MECHANICAL TESTING OF THE RETENTION OF SOME CAST CROWNS FIXED WITH VARIOUS TYPES OF CEMENTS

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Abstract

The retention and stability of the cast crowns on the prepared stumps are the most important biomechanical objectives of prosthodontics, determining the success or failure of prosthodontic therapy. Purpose: This study aims at comparing the retention for three types of cast crowns (metallic, ceramic, composite), fixed with the help of three types of anchorage cements (FOZ, CIS, resin cement) on metal stumps with three different geometries. The assessment of the retention is done by measuring the traction force necessary for the removal of the crown from the stump for each sample. Material and method: 27 samples were tested by applying an increasingly growing traction force until the crowns detach from the stumps. The maximum traction force for each type of crown, cement and stump was registered with the help of an original testing and measuring device conceived and manufactured for these very purposes. Findings: the highest values for the traction forces and implicitly the best retention was obtained for the samples cemented on higher stumps, with a larger diameter, regardless of the type of crown. Also, the additional retention grooves proved their utility for the improvement of these properties, in comparison with the samples fixed on stumps having the same dimensions, but without grooves. From the perspective of anchorage cements, the worst results are invariably registered by the FOZ, and the best retention is obtained by the resin cement; CIF has intermediate, but sufficiently good retention qualities, being positioned between the FOZ and the resin cement, and can thus be recommended, together with the latter, for the anchorage of all types of dentures belonging to the cast crown type. Conclusions: The geometry of the stump and the type of anchorage cement used for the cementing of the samples are the essential factors that influence retention in a decisive manner, whereas the biomaterial used for manufacturing the cast crown is less important from this perspective.

Key words: RETENTION, ADDITIONAL RETENTION GROOVES, STUMP GEOMETRY, CEMENT, CROWN, ORIGINAL DEVICE.

The purpose of this study is the quantification of the retention of three types of cast crowns (metal, ceramic, composite), fixed with the help of three types of anchorage cements (zinc phosphate, glass ionomer, resin cement) on three types of metal stumps. The retention was assessed by measuring the traction force necessary for the dislocation of the crowns from the stumps with the help of an especially conceived, unconventional testing device.

The traction test consisted in the application of a force on the samples until the fracturing of the metal stump – cast cover ensemble and aimed at determining the values of the forces necessary for the ensemble to break, for each type of cement, crown, stump.

In order to assess the maximum resistance strength of the cements to the traction stress, we conceived and manufactured a simple device, which is easy to handle and does not require sophisticate measuring tools.

Material and method

For this experiment we used:
- 6 crowns of the second mandibular molar - 2 made of metal, 2 of ceramics, 2 composite. For each type of biomaterial we took into consideration 2 dimensions of the crowns, corresponding to two types of stumps: a larger one for higher and thicker stumps and a smaller one for shorter and thinner stumps (fig. 1);

Fig. 1
Stumps of various dimensions, corresponding crowns, samples after cementation

- 2 types of metal stumps made of stainless
steel - a higher one (4.6mm) with a larger diameter (6.3mm), and a shorter one (3.2 mm) with a smaller diameter (4.5 mm); subsequently, in order to verify how the retention is influenced, we made two small retention grooves on the small stumps, diametrically opposite. We preserved a 6º convergence of the walls for all the stumps; this value of the convergence angle showed the best results from the perspective of the retention (1, 2, 3); - 3 types of cement – zinc phosphate (Shofu); glass ionomer (Glass Ionomer Base Cement – SHOFU); adhesive resin (MonoCem™ - SHOFU).

A total of 27 samples were tested: each type of crown was cemented with each of the three types of cement on each of the three types of stump.

The measuring device was manufactured as follows: a screw-nut ensemble, stabilizing device, an ensemble made of stump 2, fixed plaque and mobile plaque 2 (fig. 2), a traction plaque with a slit of a smaller size than the dimension of the crown (the traction plaque comes into contact only with the crown, not with the stump) and two traction arches identical with the elasticity constant: kT = 48 N/mm (maximum force developed by an arch Fmax = 1230N). The increasing force is continuously applied, under a static regime, until the first sign of fracture appears. The direction of the force coincides with the axis of the tooth, in a static regime, until the appearance of the first sign of fracture. The direction of the force coincides with the axis of the tooth, perpendicularly on the occlusal face.

