In vitro mechanical assessment of 2.0-mm system three-dimensional miniplates in anterior mandibular fractures

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Abstract. This study constituted a comparative assessment of the mechanical resistance of square and rectangular 2.0-mm system three-dimensional miniplates as compared to the standard configuration using two straight miniplates. 90 polyurethane replica mandibles were used for the mechanical trials. Groups 1, 2, and 3 simulated complete symphyseal fractures characterized by linear separation of the central incisors; groups 4, 5, and 6 simulated parasympyseal fractures with an oblique configuration. Groups 1 and 4 represented the standard method with two straight miniplates set parallel to one another. Square miniplates were used in groups 2 and 5, and rectangular miniplates in groups 3 and 6. A universal testing machine set to a velocity of 10 mm/min and delivering a vertical linear load to the first left molar was used to test each group. Maximum load values and load values with pre-established dislocation of 5 mm were obtained and submitted to statistical analysis using a calculated reliability interval of 95%. The mechanical performances of the devices were similar, except in the case of rectangular plates used in the parasympyseal fractures. The innovative fixation methods used showed significantly better results in the case of symphyseal fractures.

In recent years, different methods have been proposed for the surgical treatment of mandibular fractures. Rigid internal fixation (RIF) is used to achieve a stable anatomical reduction, thereby reducing the risk of postoperative displacement of fractured bone fragments, avoiding the need for maxillomandibular fixation and favouring an early return to normal functioning. The mandible is subject to forces generated by the chewing muscles transmitted via the teeth and the temporomandibular joints. During treatment, tensions and deformations occur according to the distribution of the external forces and the properties and geometry of the material being used. It is well known that the mandible is normally subjected to tensioning forces on its superior border and compression forces on its inferior border. However, that is only true for fractures in the body and angle of the mandible; in the case of fractures in the symphyseal and parasympyseal regions, the opposite situation prevails and a single form of biomechanical behaviour can be expected for this latter region as a whole. Irrespective of the fixation method used, stability is a key factor for the successful...
treatment of the symphysal fracture.9,10 This can be evaluated by mechanical tests that simulate the forces that the mandibular fractures will be subjected to, making it possible to determine the resistance of the fixation material and the behaviour of the fractured region.4

The symphysal is one of the most common mandibular fracture sites, with reports of prevalence varying from 9% to 57%; it is only surpassed by fractures of the condyle or of the angle.8,9 Each mandibular region has its own peculiarities, including variations in the forces exerted by the chewing muscles, zones of fragility, and the possible presence of mechanical forces acting in different directions. These factors determine the extent of a region’s susceptibility to trauma and its propensity for a favourable response to treatment.3,11

Recent work done by Madsen et al.12 and by Oliveira and Passeri13 has involved the comparative biomechanical assessment of different fixation techniques applied to symphysal and parasymphysal mandibular fractures, but they did not make use of three-dimensional (3D) fixations.

Farmand11, who was the first to undertake a biomechanical investigation of 3D plates in 1996, studied the performance of a plate in the shape of the four sides of a square open in the middle. In his view, the device, which was fixed by screws, would foster stability in three dimensions, and its biomechanical characteristics were comparable to those of conventional miniplates. The open-centred square configuration would be the smallest possible one for a 3D plate component. In that study, the clinical results and investigations showed that 3D plates provided good stability during osteosynthesis associated with more complicated cases of mandibular fracture. The author also stated that the 1-mm profile of the connecting arms of the device made its adaptation to the bone without distortions easier, and that the untrammelled areas between the connecting arms ensured a good blood supply to the bone.

In spite of the small number of in vitro studies using 3D plates in fractures in the anterior region of the mandible, there are some authors who have reported the efficacy of the method. In two clinical studies, Jain et al. demonstrated the effectiveness of 3D miniplates for fixation in the treatment of mandibular fractures in that region and analysed their advantages and disadvantages over a 2-month follow-up period. In the configuration used in their work, the material used proved to be less costly and readily adaptable, as well as reducing the operation time and providing greater stability.12,13

While there have been some investigations using 3D plates as the fixation method, there is no scientific evidence concerning their use in the symphysal/parasymphysal region.4,8,14–17 Thus the present work was undertaken to perform a laboratory evaluation of the resistance and performance of square and rectangular 2.0-mm system 3D miniplates used to stabilize fractures in the anterior region of the mandible, as compared to the performance of standard pattern plates, namely two straight plates also of the 2.0-mm (screw diameter) system.

