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KREJCI, Ivo, *et al.*

Abstract

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Reference

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Marginal Adaptation, Retention and Fracture Resistance of Adhesive Composite Restorations on Devital Teeth With and Without Posts

I Krejci • O Duc
D Dietschi • E de Campos

Clinical Relevance

Using minimally invasive adhesive techniques to restore devital teeth is a promising alternative to conventional treatment modalities.

SUMMARY

This *in vitro* study generated data on the quality of marginal adaptation, fracture resistance and retention of several indirect adhesive composite configurations on root-treated premolars before and after a long-term fatigue test and compared these results to a control group of adhesive onlays on "vital" teeth.

Six root-treated extracted human premolars per group, with four different restorative configurations with and without adhesive fiber posts,

were evaluated. Another group of six premolars, "revitalized" by using diluted horse serum to simulate pulpal fluid and restored with adhesive composite onlays, served as the control. Marginal adaptation before and after long-term occlusal loading (1,200,000 occlusal loading cycles at max 49 N) was assessed by using the replica technique and quantitative evaluation in SEM at 200x magnification. The number of lost restorations was recorded after loading. Fracture resistance and fracture patterns were evaluated by using a universal-testing machine on the fatigued samples.

No significant differences ($p>0.05$) between groups were detected before and after loading for the percentage of "continuous margin" at the total marginal length. Loading had a significant ($p<0.05$) effect on the percentage of "continuous margin" for the total marginal length of two groups only. No significant difference ($p>0.05$) for fracture resistance was detected and no lost restorations were observed.

The results suggest that for both the less decayed and the more significantly decayed devital teeth, the minimally invasive adhesive restorative approach is promising.

*Ivo Krejci, prof dr, chairman, Division for Cariology and Endodontology, School of Dentistry, University of Geneva, Geneva-Switzerland

Olivier Duc, dr, assistant, Division for Cariology and Endodontology, School of Dentistry, University of Geneva, Geneva-Switzerland

Didier Dietschi, dr, senior lecturer, Division for Cariology and Endodontology, School of Dentistry, University of Geneva, Geneva-Switzerland

Edson de Campos, prof, visiting professor, Division for Cariology and Endodontology, School of Dentistry, University of Geneva, Geneva-Switzerland

*Reprint request: rue Barthélemy-Menn 19, CH-1205 Geneva-Switzerland; e-mail: ivo.krejci@medecine.unige.ch

INTRODUCTION

Restoring devital teeth represents a major challenge for the practitioner, because it requires profound knowledge in endodontics, periodontics and restorative therapy (Morgano & others, 1994). The situation is further complicated by the fact that clinical concepts regarding the restoration of devital teeth have often been based on empirical philosophies due to the lack of sound scientific data (Cariso & others, 1987; Morgano & others, 1994; Robbins, 2001). Among the three factors mentioned above, restorative therapy for endodontically treated teeth may be the most important. Non-restored, endodontically treated teeth are prone to fracture and coronal leakage, leading to bacterial contamination (Trabinejad, Ung & Kettering, 1990; Ray & Trope, 1995; Ricucci, Grondahl & Bergenholtz, 2000; Tronstad & others, 2000). In restored, endodontically treated teeth, catastrophic failures are mainly induced by failed restorations—in most cases, crown fractures due to secondary caries—leading to extraction. Tooth loss due to periodontal reasons or failed endodontics are relatively scarce (Vire, 1991; Fuss, Lustig & Tamse, 1999). Poor endodontic therapy leads to failure irrespective of the quality of restorative treatment. However, success of a well done endodontic treatment is significantly increased by a good quality coronal restoration (Bishop & Briggs, 1995; Tronstad & others, 2000).

Traditional restorative therapy of devital teeth involves a combination of root canal filling, conventionally cemented prefabricated or custom made metallic post with a metallic core and coverage with a conventionally cemented full crown (Colman, 1979). Under the conditions of proper planning and meticulous clinical work, this restorative complex may serve for decades (Nanayakkara, McDonald & Setchell, 1999). However, the traditional method of restoring devital teeth comprises several drawbacks and risks that have given rise to serious criticism (Stockton, Lavelle & Suzuki, 1998). One drawback is the considerable treatment time spent on such complex restorations, making them extremely costly (Shugars & others, 1997). Another drawback is the considerable amount of sound tooth structure that often has to be sacrificed (Sornkul & Stannard, 1992). In particular, the risks are root perforations and root fractures due to placing radicular posts and the decementation of posts (Nanayakkara & others, 1999; Fuss & others, 2001; Gher & others, 1987; Alhadainy, 1994; Fuss & Trope 1996).

