Influence des bases résineuses et de leur traitement sur l'adaptation externe et interne de restaurations indirectes en composite

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"Influence des bases résineuses et de leur traitement sur l'adaptation externe et interne de restaurations indirectes en composite."

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RESUME

Le but de cette étude in vitro était d’évaluer l’influence de l’élasticité et du traitement de surface de deux bases résineuses sur l’adaptation interne et marginale d’inlays composites après test de fatigue mécanique. Des larges cavités de Classe II pour des restaurations type inlay en composite ont été préparées dans des molaires humaines extraites avec la marge cervicale en cément. Une base résineuse de 1 mm a été insérée dans les cavités. Les échantillons ont été répartis dans l’un des 4 groupes expérimentaux : aucune base (Control group), base en composite fluide et abrasion au bicarbonate (Ex1), composite fluide et sablage (Ex2), composite de restauration et sablage (Ex3). L’interface dent-restauration externe et interne a été analysée au MEB avant et après le test de fatigue. Au niveau de l’émail, la qualité marginale a été prouvée satisfaisante pour les 4 groups. Au niveau de la dentine cervicale, l’ « adaptation parfaite » diminue soit avant la mise en charge soit après. Aucun décollement n’a été observé entre les bases résineuses et le composite de scellement indépendamment du traitement de surface.

INTRODUCTION

L'utilisation de techniques de polymérisation incrémentales (Lutz and Kull 1980; Lutz, Krejci et al. 1986; Lutz, Krejci et al. 1986; Weaver, Blank et al. 1988), d'inserts en céramique (Donly, Wild et al. 1989) ou de matériaux de coiffage (Lutz, Krejci et al. 1986; Friedl, Schmalz et al. 1997) ont été proposées afin de limiter les effets néfastes de la contraction de polymérisation des résines composites lors des restaurations directes de classe II. Certaines techniques restent indiquées en raison des stress fonctionnels appliquées au niveau des dents postérieures et ce malgré les améliorations apportées aux résines composites modernes (Weinmann, Thalacker et al. 2005)

Si ces stratégies se sont révélées efficaces dans le cas de cavités de faible étendue (Gaengler, Hoyer et al. 2001; Pallesen and Qvist 2003), une majorité de praticiens préfère utiliser des restaurations indirectes dans le cas de cavités de plus grande étendue (Dietschi and Spreafico 1997).

En effet, en présence de cavités plus larges, les limites de préparation se trouvent souvent localisées sous-gingivalement ou présentent des zones rétentives qui nécessitent des modifications importantes de forme, elles même responsables de pertes tissulaires supplémentaires. Ainsi, certains auteurs suggèrent l'utilisation de matériaux de restauration internes ou bases collées sous une restauration indirecte. Les bases résineuses ont l'avantage d'offrir un renforcement mécanique des tissus résiduels, une conservation tissulaire maximale et la possibilité de relocaliser les marges de la préparation dans des zones accessibles, sans modification du niveau d'attache parodontale (Dietschi and Spreafico 1998; Rocca and Krejci 2007).

Si les ciments au verres-ionomères modifiés à l'aide de résines ont été proposés pour ce type d'application, différentes études cliniques ont cependant mis en évidence des problèmes importants de dissolution et de dégradation en fonction (Tolidis, Nobecourt et al. 1998; Dietrich, Losche et al. 1999; Dietrich, Kraemer et al. 2000); (van Dijken, Kieri et al. 1999; Andersson-Wenckert, van Dijken et al. 2004).

De nos jours, seules des résines composites de restauration ou fluides sont encore utilisées à cet effet. Théoriquement, ces matériaux devraient jouer un rôle d'absorbeur de stress lors du collage de la restauration indirecte (Kemp-Scholte and Davidson 1990; Kemp-Scholte and Davidson 1990; Ausiello, Rengo et al. 2004). Les résines composites fluides offrent également un avantage clinique certain en termes de facilité d'application. Différents traitements de surface ont été décrits pour assurer la cohésion du système base--composite de scellement--restauration indirecte (Magne and Knezevic 2009; Rodrigues, Ferracane et al. 2009). Cependant, peu d'études se sont intéressées aux interactions entre ces différentes couches résineuses après tests de fatigue mécanique.

Le but de cette étude in vitro était d'évaluer l'influence de l'élasticité et du traitement de surface de deux bases résineuses sur l'adaptation interne et marginale d'inlays composites après test de fatigue mécanique.

MATERIEL ET METHODES

Préparation de spécimens

32 cavités de classe II (une par dent, OD ou OM) ont été préparées dans des molaires humaines fraîchement extraites. Les dimensions des préparations étaient 4.0 mm de largeur et 2.0 mm de profondeur au fond de la cavité proximale, et 3.0

mm de largeur et de profondeur pour l'isthme occlusal ; toutes les parois axiales étaient divergente de 10 à 15° (Fig.2). La marge pr oximale se situait à 1.0 mm en dessous de la jonction émail-cément. Les échantillons ont été répartis dans l'un des 4 groupes expérimentaux (Table 1).

Procédés de restauration

Un système adhésif (OptiBond FL) a été appliqué pour sceller la surface dentinaire (Contrôle) avant l'application d'une couche (1 mm) de composite fluide (Groupes Ex1 et Ex2) ou de restauration (Groupe Ex3) (Fig 3). Les marges d'émail ont été finies à l'aide de fraises diamantées à grain fin et une empreinte de la préparation a été réalisée. Lors du scellement, les cavités ont été soumises à deux différents traitements de surface : d'une part (Groupe Ex1) une abrasion à l'aide de particules de bicarbonate de Sodium (100 µm - 3 bar) d'autre part un sablage (Al_2O_3 de 27 µm-3 bar) (Groupe Ex2 et Ex3) soit à aucun traitement de surface (Groupe CTR).

Trente-deux inlays ont été fabriqués en composite hybride de restauration puis sablés (Al_2O_3 27µm - 3 bar), silanisés et enduites d'une fine couche de résine adhésive.

A l'intérieur des cavités, les marges d'émail ont été mordancées à l'acide orthophosphorique pendant 30s et l'adhésif a été appliqué sur toute la préparation. Après insertion du composite de scellement dans la cavité, les pièces ont été condensées à l'aide d'ultrasons. Les restaurations ont été polymérisées pendant 40s par surface et immédiatement polies. En vue de l'analyse de l'adaptation marginale des restaurations en microscopie électronique à balayage (MEB), des répliques ont été réalisées.

Test de fatigue

24 heures après collage des inlays, les spécimens ont été soumis à une charge occlusale de 100 N pour 1 million de cycles (1,5 Hz) dans un environnement aqueux à température de 20℃ (Fig. 1). A la fin du test de fatigue, des répliques de l'adaptation marginale des restaurations ont été réalisées.

Evaluation au SEM de l'adaptation marginale et interne

Pour l'évaluation de l'adaptation marginale, les segments émail occlusal, émail proximal et dentine cervicale ont été observés au MEB (x200) (Fig. 4). Seul le critère «adaptation parfaite » a été quantifié et exprimé en pourcentage de la longueur totale de la marge. Les résultats, avant et après la mise en charge, ont été comparés.

Pour l'évaluation de l'adaptation interne, les échantillons ont été sectionnés axialement et la tranche centrale a été utilisée pour quantifier l'adaptation interne de la restauration (Fig. 5). Les résultats étaient exprimés en pourcentage d'« adaptation parfaite » observables au niveau de la dentine occlusale, axiale et cervicale.

Les résultats des analyses au MEB ont été soumis à une analyse statistique à l'aide de tests non-paramétriques (Kruskall Wallis, test Nemenyi, Wilcoxon, $p<0.05$).

RESULTATS

Les résultats de l'adaptation marginale au niveau de l'émail occlusal et proximal n'ont pas mis en évidence de différences significatives entre les différents groupes avant et après le test de fatigue. Au contraire, la différence des valeurs avant et après la mise en charge dans chaque groupe a été significative à l'exception du groupe Ex1 au niveau de l'émail occlusal (Table 3 ; Figures 6,7,12,13). Les résultats de l'adaptation marginale au niveau de la dentine cervicale n'ont pas mis en évidence de différences significatives entre les groupes avant et après le test de fatigue. Des différences significatives ont été uniquement détectées entre les groupes CTR et Ex2 en rapport à la différence des valeurs avant et après le test de fatigue (Table 3 ; Figures 8,14,15).

Les résultats de l'adaptation interne n'ont pas mis en évidence de différences significatives entre les différents groupes après le test de fatigue bien qu'une tendance à la diminution de la qualité des marges ait été observée au niveau de la dentine cervicale (Table 4 ; Figures 9 à 11 et 16).

