Assessment of the tensile strength of hexagonal abutments using different cementing agents

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Abstract: The aim of this study was to assess the uniaxial tensile strength after thermal cycling in replicas of CeraOne® abutments (abutment and coping sets), using four types of cements (n = 10). A zinc phosphate cement (Fosfato de Zinco® / SSW), a resin-modified glass ionomer cement (RelyX® luting / 3M-ESPE), a zinc oxide-eugenol cement (ZOE® / SSW) and a zinc oxide cement without eugenol (TempBond NE® / KERR) were used. After cementation, the samples were submitted to thermal cycles (1,000 cycles, 5°C ± 2° to 55°C ± 2°) for thirty seconds in each bath. Next, the samples were submitted to the tensile test in a universal test machine (0.5 mm/min). The data were submitted to ANOVA and the Tukey-Kramer test ($p < 0.05$), and statistically significant difference was found among the cements. The highest tensile strength mean value found was for zinc phosphate cement (33.6 kgf) followed by the resin-modified glass ionomer cement (20.5 kgf), zinc oxide-eugenol cement (8.4 kgf) and the temporary cement (3.1 kgf). Therefore, it was found that the permanent cements presented higher tensile strength, and the temporary cement could be used in situations requiring reversibility and the removal of cemented dental implant-supported prostheses.

Descriptors: Dental implants; Zinc oxide-eugenol cement; Zinc phosphate cement; Glass ionomer cements.

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Introduction

Since 1986, when Jemt presented the use of implants to replace a single tooth, there has been notable progress.[1] There are now several options for prosthetic designs. In 1991, Nobel Biocare introduced the CeraOne® system consisting of a hexagonal abutment, with the intention of solving the problem of screw loosening. As a result, the CeraOne® restoration could be cemented to the implant abutment without fear of screw damage, thus providing an implant with greater lingual comfort, since it eliminated the need for a screw with lingual access.[2]

Furthermore, different options of materials or procedures for cementing or fixing restorations to implants also appeared.[3] The question of the method by which the prostheses are connected to the base of the implant, either screwed or cemented, deserves more detailed study.[4] Cemented dental prostheses have peculiar characteristics when compared with screwed prostheses, some of their positive characteristics being greater lingual comfort, a better emerging profile, more adequate restoration outline, and easier cleaning.[2] One of their negative characteristics is lack of success with reversibility and removal of cemented dental implant-supported prostheses.[2] There are concepts that influence the increased retention of a cemented prosthesis: parallelism between the abutments, surface area and height, surface roughness and the type of cement.[5] Regarding this aspect, the type of cement is a relevant and decisive factor for retention.[6]

However, there are questions about the possibility of using temporary bonding agents instead of permanent cements to remove the prostheses without causing damage.[7] Carter *et al.*[4] (1997) have recommended the use of a weaker bonding agent at first, and progressing to a stronger one until the desired amount of retention is achieved. This approach allows occlusion and tissue reaction to be assessed. However, the use of highly resistant cements has become more popular with a reliable increase in stability of the tooth-abutment/implant support of the screw connection and a high survival rate of osseointegrated implants.[8] The permanent cements commonly used for traditional prostheses resist any attempt at the removal of prostheses from the abutments, making posterior access to the implants difficult. Therefore, their use must be well indicated.[3]

The dental cements used for cementing implant-supported prostheses may present different effects when compared with those used on teeth.[8] Therefore, the aim of this study was to assess the uniaxial tensile strength of hexagonal abutments, used with different types of cementing agents after thermal cycling.

Material and Methods

Forty replicas of hexagonal tin abutments with their titanium copings (Neodent, São Paulo, SP, Brazil), cemented with four different bonding agents (n = 10), were submitted to the tensile test: temporary zinc oxide cement without eugenol (TempBond NE® / KERR, Orange, CA, USA), zinc oxide-eugenol cement (ZOE® / SSW, Rio de Janeiro, RJ, Brazil), permanent resin-modified glass ionomer cement (RelyX® luting / 3M-ESPE, Sumaré, SP, Brazil), and permanent zinc phosphate cement (Zinc Phosphate® / SSW, Rio de Janeiro, RJ Brazil). Table 1 describes the manufacturers, batch numbers and compositions

Table 1 - Commercial brand, manufacturer, composition, and batch number/use by date of the cements.