In the 1980s, unfilled resins were proposed as luting agents for metallic posts to increase retention (Goldman & others, 1984). However, the true breakthrough in the field of modern restoration of endodontically treated teeth was the introduction of the adhesive technique, especially propelled by the development of

efficient dentinal adhesives (Van Meerbeek & others, 2001). Because the retention of adhesive restorations is mainly based on adhesion and does not require macroretentive elements (Tjan, Munoz-Viveros & Valencia-Rave, 1997), minimally invasive preparations with maximal conservation of dental tissues can be realized (Robbins, 1990; Tjan & others, 1997; Bindl & Mörmann, 1999). In addition, the insertion of radicular posts often becomes obsolete.

Although the trend towards minimally invasive restorations is overwhelming, even in modern adhesive concepts, full coverage crowns with post and cores are recommended for restoring seriously damaged teeth and cuspal coverages for minimally damaged posterior devital teeth are deemed necessary (Smith & Schuman, 1997). However, in view of the new possibilities given by adhesive techniques, the question arises whether these guidelines are still justified.

Therefore, this study generated data on the quality of marginal adaptation, fracture resistance and the retention of different types of indirect adhesive restorations on devital teeth before and after a long-term fatigue test. These results were to be compared to a control group of adhesive composite onlays on "vital teeth." The working hypothesis was that marginal adaptation before and after loading would not be significantly different between the control and experimental groups and there would be no significant difference in respect to fracture resistance among the different groups and no lost restorations.

METHODS AND MATERIALS

Specimen Preparation

Thirty caries-free extracted human premolars with completed apexification, stored in 0.5% thymol solution for at least three months at 4°C until initiation of the experiment, were used for this study. They were randomly divided into five equal groups.

The root length of each tooth was adjusted to fit into the chamber of the mechanical loading device (Department of Cariology, Endodontics & Pedodontics; Laboratory of Electronics of the Faculty of Medicine; University of Geneva) (Figure 1). After sealing the apex of each tooth with a filled light-curing dentinal adhesive (Optibond FL, Kerr Corp, Orange, CA 92867, USA), all the specimens were fixed with light-curing composite (Herculite XRV, Kerr) on custom-made metallic holders (Provac; FL-9496 Balzers, Liechtenstein) and their root bases were further stabilized with self-curing acrylic resin (Technovit 4071, Heraeus-Kulzer GmbH, D-61273 Wehrheim, Germany). In the reference group that simulated vital teeth, a metallic tube was inserted into the pulp chamber in the upper third of the root and sealed with a filled light curing dentinal adhesive

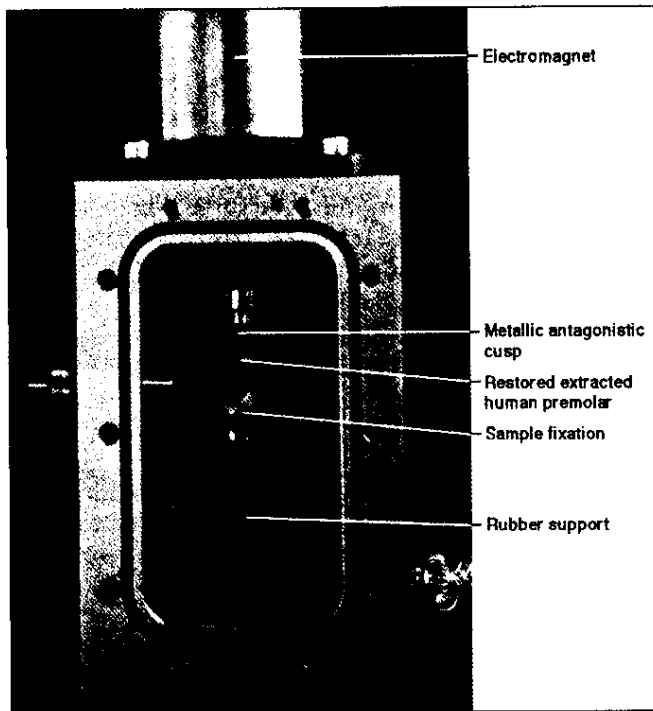


Figure 1. One out of the six chambers of the custom made device was used for occlusal loading of the samples.

