

Influence of Fiber Post Cementation Length on Coronal Microleakage Values *in vitro* and Finite Element Analysis

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ABSTRACT

Aim: This study aims to evaluate, the influence of different fiber posts cementation lengths by finite element analysis (FEA) and coronal microleakage.

Materials and methods: Fifty anterior bovine teeth were sectioned to obtain roots with 16 mm length. The coronal length of the post was 6 mm for all groups, while the radicular length were varied 6, 8, 10 or 12 mm. The fiber posts surfaces were cleaned with alcohol and silanized. Then the posts were cemented using a two steps total etch-and-rinse adhesive system + conventional resin cement. Forty teeth were submitted to mechanical cycling (45°; 2.000.000 cycles; 90N; 4Hz; 37°C) and ten teeth with radicular length of 12 mm was not submitted, serving as control. So, the experimental design was composed by different ratios of post coronal length/post radicular length and mechanical cycling (MC): Gr1- 1/1 + MC; Gr2- 3/4 + MC; Gr3- 3/5 + MC; Gr4- 1/2 + MC. All groups were immersed in a 1% toluidine blue solution. After 24 hours, the teeth were longitudinally sectioned and the microleakage scores was given by a blind operator. Data were submitted to Kruskal-Wallis test ($p = 0.05$). The experimental variables were simulated in two-dimensional finite element analysis (2D-FEA). The maximum principal stress distributions were compared.

Results: No difference was observed in microleakage values between the cycled groups, whilst the control groups showed

the lowest values. FEA analysis showed similar maximum principal stress distribution between the groups.

Conclusion: Mechanical cycling affected the values of coronal microleakage and different cementation length generated similar values of coronal microleakage and stress distribution.

Clinical significance: These results showed that from the microleakage point of view, more conservative cementation lengths have the same effect as longer cementation lengths.

Keywords: Mechanical cycling, Biomechanical behavior, Coronal microleakage, Intraradicular post.

How to cite this article: Bergoli CD, de Carvalho RF, Balducci I, Meira JBC, de Araújo MAM, Valera MC. Influence of Fiber Post Cementation Length on Coronal Microleakage Values *in vitro* and Finite Element Analysis. J Contemp Dent Pract 2014; 15(4):444-450.

Source of support: Nil

Conflict of interest: None declared

INTRODUCTION

Endodontically treated teeth are more susceptible to biomechanical failures than vital teeth.¹ When endodontic treatment is inevitable, and there is not sufficient dentin to support a restoration, a post is essential to retain the core, so the main purpose of a post is to provide adequate retention of the core material.² Actually, fiber posts, with elastic modulus similar to dentin, have showed good clinical results, being the first option of use.^{3,4}

Retention of fiber posts in the root is crucial for the success of restorative therapy.^{5,6} In order to achieve a good retention, a good radicular post length (between one half to two thirds of the root length)⁷ is usually recommended. However, some authors have indicated smaller lengths for fiber postcementation.⁸⁻¹⁰ One of the reasons to decrease the postradicular length is to reduce the risk of radicular perforation, because of irregularities in root anatomy.^{5,11} Another reason is the difficulty to control the adhesive layer thickness and polymerization in deep preparations, generating poor bonding at the apical root third.^{12,13}

Recent studies have showed that teeth restored with short fiber post generates fracture resistance, fatigue resistance and stress distribution pattern similar to teeth restored with long fiber posts.⁸⁻¹⁰ However, clinical failures

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of tooth restored with intraradicular post are mostly due to microleakage than to fracture of the post.¹⁴ Microleakage is an important parameter to evaluate, because it can cause secondary caries and failure of endodontic treatment. Microleakage is related to the solubility of the cement¹⁵ or marginal debonding between tooth and restorative materials.

In clinical scenario leakage is caused by fatigue that occurs as a result of repetitive loads.¹⁶ Therefore, in experimental test design, the mechanical cycling is usually used in order to better simulate the repetitive loads pattern. The finite element method is useful for the interpretation of the distribution of stresses along a specific interface and to understand the behavior of the system.¹⁸ The use of nondestructive tests, such as analysis by the finite element method, associated with laboratory tests, allow a better understanding of the overall behavior of the system.^{19,20}

The present study aims to evaluate the influence of post length on the risk of marginal debonding between tooth and restorative material, after mechanical cycling, associating microleakage test with FEA. The tested hypothesis was that the radicular post lengths would not influence the microleakage values, when a fiber post was cemented using an adhesive cementation protocol.