**Fig. 2**
Scheme of the traction device

**Fig. 3**
Device for the measurement of the traction force

The components of the above scheme: 1 – crown; 2 – stump; 3, 4 – traction arches; 5 – traction plaque; 6 – mobile plaque; 7 – screw; 8 – fixed nut; 10, 11 – guiding device.

The device functions as follows: when the screw (fig. 2, position 7) is rotated, the mobile plaque (figure 2, position 6) moves along with the screw, acting as a force on the two traction arches (figure 2, positions 3, 4). These, in their turn, act with the same force on the traction plaque (figure 2, position 5), which transmits this force upon the crown (figure 2, position 1). Since the stump device (figure 2, position 2) is fixed, the force acts on the crown and implicitly on the cement.

Practically, with the rotation of the screw, due to the fact that the traction plaque does not move, since it is blocked by the crown, and the mobile plaque moves with the screw (it only has a translation movement), the two arches will be deformed. Following the deformation, the maximum total force developed by the two arches (taking into account the fact that, when the arches are parallel, the force developed by them is calculated as the sum of the forces developed by each arch in particular) (4), is calculated according to the formula:

$$F = 2 \cdot k_T \cdot \left( n + \frac{\alpha}{360} \right) \cdot p$$

where:

- F = force developed by the arch [N];
- kC = elasticity constant of the compression arch;
- α = the rotation angle of the screw[o];
- p = screw turn [mm].

The measurement principle is the following: we fix the T which is attached to the screw in horizontal position (taking a set square as a...
reference), then we rotate the screw, one turn at every two seconds, until we notice that the cement breaks (opens the crown from the stump, and the arches go back to the rest dimension).

During the rotation of the screw we register the number of complete turns – n. At the end, we measure the angle α that forms between the T and the horizontal. By applying the above mentioned equation, we can calculate the force at which the cement breaks.

**Findings**

I. In case the used cement is FOZ, following the performed measurements and calculations, the diagrams in figure 4 resulted.

Comparing the 3 diagrams we may observe that for all the 3 types of crowns, the samples that lasted the least to the traction were the ones cemented on shorter stumps (168N – 210N). In the case of crowns cemented on stumps with additional retention grooves, we may notice that the traction resistance is far superior (207N – 264N) when compared to the crowns cemented on short stumps, and the cemented samples on high stumps registered the highest values of maximum traction forces (224N – 272N).

The values of the maximum forces registered for the removal of the crowns from the three types of stumps, for zinc phosphate cement, are presented in table I:

<table>
<thead>
<tr>
<th>Crown Type</th>
<th>Maximum force, high stump (N)</th>
<th>Maximum force, short stump with grooves (N)</th>
<th>Maximum force, short stump (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal crown</td>
<td>272</td>
<td>264</td>
<td>210</td>
</tr>
<tr>
<td>Ceramic crown</td>
<td>255</td>
<td>220.5</td>
<td>196</td>
</tr>
<tr>
<td>Composite crown</td>
<td>224</td>
<td>207</td>
<td>168</td>
</tr>
</tbody>
</table>

During the rotation of the screw we register the number of complete turns – n. At the end, we measure the angle α that forms between the T and the horizontal. By applying the above mentioned equation, we can calculate the force at which the cement breaks.

**Table I**

Values of the maximum traction forces that can be handled by the zinc phosphate

The values in the table are very similar for the same type of stump, which means that the traction and implicitly the retention are not influenced by the biomaterial of which the crown is made.

We may notice that, as stated by most authors (1, 2, 3, 5, 6), the geometry of the stump, respectively the additional retention elements significantly influence the traction resistance and implicitly the retention of the crown on the stumps. Thus, for zinc phosphate cement, the differences between the measured values of the traction force for various stump geometries are: 62N for the metal crown, 59N for feldspathic porcelain, respectively 56N for the composite crown.