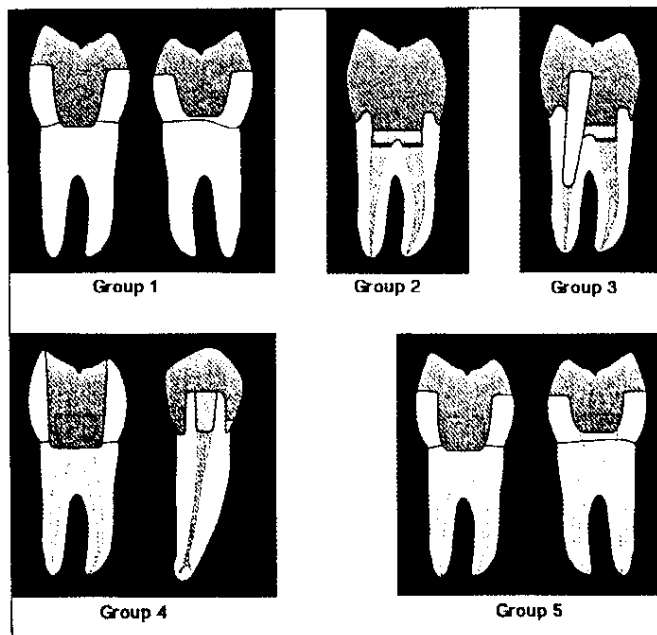


Figure 2. Schematic representation of the experimental groups.

(Optibond FL). This tube was connected by a flexible silicone hose to an infusion bottle placed 34 cm vertically above the test tooth. The infusion bottle was filled with horse serum diluted in a 1:3 ratio with 0.9% NaCl (Pashley & others, 1981) to simulate the dentinal fluid under normal hydrostatic pressure of about 25 mm Hg (Tao & Pashley, 1989). Twenty-four hours

before starting the cavity preparation, using a three-way valve, the pulp chambers were evacuated with a vacuum pump and, subsequently, bubble-free filled with the diluted horse serum. At that moment, the intrapulpal pressure was maintained at 25 mm Hg throughout testing, that is, during cavity preparation, restoration placement, finishing and stressing.

Group 1 simulated the restoration of vital teeth. Class II cavities (MOD) were first prepared by using coarse diamond coated burs (Universal Prep Set, Intensiv SA, CH-6962 Viganello, Switzerland) in a high speed handpiece (Intramatic Lux 2 24LN, KaVo, D-88400 Biberach, Germany) under profuse water spray cooling with proximal margins located 1.0 mm below (mesial) and 1.0 mm above (distal) the cementum-enamel junction. The standardized dimensions of the tapered preparations were 4.0 mm in width and 1.5 mm in depth at the bottom of the proximal box, and 4.0 mm in width and 3.5 mm in depth for the occlusal isthmus, all walls having 10° of divergence against the occlusal plane. Subsequently, 2.0 mm of the lingual and the buccal cusp were reduced, thus, creating an onlay cavity. All internal cavity surfaces and cavity margins were finished under the stereo microscope (MZ6, Leica, D-6330 Wetzlar, Germany) at a 15x magnification.

In Group 2, endodontically treated non-vital teeth with completely destroyed clinical crown were simulated. The root canal preparations were performed using NiTi rotary instruments (Hero 642, MicroMega, F-25000 Besançon, France) in a low speed handpiece (Intramatic Lux 29LN, KaVo, D-88400 Biberach, Germany) under intermittent rinsing with 5% NaOCl. An epoxy sealer (AH Plus, Batch 0102000063, Dentsply Caulk, Milford, DE 19963, USA) and the vertical guttapercha condensation technique (Obtura II, Obtura Corp, Fenton, MO 63026, USA) were used as the canal obturation system. An 0.5 mm layer of glass-ionomer cement (KetacBond, 3M-ESPE, St Paul, MN 55144, USA) was applied on top of the filled root canal to facilitate future re-entry. The clinical crown was completely removed and the remaining tooth prepared as follows: A central inlay 2 mm in depth was cut into the pulp chamber and a chamfer 1.0 mm width and 1.5 mm in height was prepared around the entire tooth periphery, 1.0 mm below the cemento-enamel junction.

In Group 3, the same preparation was used as for Group 2. However, instead of using a glass-ionomer layer on top of the root filling, the root canal was prepared to fit an adhesive post to a length of 7.5 mm.

Group 4 represented devital teeth with inlay restorations. The dimensions of the preparations corresponded to those of Group 1 but without occlusal reduction of the cavity walls, and the root canal treatment was

conducted according to the procedure described in Group 2.

Group 5 corresponded to Group 4, but both cusps were reduced by 2.0 mm, creating a devital onlay situation (Figure 2).

Restorative Procedures

A composite (Targis, Batch No enamel 10563 and dentin 13330, Ivoclar-Vivadent AG, FL-9494 Schaan, Liechtenstein), a dual-cured luting composite (Variolink II, Batch No base 14589 and catalyst 15619, Ivoclar-Vivadent AG, FL-9494), an organic silane (Monobond S, Batch No 07717, Ivoclar-Vivadent AG, FL-9494) and a multi-functional adhesive (Syntac Classic, Batch No Primer 05853, Adhesive 05896, Heliobond 05896, Ivoclar-Vivadent AG) were used for all groups.

