

DO RESIN CEMENTS INFLUENCE THE CUSPAL DEFLECTION OF TEETH RESTORED WITH COMPOSITE RESIN INLAYS?

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ABSTRACT

The aim of this study was to evaluate the influence of different resin cements on the cuspal deflection of endodontically treated teeth restored with composite resin inlays. Sixty upper premolars were randomly divided into five groups ($n=12$): 1 – sound teeth; 2 – cavity; 3 – Rely X ARC; 4 – RelyX Unicem; 5 – SeT. The teeth from groups 2, 3, 4 and 5 received a MOD preparation and endodontic treatment. Impressions were made with vinyl polysiloxane and poured using type IV die stone in groups 3, 4 and 5. Inlays with composite resin were built over each cast and luted with the resin cements. A 200 N load was applied on the occlusal surface, and cuspal deflection was measured using a micrometer. After 24 h, cuspal deflection was measured again using a 300 N load. The Student *t*-test showed that there

was no statistically significant difference between the 200 N and 300 N occlusal loads only for the sound teeth group ($p = 0.389$) and the RelyX ARC group ($p = 0.188$). ANOVA and Tukey test showed that the sound teeth had the lowest mean cuspal deflection, differing statistically from the other groups ($p < 0.05$). The highest cuspal deflections were obtained in the SeT group and the cavity group, with no statistical difference between them. Intermediate values were obtained in RelyX ARC group and RelyX Unicem group, which differed statistically. The self-adhesive resin cements RelyX Unicem and SeT showed less capacity to maintain the stiffness of the tooth/restoration complex than the conventional resin cement RelyX ARC.

Key words: endodontics; resin cements.

OS CIMENTOS RESINOSOS INFLUENCIAM A DEFLEXÃO DE CÚSPIDES DE DENTES RESTAURADOS COM INLAYS EM RESINA COMPOSTA?

RESUMO

O objetivo deste estudo foi avaliar a influência de diferentes cimentos resinosos na deflexão de cúspides de dentes tratados endodonticamente e restaurados com inlays em resina composta. Sessenta pré-molares foram divididos aleatoriamente em cinco grupos ($n=12$): grupo 1 – dentes hígidos; 2 – cavidade; 3 – Rely X ARC; 4 – RelyX Unicem; 5 – SeT. Os dentes dos grupos 2, 3, 4 e 5 receberam preparos cavitários MOD e tratamento endodôntico. Foram realizadas moldagens com silicone por adição nos grupos 3, 4 e 5, seguido de vazamento de gesso tipo IV. Inlays em resina composta foram construídas sobre os modelos de gesso, sendo as inlays cimentadas com os cimentos resinosos. Uma carga de 200 N foi aplicada na face oclusal, e a deflexão de cúspide foi medida usando um micrômetro. Após 24 h, a deflexão de cúspide foi medida novamente sob carga de 300

N. De acordo com o teste *t*-Student, não houve diferença estatística na deflexão de cúspides apenas para o grupo dos dentes hígidos ($p = 0.389$) e o grupo do RelyX ARC ($p = 0.188$) quando comparada as duas cargas. De acordo com ANOVA e o teste de Tukey, os dentes hígidos tiveram a menor média de deflexão de cúspides, diferindo estatisticamente dos outros grupos ($p < 0.05$). A maior deflexão de cúspides foi obtida com o grupo SeT e o grupo cavidades, não diferindo estatisticamente entre si. Valores intermediários foram obtidos para os grupos RelyX ARC e RelyX Unicem, diferindo estatisticamente entre si. Os cimentos resinosos autoadesivos RelyX Unicem e SeT mostraram menor capacidade de manter a rigidez do complexo dente/restauração em comparação com o cimento resinoso RelyX ARC.

Palavras-chave: tratamento endodôntico; cimento resinoso.

INTRODUCTION

As a result of their structural design, posterior teeth naturally suffer cuspal deflection under load. When endodontic treatment and mesio-occlusal-distal (MOD) preparations are performed, this trend

towards cuspal deflection under masticatory loads is increased^{1,2} due to the decrease in the stiffness of the tooth³. It is a consequence of the removal of dental tissues, which leads to greater fragility of the dental structure^{4,5}.

Numerous techniques and restorative materials have been indicated to recover the stiffness of endodontically treated teeth^{6,7}. The most frequently used materials are composite resins and ceramics, due to esthetic demands. In the case of composite resin restorations, the indirect technique is considered the best treatment option to restore teeth with large cavities and to overcome polymerization shrinkage⁸. These indirect restorations are luted with adhesive materials, such as adhesive systems associated with resin cements, which favor reinforcement of the weakened tooth⁹⁻¹¹. The conventional adhesive luting procedure consists of applying an adhesive system followed by a resin cement. However, self-adhesive resin cements have gained popularity with clinicians because they are easy to use, and the luting procedure takes less time than resin cements, which require the application of an adhesive system. Without the adhesive system, part of the sensitivity of the technique is eliminated^{12,13}.

