A biomechanical comparison between original and used titanium miniplates

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SUMMARY. Four dogs were chosen for this study. An experimental fracture was made in the mandibular symphysis region of each dog. Two miniplates and eight screws were applied, and removed three and six months postoperatively.

In this study, the surface and mechanical characteristics of titanium miniplates were evaluated. Study materials consisted of four groups. In each of the groups, there were six miniplates. The groups are as follows:

Group A: Original plates (not used) as a control group (i.e. used as a reference in comparisons)
Group B: Original plates bent as in operation but not left in tissue
Group C: Plates removed at third month postoperatively
Group D: Plates removed at sixth month postoperatively.

After evaluation of all groups, there was no difference in the microstructure of the surfaces but some differences in mechanical characteristics were apparent.

INTRODUCTION

Treatment of mandibular fractures is an important part of oral surgery. Mandibular fractures have been treated in different ways (Johansson et al., 1988). Intermaxillary fixation for six weeks, open reduction with wire fixation and intraoral and extraoral pin fixation have been used, alone or in combination, as a result of local therapeutic tradition and surgical experience (Michelet and Moll, 1971; Borchbakan, 1980; Hardman, 1982). Compression osteosynthesis using a bone plate gives rigid fixation. This approach is particularly useful for osteosynthesis in the mandible, which is subject to strong biomechanical forces (Luhr, 1970; Schilli, 1977).

During the past two decades, the operative treatment of mandibular fractures has been influenced and modified by a variety of experimental studies. In the search for a simple osteosynthesis technique that would guarantee fracture healing without intermaxillary fixation and without compression, the monocortical plate osteosynthesis of Michelet and Moll (1971) and Michelet et al. (1973) was modified and developed into a practical clinical method (Champy et al., 1975, 1976a,b; 1977; 1978a,b; Champy and Lodde, 1976, 1977). Rational fracture treatment must take account of these biomechanical facts and the forces acting on the mandible. Therefore, maximum masticatory forces were measured in young men with healthy teeth (Champy et al., 1976a) and the following values have been ascertained for maximal biting forces: incisor region - 29 DaN (Deca Newtons), canine region - 30 DaN, premolar region - 48 DaN, molar region - 66 DaN, and intercanines - 100 DaN.

The purpose of this study was to investigate the biomechanical differences between the original and the used miniplates. We wanted to reveal the reason whether the mechanical differences are due to the manipulation of the plates or the period of time the plates are left in the tissues. Tests were set up in order to measure the plate characteristics and to relate these to the biological displacement forces likely to be encountered, based on the previous work by Champy et al. (1978a).

MATERIALS AND METHODS

In this study, four dogs having had experimental fractures made in the mandibular symphysis region, were treated (Fig. 1) by Champy's (1978a) miniplate technique, originally invented by Michelet and Moll (1971). The size of the titanium miniplates* which we used were 22 × 2 × 0.9 mm. The miniplates were removed three and six months postoperatively. All the operations were carried out under general anesthesia and the dogs were not killed.

Study materials consisted of four groups. In each of the groups, there were six miniplates. The groups are as follows:

Group A: original plates (not used) as a control group (i.e. used as a reference in comparisons)
Group B: original plates manipulated as in operation but not left in tissue
Group C: Plates removed at third month postoperatively
Group D: Plates removed at sixth month postoperatively.

*: Medicon EG. D-7200 Tutlingen-W. Germany.
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Table 1 - Hardness test results of plates in each group

<table>
<thead>
<tr>
<th>Group A (KHN*)</th>
<th>Group B (KHN)</th>
<th>Group C (KHN)</th>
<th>Group D (KHN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>197</td>
<td>178</td>
<td>193</td>
<td>197</td>
</tr>
<tr>
<td>199</td>
<td>181</td>
<td>227</td>
<td>208</td>
</tr>
<tr>
<td>174</td>
<td>181</td>
<td>206</td>
<td>225</td>
</tr>
<tr>
<td>195</td>
<td>178</td>
<td>203</td>
<td>215</td>
</tr>
<tr>
<td>199</td>
<td>178</td>
<td>208</td>
<td>208</td>
</tr>
<tr>
<td>Average</td>
<td>192.8</td>
<td>179.2</td>
<td>207.4</td>
</tr>
</tbody>
</table>

*KHN (Knoop Hardness Number) = Kg/mm²

Results of the first experiment

In the examination of the hardness of the plates, it was found that the hardness of miniplates (i.e. only manipulated as in operation) was decreased but the hardness of the others increased when compared with the control group. The highest increase in hardness
was found in the miniplate which was removed after six months (Table 1).