Except for Group 3, the adhesive system was applied and light-cured (Optilux 501, Demetron/Kerr Corp, Danbury, CT 06810, USA), and relative intensity was measured with the Curing Radiometer Model 100 (Demetron/Kerr Corp) $> 1000 \text{ mW/cm}^2$ for 60 seconds on the cavity surfaces according to the manufacturer's instructions in order to seal the cavity. Thereafter, cavity margins were finished with a fine diamond bur (Geneva Prep Set, Batch S9901, Intensiv SA, CH-6962 Viganello, Switzerland) according to the principles of the selective bonding technique (Krejci & Stavridakis, 2000), where complete adhesion is confined to the cavity margins only.

In Group 3, fiber-reinforced composite posts (Vectrispost, Size S, Batch No ZZ9265, Ivoclar-Vivadent AG, Schaan, FL-9494) were inserted into the root canals, and the preparations for all groups were then replicated by using a polyvinylsiloxane material (Aquasil light and heavy, Dentsply Caulk) in custom made trays. All impressions were poured with hard stone (Fujirock; Fuji, GC Europe NV, B-3000 Leuven, Belgium), resulting in individual stone dies. Two thin layers of a water soluble glycerine gel (Model separator, Batch No A12029, Ivoclar-Vivadent AG, FL-9494) were applied on each die as a separating medium, and indirect composite restorations were fabricated on these dies by using an incremental technique. Each increment was light cured for 20 seconds (Optilux 501). The finished workpieces were coated with glycerine and subjected to a light and heat post-curing process (Programm P1, Targis Power, Ivoclar-Vivadent AG, FL-9494). The bond between the composite workpieces and the posts in Group 3 was assured by sandblasting the surface of the post with 50 microns Al_2O_3 at 2 bar pressure, silanization (Monobond S, Batch No 07717, Ivoclar-Vivadent AG, FL-9494) and applying a bonding agent (Heliobond, Batch No 05896, Ivoclar-Vivadent AG).

The workpieces were adhesively luted. For this purpose, the enamel margins were acid etched for 30 seconds using 37% phosphoric acid (Total Etch, Batch No 30606, Ivoclar-Vivadent AG) (Munehika & others, 1984). After rinsing and drying, Primer, Adhesive and Heliobond were applied in a thin layer on enamel and dentin according to the manufacturer's instructions and Heliobond was pre-cured for 60 seconds (Optilux 501). The internal surfaces of the composite workpieces were sandblasted with Al_2O_3 at a pressure of 2 bar, silanized (Monobond S) and coated with bonding resin (Heliobond). Variolink II dual cured composite served as the luting agent that was light-cured (Optilux 501) from the oral, facial and occlusal direction, each mesially and distally, for 60 seconds.

Finishing and polishing was performed immediately after polymerization of the luting composite by using fine diamonds (Geneva Prep Set) and finishing discs with descending abrasives (Sof-Lex, 3M-ESPE).

Mechanical Loading

The stress test was initiated after seven days of storage in water at 37°C in the dark. All specimens were submitted to 1,200,000 cycles with maximum 49N loading force by using artificial cusps made of stainless steel with a hardness similar to natural enamel (Vicker's hardnesses: enamel = 320-325; steel = 315); the diameter of the cusps was 4 mm and they contacted the occlusal surface of the restoration about 1.5 mm out of the central fossa. The axial force was exerted at a frequency of 1.5 Hz, following a half-sinus curve. By having the specimen holders mounted on a rubber disc, a sliding movement of the tooth was produced between the first contact on an inclined plane and the central fossa (Krejci & others, 1990; Dietschi & others, 1995). These conditions are believed to simulate approximately five years of clinical service (Krejci & Lutz, 1990).

Marginal Adaptation

Before and after the stress test, gold sputtered (SCD 030, Provac, FL-9496 Balzers, Liechtenstein) epoxy resin replicas (Epofix, Stuers, D-2610 Rodovre, Denmark) of all samples were fabricated by using polyvinylsiloxane impressions (President light body, Coltène-Whaledent AG, CH-9450 Altstätten, Switzerland). They were subjected to the quantitative evaluation of marginal adaptation at a standard 200x magnification in a SEM (XL20, Philips, NL-5600 Eindhoven, Netherlands) by using a custom made module programmed within image processing software (Scion Image, Scion Corp, Frederik, MA 21703, USA). The following criteria were applied and reported as percentages relative to the entire marginal length: "Continuous margin," "marginal opening," "marginal tooth fracture," "marginal restoration fracture," "overhangs" and "underfilled margins." The data were sub-

mitted to parametric statistical analysis by using ANOVA and Sheffe's F test at a 95% level of significance.