If we compare the maximum values of the traction forces for the short stump and an identical stump equipped with additional retention grooves, we will notice that, in the latter case, the values of the forces are superior.
for all the tested samples; but the differences are rather small, if we consider the normal values of the forces that manifest at the level of the stomatognat system: 54 N for the metal crown, 24.5 N for the ceramic crown and 39 N for the composite crown.

<table>
<thead>
<tr>
<th></th>
<th>Maximum force for high stump (N)</th>
<th>Maximum force for short stump (N)</th>
<th>Maximum force for short stump with grooves (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal crown</td>
<td>391.78</td>
<td>298.56</td>
<td>283.56</td>
</tr>
<tr>
<td>Ceramic crown</td>
<td>304.2</td>
<td>239.85</td>
<td>228.73</td>
</tr>
<tr>
<td>Composite crown</td>
<td>486</td>
<td>332</td>
<td>385.4</td>
</tr>
</tbody>
</table>

II. In case the used cement is glass ionomer (Glass Ionomer Base Cement – SHOFU), following the performed measurements and calculi, the resulted diagrams are similar to those in figure 4, in the sense that they preserve the same monotony of the charts, but the forces are significantly different from the perspective of the values of the forces.

Table II presents the maximum values of the traction forces, at which their detachment from the three types of stumps occurs, in the case of the glass ionomer cement.

<table>
<thead>
<tr>
<th></th>
<th>Maximum force for high stump (N)</th>
<th>Maximum force for short stump (N)</th>
<th>Maximum force for short stump with grooves (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal crown</td>
<td>1488.18</td>
<td>1335.23</td>
<td>1271.65</td>
</tr>
<tr>
<td>Ceramic crown</td>
<td>1507.24</td>
<td>1396.95</td>
<td>1330.43</td>
</tr>
<tr>
<td>Composite crown</td>
<td>1572.34</td>
<td>1421.22</td>
<td>1366.55</td>
</tr>
</tbody>
</table>

In these cases, as in the previous ones, we will notice that the smallest resistance to traction is presented, invariably, by the crowns cemented on short stumps (239 N -385N), followed by those cemented on stumps equipped with additional retention grooves (228N – 332N), and the highest values are registered by the crowns cemented on high stumps (304N – 486N).

In other words, for the samples cemented with glass ionomer cement as well, the retention, given by the values of the maximum traction forces, is much more influenced by the geometry of the stumps than by the biomaterial of which the crown is made. As for the zinc phosphate cement, we will observe that the additional retention elements do not significantly improve retention, the differences between the measured values of the traction forces necessary for the removal from the stumps equipped with such elements and the stumps without retention grooves being rather small: 15N for the metal crown, 11, 12 N for the ceramic crown, respectively 53.4 N for the composite crown.

As you may observe, the values are in the same size range, being slightly higher for composite crowns cemented with glass ionomer cement. Nevertheless, unlike the crown cemented with zinc phosphate (168N – 272N), this time the maximum traction forces are much higher, even double (228N – 486N), emphasizing the retentive qualities far superior to the glass ionomer cement in comparison with those of the zinc phosphate cement.

III. If the used cement is adhesive resin MonoCem™ - SHOFU, following the performed measurements and calculi, the obtained diagrams have the same profile as in the previous cases. The maximum values of the traction forces that the resin cement can handle are, though, much higher in comparison with the other two types of cements, being presented in table III.

<table>
<thead>
<tr>
<th></th>
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</table>

This time as well, we may notice the same monotony as in the previous cases, which means that crowns fixed on high stumps (1488.18N – 1572.34N) have the best resistance to traction, followed by crowns cemented on short stumps but equipped with additional retention grooves (1330.43N – 1421.22N), the smallest values being registered for the crowns cemented on stumps without retention grooves (1271.65N – 1396.95N).

For the tested resin cement, we may observe that the additional retention elements do not
significantly improve the values of the traction forces in comparison with those obtained by smaller stumps without grooves (if we consider the size range for the maximum values obtained during this test), but that the have a slight contribution if we consider the values of the forces that develop at the level of the stomatognat system. The differences are: 63.58 N for metal crowns, 66.52 for ceramic crowns, respectively 54.67 for composite crowns.