**Results of the second experiment**

In the examination of the surface differences in the plates, we did not see any difference in the microstructure of the surfaces under a light microscope which enlarges 300 times (Fig. 4A,B).

**Results of third experiment**

In the examination of the tensile strength of the plates, all values were decreased when compared with the control group (Table 2).

**DISCUSSION AND CONCLUSIONS**

Miniplate osteosynthesis provides rigid fixation with the use of a simple surgical procedure (Champy et al., 1978; Gerlach et al., 1982). In addition to this advantage, the miniplate can be easily adapted to the varying degrees of bone curvature because of the malleability of this type of plate, thus avoiding malocclusion caused by incorrect adaptation of the plate and facilitating plate manipulation. These properties of miniplates are due to their biomechanical characteristics.

The purpose of our study was to investigate biomechanical differences between the original and the used miniplates.

Champy et al. (1986) reported the mechanical characteristics of osteosynthesis material as follows: hardness = 120–180 Brinel*, tensile strength = 450–700 N/mm². The following values were ascertained for some mechanical characteristics of titanium miniplates as a result of experiments: hardness; Original plates (group A) = 192.8 KHN, the others (group B,C,D) = 179.2–210.6 KHN. Tensile Strength; Original plates (group A) = 910.85 MPa, the others (group B,C,D) = 647.935–815.177 MPa. The mechanical properties of the osteosynthesis material ensure that the induced tension and torsion forces are neutralized. In general, however, physiological forces acting directly on the bone can be tolerated (Champy et al., 1986). Our findings confirm the study of Champy et al. (1986).

The results of our study showed that although the used miniplates have changes in their mechanical properties, they may be used in a second operation to fix fragments. However, the results that we found for hardness and tensile strength were larger when

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**Table 2 - Tensile strength test results**

<table>
<thead>
<tr>
<th>Group</th>
<th>Dimension of plates (width x thickness) (mm)</th>
<th>Area (mm²)</th>
<th>Traction force (Kg)</th>
<th>Tensile strength in Kg/mm²</th>
<th>Tensile strength in MPa*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>1.4 x 0.85</td>
<td>1.19</td>
<td>110.5</td>
<td>92.857</td>
<td>910.857</td>
</tr>
<tr>
<td>Group B</td>
<td>1 x 0.80</td>
<td>0.80</td>
<td>66.5</td>
<td>83.125</td>
<td>815.177</td>
</tr>
<tr>
<td>Group C</td>
<td>1 x 0.75</td>
<td>0.75</td>
<td>57.0</td>
<td>76.000</td>
<td>745.305</td>
</tr>
<tr>
<td>Group D</td>
<td>1.05 x 0.80</td>
<td>0.84</td>
<td>55.5</td>
<td>66.071</td>
<td>647.935</td>
</tr>
</tbody>
</table>

* width x thickness = area (mm²); traction force (kg)/area (mm²) = tensile strength (kg/mm²); tensile strength in kg/mm² x 9.80665 = tensile strength in MPa (Mega Pascal), where 9.80665 is a conversion factor from kg/mm² to MPa.

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*Brinel = 1.09 KHN (approximately).*
compared with Champy's (1976a) maximal biting forces.

Zaki and Carter (1990) compared Hall's and Champy's miniplates biomechanically, Hall's test plates fractured at the bridge during testing, but Champy's test plates fractured through screw-holes with secondary distortion of opposing screw holes.

The plates we used in our study were of the same type and shape which Champy used in his study (1986). During the tensile test in our groups, we reduced the cross-sectional area of the miniplates in order to make the miniplate fracture easily at the bridge. Reducing the dimensions of miniplates was for experimental purposes only and it did not affect the results, because the ratio of force to area stays constant. Other authors (Zaki and Carter, 1990) used and compared different types of plates, however in our study we compared the same plate before operation and after removal.

In our study, the hardness and tensile tests showed that the results in the B, C and D groups were different to the control group (Tables 1 and 2). In group B, the values in hardness and tensile tests decreased when compared with the control group. In C and D groups, the values in the hardness test increased but the values in the tensile test decreased.

A positive correlation was found in C and D groups, but surprisingly this correlation was not found in group B. For this reason, the tests were repeated for the second time. Results were approximately the same.

Our study shows that the result of the bending action as in an operation affects the hardness of the test plates negatively. However, the period in tissue affects the hardness of the test plates positively.

In conclusion, we can say that either negative or positive effects on hardness of the plates change the original mechanical properties. This increases the fragility of the plates.

References


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