Retention

Lost restorations were recorded after completing the load cycle and their number was reported per group.

Fracture Resistance

The fracture resistance test was performed using a universal testing machine (Instron Model 1114, Instron Corp, High Wycombe, HP 12 357, Great Britain) on the fatigued samples. After embedding the teeth up to 2 mm beneath the CEJ in cold curing resin (Epofix), a spherical headpiece 5.0 mm in diameter was used to apply axial compression force in the middle of the occlusal surface of the samples (Figure 3). The crosshead speed was 1.0 mm/minute and compression force was applied until the specimen fractured.

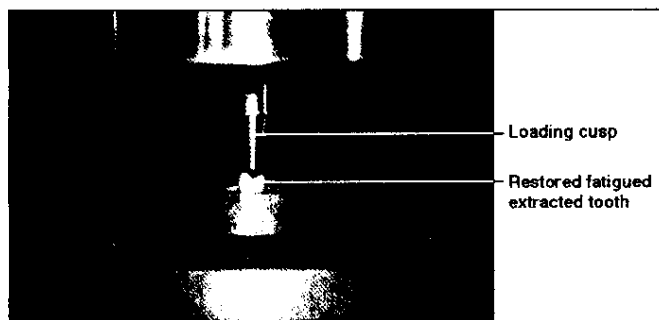


Figure 3. This figure represents the fracture strength test design.

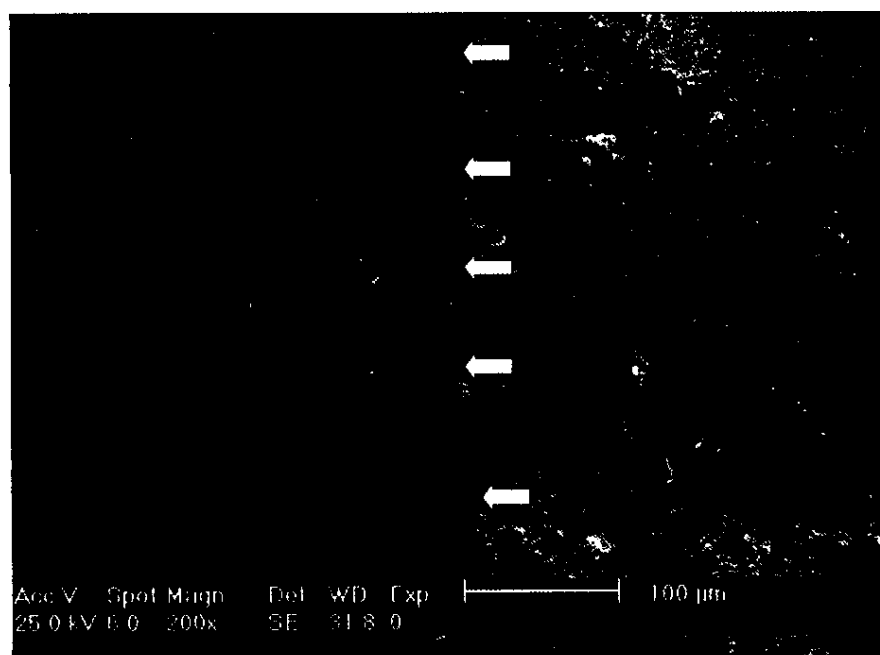


Figure 4. The continuous margin (flashes) at the axial wall of an onlay of Group 4 after loading. Left: enamel; right: restoration (SEM, original magnification 200x).

The data of the fracture resistance evaluation were submitted to ANOVA and Student-Newman-Keuls test.

RESULTS

All restorations were in place after completing the stress test, meaning that retention amounted to 100% for all groups.

The results of the marginal adaptation at the interface between the tooth and luting composite are represented in Tables 1 through 3. No significant differences ($p > 0.05$) between groups were detected before and after loading for the percentage of "continuous margin" (Figure 4) at the total marginal length (Table 1). The same was true for dentinal margins prior to loading (Table 2). After loading, however, significant ($p < 0.05$) differences were found between Groups 3 and 4 and Groups 3 and 5 at dentinal margins, with Groups 4 and 5 showing the best marginal adaptation.

Loading had a significant ($p < 0.05$) effect on the percentage of "continuous margin" for the total marginal length of Groups 2 and 4. However, only Group 2 showed a significant difference due to loading at the dentinal margins.

The predominant marginal defect in all groups was the pure marginal opening (Figure 5 and 6). However, several groups also showed some "marginal enamel fractures" (Figures 7 and 8), with a significant ($p > 0.05$) increase after loading for Group 5 (Table 3).