Materials and methods

For the purposes of this study, two rigid polyurethane mandible models with complete sets of teeth were prepared (Nacional Ososs, Jaú, São Paulo, Brazil) and two different ‘fractures’ in the form of cuts were made in them using a metal disc at low speed rotation. The ‘ostotomies’ simulated symphysal and parasymphysal fractures. The simulated symphysal fracture consisted of a linear cut in the centre of the mandible, from between the median incisors down to the basal part of the mandible. The parasymphysal fracture was represented by an oblique cut originating between the median incisors and going down in a slightly posterior direction to the base of the mandible on the right side. The two models were sent to the model company, which then produced 90 standardized replicas, 45 for each type of ‘fracture’.

Four hundred and eighty titanium–aluminium–vanadium alloy (Ti–6Al–V) screws (PROMM, Indústria de Materiais Cirúrgicos, Porto Alegre, Rio Grande do Sul, Brazil) were used, of which 240 were 6 mm long and 240 were 12 mm long, all compatible with the 2.0-mm system. 120 miniplates were used as follows: 60 straight four-hole miniplates that are the standard pattern for the 2.0-mm system, 30 square four-hole miniplates, and 30 rectangular four-hole miniplates. The square and rectangular miniplates were designed by the authors and made to order by the suppliers (PROMM, Indústria de Materiais Cirúrgicos).

Sample preparation

The rigid polyurethane mandibles were divided into six groups of 15 mandibles each for mechanical trials in accordance with a statistical design obtained using a programme for sample size determination (Diman 1.0); the confidence interval established was 95%.

The mandibular fractures in the replicas of groups 1 and 4 were stabilized using two straight four-hole miniplates of the 2-mm system on each. These were fixed in parallel, one in the superior position and the other in an inferior position, with care taken so that the superior plates were always lower than the level of the dental root apices. These two groups were considered to be the standard pattern or control groups. Fixation in groups 2 and 5 used square miniplates, and in groups 3 and 6, rectangular miniplates were used. Each square and rectangular miniplate was stabilized with four screws (Figs. 1–3). In all groups, the screws that were nearest to the dental apices were 6 mm long, while those inserted near the inferior border of the mandible were 12 mm long.

The three different fixation methods were used on both types of fracture, i.e., on the linear fracture (symphysal) and the oblique fracture (parasymphysal). The symphysal fracture was present in groups 1, 2, and 3, and the parasymphysal fracture in groups 4, 5, and 6.

To ensure uniformity in the miniplate positioning, each one was pre-moulded to the surface of the fractured mandible using specific bending tools and a standardized template, thereby diminishing the possibility of alterations among them that might result from manual preparation of the samples.

At the time of miniplate fastening, the semi-mandible was stabilized using drops of prefabricated self-polymerizing resin and the miniplates positioned to make perforation possible. The same operator carried out all perforations.

Mechanical testing

The equipment used for load testing was the Autograph AG-X 300 kN model of the Shimadzu Universal Mechanical Testing Machine (Shimadzu Corporation, Chiyoda, Tokyo, Japan). For testing purposes, a specifically designed clamp was constructed to stabilize the polyurethane mandible during the application of the test loads (Fig. 4). This clamp was perfectly adapted to tightly hold the posterior region of the right mandible, accommodating the border of the ramus from the angle to the condyle. To make testing feasible, a metal rod was prepared and adapted to the universal testing machine in such a way that the point of application of the test loads was aligned with the central fossa of the first left molar (Fig. 5).
The velocity of the load test was calibrated at 10 mm/min on the basis of the results of pilot studies experimenting with various velocities, and the test was orientated by the protocol used by Oliveira and Passeri. Two readings were obtained, one at the moment that the metal rod attained a displacement of 5 mm under the constant load applied to the system at the pre-established velocity, and the other was taken when the maximum load that the system could resist was attained. Values were registered in Newtons (N).