DISCUSSION

Bien que les tests *in vitro* évaluant l'adaptation marginale des restaurations adhésives aient été récemment critiqués par certains (Heintze 2007), d'autres études démontrent que la dégradation clinique des interfaces de collage est responsable de l'apparition de sensibilités post-opératoires, d'inflammation pulpaire et de caries secondaires (Hickel and Manhart 2001; Manhart, Chen et al. 2004). De ce fait, la validité de ces tests in vitro reste indiscutable pour autant que l'on prenne soin de simuler le mieux possible les différents facteurs impliqués dans la dégradation clinique des résines composites. Parmi ceux-ci on distingue l'utilisation de tissus dentaires naturels, un milieu de test simulant l'humidité de la cavité orale, des forces mécaniques reproduisant les contraintes masticatoires physiologiques (Dietschi 2003).

Le placement d'une base résineuse sous une restauration indirecte en composite présente plusieurs avantages. Du point de vue clinique, elle a pour rôle de protéger l'organe pulpo-dentinaire de toute irritation pendant les phases de fabrication de la restauration indirecte et permet de relocaliser les marges de la préparation dans des zones accessibles pour la prise d'empreinte. Du point de vue théorique, la présence d'une couche intermédiaire élastique permettrait également un meilleur transfert des contraintes de polymérisation et d'éviter des décollages prématurés des différentes interfaces adhésives (Kemp-Scholte and Davidson 1990; Ausiello, Apicella et al. 2002; Dietschi, Olsburgh et al. 2003; Ausiello, Rengo et al. 2004; Chuang, Jin et al. 2004; Dewaele, Asmussen et al. 2006). De plus, d'autres travaux mettent en évidence des performances adhésives améliorées dans le cas de couronnes prothétiques, obturations directes de classe II et de facettes (Bertschinger, Paul et al. 1996; Paul and Scharer 1997; Dietschi and Herzfeld 1998; Magne and Douglas 1999; Magne, So et al. 2007).

Les résultats de cette étude confirment le rôle prépondérant des contraintes mécaniques dans la dégradation des interfaces collées (Dietschi and Moor 1999). En effet, une diminution des pourcentages de marges sans solution de continuité a été observée quelque-soit le groupe ou l'interface de collage (email ou dentine) considéré. Ces résultats corroborent les observations rapportées précédemment pour d'autres types de restaurations par d'autres études (Bortolotto, Mileo et al. 2010). Cependant, cette diminution était significativement plus importante au niveau de la dentine cervicale pour les échantillons du groupe contrôle qui ne possédaient pas de base résineuse. Ce résultat renforce le concept de la mise en place d'une base résineuse en vue d'améliorer la longévité clinique d'une restauration indirecte collée. Dans les différents groupes expérimentaux réalisés dans cette étude, aucun avantage significatif n'a pu être mis en évidence en ce qui concerne les propriétés élastiques de la base résineuse ni même en ce qui concerne le traitement de surface appliqué. Seules les restaurations collées à une base en composite fluide sablée à l'aide d'une poudre d'oxyde d'aluminium (27 microns) ont généralement subi moins de détérioration au niveau de l'interface dentine-résine après stress mécanique. D'une manière générale, les résultats d'adaptation marginale observés au niveau de la dentine cervicale après fatigue mécanique étaient significativement inférieurs à ceux observés au niveau de l'émail occlusal et proximal. Ce résultat pourrait être expliqué par la qualité de la dentine cervicale qui offre un potentiel d'adhésion inférieur tels que l'ont mis en évidence différents auteurs (Bouillaguet, Ciucchi et al. 2001 ;(Purk, Dusevich et al. 2007).

CONCLUSION

Dans les limites imposées à cette étude, l'adaptation marginale et interne d'inlays composites type Classe II après test de fatigue mécanique ne semble pas être influencée ni par la base résineuse ni par les différents traitements de surface. Le comportement *in vitro* de ces différents matériaux de restauration a été prouvé satisfaisant au niveau de l'émail. Une dégradation de la qualité marginale a été par contre démontrée au niveau de la dentine cervicale à la suite du test de fatigue pour tous les groupes. En conséquence, les résultats confortent l'utilisation de résines composites de restauration et fluides comme bases résineuses dans des cavités type inlays Classe II en composites. L'abrasion à l'aide du bicarbonate comme traitement de surface de ces bases peut représenter une alternative efficace au traitement classique par sablage.

ABSTRACT

The present study evaluated the influence of different composite bases and surface treatments on marginal and internal adaptation of class II indirect composite restorations, after simulated occlusal loading. Thirty-two Class II inlay cavities were prepared on human third molars, with margins located in cementum. A 1 mm composite base extending up to the cervical margins was applied on all dentin surfaces in the experimental groups; impressions were made and composite inlays fabricated. The following experimental conditions were tested: no liner (CTR group), flowable composite treated with soft air-abrasion (Ex1), flowable composite sandblasted (Ex2) and restorative composite sandblasted (Ex3). All specimens were submitted to 1’000’000 cycles with a 100N eccentric load. Tooth-restoration margins were analyzed semi-quantitatively by SEM before and after loading; internal adaptation was also evaluated on sections after test completion.

The percentage of perfect adaptation in enamel was 79.5% to 92.7% before loading and 73.3% to 81.9% after loading. Perfect adaptation to dentin was reduced before loading (54.8% to 77.6%) and after loading (41.9% to 63%); a significant, negative influence of cyclic loading was observed. No debonding occurred between the base and composite luting.

INTRODUCTION

In direct class II adhesive restorations, incremental methods (Lutz and Kull 1980; Lutz, Krejci et al. 1986; Lutz, Krejci et al. 1986; Weaver, Blank et al. 1988; Bertolotti 1991), the use of ceramic inserts (Donly, Wild et al. 1989) or the application of a base (Lutz, Krejci et al. 1986; Friedl, Schmalz et al. 1997) have been proposed to reduce the stresses developed within the tooth-restoration system due to composite polymerisation shrinkage (Bowen, Nemoto et al. 1983; Davidson, de Gee et al. 1984; de Gee, Feilzer et al. 1993) and post-curing, taking place up to several days after restoration placement (Kildal and Ruyter 1997). Despite the reduction of volumetric shrinkage and elasticity modulus of modern composite formulations the aforementioned techniques are still considered perfectible in large class II restorations because of the combined "negative" effect of composite polymerization and functional stresses. One could also mention clinical limits or contra-indications of the direct technique due to the difficulty in creating an optimal proximal and occlusal anatomy, tight interdental contacts and achieving perfect aesthetics. The industry has recently introduced silorane, a new type of low-shrinkage and E-modulus composite resin (Weinmann, Thalacker et al. 2005) but in the absence of proven satisfactory clinical behaviour and longevity, the majority of clinicians still exploit the documented long-term performance of conventional hybrid composite formulations (Gaengler, Hoyer et al. 2001; Pallesen and Qvist 2003). Then, an accepted and adequate solution to counteract both the detrimental effect of polymerization shrinkage and the practical limits of direct techniques in large class II cavities is to use an indirect or semidirect technique (Dietschi and Spreafico 1997). Large cavities frequently show undercuts and proximal extensions close or even below the cement-enamel junction. This can lead to unnecessary tissue loss if the appropriate cavity design is achieved only by additional preparation and otherwise generates clinical difficulties for placing rubber dam, controlling restoration adaptation and fit or removing cement excesses. Moreover, unprotected dentin surfaces are more susceptible to contamination or environment influence during the temporary phase. The application of a base or liner underneath semi-direct and indirect restorations fulfils many requirements, such as reinforcing undermined cusps, filling undercuts and providing the necessary geometry for an inlay/onlay restoration; it also represents a common, non-invasive alternative to surgical crown lengthening in order to relocate cavity margins supra-gingivally (Dietschi and Spreafico 1998; Rocca and Krejci 2007). The application of a base or liner is thus considered the standard of care.

In vitro research has suggested glass ionomers and resin-modified glass ionomers (RMGIC) as feasible materials for this application (Tolidis, Nobecourt et al. 1998; Dietrich, Losche et al. 1999; Dietrich, Kraemer et al. 2000); however long-term clinical trials have shown an increased incidence of restoration or tooth fractures for both materials or problematic dissolution of RMGIC base and liners (van Dijken, Kieri et al. 1999; Andersson-Wenckert, van Dijken et al. 2004), the reason of such severe failures being related to the relative hydrophilicity of the latter products. In addition, the expected carious-protective impact of fluoride release by glass ionomers has been comprehensively reviewed and is considered insignificant in-vivo (Randall and Wilson 1999; Wiegand, Buchalla et al. 2007). The aforementioned findings have of course limited the indication of glass ionomers as base/liner underneath indirect tooth-coloured posterior restorations. The only remaining alternative then is composite resin, in a restorative or flow consistency. The elastic modulus of restorative and flowable composite materials, among other physical properties, influences their potential stress absorbing effect (Lutz, Krejci et al. 1986; Friedl, Schmalz et al. 1997). Actually, depending on the material's stiffness, stresses within the adhesive interface can be lowered or just passed on the next interface with limited or no absorption (high elastic modulus). The concept and rationale of an « elastic » stress breaking liner or interface has been extensively evaluated since the first works of Davidson and co-workers(Kemp-Scholte and Davidson 1990; Kemp-Scholte and Davidson 1990; Ausiello, Rengo et al. 2004) and appears in favour of the use of flowable composites. Flowable composites also have the advantage of an easier placement and do not require further adjustments; this for instance eliminates the risk of losing the dentin seal.