No more than 3% of the "marginal restoration fractures," "overhangs" and "underfilled margins" were found before and after loading, with no significant differences among the groups.

The marginal adaptation at the interface between luting composite and workpiece was perfect in all groups, both before and after loading.

Very inhomogenous fracture patterns with no preferential fracture behavior were observed in all groups after the fracture resistance test. However, most fractures followed an almost axial direction through the restoration and radicular dentin. In addition, vast standard deviations were present in the quantitative measurements, so that despite rather large differences between the mean fracture force values, no statistical significance could be detected (Table 4).

DISCUSSION

The experimental groups in this study consisted of extracted human premolars because they represent a more severe situation than molars due to longer clinical

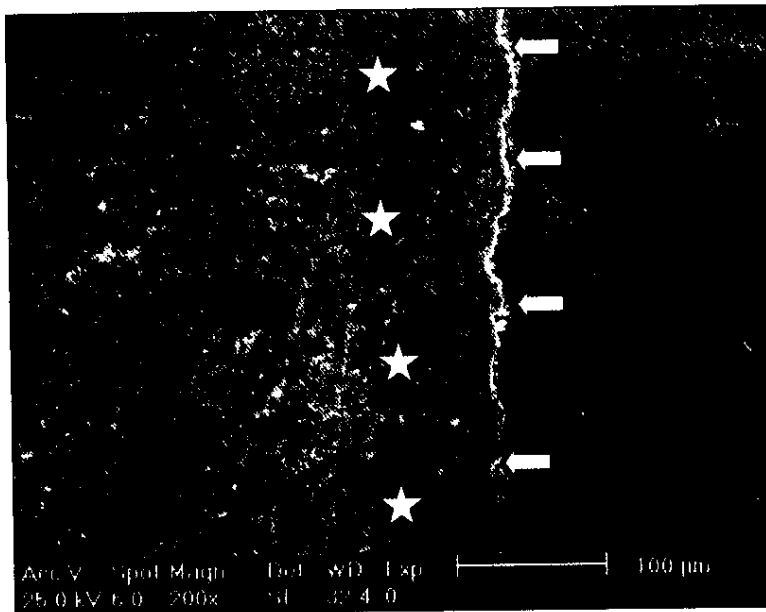


Figure 5. Marginal gap (flashes) at the interface between enamel (right) and luting composite (middle) and the excellent adaptation (stars) between luting composite (middle) and composite restoration (left) at the axial wall of an onlay of Group 5 after loading (SEM, Original magnification 200x).

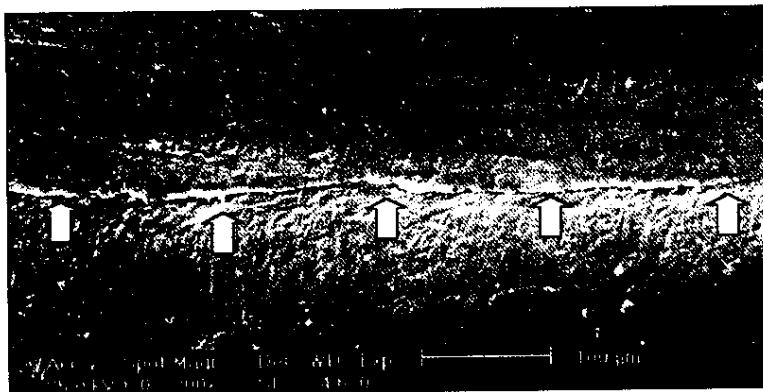


Figure 6. Marginal gap (flashes) at the cervical margin between dentin and luting composite in Group 1 after loading (SEM, Original magnification 200x).

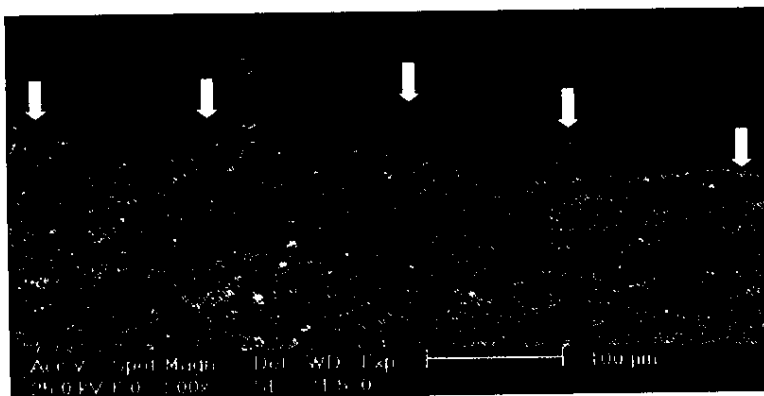


Figure 7. Marginal enamel fracture (flashes) at the occlusal margin of Group 3 after loading. On the upper part of the photo: enamel; in the lower part: luting composite (SEM, Original magnification 200x).

crowns and less dentinal surface for bonding (Robbins, 2001). In this way, an extreme clinical situation was simulated.