MATERIALS AND METHODS

Sample Selection and Preparation

Fifty uniradicular bovine teeth were selected, cleaned, disinfected in a 2% chlorhexidine digluconate solution for 48 hours, and stored in distilled water (5°C). Teeth with cracks or fissures on the root surface, or apices with incomplete rhizogenesis were excluded.

The coronal portion of the teeth was removed with a cylindrical diamond bur, mounted in a high speed pen under constant cooling, and the remainder of the root was standardized to a length of 16 mm. After sectioning, the root canal diameter was measure in the vestibular/lingual and mesio/distal directions, using a digital pachymeter (Starrett® 727, Starrett, Itu, Brazil). Specimens with a diameter larger than that of the post used in the study ($\phi = 2.0$ mm, White Post DC #3, FGM, Joinvile, SC, Brazil) were discarded and

replaced by others that met with this criterion. The canals were then instrumented with endodontic files (NiTi #40, Maillefer, Brazil), to remove the pulp remainder, under constant irrigation with 0.5% sodium hypochlorite.

Randomization and Preparation of the Root Canals

After the specimens were prepared, they were numbered from 1 to 50 and five random sequences of ten numbers ($n = 10$) were generated by the computer program 'Random Allocator', according to the length of cementation and presence or absence of mechanical cycling (Table 1).

After randomization the specimens were prepared at low speed with the respective bur of the post system (White Post DC #3, FGM), by only one previously trained operator, according to the lengths described in Table 1. After the preparations, the posts were tried-in in the root canal to verify whether the adequate length had been achieved. The coronal length of the post was standardized at 6 mm.

Simulation of the Periodontal Ligament and Embedding

To simulate the periodontal ligament the measurements of the vestibular/lingual and mesio/distal dimensions of three points of the root were obtained. Afterwards, utility wax was liquefied at a temperature of 70°C and applied on the root using a paint brush. New measurements of the root dimensions, at the same points as those previously measured, were taken until a homogeneous thickness of 0.3 mm was obtained.²¹ The wax was applied up to 3 mm below the cervical portion of the root.

After wax application the roots were embedded in metal matrices, with self-polymerizing acrylic resin, up to 3 mm of the most cervical portion, according to the methodology described by Bergoli et al (2011).²² After the acrylic resin had set, the roots were removed from the cylinders. After this the wax was removed, generating adequate space for the insertion of the material to reproduce the ligament. Polyether (Impregum, 3M ESPE, ST Paul, MN, USA) was manipulated, inserted into the space created by the wax. The root was repositioned in the cylinder, the time was

Table 1: Experimental design of the study

Groups	Length of coronary post (mm)	Length of cementation (mm)	Mechanical cycling	Relation length post/root	Relation length of coronary post/cementation
Gr1	6	6	Yes	0.375	1/1
Gr2	6	8	Yes	0.5	3/4
Gr3	6	10	Yes	0.6	3/5
Gr4	6	12	Yes	0.75	1/2
Gr5*	6	12	No	0.75	1/2

*Control Group (not cycled)

Table 2: Classification of the depth of leakage in the tested samples

Score	Depth of infiltration
0	No infiltration
1	Infiltration of the first slice
2	Infiltration of the first and second slices

waited for the polyether to set, and the excess was removed with a scalpel.

Cementation Procedures

Initially the posts were section with diamond burs, their length was standardized according to the length of cementation and coronal length. After this all the posts received the same surface treatment: cleaning with 97% alcohol, followed by application of the silane bonding agent (Prosil, FGM).

For cementation, a 2-step total acid etching adhesive system was used, associated with a conventional dual resin cement. Initially the root canal was etched with 37% phosphoric acid for 15 seconds (FGM), abundantly washed with distilled water (60 seconds) and dried with absorbent paper cones #80. After this stage the dentinal adhesive (Ambar, FGM) was applied in the root canal with the aid of a microbrush (Cavibrush Longo, FGM), the excess was removed with paper cones and light activation was performed with high power LED 1200 mW/cm² (Radii Cal, SDI, Australia), on the coronal surface for 30 seconds. For cementation, equal portions of base and catalyzer pastes of the resin cement (Allcem, FGM) were manipulated and inserted into the canal with the aid of a Lentulo #40 bur. After this stage, the post was inserted into the canal, kept in position under finger pressure for 60 seconds, the excess cement was removed and the cement was light activated for 40 seconds (Radii Cal, SDI) from the occlusal surface of the fiber post.