When applying a base or liner underneath indirect restorations, the interface quality between the resinous base and luting composite and between the luting composite and inlay, resulting from micro-mechanical retentions or copolymerisation, was also found to be critical. (Scott, Strang et al. 1992; Krejci, Fullemann et al. 1994) Some procedures such as soft air-abrasion or airborne-particle abrasion (Magne and Knezevic 2009; Rodrigues, Ferracane et al. 2009) are used daily by many practitioners with the aim to clean the cavity and to increase micro-mechanical retention between the resinous base and the luting cement.

The aim of this in vitro study was to test the hypothesis that the elastic modulus or viscosity of composite bases as well as the surface treatment have the potential to influence the marginal and internal adaptation of class II indirect composite restorations, after simulated occlusal fatigue loading. Attention was also paid to the quality of all interfaces and cavity regions, in order to identify the restoration's most vulnerable areas.

MATERIALS & METHODS

Specimen preparation

Freshly extracted human third molars were used for this study. The inclusion criteria were absence of carious lesions and a complete root formation. The teeth were stored in a sodium azide solution (0.2%) at 4℃ until the experiment onset.

For each specimen, the root length was adjusted to fit into the test chamber of the mechanical loading device (Department of Cariology, Endodontics & Pedodontics; Laboratory of Electronics of the Medicine Faculty; University of Geneva) (Fig.1). After the specimen was properly positioned, it was fixed with light-curing composite on a metallic holder (Baltec; Balzer, Liechtenstein); then, the root base was embedded with self curing acrylic resin to complete the tooth stabilisation. Class II cavities (2 surfaces, OD or OM) were prepared, with the proximal margin located 1.0 mm below the cementum-enamel junction. The dimensions of the tapered preparations were 4.0 mm in width and 2.0 mm in depth at the bottom of the proximal box, and 3.0 mm in width and depth for the occlusal isthmus, all walls having 10 to 15° of divergence (Fig.2). The cavities were prepared using coarse diamond burs under profuse water spray (Cerinlay No 3080.018 FG; Intensiv, Viganello, Switzerland) and finished with fine grained burs of the same shape (Cerinlay No 3025.018 FG; Intensiv, Viganello, Switzerland).

The 32 prepared teeth were randomly assigned to one of the 4 experimental groups, corresponding to the combination of restorative materials described in Table 1.

Restorative procedures

After completion of the preparation, an “etch & rinse” multi-functional adhesive system (Optibond FL, Kerr, Orange, CA, USA) was used to treat the dentin surfaces, according to the manufacturer’s instructions. This implied drying of the substrate followed by etching (10-15s) and rinsing with suction, exerting great care to prevent tissue dehydration or moisture excess. With exception of the control group (CTR), a 1mm thick lining was then applied on all dentin surfaces, including the gingival margin; a flowable (Premise Flow A2, Kerr, Orange, CA, USA) (groups Ex1 and Ex2) or a restorative material (Premise A2, Kerr, Orange, CA, USA) (group Ex3) were used for this purpose. The 1mm lining material was applied after placing a transparent matrix. The base extended up to the cavity’s gingival margin (Fig.3). The material was light-cured for 30s. Table 2 summarizes the physical properties of the products under evaluation. The light curing unit (Bluephase, Ivoclar-Vivadent, Schaan, Liechtenstein) equipped with a new bulb, had a power density of 1200 mW/cm^2. After liner application, the enamel cavity margins were finished with fine diamond burs (Cerinlay No 3025.018 FG, Intensiv, Viganello, Switzerland), and impressions were made with polyvynilsiloxane impression material (President light and heavy bodies, Coltène, Alstätten, Switzerland). After impression, the cavities were coated with a water-based glycerine gel (Airblock, DeTrey-Dentsply, Constance, Germany). Teeth were provisionally restored with a soft light-curing resin (Fermit N, Ivoclar-Vivadent, Schaan, Liechtenstein) and kept in saline for 7 days at

32℃. At completion of this interval, cavities were submitted to either soft-air-abrasion with 100 µm Sodium Bicarbonate particles at about 3 bar (Airflow Handy 2+, EMS, Nyon, Switzerland) (group EX1) or airborne-particle abrasion with 27µm Al_2O_3 particles at about 3 bar (Kavo EWL, Type 5423, Biberach, Germany) (group EX2 and EX3), or no surface treatment (group CTR).

A hard stone (Fujirock EP, Gc, Alsip, IL, USA) was poured into the impressions to produce individual dies. When present, small undercuts were filled with wax prior to the impregnation of dies with a hardening liquid (Margidur, Benzer Dental, Zurich-Switzerland). Finally, each die was isolated with a thin layer of vaseline before the fabrication of the inlays. All inlays were made with the same micro-hybrid composite (Premise A2). The inlays were also submitted to a photo-thermal treatment (T = 110^{o}C) for 7 min in a post-curing unit (D.I 500 oven, Coltène, Alstätten, Switzerland). The internal surfaces of the inlays were sandblasted with 27 µm aluminium-oxide powder at about 3 Bar pressure and covered with a pre-hydrolized organic silane (Monobond S, Ivoclar-Vivadent, Schaan, Liechtenstein) and a thin layer of bonding resin (Optibond FL, Adhesive, Kerr, Orange, CA, USA), prior to cementation. The bonding resin was left uncured and the restoration was placed in a box, protected from light (Vivapad, Ivoclar-Vivadent, Schaan, Liechtenstein) until cementation.

Then, enamel margins were acid-etched for 30 s and the adhesive (Optibond FL, Kerr, Orange, CA, USA) was applied onto all surfaces of the preparation, without light-curing. The cavity was covered with a thin layer of Premise A2 before insertion of the inlay. The restoration was placed first with manual pressure and then with the assistance of a specific ultra-sonic device (Cementation tip, EMS, Nyon, CH). After removal of excesses with a probe and a dry microbrush, each restoration surface was light-cured for 40 s. Restorations were then immediately finished and polished, using flame and pear-shape fine diamonds burs (40, then 25 µm grain size) (Intensiv No 4205L, 4255, 5205L and 5255, Intensiv, Viganello, Switzerland) for occlusal margins and discs of decreasing grain size (Pop On XT, 3M, St. Paul, MN, USA) for proximal margins.

Mechanical loading

The stress test was carried out 24 h after cementation. The pulp chamber was penetrated buccally or palatally with a tube (sealed with DBA), which was connected to a simulated pulpal circulation of horse serum under a pressure of 14.1 cm H_2O (Andrews, Van Hassel et al. 1972; Ciucchi, Bouillaguet et al. 1995) (Fig.1). All specimens were subjected to 1'000'000 cycles with 100 N eccentric occusal loading force. The axial force was applied at a 1.5 Hz frequency following a one-half sine wave curve. These conditions are taken to simulate about 4 years of clinical service (Krejci, Heinzmann et al. 1990; Krejci, Reich et al. 1990). Restored teeth were contacted by antagonist artificial cusps, made of stainless steel with a hardness similar to natural enamel (Vickers hardness: enamel = 320-325; steel = 315); the diameter of the cusps was 4 mm. By having the specimen holder mounted on a hard rubber disc, a sliding movement of the tooth was produced between the first contact on an inclined plane and the central fossa (Fig.1B). The functions of this experimental device are similar to the machine developed by Krejci and co-workers (Krejci, Reich et al. 1990).

Specimen evaluation

SEM evaluation of marginal and internal adaptation

Before the fatigue test, as well as after completion of each loading phase, the restoration's margins were cleaned with a brush and fine pumice. Then, gold sputtered epoxy resin replicas (Epofix, Struers, Rødrove, Denmark) were made from polyvinylsiloxane impressions (President light, Coltène). The following segments were observed: enamel margins on the occlusal and proximal sides and dentin margins on the proximal side, below the cementum-enamel junction (Fig.4). The tooth-restoration interface was analyzed semi-quantitatively by scanning electron microscopy (SEM) (Digital SEM XL20, Philips, Eindhoven, Netherlands) by employing an established evaluation method (Luescher, Lutz et al. 1977; Roulet 1990); The restoration margins were observed at a standard 200x magnification or when necessary for assessment accuracy, higher magnifications up to 1000x were used. The following evaluation criteria were tentatively considered: perfect adaptation (continuity), overfilling, underfilling, marginal opening, marginal restoration or tooth fracture. Results for the restoration marginal adaptation, before and following the loading phase, were expressed as percentages of "perfect adaptation" (defect free) for occlusal and proximal enamel margins and cervical dentin. Percentages were calculated as the ratio between the cumulative distance of all segments showing the same morphological quality and the whole interface length.