A consensus can be found in the newer literature that posts do not strengthen devital teeth (Assif & Gorfil, 1994; Stockton & others, 1998; Baratieri & others, 2000). However, they are still considered necessary for the retention of the restoration, especially in the case of severely damaged teeth (Zalkind & Hochman, 1998). Although this study might have some limitations in respect to its clinical relevance, the direct comparison between Groups 2 and 3 suggest that radicular posts have no relevant influence on retention if used in an adhesive restorative design. In these two groups with missing clinical crowns, the restorations remained in place with and without posts, and there was no significant difference between their marginal adaptation before and after loading. In addition, no significant differences in respect to fracture strength and fracture patterns were recorded. These results indicate that the posts might need re-evaluation. It is obvious that with conventional, non-adhesive restorations, such as amalgam or gold, posts increase retention in a relevant way (Standlee, Caputo & Hanson, 1978). However, this effect may become far less important where adhesive restorations are concerned. The crucial factor here may be the direction of the load. In this experiment, the axial forces were applied to the center of the crown, thus, simulating a normal occlusal situation on a premolar. Since it is well known that fracture resistance depends on the angle of applied load (Kern, von Fraunhofer & Mueninghoff, 1984; Christian & others, 1981; Plasman & others, 1986) and axial forces are less detrimental than oblique forces (Loney, Moulding & Ritsco, 1995), future work needs to determine whether shear forces would change the outcome of the study. Another limitation of this study may be that occlusal loading was applied without simultaneous thermal cycling. It has been suggested that thermal cycling may further stress and weaken the adhesive bond, thus, decreasing fracture strength and increasing microleakage (Eakle, 1986).

Cuspal coverage is thought necessary for the conventional restoration of devital posterior teeth to avoid cuspal fractures (Sorensen & Martinoff, 1984; Smith & Schuman, 1997). Comparing the results of Groups 4 and 5 suggest that this recommendation might be modified for adhesive restorations in the future. No cuspal fractures after the load test were seen in Group 4 with large inlay restorations on devital teeth, even though the buccal and lingual walls were very thin.

Marginal adaptation before and after loading and fracture strengths were not significantly different between Groups 4 and 5. In addition, the fracture patterns were never localized at the restoration/cusp interface and the amount of marginal enamel fractures was even lower in Group 4 than in Group 5. The adhesively restored teeth were apparently sufficiently strengthened to withstand the extensive occlusal loading applied during this experiment (Morin, Delong & Douglas, 1984). However,

the same limitations for the interpretation of these results are true for Groups 2 and 3 because this study simulated axial loads only; the situation may be different with shear forces, especially if directly applied to the cusps (Uyehara, Davis & Overton, 1999) and, therefore, has to be evaluated in future experiments. In addition, the influence of thermal changes will have to be determined.

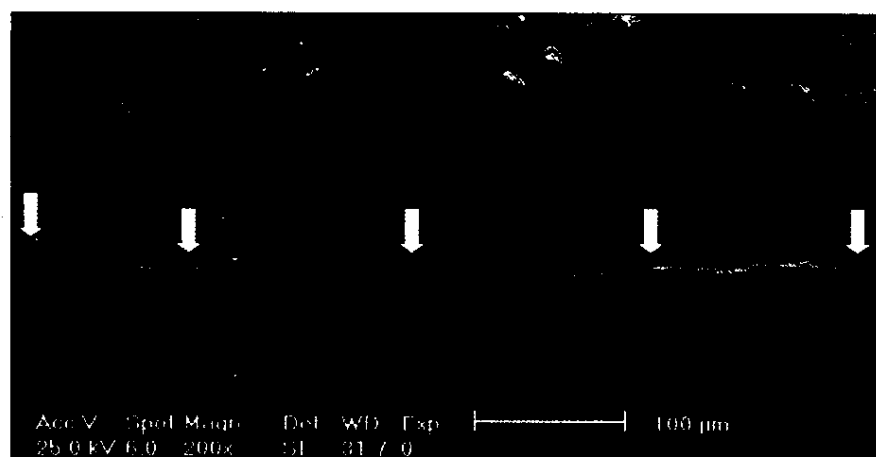


Figure 8. Marginal enamel (flashes) at the cervical margin located in enamel of Group 5 after loading are featured. The upper part of the image is luting composite; the lower part is enamel.