Coronal Reconstruction

For reconstruction a micro-hybrid resin composite (Opallis, FGM) was used with the aid of standardized plastic matrices. To fabricate the matrices, a human central incisor (coronal portion 10 mm high) was molded with addition silicone, dies were obtained with special stone plaster, and plastic matrices were fabricated. Initially, the coronal dentin was etched with 37% phosphoric acid (FGM) for 15 seconds, washed abundantly with water and carefully dried with absorbent paper. Afterwards a layer of dentinal adhesive (Ambar, FGM) was applied on the dentin, using a microbrush (Cavibrush, FGM), a light jet of air was used to evaporate the solvent, and adhesive thickness homogenization and light activation were performed for 30 seconds (RadiiCal, SDI). For reconstruction the matrices were filled with resin

composite and placed on the coronal surface of the tooth. After this light activation was performed for 20 seconds per surface (Radii Cal, SDI). The matrices were removed with a scalpel, and finishing was performed with an ultrafine diamond bur (Broca 3118F, KG Sorensen, Cotia, SP, Brazil), abrasive paper disks (Sof-Lex, 3M ESPE, St Paul, MN, USA) and polishing with silicone tips (Poligloss, Microdont, São Paulo, SP, Brazil).

Mechanical Cycling

The specimens submitted to cycling were placed at an angle of 45° in a mechanical cycling machine (ER 11000, Erios, São Paulo, Brazil), in which a piston ($\phi = 1.6$ mm) induced 2,000,000 cycles with a load of 90 N, at a frequency of 4 Hz, 2 mm below the incisal edge on the palatine face of the specimen. During this period, the specimens remained immersed in water at a temperature of 37°C ($\pm 2^\circ$ C).