Self-adhesive resin cements interact superficially with tooth hard tissues, and the formation of a hybrid layer or resin tags was not observed¹⁴⁻¹⁶. Self-adhesive resin cements have lower bond strength with enamel than do resin cements requiring an adhesive system^{12,17}. In relation to dentin, studies have shown that self-adhesive resin cements perform comparably to multistep systems on coronal dentin^{12,14,17-19}. In contrast, other studies have shown significantly lower bond strengths of these materials to dentin²⁰⁻²².

In an inlay restoration, the luting material occupies the space between the restoration and the tooth, and is responsible for connecting these different substrates. Regardless of the luting technique, the tooth/restoration complex must be capable of restoring the stiffness of the original tooth to a certain degree, in order to decrease mechanical fatigue of the cusps²³, which increases with higher occlusal

loads¹. However, there is no study showing the influence of resin cements on cuspal deflection under different occlusal loads.

The aim of this study was to evaluate the influence of three resin cements on cuspal deflection, under two different occlusal loads, of endodontically treated maxillary premolars restored with composite resin inlays. This study was conducted under the hypotheses that there are differences in the amount of cuspal deflection between inlays luted with the different resin cements.

MATERIALS AND METHODS

MOD preparation

Sixty sound maxillary first premolars, extracted for therapeutic reasons, were obtained from a tooth bank after the approval of the Ethics Committee of the Pontifical Catholic University of Rio Grande do Sul. The teeth were cleaned and disinfected in 10% thymol for 24 h and stored in 4°C distilled water. The water was changed every week, and the teeth were used within 6 months. The buccal–palatal and mesio–distal dimensions of each tooth were measured with a digital caliper (Mitutoyo, Suzano, SP, Brazil). A variation of 0.5 mm was allowed for each measurement to standardize the dimensions of the teeth.

Each tooth was mounted vertically in a plastic cylinder with self-cured acrylic resin (Jet Classico, São Paulo, SP, Brazil), up to 2 mm below the cement–enamel junction (CEJ). The teeth were randomly divided into 5 groups ($n=12$): Group 1, sound teeth (control); Groups 2, 3, 4, and 5, teeth with MOD preparation and endodontic treatment. Group 2 was not restored, and the other groups were restored with composite resin inlays, which were luted with RelyX ARC (Group 3), RelyX Unicem (Group 4), and SeT (Group 5). Table 1 shows the composition and manufacturer details of the materials used.

Table 1: Resin cements used in the study.

Material	Composition	Manufacturer
RelyX ARC (conventional)	Bis-GMA, tri-ethyleneglycol dimethacrylate, zircon/silica filler, photoinitiators, amine, benzoic peroxide, pigments	3M/ESPE, St. Paul, MN, USA
RelyX Unicem Clicker (self-adhesive)	Methacrylate monomers containing phosphoric acid groups; methacrylate monomers, silanated fillers, initiator components, stabilizers	3M/ESPE, St. Paul, MN, USA
SeT (self-adhesive)	Acidic monomer, camphorquinone, fluoroaluminosilicate glass, urethane dimethacrylate	SDI, Bayswater, VIC, AS

Bis-GMA: bisphenol-A-glycidyl methacrylate; HEMA: 2-hydroxyethylmethacrylate; GPDM: glycerol phosphate dimethacrylate.

A single operator performed the MOD preparations using a standardized preparation machine. This device consisted of a high-speed handpiece (Kavo, Joinville, SC, Brazil) attached to a mobile base. The mobile base moves vertically and horizontally, in 3 mm increments, with the aid of a micrometer (Mitutoyo, Tokyo, Japan). The long axis of the tooth was positioned vertically on the preparation machine, and the tooth was cut using a #4159 diamond bur (KG Sorensen, Barueri, SP, Brazil) attached to the high-speed handpiece under constant water and air cooling. The preparations presented rounded internal angles, divergent walls, and an occlusal box width of two-thirds of the intercuspal distance. The depth of the proximal boxes was located 1 mm above the CEJ. The preparations had only buccal and palatal walls, and a common floor from mesial to distal, so that the pulp floor of the occlusal box and the gingival floor of the proximal boxes were unified on the same level. The diamond bur was replaced after every five preparations.