At completion of the mechanical loading and after sample replication, the teeth were embedded in a slow-curing epoxy resin (Epofix, Struers, Rødrove, Denmark) and sectioned mesio-distally into three parts, with a central slice of 1 mm using a slow rotating saw (Isomet 11-1180, Buehlers, Lake Bluff, USA). (Fig.5). The sections were successively polished with 200, 400 and 600 grit SiC paper. Impressions were then taken from the 2 external surfaces available for fabricating gold sputtered resin replicas. In order to prevent observation artifacts, special care was taken to not dehydrate the samples prior to taking the impression with a “moisture tolerant” material (President light, Coltene). The restoration internal adaptation was assessed semi-quantitatively on the gold-sputtered replicas under SEM at 200x magnification or when necessary for assessment accuracy, higher magnifications up to 1000x were used. The restoration internal adaption was evaluated according to two criteria: continuity and interfacial opening. Results were expressed as the percentage of “perfect adaptation" (defect free) for occlusal, axial and cervical dentin segments. For each specimen, results of the internal analysis were expressed as a mean value of “perfect adaptation” resulting from the evaluation of the 2 surfaces. As for marginal adaption, percentages were expressed as a proportion of the whole internal restoration interface length. A single and trained evaluator performed all SEM observations but without knowledge of group composition, restorative techniques or materials employed.

All results of the SEM analysis were subjected to a non-parametric statistical analysis. The Kruskall Wallis test and in case of significance, the Nemenyi test, were applied for comparing the different restorative protocols at baseline and after the loading test for marginal adaptation and after the loading test, for internal adaptation. In addition, the effect of the restorative protocol on the difference between pre- and post-loading marginal adaptation was examined using the same statistical analysis. The difference in marginal adaptation between pre- and post-loading was tested for significance by a Wilcoxon test. All tests were carried out at a 5% level of significance.

RESULTS

The results and statistical analysis for the restorations marginal adaptation in enamel and dentin, before and after loading, are presented in table 3 and in figures 6 to 8. The results and statistical analysis for the restoration internal adaptation in dentin after loading are presented in table 4 and in figures 9 to 11.

Marginal adaptation to enamel (occlusal or proximal) has shown no influence of the liner presence and type or surface treatment between the 4 groups for pre and post-loading. Perfect adaption percentages did vary from 88.9% (CTR) to 79.5% (EX1) occlusally and from 92.7% (CTR) to 86.7% (EX1) proximally, before loading. After loading, the percentages drecresed and ranged from 75.9% (EX3) to 76.6% (EX1) occlusally and from 73.3% (EX1) to 81.9% (EX3) proximally (Figs. 12 and 13). These differences in marginal adaptation between pre- and post-loading, within groups, proved significant, except for EX1 (Premise flow liner with Prophy-Jet treatment), in occlusal enamel. Marginal adaption to cervical dentin has shown no influence of the liner presence and type or surface treatment for pre and post-loading. Perfect adaptation in cervical dentin ranged from 54.8% (EX1) to 77.6% (EX3) before loading and from 41.9% (CTR) to 63.1% (EX3) (Figs. 14 and 15). These differences between pre and post-loading were significant within groups, except for EX2 (Premise flow liner with airborne-particle abrasion treatment). A significant difference in dentin adaptation between pre and post-loading was found for the comparison CTR (no liner) and EX2 (Premise flow liner with airborne-particle abrasion treatment), meaning a more severe marginal degradation after the loading test.

There was no difference evidenced for internal adaption after occlusal loading between the different interface segments (occlusal, axial dentin and cervical dentin). However, more gaps were found on the proximal preparation shoulder (Fig.16). Perfect adaptation in cervical dentin did actually range from 51.9% (EX1) to 74.0% (EX3), compared to occlusal and axial dentin, with percentages of perfect adaptation varying respectively from 80.1% (EX2) to 90.8% (EX1) and from 77.8% (EX2) to 89.1% (EX1). When present, gaps were located above the hybrid layer (Fig.16). No defect between flowable or restorative composite base and luting composite was observed in either group or sample.

DISCUSSION

Despite a recent and controversial review questioning the relevance of marginal-internal adaptation tests (Heintze 2007) one has to admit that phenomena such as nano-leakage, leakage, pulpal complications and secondary caries which are induced by interface breakdown represent the majority of clinical failures observed in all types of direct restorations (Hickel and Manhart 2001; Manhart, Chen et al. 2004). Then, the absence of correlation between clinical and in-vitro studies regarding with the performance of class V restorations should not be imputed to a possible irrelevance of marginal tests but rather to methodological and sensitivity issues related to the clinical and the in-vitro studies under review. This underlines the importance of extremely well standardized study protocols and proper simulation of the oral environment (i.e.:functional loading). Evaluating the behaviour of adhesive restorations and interfaces with natural tissues under simulated function, pulpal pressure and moist environment helps in identifying weak points and better understand how to reduce the incidence of defects underneath or around the restoration (Dietschi 2003). This reasoning then validates and strengthens the relevance of marginal and internal adaption tests such as applied in the present study.

The rationale for using a base or liner underneath direct or indirect large class II restorations is multifactorial. In particular, the concept of “stress breaking” layer or flexible liner and base has been extensively described in the literature (Kemp-Scholte and Davidson 1990; Ausiello, Apicella et al. 2002; Dietschi, Olsburgh et al. 2003; Ausiello, Rengo et al. 2004; Chuang, Jin et al. 2004; Dewaele, Asmussen et al. 2006); it is actually considered that the presence of such a layer assists in absorbing stresses resulting from composite polymerization, in case of a direct restoration, and in general contributes to lower strains exerted on the adhesive interface by functional stresses. These forces may actually induce debonding which in turn can trigger post-operatve sensitivity (induced by hydro-dynamic phenomena) (Brannstrom 1966), reduce the restoration’s tooth strengthening effect or allow fluid movements or bacterial penetration toward the pulp when the gap extends to the margin. A base or liner placed underneath inlays and onlay also contributes to avoid unnecessary tissue sacrifice to meet geometry restrictions of indirect restorations and functions as an ideal protection of the pulpo-dentinal complex during the temporary phase (Dietschi and Spreafico 1998; Rocca and Krejci 2007). In addition, it was proven to increase bond strength and adhesive interface quality in either full crown preparations, class II restorations and veeneers as well (Bertschinger, Paul et al.

1996; Paul and Scharer 1997; Dietschi and Herzfeld 1998; Magne and Douglas 1999; Magne, So et al. 2007). The thickness of the layer (Chuang, Jin et al. 2004) as well as the stiffness of the liner have various effects on restoration quality and adaptation; actually, with a low E modulus, adaption was found inferior to a restoration without base while the optimum “stress absorbing effect” is thought to be at around 7-7,5 Gpa (Dietschi, Olsburgh et al. 2003). In the same study, the restorative material had shown more interfacial defects, from the restoration placement already. This latter finding was considered to be related to a reduced wetting capability of the selected brand and the present study aimed at confirming whether a base made of restorative material was appropriate or not.

Restoration and tooth fractures are considered as infrequent complications for fully bonded composite restorations unless a selective bonding approach is applied or a resin-modified glass ionomer is placed underneath the restoration (Andersson-Wenckert, van Dijken et al. 2004; da Rosa Rodolpho, Cenci et al. 2006). Actually, reducing the surface available for adhesion in the case of a conventional GI base has shown to negatively influence restoration long-term behaviour, due logically to a reduced stabilization and reinforcement of the natural tooth structure (da Rosa Rodolpho, Cenci et al. 2006). With some resin-modified glass ionomers, a rather high water uptake induced material expansion and dissolution, resulting in unacceptable tooth and restoration fracture (Andersson-Wenckert, van Dijken et al. 2004); as well in-vitro, a compomer base has shown high rates of marginal gaps when the material extended up to the margins (Dietschi, Olsburgh et al. 2003). Moreover, in the absence of proven in-vivo cario-proctective effect of fluoride release from dental materials (i.e.: glass ionomers and resin modified glass ionomers) (Wiegand, Buchalla et al. 2007) the aforementioned options appear as less suitable for lining or as a base underneath large direct or indirect class II cavities. Restorative or flowable composites then remain the only option as they may potentially assume many of the aforementioned roles and also provide cohesion of the restoration through the adhesive interface with natural tissues and polymerization onto luting material.