Brand Name	Manufacturer	Composition	Batch number / Use by date
Temp Bond NE®	KERR (Orange, CA USA)	Base - zinc oxide Accelerator - polyorganic acid	5-1244 2007/09
ZOE®	SSW (Rio de Janeiro, RJ Brazil)	Powder - Zinc oxide, Zinc stereate, Zinc acetate Liquid - Eugenol, olive or cotton seed oil	002 2009/10/16
RelyX luting®	3M-ESPE (Sumaré, SP Brazil)	Powder - radiopaque aluminum fluoride silicate glass	4BP 2006/09
Zinc Phosphate®	SSW (Rio de Janeiro, RJ Brazil)	Powder - ZnO, MgO, SiO_4 Liquid - H_3PO_4, $ZnPO_4$, H_2O	002 2010/05/17

of the cements used. The factors being studied were randomly designated to the experimental units.

Forty machined test specimens were used, these being same size replicas of the hexagon abutment (tin analog) designed without the central perforation through which the retention and stabilization screw passes in the original part (Neodent São Paulo/SP, Brazil). Machined titanium copings, compatible with the hexagonal abutment, were cemented onto these, with the following characteristics: an internally hollow hexagon-shaped titanium cylinder to allow it to be coupled to the hexagon abutment with a maximum of fit, and externally, a shoulder with a diameter 0.5 mm larger. No additional device was incorporated into the coping and analog, thus preserving their originality, without the need to cast or weld loops to their components. Ten test specimens, each consisting of a set comprising a titanium coping and hexagonal tin abutment analog, were used for each type of cement (Figure 1).

The cements were manipulated in accordance with the recommendations of each manufacturer, in a room with the temperature controlled at 23°C to 25°C. A calibrated 1 ml/cc syringe (INJEX U-100, Ourinhos, SP, Brazil) was used to insert the cement into the titanium copings, and 0.1 ml of cement was used to cement each coping to the abutment. The copings were placed on the abutment manually with digital pressure. After that, they were placed in a manual press and submitted to 5 kgf pressure for a total time of 10 minutes.[3] Excess cement around the samples was removed with the aid of an exploratory probe n. 5 and the samples were stored in distilled water at a temperature of 37°C in vials for 15 days. Then, the samples were submitted to 1,000 thermal cycles (Cycling machine MSCT-3, Marcelo Nucci-ME, São Carlos, SP, Brazil) at a temperature ranging between 5° ± 2°C and 55° ± 2°C, remaining 30 seconds in each bath.[2,9,10]

After 15 days, the test specimens were submitted to shear strength tests in a universal test machine (EMIC, São José dos Pinhais, PR, Brazil) at a standard speed of 0.5 mm/min and a 200 kgf load cell. To perform the tests, a device was constructed so that no artifact was welded to the copings and analogs. For this purpose a 12 mm screw with the required measurement was turned internally, so that the portion of the tin hexagon abutment analog would pass through the middle of the screw. In its original conformation, the titanium coping, made as previously described, had a cervical shoulder external to the titanium cylinder whose diameter was 0.5 mm larger than that of the remainder of the cylinder. This shoulder was used as retention by mechanical misalignment at the moment of the tensile test, as it remained internally fixed to the screw (Figures 2A, 2B and 3). Another device was made by hollowing a steel cylinder so that the groove in the apical portion of the hexagonal abutment analog would fit and remain fixed. Thus, traction was applied without the aid of any device welded to or cast on the coping and the analog abutment (Figure 4). After the tensile test, the data obtained in kgf were submitted to the analysis of variance ($p < 0.05$) for comparison of the experimental groups, and the

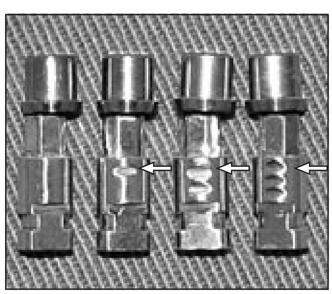


Figure 1 - Tin analogs and titanium copings. In the detail: Markings identifying the groups (without a mark, TempBond NE®; one mark, Zinc Phosphate®; two marks, ZOE®; and three marks, RelyX luting®).