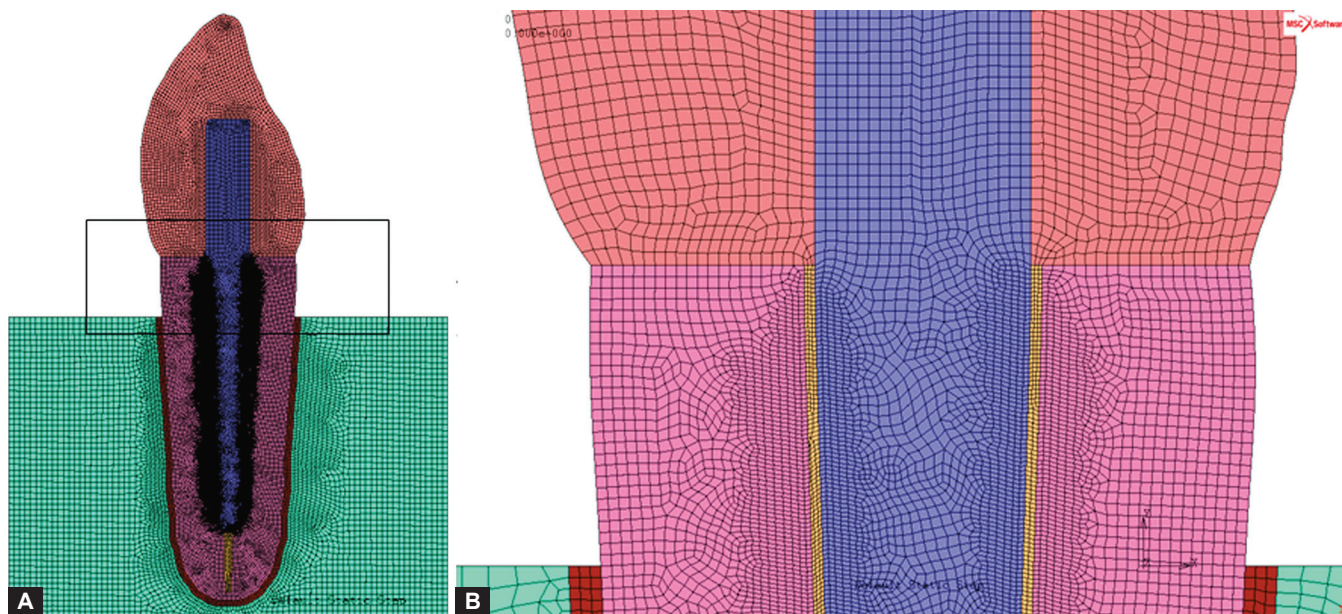
Microleakage Test

Initially all the specimens were removed from the acrylic resin cylinders and their roots were sealed with layers of cosmetic varnish (Revlon Incorporated, New York, NY, United States of America), up to 1 mm below the cervical limit, thereby avoiding infiltration of the dye through a surface that was not of interest to the study.²³⁻²⁵ After this the specimens were immersed in a solution of 1% toluidine blue for 24 hours.²⁶ A fresh solution was always used for all the groups. After the period of immersion, the samples were washed in running water and cleaned with a brush to eliminate any remaining residue of the dye. Finally the specimens were reinserted in their respective matrices, taken to a cutting machine (Labcut 1010, Exttec, Enfield, USA) and sectioned perpendicular to their long axes to obtain two slices. The first cut was made at the interface of the bond between the resin composite and cervical margin of the root. From this point two slices (2 mm thick) were obtained to evaluate leakage. The slices were analyzed under a stereomicroscope (Discovery V-20, Zeiss, Germany), at 30× magnification, by an operator who was blind to the experimental groups. The operator identified the levels of leakage and checked the scores according to the depth of dye infiltration (Table 2).

Taking into consideration that each group was composed of 10 specimens, the sum of the scores of the 10 specimens of each group ($n = 10$) was used for statistical analysis. Data were submitted to the Kruskal-Wallis statistical test, at a 5% level of significance.

Finite Element Analysis

Four 2D FEA models were created, reproducing the different lengths of cementation of the fiber posts and representing



Figs 1A and B: (A) Mesh of the model of the group with the post cemented to 12 mm, (B) approximate view of the same model showing the convergence between the elements

acrylic resin, simulated periodontal ligament, dentin, fiber post, post cement and resin composite crown (Fig. 1). Quadrilateral plane strain elements (quad 8) were used and the quantity of elements and nodes varied for each model: Gr1 – 27303 elements and 29262 nodes; Gr2 – 23063 elements and 25066 nodes; Gr3 – 22542 elements and 24617 nodes; Gr4 – 25084 elements and 25323 nodes.

All the surfaces were considered perfectly bonded and the materials considered isotropic, homogeneous and linearly elastic (see modulus of elasticity and Poisson coefficient in Table 3).

Nodes located at the bottom and the sides of the acrylic resin were considered fixed.

An oblique force of 90N and 45°, was applied in the palatine region, at a point situated 2 mm below the incisal edge of the crown (Fig. 1).

The program MSC/PATRAN2005r2 was used for pre-processing and the program MSC. Marc2005r2 for processing and postprocessing. The maximum principal stress values and direction at the nodes located at the interface resin composite crown/root dentin were observed.

RESULTS

The Kruskal Wallis test showed statistical difference among the groups ($p = 0.000$). Comparison of the means among the groups is shown in Table 4.

All the specimens in groups Gr1 and Gr3 presented score 2 for the degree of infiltration. Groups Gr2 and Gr4 presented a predominance of specimens with score 2, and both presented one specimen with score 1. Differently from the other groups, Group Gr5 presented only specimens with score 0 and 1 for the degree of infiltration.

Analysis by the finite element method showed a small difference in the Maximum Principal Stress values among the groups (Fig. 2). The direction of the tensile vectors found in the crown of all the groups was in an apicalcoronal direction, with a clear tendency to generate displacement of the restoration and its separation from the adhesive interface, as may be observed in Figure 3 (representative of the group with the fiber post cemented to 12 mm).

DISCUSSION

Some studies have observed that the reduction of the cementation length of fiber posts generated similar fracture strength values and good failure patterns when compared with longer cementation lengths.^{9,10} These results point to the possibility of making a more conservative preparation of the canal, without influencing the mechanical properties of the tooth and minimizing the risk of root perforations.⁸⁻¹⁰ However, studies on the deflection of the fiber posts when they are cemented with different lengths and their interference in the coronal microleakage values are scarce, thus making this verification necessary.

In the present study, irrespective of the radicular post length used, all the cycled groups showed no statistical difference for the microleakage values, confirming the hypothesis of the study.