After the preparations were completed, endodontic access was prepared with a #8 spherical carbide bur (SS White, Lakewood, NJ, USA). The preparation of the chamber was round and expulsive. Flexo-File files (Kerr, Orange, CA, USA) from number 15 to 40 were manually placed in the root canals to standardize the preparation. A 2.5% sodium hypochlorite solution was used to irrigate and clean the root canal. After the root canal preparation, all teeth were filled with gutta-percha cones (Dentsply Maillefer, Ballaigues, Switzerland) and N-Rickert endodontic sealer (Inodon, Porto Alegre, RS, Brazil) using the lateral condensation technique. Excess sealer was removed from the cavity using a cotton pellet soaked in 70% ethanol. The access to root canals was covered with gutta-percha.

Restorative procedures

Impressions of the preparations were taken with Express XT polyvinyl siloxane (3M Espe, Saint Paul, MN, USA) using individual trays made from self-cured acrylic resin (Jet Classico, São Paulo, SP, Brazil) with the putty/wash one-step technique. The impression material was allowed to set for 10 min before removal from the preparation. After 1 h, the impressions were poured using Durone Type IV stone (Dentsply, York, PA, USA). After 1 h, the casts were removed from the impression, numbered according to their group, and placed in dry storage. Cavity surfaces were lined with two coats of a die spacer, maintaining a distance of 1.0 mm to the mar-

ginal areas. Four horizontal layers of Filtek Z250XT composite resin (3M Espe, Saint Paul, MN, USA) were inserted in the casts, with Thompson spatulas no. 2 and 12, which resulted in a 90° inclination between the internal slopes and cusps. Each resin layer was light cured for 40 s. Restorations were then light cured for 60 s on each free surface, followed by finishing with flexible disks (TDV, Pomerode, SC, Brazil) and 8093F and 8093 FF silicone tips (KG Sorensen, Cotia, SP, Brazil). Throughout the experiment, a quartz-tungsten-halogen curing unit (Optilux Plus, Ribeirão Preto, SP, Brazil) was used for photopolymerization. The light intensity was controlled by a radiometer (model 100, Demetron/Kerr, Danbury, CT, USA) in the interval between 450 and 500 mW/cm².

Luting procedures

The internal surfaces of the inlays were sandblasted with 50 µm aluminum oxide for 5 s, followed by silane application (Ceramic Primer, 3M Espe, Saint Paul, MN, USA). In Group 3, Scotchbond Multi-Purpose adhesive system (3M Espe, Saint Paul, MN, USA) was applied. The tooth preparations were etched with 37% phosphoric acid for 15 s, followed by rinsing with air and water spray for 15 s. Excess water was removed with absorbent paper. A layer of primer was applied, followed by gentle air drying for 5 s. Then the bond was applied with a microbrush and light cured for 10 s. Equal lengths of base and catalyst pastes of RelyX ARC resin cement were mixed for 15 s and put on the inlay and preparation. In Group 4, equal quantities of base and catalyst pastes of RelyX Unicem were mixed and applied on the inlay and preparation. In Group 5, the internal content of a capsule of SeT was activated for 10 s and applied on the inlay and preparation. In Groups 3, 4, and 5, the inlay was placed on the preparation and a 10 N load was applied by means of a metallic tool. After 2 min, excess cement was removed with a microbrush, followed by light curing for 60 s on each free surface. The specimens were stored in distilled water at 37° C for 72 h and then submitted to the cuspal deflection test.

Cuspal deflection testing

Resin spheres (approximately 1.5 mm in diameter) were fixed with adhesive on both cusps. Following the methodology described by González-López et al.² the spheres were positioned on the cuspal apexes and

served as reference points for measuring the intercuspal distance, using a precision micrometer (Mitutoyo, Suzano, SP, Brazil) to the nearest 1 μm . A device was used to fix the micrometer in the same position for every measurement. Each specimen was attached to the lower platen of a universal testing machine (Emic DL-2000, EMIC, São José dos Campos, PR, Brazil), and a steel sphere with an 8 mm diameter was used to apply a 200 N occlusal load at a cross-head speed of 0.5 mm/min. The load was applied parallel to the long axis of the tooth, simultaneously contacting the buccal and palatal cuspal inclines (Fig. 1). When the 200 N load was achieved, the machine was locked and three consecutive measurements of the cuspal deflection were made. The mean distance of the composite resin spheres prior to application of the load was subtracted from the mean distance of the spheres after application of the load. Thus, the cuspal deflection value was obtained. After 24 h, the cuspal deflection was measured again using a 300 N load.