In comparison with the other two types of cements, our attention is captured by the special retention performances of the tested resin cement. If, for the zinc phosphate and the glass ionomer cements, the maximum traction forces equaled some hundred Newtons (168N – 272N for FOZ, respectively 239.85N – 486N for the glass ionomer), for the resin cement the values are far superior, reaching thousands Newtons (1271.65N – 1572.34N).

**Discussions**

Most studies related to retention and the factors that influence it were performed on human teeth (2, 3, 5, 6, 7, 8) extracted for periodontal or orthodontic reasons, eventually on bovine teeth (9), or even on artificial teeth, made of acrylic resins (10, 11, 12). Although human teeth are selected according to very strict criteria, there are considerably big differences as concerns the structure, dimensions, water content, and degree of calcification and preexistence of microfissures, aspects that can lead to great standard deviations of the results. Bovine teeth, although similar to human teeth as concerns the elasticity module and the resistance to traction, are much larger from the perspective of their dimension. The teeth made of acrylic resins can be standardized in shape and material, but cannot adequately stimulate the properties and the microstructure of the human dentine, which determines a certain type of connection with restorative materials and, therefore, a certain type of biomechanical behavior.

Accordingly, for the purposes of this study we decided to use some metal stumps, made of stainless steel, at the cost of sacrificing an important parameter from the perspective of dental prosthodontics - the connection with the dentine. The use of some biological structures instead of metal stumps, eventually anchored in an elastic layer meant to simulate the periodontal support, would have not lasted to values of the forces similar to those analyzed in this study. Moreover, from the perspective of the material constants, the metal stumps have constant and known values (since we deal with stainless steel) and this consideration would have been impossible to comply with when using natural teeth (whose biomechanical value can considerably vary). The metal stumps had an advantage from a geometric perspective as well, being sized with mathematically precision (height, wall convergence, diameter, additional retention elements).

A common feature of most mechanical tests performed in vitro is the fact that they are static and consist in applying a continuous force whose value is constantly increasing. Moreover, they introduce a series of simplifying hypotheses, turning details, sometimes essential for the real situation into abstract elements. Thus, from this perspective, we considered the ideal situation where the direction of the force coincides with the axis of the molar, without taking into account other forces that differ in direction, sense, intensity, usually met in the oral cavity.

From the perspective of the results, the study proves once again the opinions of most researchers on the factors that influence the retention of microdentures (1, 2, 3, 5, 13), performing at the same type a quantification of the forces necessary for the removal. From the perspective of the traction forces necessary for the removal, it is obvious that the best retention is obtained for longer stumps, followed by the short ones equipped with additional retention grooves, and the worst retention is obtained for short bumps with no additional retention elements, thus consolidating the unanimously accepted idea according to which the geometry of the prepared stump is vital for the retention of the microdenture.

The study also outlines the different retentive performances of the fixation cements, registered and measured with the help of an original device, especially conceived for these purposes. Maxwell (2), Witwer (5) and Craig (14) reported
similar values of the traction forces to which the cements tested in this study can resist.

This paper also stresses the fact that the biomaterial of which the crown is made is not of primordial importance as concerns the retention of the microdenture, although the elasticity modules of the three types of materials present significant differences: 103 GPa – metal; 63 GPa – feldspathic ceramics; 21 GPa – composite (13).

**Conclusions**

The geometry of the stumps, as well as the presence of additional retention elements, together with the type of cement selected for fixing the crown on the stump, are the factors with a decisive impact for the execution of the biomechanical objectives concerning the retention and stability of microdentures. Thus, the success of the cast crown therapy can be foreseen from the very first treatment stages, via the execution of an appropriate preparation, as well as during the final stage, by choosing the optimum cement for the respective case.

The biomaterial of which the crown is made does not turn out to have a significant role in retention. The maximum values of the traction forces were measured via an unconventional method, with the help of an original device, especially conceived for these purposes, and the obtained results are within the limits mentioned by other specialized studies.

**References**