**Statistical analysis**

After the average of the load readings at 5 mm displacement of the rod and at maximum load had been obtained for all the study groups, the data were subjected to statistical analysis for quantitative and comparative purposes. The data were also analysed after grouping by type of simulated fracture cut. SPSS software was used for the analysis (SPSS version 19 for Windows; IBM Corp., Armonk, NY, USA), and the calculated confidence interval was 95% (95% CI).
Results

Load readings in Newtons were obtained for each sample in the symphyseal and parasymphyseal fracture groups at the moment that rod displacement reached the 5 mm mark.

For the symphyseal fractures, no statistically significant differences were observed in the average values and the standard deviations among the different types of fixation used. At that predetermined moment of displacement, the highest average value was obtained by group 1 (straight miniplates), followed by groups 2 (square miniplate) and 3 (rectangular miniplate), respectively (Table 1).

In the case of the parasymphyseal fractures, there was no statistically significant difference between groups 4 (straight miniplates) and 5 (square miniplate). However, the value in group 6 (rectangular miniplate) was significantly lower than in groups 4 and 5 (Table 2).

Next, the maximum load values (N) were obtained for the moment when the system still supported the load, but beyond which its resistance started to decrease showing that fixation failure had occurred.

In the case of the symphyseal fractures, the average values and the standard deviation values for maximum load showed that the maximum force attained and applied to the system was higher in group 1 (the standard or control group) than in groups 2 and 3. However, there were no statistically significant differences between groups 2 and 3 and the control group (Table 3).

In the case of the parasymphyseal fractures, the highest load resistance figure was obtained for group 4 (the control group), followed by group 5 and group 6. The difference between group 4 and group 5 was not statistically significant; however, the maximum load in group 6 was significantly lower than that in group 4. There was no statistically significant difference between group 5 and group 6 figures in this respect (Table 4).

When the two fracture groups (symphyseal vs. parasymphyseal) were compared, the maximum registered force supported by the system was found for the symphyseal fractures. The difference in maximum force measurements between the symphysis and parasymphyseis groups was statistically significant (Table 5).

Discussion

In vitro tests have been carried out to describe the biomechanical behaviour of supporting devices in a bid to validate the various modes of fixation. Although scientific research has been carried out to assess the biomechanical performance of the different fixation methods used in oral and maxillofacial trauma, there has been far less attention paid to fixation of the mandibular symphysis, and this is true even for the use of 3D fixation devices in that region.
Anatomically accurate models used as test specimens can effectively simulate physiological conditions.\textsuperscript{23} In the case of polyurethane, its modulus of elasticity, an important factor in choosing this type of material, is very similar to that of bony structures, thereby justifying its use in biomechanical testing. It has a value for this modulus of around 0.07 GPa, which places it within the range of values obtained for human bone: Cordey\textsuperscript{19} reported values ranging from less than 0.1 GPa in bone marrow to 2 GPa in cortical bone tissue.

The force mechanisms involved in chewing and the forces experienced by the bones involved are highly complex.\textsuperscript{19} Axial loads are those that produce compression forces or tensions in a structure.\textsuperscript{20,26} They act at points of contact that may serve as a screen or friction zone and consequently they may be influential in inducing rotation or displacement.\textsuperscript{19} In a clinical situation, it is important to be aware that effects of bending forces are far more important than those of axial forces.

The third type of force involved is torque, which produces or tends to produce rotation or twisting.\textsuperscript{20} It is known that bone is normally subject to tension forces on its upper border and compression forces on its lower border.\textsuperscript{6,8,17,24} However, that is only true for fractures in the body and angle of the mandible, and in the case of symphyseal and parasymphysial fractures, the opposite situation prevails. Thus a complex form of biomechanical behaviour can be expected for the region as a whole.\textsuperscript{6,16}

According to research conducted by Tams et al.\textsuperscript{25}, the symphyseal region has one of the highest negative moments of force (defined as being the reduction in the distance between the fragments on the alveolar border) as compared to other mandibular regions, and this generates great tension at the inferior border and compression at the superior border. These researchers found little evidence of shear forces in this region, but found that moments of force are more intensely present than in other regions. The same study reported that moments of flexure (bending) are 1.5 times greater than torque forces in the anterior region of the mandible.