Statistical analysis

All statistical analyses were performed using SPSS version 10.0 (SPSS Inc., Chicago, IL, USA). After data collection, cuspal deflection data were submitted to the Kolmogorov–Smirnov normality test. To compare the study groups under the same load, the ANOVA and Tukey parametric statistical tests were applied. To compare each group under the different loads, student t-test for dependent samples was applied. The significance level was 5%.

RESULTS

The ANOVA showed that there were statistically significant differences among the groups ($p < 0.05$). For both occlusal loads, the sound teeth had the

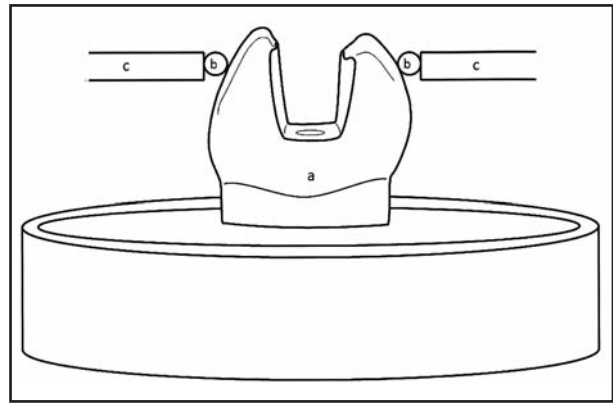


Fig. 1: Schematic figure of the cuspal deflection test: a) tooth; b) resin spheres; c) micrometer.

lowest mean cuspal deflection, differing statistically from the other groups. The highest cuspal deflections were obtained in SeT group and cavity group, with no statistical difference between them. Intermediate values were obtained in RelyX ARC group and RelyX Unicem group, which differed statistically. The Student t-test showed that there were statistically significant differences between the 200 N and 300 N occlusal loads for the cavity group ($p = 0.002$), the RelyX Unicem group ($p = 0.000$), and the SeT group ($p = 0.004$). There was no statistical difference for the sound teeth group ($p = 0.389$) or the RelyX ARC group ($p = 0.188$) (Table 2).

DISCUSSION

The hypothesis was accepted, as there were differences in cuspal deflection among the experimental groups.

Premolars were used in this study because they have an unfavorable anatomic shape, crown volume and crown/root proportion, making them more suscep-

Table 2: Mean cuspal deflection and standard deviation of the groups under 200 N and 300 N loads.

Group	n	Mean (μm) and standard deviation 200 N	Mean (μm) and standard deviation 300 N
Group 1 – Sound teeth	12	3.42 ^{aA} (1.44)	3.92 ^{aA} (1.68)
Group 3 – RelyX ARC	12	6.83 ^{bA} (3.16)	8.83 ^{bA} (3.41)
Group 4 – RelyX U100	12	13.42 ^{cA} (8.75)	16.92 ^{cB} (8.68)
Group 5 – SeT	12	42.83 ^{dA} (12.71)	57.00 ^{dB} (14.02)
Group 2 – Cavity	12	65.50 ^{dA} (18.58)	79.00 ^{dB} (20.85)

Means in the columns followed by the same lowercase letter did not differ statistically according to Tukey's test at a 5% significance level. Means in the rows followed by the same capital letter did not differ statistically according to Student's t-test for dependent samples at a 5% significant level.

tible to cuspal fractures than other posterior teeth when submitted to occlusal load²⁴. The dimensions of the cavity preparation were standardized in all groups, representing a clinical situation of advanced caries, for which preparation becomes extensive.

Cuspal deflection is a non-destructive methodology that verifies the deformation of the cusps when a load is applied in the occlusal region. In this study, a 200 N occlusal load was applied to perform the cuspal deflection test. The 200 N load is the intermediate value between 100 and 300 N, which corresponds to the range of normal biting force for maxillary premolars^{25,26}. Cuspal deflection under a 300 N load was also verified. According to Jantarat et al.¹, a load of up to 300 N can be applied without the risk of tooth fracture. The results showed that the application of greater occlusal load produced an increase in intercusp distance, in agreement with the study by González-López et al.². This finding proves that the deformation depends on the intensity of the force applied¹.

The highest cuspal deflection was obtained for the cavity group, and the lowest values for the sound teeth. This small cuspal deflection in sound teeth is due to the very stiff behaviour of sound teeth under load¹. Intact teeth with a complete enamel covering are very stiff, and an occlusal load causes only a small deformation. Sound teeth distribute load-generated stress more homogeneously, because the enamel is not appreciably deformed and the deformation is transferred to the more resilient dentin²⁷. When the continuity of the enamel is lost as a result of preparation, the properties of the dentin play a major role in cusp behaviour²⁸. Loss of dental structure causes a decrease in tooth stiffness, and consequently there is an increase in cuspal deflection under occlusal loads^{1,2}. It is important to recover the stiffness of the teeth after restoration. Nevertheless, when the teeth were restored with composite resin inlays and luted with RelyX ARC, RelyX Unicem or SeT, none of the groups replicated the stiffness of natural teeth.