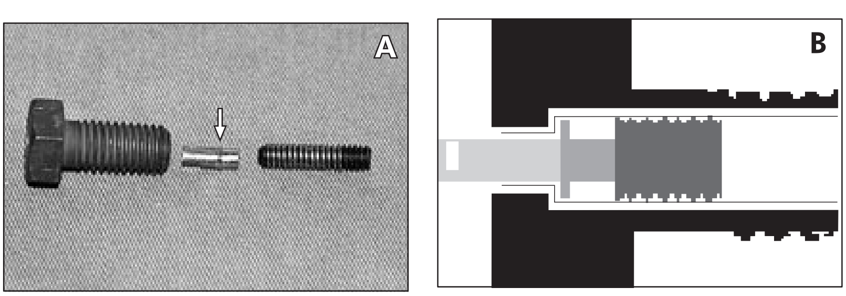


Figure 2 - A: Screw turned for inserting in the sample. In the detail: Shoulder used for retention on the screw. **B:** Diagrammatic view of shoulder placement inside the machined screw.

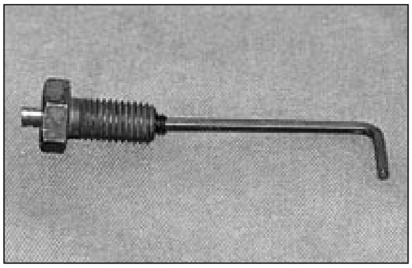


Figure 3 - Sample fixed inside the screw.

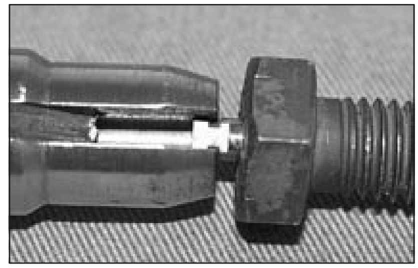
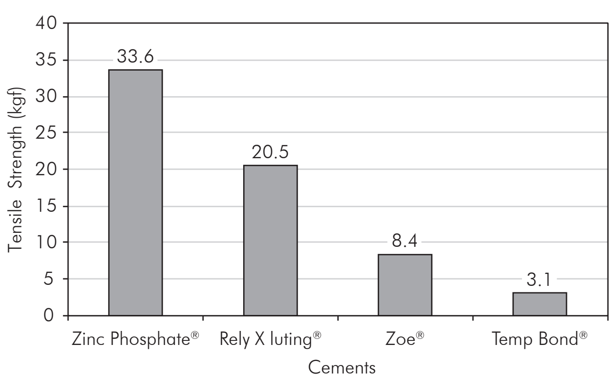


Figure 4 - Sample coupled to the traction device.

Table 2 - Mean (kgf) and standard deviation of tensile strength of the abutment as a result of the cement.

Cement	Mean (kgf)	Standard Deviation	Tukey test
Zinc Phosphate®	33.6	7.0	A
Rely X®	20.5	8.2	B
Zoe®	8.4	1.9	C
Temp Bond®	3.1	1.5	D

Means followed by different letters in the vertical differ by the Tukey test ($p < 0.05$).



Graph 1 - Tensile strength of the abutments as a result of the cements.

Tukey-Kramer test was used for multiple comparison of the means.

Results

By means of one way analysis of variance, it was observed that there was statistically significant difference among the types of cements used. Table 2 and Graph 1 demonstrate the result of the Tukey test ($p < 0.05$) for the different types of cement.

In Table 2 and in Graph 1, it can be seen that the zinc phosphate cement presented the highest tensile strength, followed by the resin-modified glass ionomer cement and zinc oxide-eugenol cement. The zinc oxide cement without eugenol presented the lowest mean tensile strength. It could be observed that the brands commercially known as being permanent demonstrated greater tensile strength when compared with the temporary cements.

Discussion

The success of a cement-retained dental prosthesis depends on the fit of the part after casting, the properties of the type of cement selected, handling and the conditions inherent to the oral environment itself.[3] With regard to the cementation technique, literature shows that not only the pressure used, but also whether it is static or dynamic, may interfere in the thickness of the film. Koyano *et al.*[11] (1978) and Silva *et al.*[12] (1998) found that dynamic pressures produced better seating than static pressures, in which the smallest thickness was obtained under static pressure followed by dynamic pressure, and that the thickness of the film was slightly smaller with vertical vibration than with horizontal vibration. In this study, the results were obtained with the use of a static pressure device of 5 kgf for 10 minutes on all the samples, with the four cements used.[3,8,12,13]

In the study of Akashia *et al.*[14] (2002), to aid the tensile test, rods were laser-welded to the cylinders/gold copings, consequently the gold cylinder did not heat and there was reduced alteration to the cervical margin. In other studies, the copies went through a waxing, embedding and casting process in order to be adapted to the respective abutments afterwards.[2,3,7-10,12,13,15,16] In the present study, machined prosthetic components were used, thus a device was developed to adapt the copings to the tensile device. This device fixed the coping in such a way that no loop or groove needed to be welded to it, or fabricated for performing the tensile test. The goal of this process was fidelity with regard to the samples, meaning greater precision in the final results.