Research using 3D models has proved that when loads are applied to chewing points in the posterior region of the mandible where the molar teeth are located, the greatest intensity of torque forces is found in the region of the symphysis. Furthermore, studies using 3D models have shown that the areas of tension and compression are not fixed but are liable to alternate with one another.\textsuperscript{6,18,26–28} Other studies evaluating the use of RIF have applied the forces to the region of the central incisors,\textsuperscript{29,30} which offers only a very small area of contact, making it difficult to accommodate the testing device and increasing the likelihood of its slipping from the point of contact and altering the results.\textsuperscript{19}

Our study took heed of the various recommendations made by Tams et al.\textsuperscript{25}, who determined the most effective positioning of the plates, and took particular care in the case of the superior border to respect the anatomical limits of the tooth root apices. However, due to the height of the anterior region of the test specimens and the fixed standard length of the vertical bars of the miniplates, it was not possible to insert the 3D devices onto the bone surface as high up as possible, which would have been more favourable for neutralizing torque. This means that ideally, to maximize efficiency, plates with a variety of dimensions should be available to the surgeon in order to address the anatomical variations that are found among individuals being treated.

**Table 1.** Force measurements at 5 mm displacement: symphyseal fracture.

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Average</th>
<th>SD</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>15</td>
<td>16.22</td>
<td>3.54</td>
<td>17.17</td>
<td>6.05</td>
<td>20.60</td>
<td>14.26–18.18</td>
</tr>
<tr>
<td>G2</td>
<td>15</td>
<td>15.32</td>
<td>3.20</td>
<td>16.50</td>
<td>7.68</td>
<td>19.79</td>
<td>13.54–17.09</td>
</tr>
<tr>
<td>G3</td>
<td>15</td>
<td>13.85</td>
<td>1.18</td>
<td>13.45</td>
<td>11.92</td>
<td>16.16</td>
<td>13.20–14.51</td>
</tr>
</tbody>
</table>

G1, straight miniplates; G2, square miniplate; G3, rectangular miniplate; SD, standard deviation; CI, confidence interval.

**Table 2.** Force measurements at 5 mm displacement: parasymphysial fracture.

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Average</th>
<th>SD</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>G4</td>
<td>15</td>
<td>12.48*</td>
<td>2.19</td>
<td>12.49</td>
<td>7.20</td>
<td>16.83</td>
<td>11.27–13.70</td>
</tr>
<tr>
<td>G5</td>
<td>15</td>
<td>12.59*</td>
<td>3.19</td>
<td>11.54</td>
<td>7.68</td>
<td>18.50</td>
<td>10.82–14.36</td>
</tr>
<tr>
<td>G6</td>
<td>15</td>
<td>9.10*</td>
<td>2.09</td>
<td>9.30</td>
<td>3.62</td>
<td>11.54</td>
<td>7.94–10.25</td>
</tr>
</tbody>
</table>

G4, straight miniplates; G5, square miniplate; G6, rectangular miniplate; SD, standard deviation; CI, confidence interval.

* Differences between the results marked with the letters ‘a’ and ‘b’ are statistically significant. Statistical testing was based on the calculated 95% CI.

**Table 3.** Maximum force measurements for the groups with symphyseal fractures.

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Average</th>
<th>SD</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>15</td>
<td>26.88</td>
<td>5.42</td>
<td>27.13</td>
<td>12.02</td>
<td>35.38</td>
<td>23.88–29.89</td>
</tr>
<tr>
<td>G2</td>
<td>15</td>
<td>22.24</td>
<td>4.09</td>
<td>22.89</td>
<td>15.35</td>
<td>29.04</td>
<td>19.97–24.51</td>
</tr>
<tr>
<td>G3</td>
<td>15</td>
<td>22.86</td>
<td>2.26</td>
<td>22.79</td>
<td>19.17</td>
<td>28.32</td>
<td>21.61–24.11</td>
</tr>
</tbody>
</table>

G1, straight miniplates; G2, square miniplate; G3, rectangular miniplate; SD, standard deviation; CI, confidence interval.

**Table 4.** Maximum force measurements for the groups with parasymphysial fractures.

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Average</th>
<th>SD</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>G4</td>
<td>15</td>
<td>19.53*</td>
<td>3.50</td>
<td>20.50</td>
<td>12.35</td>
<td>27.23</td>
<td>17.59–21.47</td>
</tr>
<tr>
<td>G5</td>
<td>15</td>
<td>17.34*</td>
<td>4.80</td>
<td>16.59</td>
<td>9.35</td>
<td>25.27</td>
<td>14.68–20.00</td>
</tr>
<tr>
<td>G6</td>
<td>15</td>
<td>15.30*</td>
<td>3.12</td>
<td>15.69</td>
<td>8.10</td>
<td>19.17</td>
<td>13.57–17.03</td>
</tr>
</tbody>
</table>

G4, straight miniplates; G5, square miniplate; G6, rectangular miniplate; SD, standard deviation; CI, confidence interval.

