applied. Statistical significance was set at $P < 0.05$.

Results

Testing of the four groups was performed with no difficulties, in accordance with the

<table>
<thead>
<tr>
<th>Group</th>
<th>Material</th>
<th>Tension area</th>
<th>Compression area</th>
<th>Incidence of force</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Metallic</td>
<td>Plate 2.0</td>
<td>Plate 2.0</td>
<td>Lower central incisor</td>
</tr>
<tr>
<td>2A</td>
<td>Metallic</td>
<td>4 screws (6 mm)</td>
<td>4 screws (12 mm)</td>
<td>Lower second premolar</td>
</tr>
<tr>
<td>1B</td>
<td>Resorbable</td>
<td>Plate 2.0</td>
<td>Plate 2.0</td>
<td>Lower central incisor</td>
</tr>
<tr>
<td>2B</td>
<td>Resorbable</td>
<td>4 screws (6 mm)</td>
<td>4 screws (12 mm)</td>
<td>Lower second premolar</td>
</tr>
</tbody>
</table>

Fig. 1. Hemimandible with metallic fixation in an acrylic model for unique plate positioning.

Fig. 2. Hemimandible with metallic fixation supported in the posterior area for standardized analysis.
Titanium vs. resorbable osteosynthesis

Fig. 3. Pressure device applying pressure at the central point of the lower central incisor; (a) resorbable system and (b) metallic system.

Fig. 4. Pressure device applying pressure at the central fossa of the lower second premolar; (a) resorbable system and (b) metallic system.

Table 2. Displacement (mm) and peak load (kgf) values for the study groups when loading was applied on the lower central incisor.

<table>
<thead>
<tr>
<th>Group</th>
<th>Displacement, mm Mean (SD)</th>
<th>Peak load, kgf Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A (metallic)</td>
<td>9.077 (0.86)</td>
<td>3.908 (1.162)</td>
</tr>
<tr>
<td>1B (resorbable)</td>
<td>8.110 (1.34)</td>
<td>3.720 (1.04)</td>
</tr>
<tr>
<td>P-value</td>
<td>0.064</td>
<td>0.778</td>
</tr>
</tbody>
</table>

SD, standard deviation.

Table 3. Displacement (mm) and peak load (kgf) values for the study groups when loading was applied on the lower second premolar.

<table>
<thead>
<tr>
<th>Group</th>
<th>Displacement, mm Mean (SD)</th>
<th>Peak load, kgf Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A (metallic)</td>
<td>6.875 (1.304)</td>
<td>5.412 (0.963)</td>
</tr>
<tr>
<td>2B (resorbable)</td>
<td>7.047 (1.692)</td>
<td>5.857 (1.719)</td>
</tr>
<tr>
<td>P-value</td>
<td>0.487</td>
<td>0.778</td>
</tr>
</tbody>
</table>

SD, standard deviation.

protocol proposed. However, for plate fixation, placement of the bicortical screw was more difficult in the resorbable system than in the metallic system.

When force was applied on the lower central incisor, the titanium plate group showed greater displacement (mean 9.077 mm) than the resorbable group (mean 8.110 mm). In contrast, when the force was applied on the lower second premolar, the resorbable plate group showed greater displacement (mean 7.047 mm) than the titanium plate group (mean 6.875 mm). The same observations were made in relation to peak load.

On comparison of the tests, the displacement in the two groups loaded at the lower central incisor level presented no significant difference (P = 0.084) (Table 2). At the level of the lower second premolar, there was also no significant difference between the two groups (P = 0.487) (Table 3).

The peak load values obtained did not differ significantly between the metallic and resorbable groups when loading occurred at the level of the lower central incisor (P = 0.776), or when loading occurred at the level of the lower second premolar (P = 0.778).

Discussion

Polyurethane mandibles were chosen for this research in order to standardize the analysis of samples and to avoid problems that occur with cadaver or animal mandibles, where standardization of the substrate is difficult. Our investigation was completed without difficulties and in accordance with the established protocol. The analysis variables were standardized, such as the installation position of the plates, the type of substrate, and stabilization of the posterior sector of the mandible, making methodological comparisons of this study possible.

Some disadvantages of metallic osteosynthesis systems have been indicated, such as migration during growth, interference in the quality of some imaging tests, palpation, and thermal sensitivity. Resorbable materials have emerged as an alternative to limit these complications. Bell and Kindsfater analyzed the treatment of facial fractures with resorbable systems in 295 patients and found a 6% complication rate; many of these were not connected to the material used. By contrast, Laine et al. reported 10 years of experience performing orthognathic surgery with the resorbable osteosynthesis, demonstrating the efficacy of the system, although they indicated the need to complete a learning curve in the effective use of resorbable materials. Clinical studies using resorbable osteosynthesis have shown efficacy similar to that of the metallic systems.

The use of polylactic acid (PLA) and polyglycolic acid (PGA) lend biological and mechanical properties to the resorbable materials. Weiler et al. indicated that PLA offers moderate mechanical resistance and that PGA presents rapid production of polymer residues, so the development of the poly L-co-DL lactic acid 70:30 material, defined as copolymers of L-lactic acid and D-lactic acid, promotes greater bending resistance to the resorbable material.

The mechanical compression load study of Cilasun et al. used metallic and resorbable systems in sagittal osteotomies performed on lamb mandibles; no difference in either the mechanical behavior or the displacement generated in the distal segment was found between the systems. Alkan et al. obtained similar results when comparing metallic and resorbable systems in a condylar fracture model using a linear load model. Bayram et al. used a mandible angle fracture model for metallic and resorbable osteosynthesis using the Chapmy technique. They concluded that there was a lack of statistical difference between the different systems used. Our results have also shown no significant differences between the different points of application or the osteosynthesis models analyzed.

Other observations have been made by Shetty et al., who indicated that resorbable screws present a decrease in tensile strength despite the screw thread used in the perforation stage. In order to overcome this problem, the resorbable material used in this research included screws with flat crystals and a thread pitch of 1.2 mm, whereas the metallic system had screws with angled crystals and a thread pitch of 0.6 mm. In this study, alterations were not observed in the installation of the screws. Bregagnolo et al. analyzed the bending resistance of metallic and resorbable material in mandibular angle fractures using the Chapmy technique, showing some failures in the resorbable material such as stretching and plate fractures; nevertheless, the authors concluded that both systems were effective in the mechanical analysis. We did not observe any of the complications observed by Bregagnolo et al., likely due to the use of plates in the area of tension and compression.

The comparison of our results with those of other studies is made difficult by the variety of compositions of the resorbable materials used, variations in the morphology of the screws, and the absence of studies on mandibular body fractures with polyurethane substrate. Nevertheless, we conclude that the two osteosynthesis systems, metallic and resorbable, did not differ significantly when applied to in vitro models of mandibular body fracture.

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**Competing interests**

None declared.

**Ethical approval**

Not required.

**References**

23. Bayram B, Araz K, Uckan S, Balci C. Comparison of fixation stability of resorbable versus titanium plate and screw in...


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