In order to maintain the cohesion between the restoration and the remaining tooth structure, a rather strong and durable interface is mandatory. Mechanisms or techniques aimed at assuming this role are various; the polymerization between the luting cement and the composite base would provide the strongest link but depends on the amount of residual free radicals which decreases over time (Burtscher 1993), which should limit the efficacy of such chemical bonding after 8 to 10 days. It is therefore considered clinically appropriate to proceed with cementation within one week following impression, even though another study has shown excellent interfacial bond strength after 12 weeks of storage and contamination with an interim restoration (Magne, So et al. 2007). Other options at hand when the optimal delay until cementation has expired are a airborne-particle abrasion or roughening of the base before the application of bonding resin, as wetting agent, to promote micro-mechanical retention; this approach is widely applied and accepted (Stavridakis, Krejci et al. 2005; Rocca and Krejci 2007; Rodrigues, Ferracane et al. 2009). A further option is to apply a silane on the composite base before applying the bonding resin; then, a chemical coupling is obteined (Tezvergil, Lassila et al. 2003). In the present study, restorations were cemented after 7 days following impression and cavities were roughened with soft air-abrasion (Ex1), airborne-particle abrasion (Ex2,Ex3) or no mechanical treatment (CTR). No debonding was observed in either sample or group, confirming that the combination of soft air-abrasion, airborne-particle abrasion and co-polymerization or the co-polymerization alone as in the control group was effective enough to generate a strong and stable interface, at least more strong than the weaker interface with dentin.

The marginal and internal adaptation percentages were found to be well correlated but failed to show any clear advantage of a specific material's consistency or filler content for use as a base/liner underneath indirect, large class II restorations. All groups exhibited a significant reduction of excellent margin proportions due to mechanical loading, thereby confirming the prominent role of mechanical, cyclic stresses in restoration interface degradation and supports the use of simulated functional loading in in-vitro tests. The only significant difference regarding marginal adaptation was found in the control group (no base), with a more pronounced reduction of excellent adaptation. Even though not statistically significant, restorations with a flowable composite liner tended to present more marginal defects in cervical dentin before loading but this trend disappeared after loading despite some rather large variations in the results. Percentages of perfect internal cervical adaptation were inferior to those found in occlusal or approximal interfaces; this suggests the critical importance of this interface and the less favourable adhesion potential of cervical dentin (Bouillaguet, Ciucchi et al. 2001; Purk, Dusevich et al. 2007). When considering both marginal and internal adaptation to cervical dentin, it appeared that the behaviour of the restorative system and products under investigation is perfectible in the present in-vitro environment and that none of the composites tested as base/liner, whatever their surface treatment was, could prevent the development of interfacial defects.

These findings thus support the current use of flowable composites as base/liner taking however in consideration some known restrictions in regard to the material thickness and filler content (Dietschi, Olsburgh et al. 2003; Chuang, Jin et al. 2004; Dewaele, Asmussen et al. 2006). In case of extended use, airborne-particle abrasion could partially remove the adhesive layer and is therefore to be considered technically more sensitive (Stavridakis, Krejci et al. 2005); then, soft-air abrasion represents a feasible alternative due to its potentially less aggressive effect than airborne-particle abrasion for cleaning and preparing cavities before cementation.

CONCLUSION

The marginal adaptation and internal adaptation of large indirect class II composite restorations was evaluated in-vitro before and after simulated functional loading and pulpal pressure. Their adaptation to either enamel or dentin was not influenced by the type of composite liner (flowable or restorative composite) nor was it affected by the surface treatment of the composite base/liners. The behaviour of the restorative system and products under evaluation was found satisfactory at the level of enamel while their cervical dentin adaptation proved perfectible and significantly degraded following fatigue loading.

The results of the present study support the use of flowable or restorative composites as base/liner underneath large class II restorations and confirm that soft-air abrasion represents a feasible alternative to airborne-particle abrasion for treating cavities and base/liner before cementation.

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Table 1: Restorative procedures under evaluation (n=8 samples per group)

Group	Adhesive	Batch No	Lining	Batch No	Lining treatment	Luting & Restorative material	Batch No
CTR	OptiBond FL	2749121	none	--	none	Premise A2	07-1144
EX1	OptiBond FL	2749121	Premise Flow A2	07-114901	Prophy-Jet	Premise A2	07-1144
EX2	OptiBond FL	2749121	Premise Flow A2	07-114901	Airborne-particle abrasion	Premise A2	07-1144
EX3	OptiBond FL	2749121	Premise A2	07-1144	Airborne-particle abrasion	Premise A2	07-1144

Table 2: Physical properties of base materials (manufacturer's data)

Product *(manufacturer)*	Filler content (W% / V%)	E-modulus (GPa)	Flexural strength (MPa)	Compressive strength (MPa)	Polymerization Shrinkage (%)
Premise *(Kerr)*	84 / 71.2	10.2	128	394	1.66
Premise Flow *(Kerr)*	72.5 / na	7.1	117	297	2.95

enamel E-module = 80 GPa, dentine E-modulus: 14-18 GPa(Rees, Jacobsen et al. 1994; Kinney, Balooch et al. 1996; Kinney, Balooch et al. 1999)

Table 3: Results of marginal restoration adaptation expressed as mean percentages (+/-SD) of "perfect adaptation" for the four groups (n=8), before and after loading.

	Occlusal Enamel			Proximal Enamel			Cervical Dentin		
	preLoad	postLoad	diff	preLoad	postLoad	diff	preLoad	postLoad	diff
CTR	88.9 (9.4)	76.4(7.2)	-12.5(7.9) S*	92.7(11)	81.6(14.2)	-11.1(7.3) S*	72.5(14.7)	41.9(16.5)	-30.6(13.1) S* a
EX1	79.5 (12.9)	76.6(14.5)	-2.9(3.9) NS	86.7(9.3)	73.3(17)	-13.4(13) S*	54.8(25.4)	42.5(27.4)	-12.3(11.7) S* a,b
EX2	87.3 (11.4)	76.1(14.3)	-11.2(13.8) S*	90.3(5.8)	81.6(15.6)	-8.7(11.4) S*	57.5(28.7)	49.4(31.3)	-8.1(9.3) NS b
EX3	87.8 (6.1)	75.9(14.9)	-11.9(15.3) S*	89.1(8.7)	81.9(11.7)	-7.1(12.7) S*	77.6(28.7)	63(32.5)	-14.6(15.6) S* a,b
	p=0.337 (NS)	p=0.996 (NS)	p=0.145 (NS)	p=0.297(NS)	p=0.736 (NS)	p=0.478 (NS)	p=0.198 (NS)	p=0.471(NS)	p=0.016 (S)

"p" values of Kruskall-Wallis test are given in the last line; in case of significance, differences between groups (at p=0.05) are revealed by different lower case letters. Statistical differences between pre- and post-loading values according to Wilcoxon test (p < 0.05) appear in the third columns (diff) for each interface segment.

Table 4 Results of internal restoration adaptation after the loading, expressed as mean percentages of “perfect adaptation” interface for the four groups (n=8) expressed as mean percentages (+/-SD).

	Occlusal dentin	Axial dentin	Cervical dentin
CTR	82.8(15.9)	86.9(10.7)	60.1(35.1)
EX1	90.8(9.3)	89.1(16)	52(30.8)
EX2	80.9(11.2)	77.8(25.7)	68.6(37.3)
EX3	83.3(12.2)	85.9(11.9)	74(26.6)
Kruskall-Wallis test	p=0.261 (NS)	p=0.538 (NS)	p=0.573 (NS)

“p” values of Kruskall-Wallis test are given in the last line

Figure 1A: Fatigue apparatus used to simulate cyclic masticatory stresses and pulpal pressure. Samples are mounted on a semi-rigid rubber base to allow for sliding movements such as encountered in natural dentition