* Differences between the results marked with the letters ‘a’ and ‘b’ are statistically significant. Statistical testing was based on the calculated 95% CI.

**Table 5.** Maximum force measurements grouped by the two types of fracture.

<table>
<thead>
<tr>
<th></th>
<th>No.</th>
<th>Average</th>
<th>SD</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symphysis</td>
<td>45</td>
<td>23.99*</td>
<td>4.54</td>
<td>23.70</td>
<td>12.02</td>
<td>35.38</td>
<td>22.63–25.36</td>
</tr>
<tr>
<td>Parasymphysis</td>
<td>45</td>
<td>17.39*</td>
<td>4.17</td>
<td>17.69</td>
<td>8.10</td>
<td>27.23</td>
<td>16.17–18.64</td>
</tr>
</tbody>
</table>

SD, standard deviation; CI, confidence interval.

a,b Difference is statistically significant. Statistical testing was based on the calculated 95% CI.
Up until now there have been very few reports published in the literature of studies comparing fixations using standard miniplates of the Champty et al. type and those using 3D miniplates in the treatment of mandibular fractures, to identify their respective advantages and disadvantages. Square and rectangular miniplates do have a disadvantage at the moment of moulding to the bone surface, as they have to be bent to their dimensions, whereas the linear plates only have to be bent in two. It is more difficult to get a perfect adaptation with the 3D plates than with the linear ones because they are objects in the form of a plane that need to be adapted to a curved surface and not just an object in the form of a straight line. This was corroborated in the present study.

The advantage of the 3D plates is that they provide improved mechanical stability as compared to the conventional miniplates, although that additional stability may be lost in the case of oblique fractures. The reason for this is that in oblique fractures it is difficult to reconcile all the recommendations for an ideal fixation using a device that consists of horizontal bars and vertical bars parallel to the fracture line. This may explain the differences in resistance encountered among the fixation devices in this study according to the type of fracture (Table 5).

The principles and utilization of 3D miniplates in mandibular fractures have not yet been fully established. In a recent research survey among 104 American and European dental surgeons belonging to the Association for Osteosynthesis/Association for the Study of Internal Fixation (AO/ASIF), only 6% declared that they made use of such materials for fixation. Furthermore, there are no case series reports available in the specialized literature and only a small number of published studies investigating their advantages as compared to traditional plates and miniplates for bone reconstruction.

With regard to the displacement value to be adopted, there are authors who have standardized the use of a displacement value of 1 mm, 3 mm, and 10 mm, or the moment when the system collapses, if the latter should occur before the predetermined displacement is registered. Madsen et al. used a continuous load right through to the moment of mechanical failure of the system, or to the limit of displacement, when evaluating symphysis fractures. Vieira e Oliveira and Passeri registered resistance values at intervals, or at the limit of predetermined displacement. As a simplified form for presenting the results and to give enough information for the evaluation of multiple data, we adopted a predetermined displacement value of 5 mm and used the maximum load to demonstrate the limits of the resistance each system is capable of.

With regard to the displacement velocity, different protocols can be found in the literature, with great variations between them. In research work comparing different RIF techniques, Asprino and Branco proposed the use of a displacement velocity of 1 mm/min. Trivellato preferred a velocity of 2 mm/min. In biomechanical studies to evaluate fixations in the anterior region of polyurethane mandibles, Madsen et al. used a velocity of 5 mm/min to deliver load to the edge of the incisors and 1 mm/min when applying load to the left molar region. Oliveira and Passeri adopted a predetermined displacement velocity of 10 mm/min for the left molar. The pilot tests that were carried out on specimens prior to this study showed greater accuracy when the predetermined displacement value of 10 mm/min was adopted, hence this value was used as the standard in the present research.