In this study we performed the coronal restoration with resin composite, because the use of this material is easier and cheapest, compared with indirect materials. On another hand, this material has inferior mechanical properties in comparison with single metal-ceramic or ceramic-ceramic crowns.^{27,28} So, the use of this material could have influenced the debonding of coronal restorations and the

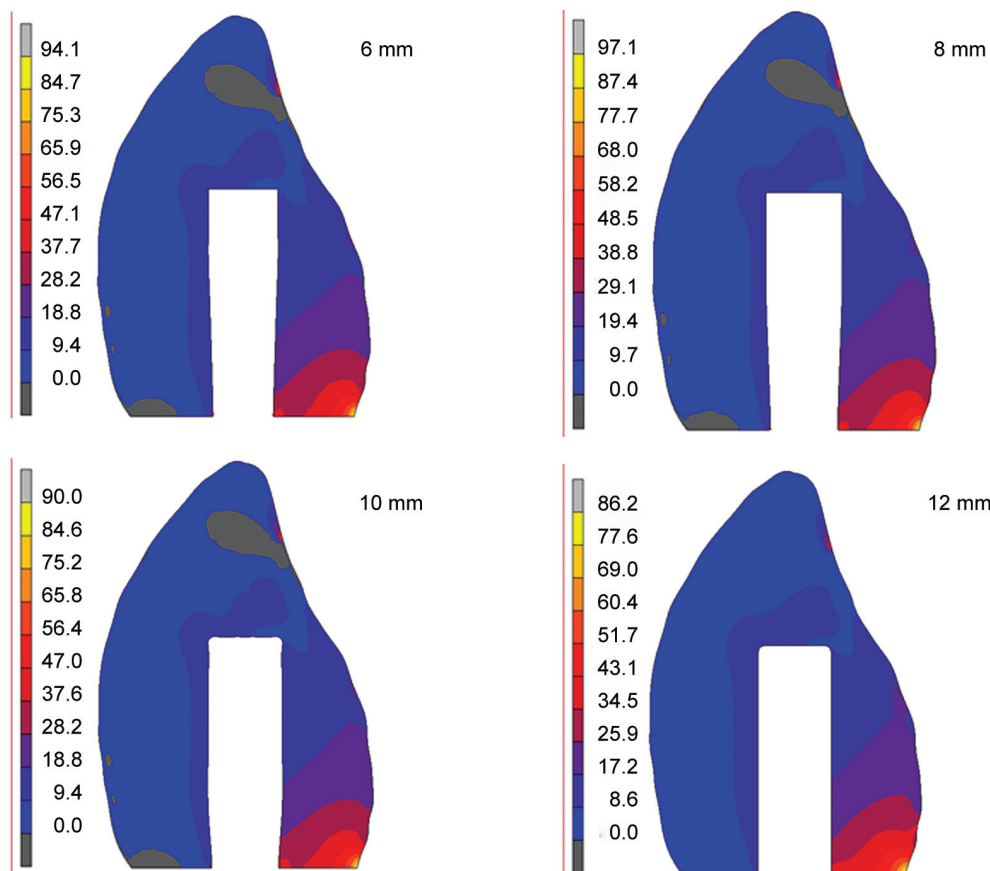


Fig. 2: Maximum principal stress distribution (MPa) for each group

Table 3: Materials, elastic modulus, poisson values and references consulted to obtain the values

Materials	Elastic modulus (GPa)	Poison	Reference
Dentin	18.6	0.31	Peyton FA, Mahler DB, Hershenov B. Physical properties of dentin. J Dent Res 1952;31:366-370.
Composite resin	15	0.24	Versluis A, Tantbirojn D, Douglas WH. Do dental composites always shrink toward the light? J Dent Res 1998;77:1435-1445.
Fiber post	40	0.32	Pegoretti A, Fambri L, Zappini G, Bianchetti M. Finite element analysis of a glass fiber reinforced composite endodontic post. Biomaterials 2002;23:2667-2682.
Resin cement	2.6	0.33	Pegoretti A, Fambri L, Zappini G, Bianchetti M. Finite element analysis of a glass fiber reinforced composite endodontic post. Biomaterials 2002;23:2667-2682.
Gutta-percha	0.14	0.45	Friedman CM, Sandrik JL, Heuer MA, Rapp GW. Composition and mechanical properties of gutta-percha endodontic points. J Dent Res 1975;54:921-925.
Polyeter	0.05	0.45	Farah JW, Clark AE, Ainpour PR. Elastomeric impression materials. Oper Dent 1981;6:15-19.
Acrylic resin	2.7	0.35	Ebadian B, Farzin M, Talebi S, Khodaeian N. Evaluation of stress distribution of implant-retained mandibular overdenture with different vertical restorative spaces: A finite element analysis. Dent Res J 2012;9(6):741-747.

statistically similarity between the groups. May be, the use of different restorative approaches could promote different results than the obtained in this study.