Figure 1B: Detailed view of one of the 8 chambers of the fatigue device

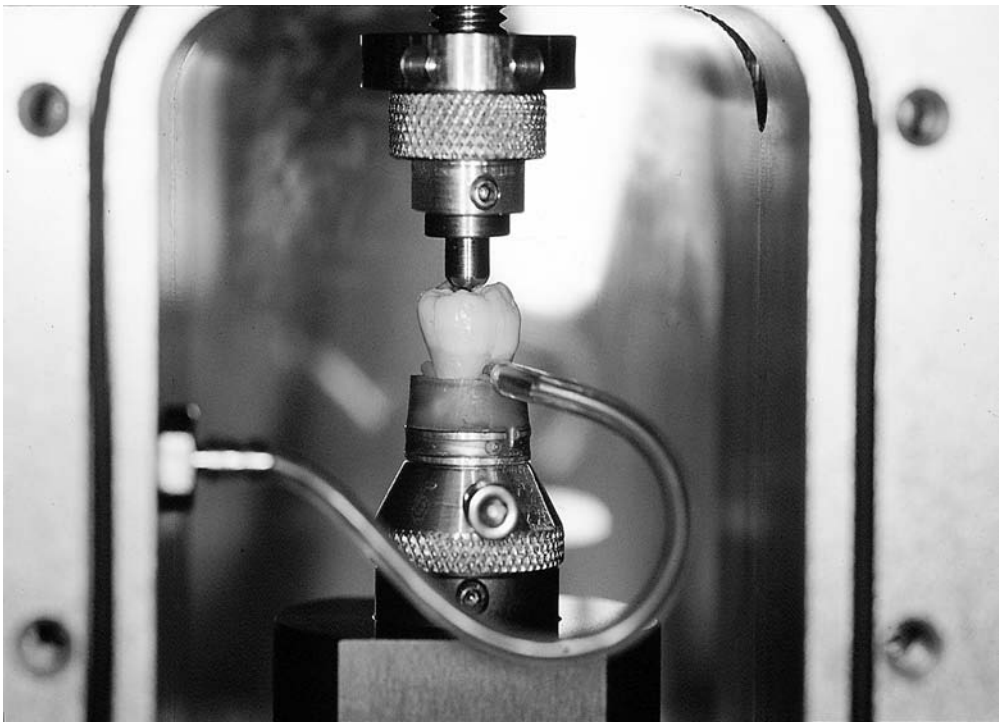

Figure 1C: The tooth is first stabilized with composite (A), before embedding the root with resin (B). The pulpal chamber of the samples is perforated (on the buccal surface) and connected to an external simulated pulpal circulation (14 cm H_2O)

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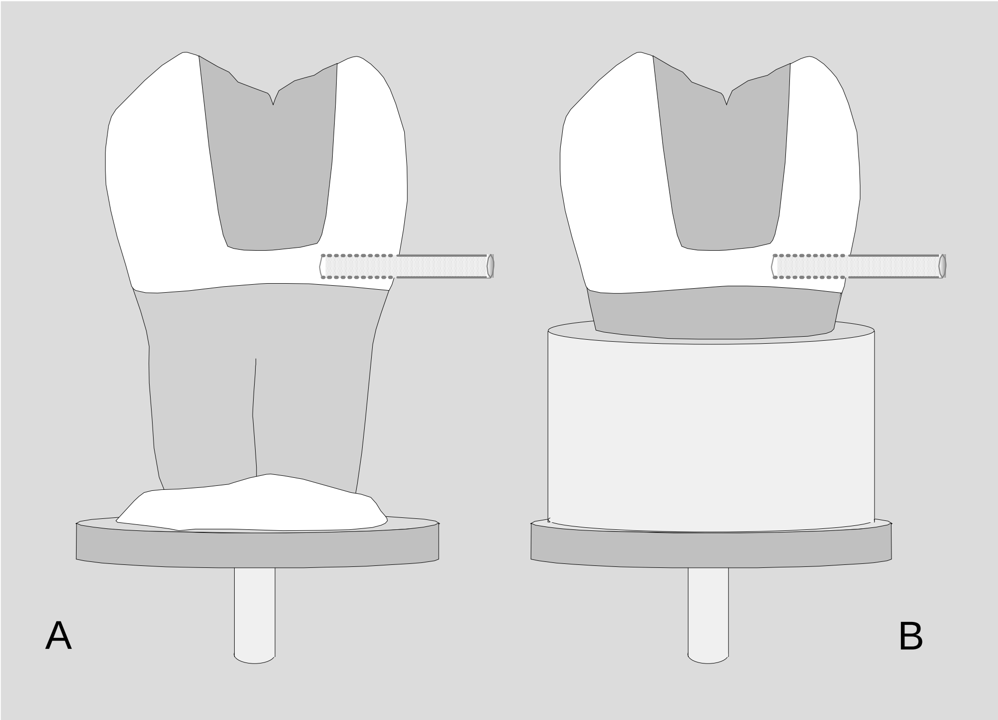


Figure 2: Cavity design and dimensions of class II cavities prepared on extracted third molars, such as used in the present study

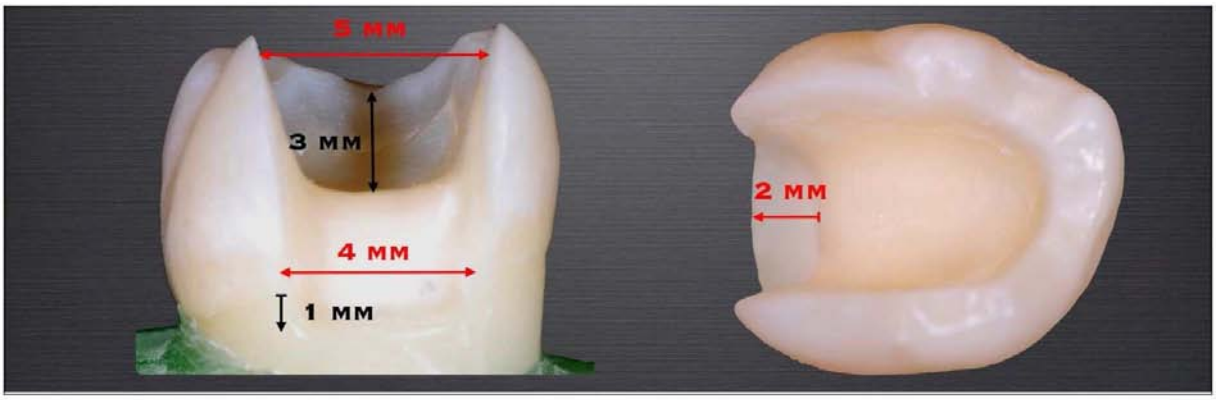


Figure 3: Diagrammatic representation of the base/lining applied underneath composite inlays

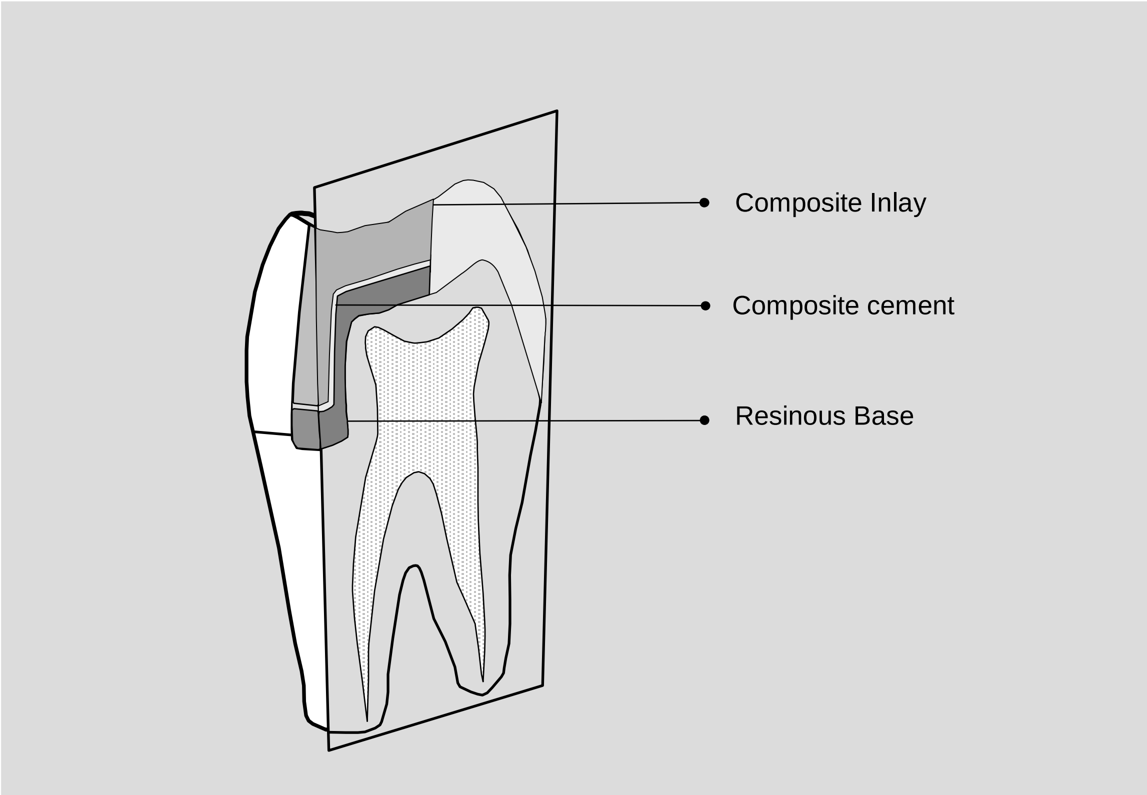
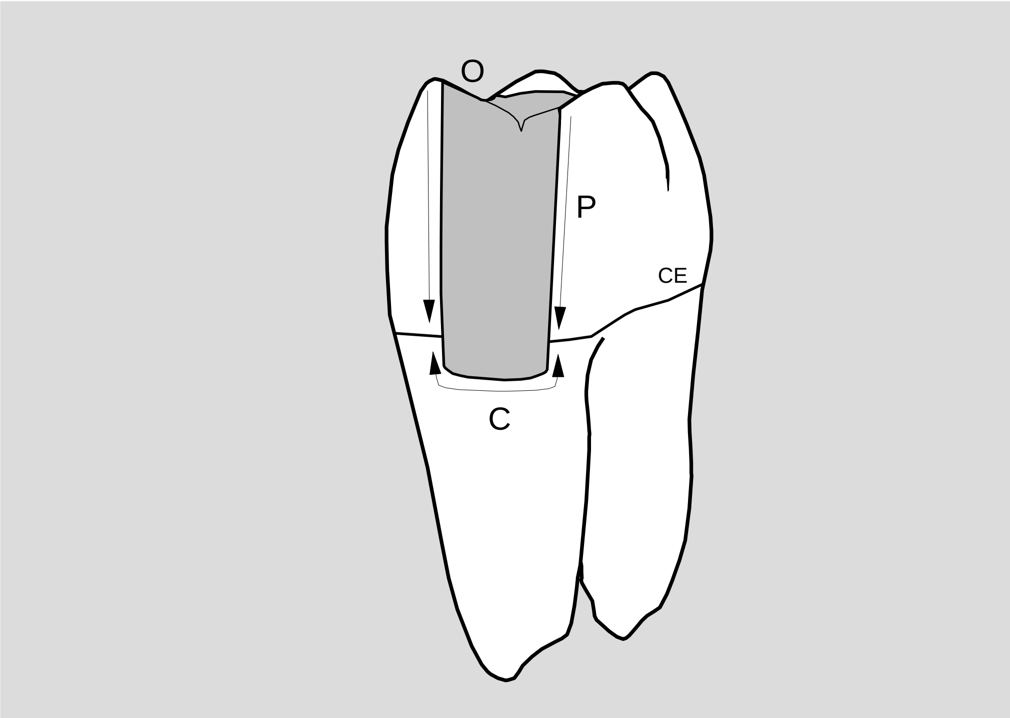