The results obtained for the symphyseal fracture groups in terms of both the predetermined 5 mm displacement values and the maximum force resisted (Tables 1 and 3), underscore the good performance of the square and rectangular devices used in comparison to the control group. These are therefore viable options for use in fractures in that particular region of the mandible. With regard to the parasymphysial fracture groups, in terms of the 5 mm displacement, the results for the rectangular miniplates were significantly different to those of the control group, which actually registered the highest values of all groups. The reduced level of resistance demonstrated by the rectangular plates when used in parasymphysial fractures may be related to the oblique configuration of the cut (which tends to interfere with the equidistant positioning of the connecting arms of the miniplates in relation to the slanting trajectory of the cut), to the lesser number of screws involved, and to the lack of a perfect adaptation of the miniplate to the polyurethane model.

While the load was being applied, the parasymphysial fractures were those that suffered the greatest rotation effects due to the configuration of the cuts, which favoured the axis of movement. Shear and compression forces in the basal region are less active in oblique cuts than in straight line cuts. This means that the left mandible side to which the force is applied undergoes greater and more intense displacement towards the opposite hemimandible when the cuts are oblique. Generally speaking, due to such force components acting in the oblique fracture groups, the tendency to displacement is greater and the use of fixation systems endowed with greater rigidity should be considered. What must be remembered, however, is that this was an in vitro trial and consequently subject to certain limitations—there is a need for more in vivo investigation into the use of 3D plates, especially in the case of rectangular miniplates. Furthermore, it has already been made clear that the forces used in biting are considerably reduced after mandibular fracture treatment, so it may possibly not be necessary to employ such very rigid systems to stabilize fractures during the healing period.

With 3D plates, the spacing of the screws means that the loads or forces acting on the plate are shared by the upper and lower sections of the plate and this enhances the resistance to rotation generated by torsion forces. In the case of the square plates, because the configuration situates the screws at small distances from one another and from the geometrical centre of the plate, the tendency for screws to lose their hold during the application of the test forces is increased. In mechanical terms, the square format and its screw positions is less stable than the rectangular format because its geometry provides less stability. However, there were no detectable statistically significant differences among these groups in the measurements taken at maximum force in either of the fracture configurations. A significant difference was only observed in one predetermined displacement of 5 mm, in which situation the square plates were more effective in the oblique fractures.

It must be stressed that the greatest displacement registered in testing the groups with fixation based on rectangular miniplates, for both kinds of cut, is caused by the greater deformation they suffer, and this is especially demonstrated by the fact that in some of the tested samples the screws did not come out but remained in place until the limits of miniplate deformation had been attained, at which point the tip of the vertical rod slipped out of the central fossa of the first left molar. The explanation for this would be that the energy provoking deformation stemming from the force being applied and the way that the system uses that energy in deforming the plate, limits the forces that might eventually displace the screw so that it becomes an event that takes longer to occur. From the biomechanical point of
view, such deformations in the plates are actually beneficial, but only up to the point where they reach the limits of their elasticity. Once that point has been passed, they no longer favour fixation stability because they are unable to go back to normal once the force has ceased and accordingly make the fracture reduction and fixation obtained by the treatment unfeasible.

The fixations showed their best results in the symphyseal fractures with differences that were statistically significant. Thus, extrapolating to the clinical situation, we would observe that 3D fixations with four screws, as tested in the study in symphyseal fractures, would probably function adequately in stabilizing such fractures, considering that they presented such a good mechanical performance. On the other hand, their loss of performance in the parasymphyseal fractures could minimize the success of 3D fixations tested in clinical situations, especially when the rectangular plates are used. The incorporation of two more screws in each segment of the 3D plates would probably lead to better results in fracture stabilization, but in that case they would no longer have any clinical advantages considering that straight plates mounted in parallel have delivered good results for years and they are easier to mould. Another aspect to consider is the modification of the biting force after the trauma, because even though the rectangular miniplates may have obtained inferior results, the stabilization they achieve may be sufficient to allow for the skeletal unit to function during the repair process because they reduce the functional demand made on it during the first 4 weeks. Clinical investigations could confirm these findings and they are important and necessary to validate this alternative form of functionally stable internal fixation in the anterior region of the mandible.

Funding
None.

Competing interests
None declared.

Ethical approval
Not required.

Acknowledgement
The authors would like to express their gratitude to PROMM® - Indústria de Materiais Cirúrgicos, Porto Alegre, Rio Grande do Sul, Brazil, for their kind support through donations of the titanium plates and screws used in this research.

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