No significant difference in retention, marginal adaptation and fracture strength was seen between the "vital" (Group 1) and "devital" (Group 5) onlays. This agrees with a study where the presence of an endodontic access did not change the fracture strength of a tooth (Steele & Johnson, 1999). For the adhesive system used, it also agrees with another study where the simulation of dentinal fluid had no influence on the marginal adaptation of the adhesive system used in this study in enamel and dentin (Krejci, Kuster & Lutz, 1993). Dentinal adhesion was very successful in this study because the values of "continuous margin" in dentin in groups with dentin and enamel margin (Table 2)

were similar to the values for the total marginal length (Table 1). In addition, the two groups with margins completely located in dentin (Groups 2 and 3) were not significantly different from the other groups.

The interface between composite and luting composite was excellent before and after loading. This confirms the results of an earlier study where sandblasting, silanization and applying a bonding agent resulted in a very good bond between a composite workpiece and a luting composite (Göhring, Peters & Lutz, 2001).

Substantial variations in fracture strength measurements make the interpretation of these results difficult. However, the inconsistent results agree with the literature and are probably due to natural variations in tooth morphology (Steele & Johnson, 1999). Though no

Table 1: Percentages of "Continuous Margin" for the Total Marginal Length Before and After Loading (Means ± SD)

| | Group 1 | Group 2* | Group 3 | Group 4* | Group 5 |
|----------------|-------------|------------|-------------|-------------|------------|
| Before Loading | 91.5 ± 2.8 | 94.9 ± 5.2 | 82.1 ± 11.2 | 91.3 ± 5.6 | 89.8 ± 8.0 |
| After Loading | 85.4 ± 11.9 | 82.5 ± 7.6 | 75.9 ± 17.9 | 72.6 ± 13.7 | 72.9 ± 6.3 |

*p<0.05 before/after loading

Table 2: Percentages of "Continuous Margin" for the Dentinal Margins Only Before and After Loading (Means ± SD)

| | Group 1 | Group 2* | Group 3 | Group 4 | Group 5 |
|----------------|-------------|------------|-------------|-------------|------------|
| Before Loading | 94.8 ± 8.8 | 94.9 ± 5.2 | 82.1 ± 11.2 | 100.0 ± 0.0 | 95.8 ± 5.2 |
| After Loading | 83.7 ± 22.7 | 82.4 ± 7.5 | 75.9 ± 17.9 | 88.2 ± 13.1 | 93.9 ± 6.5 |

*p<0.05 before/after loading

Table 3: Percentages of "Marginal Enamel Fracture" for the Total Marginal Length Before and After Loading (Means ± SD)

| | Group 1 | Group 2** | Group 3** | Group 4 | Group 5* |
|----------------|-----------|-----------|-----------|-----------|------------|
| Before Loading | 4.0 ± 3.6 | - | - | 4.6 ± 4.1 | 3.7 ± 4.5 |
| After Loading | 5.6 ± 4.7 | - | - | 3.2 ± 3.1 | 12.3 ± 8.1 |

*p<0.05 before/after loading

**No enamel margins present

Table 4: Fracture Strength (Means ± SD)

| | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 |
|------------|--------------|-------------|-------------|-------------|-------------|
| Load in kg | 109.7 ± 32.5 | 88.5 ± 57.4 | 83.5 ± 20.3 | 82.3 ± 38.4 | 74.1 ± 30.7 |

significant differences between the groups were detected, a certain trend was observed in the sense that the control, consisting of "vital" teeth (Group 1) was somewhat stronger than all the variations of the non-vital tooth restoration. It was also interesting to note that the fracture pattern of Group 3 did not differ from the fracture pattern of Group 2. This shows that the presence of a fiber-reinforced composite post had no relevant influence on the distribution of the axial forces.

CONCLUSIONS

Under the limitations of the experimental set-up, several conclusions may be drawn from this study: If normal occlusion is present, adhesive inlay restorations should be considered as the restorative treatment of choice for devital teeth without the need for posts and cuspal coverage. Posts may not be necessary for the restoration of largely destroyed teeth where the clinical crown is fully missing. The marginal adaptation in dentin, even after extensive occlusal loading, was similar to the marginal adaptation in enamel. This shows that dentinal adhesion may be as reliable as enamel adhesion, even under the influence of simulated dentinal pressure. No relevant difference was present between a "vital" and a "devital" restored tooth in respect to retention, marginal adaptation and fracture strength, showing that devital teeth may be treated in the same way as vital teeth. However, the conclusions drawn out of an *in vitro* study need to be backed up with controlled clinical trials before they can be used as recommendations for routine clinical work.

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