Figure 4A: Segments considered for the evaluation of marginal adaptation
O = Occlusal enamel; P = Proximal enamel; C= cervical dentin



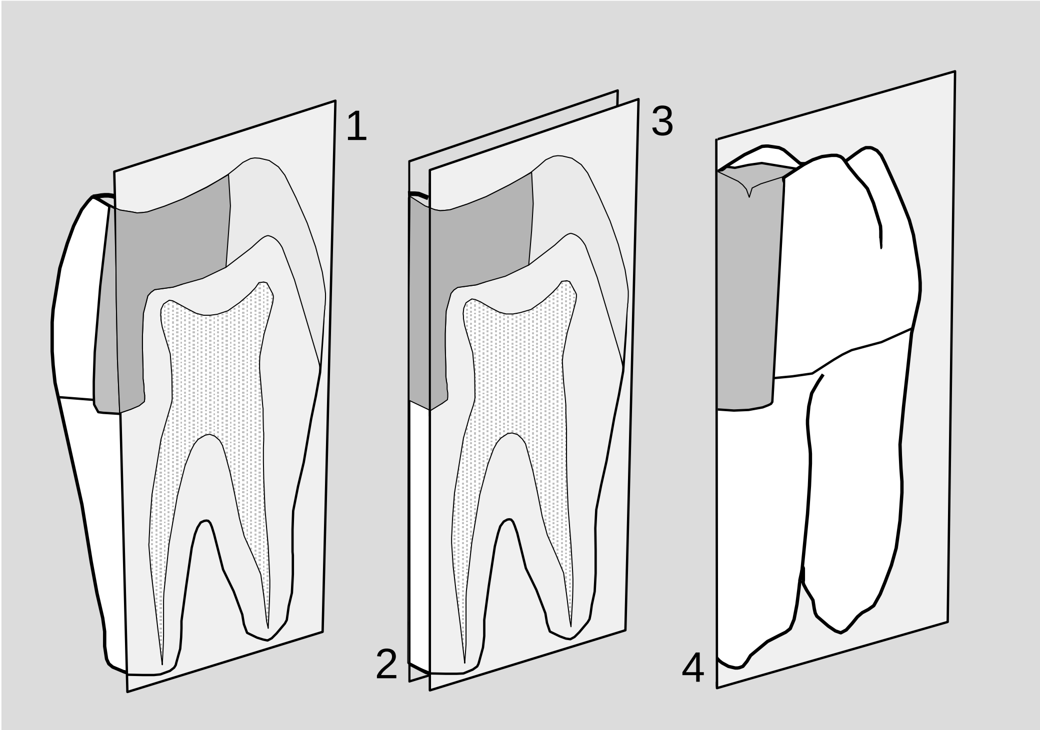


Figure 5A: The internal adaptation is evaluated on 2 surfaces (1 and 4). The medium section has a 1mm thickness

Figure 5B: Evaluation areas considered for the internal adaptation of restorations

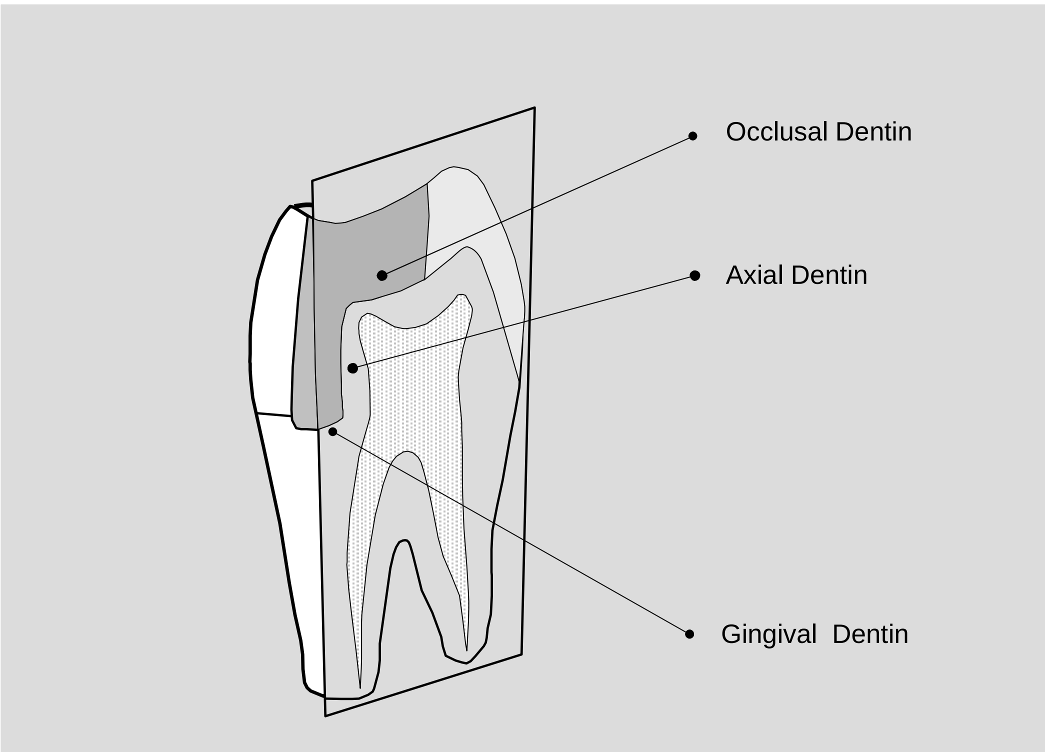


Figure 6: Percentages of marginal adaptation for *occlusal* enamel margins expressed as percentage of “perfect adaptation” before (pre) and after loading