With regard to the materials assessed, zinc phosphate has small particles that influence strength and setting time, its solubility in water is relatively low, and bonding occurs mainly by mechanical misalignment between the interfaces, and not by means of chemical interactions.[17] Bresciano *et al.*[16] (2005) proved these characteristics in their tests, obtaining a resistance of 61 kgf with this cement. In the same study, zinc phosphate cement presented the highest tensile strength mean value.

Glass ionomer cement is obtained by the reaction of silicate glass powder and polyacrylic acid. Replacing part of the polyacrylic acid with hydrophilic monomers resulted in a light- or chemically-activated hybrid material denominated resin-modified glass ionomer cement. The susceptibility of this material to humidity and the slow acid-base setting reaction allow syneresis and imbibition processes that diminish the immediate strength of the material.[17] In this study, the hybrid glass ionomer cement obtained intermediate tensile strength values lower than those of zinc phosphate and higher than those of zinc oxide based cements.

In this study, the zinc oxide-eugenol cement presented lower tensile strength than the permanent cementing agents, but higher than that obtained with the temporary zinc oxide-based cement without eugenol. It is known that the presence of free eugenol in the temporary cement can interfere in the appropriate polymerization of the composites, therefore, acids such as polyorganic acid (Temp Bond) can be used to replace eugenol and produce a cement similar to zinc oxide-eugenol cement.[17] The difference in shear bond strength between the two zinc oxide-based cements is probably because of the size of the particles in each cement. The large size of the particles negatively affects the strength of the two zinc oxide-based cements and increases the materials' shrinking coefficient, thus diminishing cement retention and producing greater solubility when compared with that of other cements.[17]

This study, like those conducted by Kent *et al.*[18] (1996), Clayton *et al.*[2] (1997), Covey *et al.*[19] (2000), confirmed that CeraOne® abutments cemented with permanent cement produced greater retentive strength than temporary cement. Clayton *et al.*[2] (1997) related that zinc phosphate cement presented approximately six times higher strength than the zinc oxide-eugenol cement. However, in the present study, the strength of the former was four times greater than that of the latter, probably due to structures such as the abutment and coping being completely polished by the process of obtaining samples. This result is justified, since the zinc phosphate cement has a higher modulus of elasticity and better mechanical properties because it has smaller particles in its composition.[17] Consequently, the tensile strength is increased when compared with that of zinc oxide cements, which have larger particles in their composition.

Bresciano *et al.*[16] (2005) found higher axial tensile strength values for zinc phosphate cement in comparison with zinc oxide when using CeraOne® abutments without the use of thermal cycling. These results are comparable with the values obtained by Kent *et al.*[18], (1996) who obtained 61.1 kgf for zinc phosphate® and 11.3 kgf for zinc oxide. In the present study, higher strength was also obtained for zinc phosphate when compared with zinc oxide, using the thermal aging process.

It was also observed that zinc phosphate obtained 63.9% higher tensile strength than the resin-modified glass ionomer cement. This difference can be justified by the characteristics of the ionomeric component of the resin-modified glass ionomer cement. This cement has a lower modulus of elasticity in comparison with zinc phosphate cement and is, therefore, far more susceptible to elastic deformation. Moreover, it can be influenced by the imbibition and syneresis processes that characterize gain and loss of water to the medium, thereby compromising the integrity of the material.[17]

There is some advantage to using temporary cement on implant supported crowns in situations where the possibility of prosthesis reversibility is desired, or when in doubt about permanent cementation.[8,14] Moreover, in some cases temporary cements have been used for fixation. Clinical studies justified the use of a weaker cement at first, in order to obtain reversibility of the prosthesis in case of loosening of a gold screw of the CeraOne® abutment.[4]

One should seek to associate adequate marginal fit with the retentiveness of temporary cements to achieve success. For the clinician that works with implant-supported prostheses, it is extremely important to know the retentive ability of the temporary cement in cases when the intention is to assure reversibility of the crowns.[14]

Conclusion

There were differences in the axial tensile strength values among all the cements used. It was found that the permanent cements presented higher tensile strength and that the temporary cement could be used in situations that require reversibility and removal of cemented dental implant-supported prostheses.

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