Another probably reason for the similar microleakage values between the groups could be the different restorations

volumes in the cervical region of the specimens (Fig. 2). Specimens with shorter fiber post cementation lengths had a higher volume of restorative material in the cervical portion, resisting better to the loads applied by mechanical cycling, exhibiting, this way, similar tensile values than specimens

Table 4: Percentage of scores to each group and Kruskal-Wallis all-pairwise comparisons test

Variables	Scores percentage (%)			Mean rank	
	0	1	2	Homogeneous groups*	
Gr1 (6 mm)	0	0	100	31.5	A
Gr2 (8 mm)	0	10	90	29.2	A
Gr3 (10 mm)	0	0	100	31.5	A
Gr4 (12 mm)	0	10	90	29.2	A
Gr5 (12 mm)**	40	60	0	6.1	B

*Similar letter indicates similar statistical results

**Control group (not cycled).

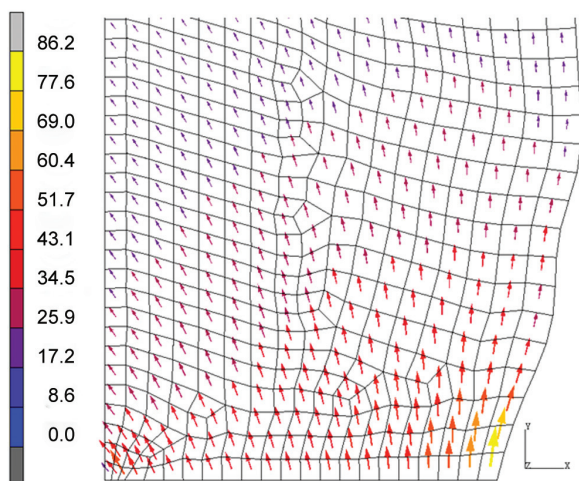


Fig. 3: Magnitude and direction of the vectors of maximum principal stress (MPa) in the group with fiber post cemented to 12 mm

restored with higher fiber post cementation lengths. So, the lower cementation length could have been compensated by the higher volume of the restoration.

Some previous studies have not showed influence of mechanical cycling on the bond values between the fiber post and root dentin,^{22,33} but is evident that the mechanical cycling had an influence on the outcome of this research (Table 2). The Figure 2 shows that the load applied at the coronal restoration by the mechanical cycling, generates a stress distribution in the restorative material. In addition, the Figure 3 shows that the direction of this tensile tend to promote the displacement of the restoration. This way, is evident that the stress promoted by the mechanical cycling could have led the creation and propagation of microcracks at the restorative interface, promoting the microleakage.

Another factor that could have promoted the debonding and the coronal microleakage is the adhesive system used to fiber post cementation. Even being indicated for this procedure, the light polymerizing adhesive systems not polymerized adequately as from the middle third of the root canal,^{30,31} once the cavity configuration of the canal prevents the transmission of light up to great depths, making it impossible for the reaction of conversion of the material to occur.³² Santos et al (2010),²⁹ in a finite element study, simulated a condition without a perfect bond between the

resin cement and root canal walls, and observed that the deflection of the retainer tended to occur, generating high values of tensions concentration on the cervical third of the root on the side of load application. The same poor bonding could have occurred in the specimens cemented with higher cementation length, helping to explain the similar microleakage values between this group and the others.

Various solutions and immersion times have been used for the detection of levels of leakage.^{15,17,24,25,34,35} In the present study, the option was taken to leave the specimens immersed in a 1% toluidine blue solution for 24 hours,²⁵ due to the material being easy to obtain and manipulate, in addition to its good dye and infiltrative properties.

For detection of the degree of infiltration of dyes various methodologies have also been used.^{15,17,23-25} However, in the same manner as Erkut et al (2008),²⁴ in the present study the option was to make transverse sections of the root. This form of sectioning enables visualization of all the faces involved in the specimen, differently from longitudinal sectioning, in which only two faces can be visualized.

In spite of the limitations inherent to *in vitro* studies, the present article found that in addition to mechanical cycling having exerted significant influence on the results, the different lengths of cementation generated similar and high microleakage values.

CONCLUSION

1. Two million mechanical cycles were capable of generating damage to the restorative set, to the point of significantly increasing the microleakage values.
2. The stress generated in the resin composite restoration appears be affected by the amount of restorative material and by the diameter of the post in the crown.
3. Different fiber post cementation lengths generate similar coronal microleakage patterns.

CLINICAL SIGNIFICANCES

These results showed that from the microleakage point of view, more conservative cementation lengths have the same effect as longer cementation lengths.

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