Among the restored groups, RelyX ARC had the lowest cuspal deflection. RelyX ARC is a conventional resin cement that is applied with an adhesive system. In this study, the preparation was etched with 37% phosphoric acid, followed by primer and bond applications, which allow hybrid layer formation on enamel²⁹ and dentin³⁰. The micro-mechanical retention obtained with the hybrid layer may explain the

smaller cuspal deflection in the RelyX ARC group than in the RelyX Unicem and SeT groups.

RelyX Unicem had the third lowest value of cuspal deflection. It is a self-adhesive resin cement that consists of alkaline fillers and specific multifunctional phosphoric-acid methacrylates, which are ionized at the time of mixing and which react with the hydroxyapatite of the mineral tissues of the tooth³¹. On dentin, this material was unable to demineralize or dissolve the smear layer completely, no decalcification and infiltration of dentin occurred and no hybrid layer or resin tag was observed^{14,17,32}. The bond mechanism of RelyX Unicem to the tooth appears to be more chemical rather than micromechanical in nature. As RelyX Unicem have lower bond strength to enamel^{12,19} and dentin²⁰⁻²² than do multistep systems, the bond to the dental tissues may not have been as strong as the bond encountered at the DEJ or when a hybrid layer is formed. This may explain the higher mean cuspal deflection of the RelyX Unicem than of the sound teeth and RelyX ARC groups.

An alternative for increasing the bond strength of self-adhesive resin cements was to apply phosphoric acid etching on the enamel^{12,19,33}, and polyacrylic acid on the dentin^{32,34} before the application of self-adhesive resin cements. The presence of the smear layer has been recognized as the weak link in bonding self-adhesive resin cements^{18,32}. These pretreatments represent an additional step in the application of self-adhesive resin cements, which were developed with the aim of simplifying the application procedure. However, it would be interesting to conduct the same study of cuspal deflection when specific pretreatments are applied on enamel and dentin before luting with RelyX Unicem, once all the inlay margins of the prepared teeth were within enamel, and a significant quantity of dentine was exposed by the inlay preparation.

The self-adhesive resin cement SeT contains an acid monomer that is responsible for etching the tooth surface. However, it is not known specifically what type of acid monomer is used, or whether it has a chemical interaction with the tooth. In the study conducted by Stona et al.³², the adhesion of SeT to dentin did not withstand the cutting methodology used to obtain the test specimens (beams) for evaluating microtensile bond strength. It probably presented less interaction with dental substrates than RelyX Unicem, explaining the highest cuspal deflection.

Comparing 200-N and 300-N occlusal loads, RelyX ARC was the only resin cement that allowed an increase in cuspal deflection without statistical difference. The micro-mechanical retention obtained with the hybrid layer formed on enamel and dentin by the 37% phosphoric acid etching and subsequent adhesive polymerization is probably important for bond stability when the load is increased.

In the case of inlay restoration, the stiffness of the tooth tends to be restored when the material used for luting bonds strongly with the tooth tissues and restorative material, with the formation of a monobloc restoration, in which two bond interfaces are formed, corresponding to the tooth/luting material and restoration/luting material. Among the experimental groups in the present study, variation occurred only at the tooth interface. The same treatment was used at the restoration interface, which consisted of sandblasting with 50 µm aluminum oxide, followed by silane application. According to Zang and Degrange³⁵, the adhesion of self-adhesive resin cements to the restorative material depends on the nature of the

multifunctional monomer contained in the formulation, and these luting agents have potential for specific adhesion to selective restorative substrates. In addition, the different viscosities and the different penetration capabilities of the RelyX ARC, RelyX Unicem and SeT into surface irregularities may have influenced the adhesion of the resin cements to the inlay restoration.

The clinical importance of cuspal deflection is that the greater the magnitude of this deflection, the greater the deformation, and consequently, the greater the possibility of fatigue failure. This type of failure, characterized by fracture in the presence of stress far below the maximum strength of the restored tooth, occurs in most dental fractures³⁶.

The result obtained for cuspal deflection showed that the self-adhesive resin cements RelyX Unicem and SeT showed less capacity to maintain the stiffness of the tooth/restoration complex than did the conventional resin cement RelyX ARC, which may foster greater longevity of the restored tooth. However, clinical studies are necessary to confirm this supposition.

CORRESPONDENCE

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