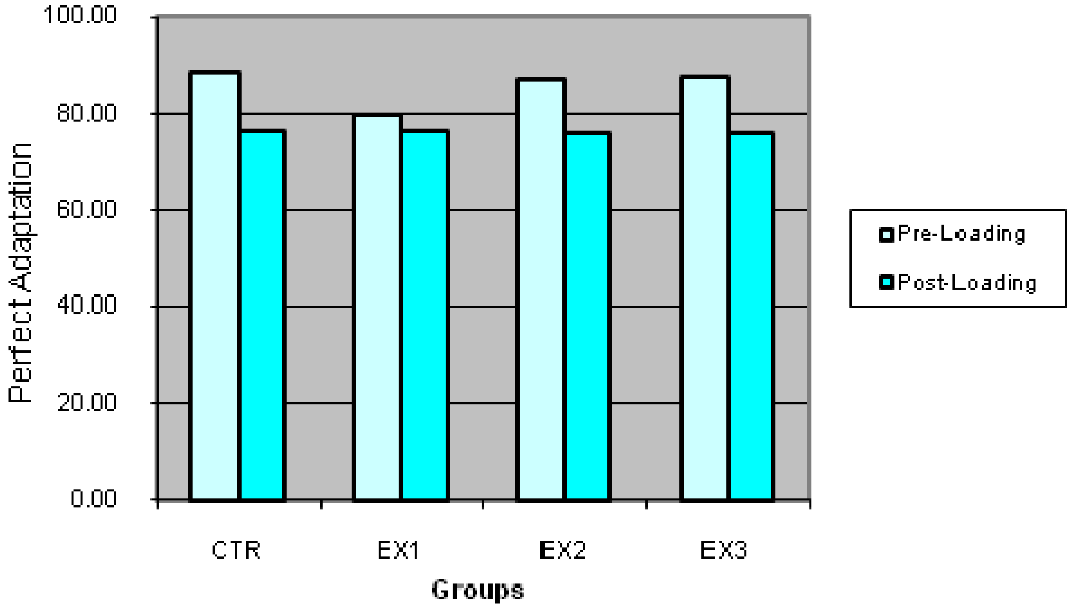


Figure 7: Percentages of marginal adaptation for *proximal* enamel margins expressed as percentage of “perfect adaptation” before (pre) and after loading

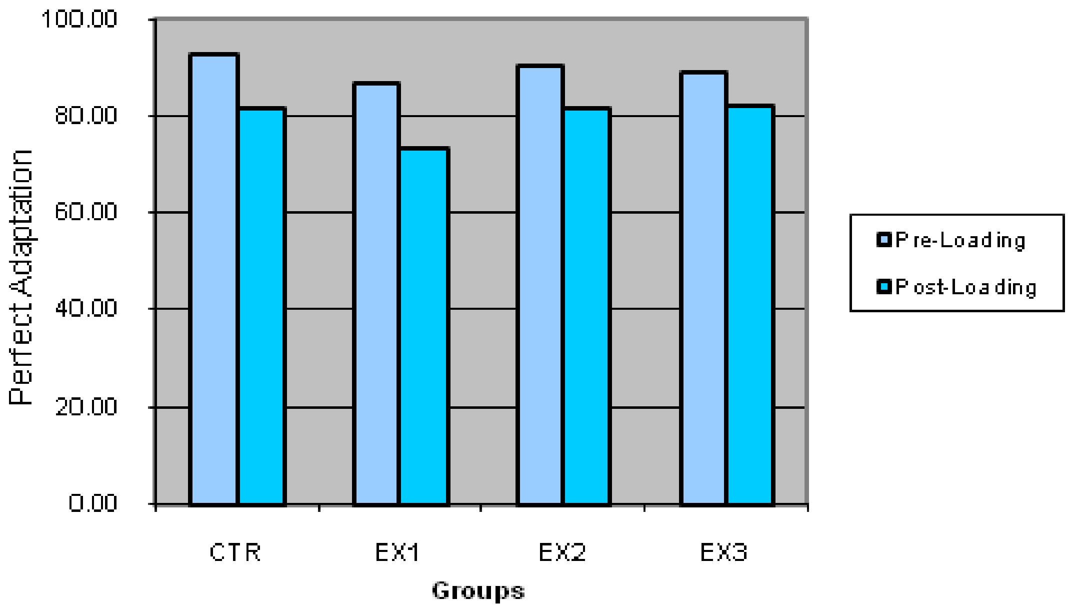


Figure 8: Percentages of marginal adaptation for *cervical* dentin margins expressed as percentage of "perfect adaptation" before (pre) and after loading

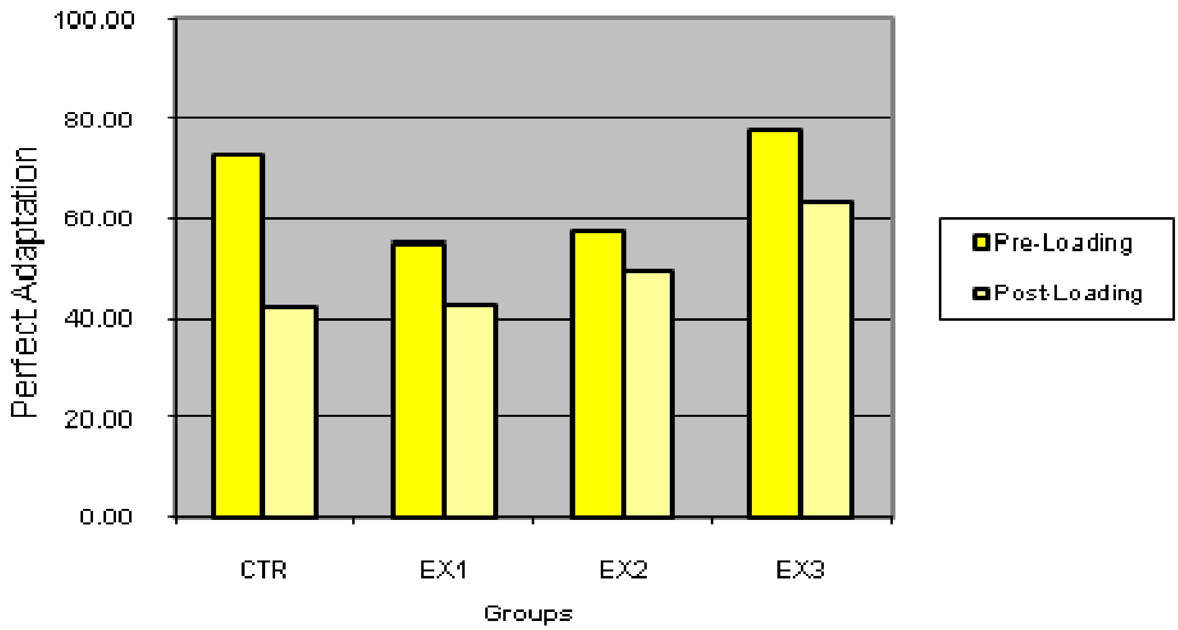


Figure 9: Percentages of internal adaptation for *occlusal* dentin interface expressed as percentage of "perfect adaptation"

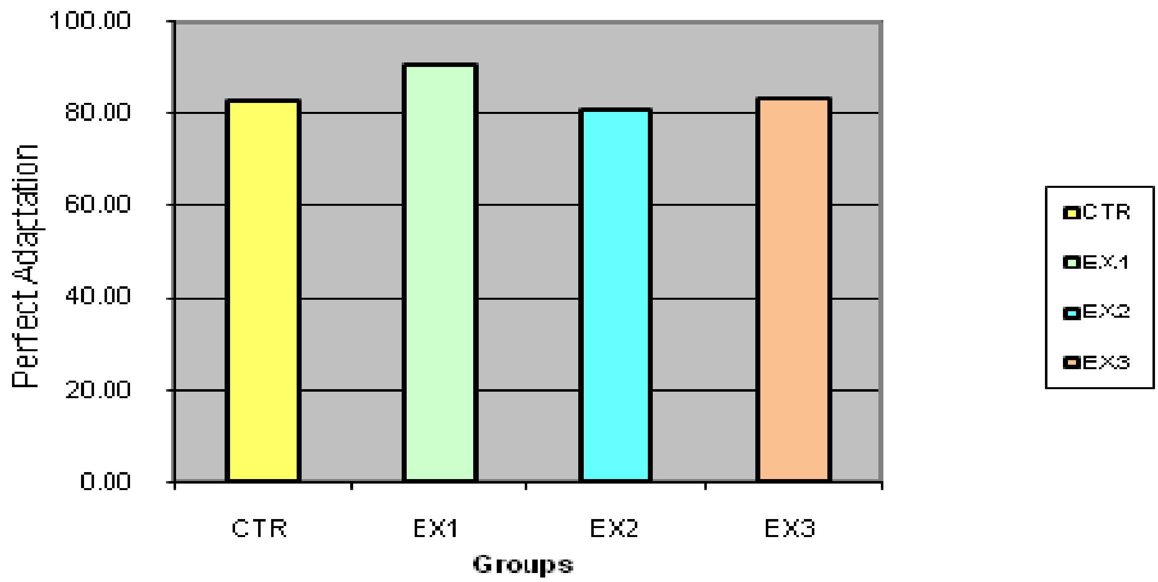


Figure 10: Percentages of internal adaptation for *axial* dentin interface expressed as percentage of "perfect adaptation"

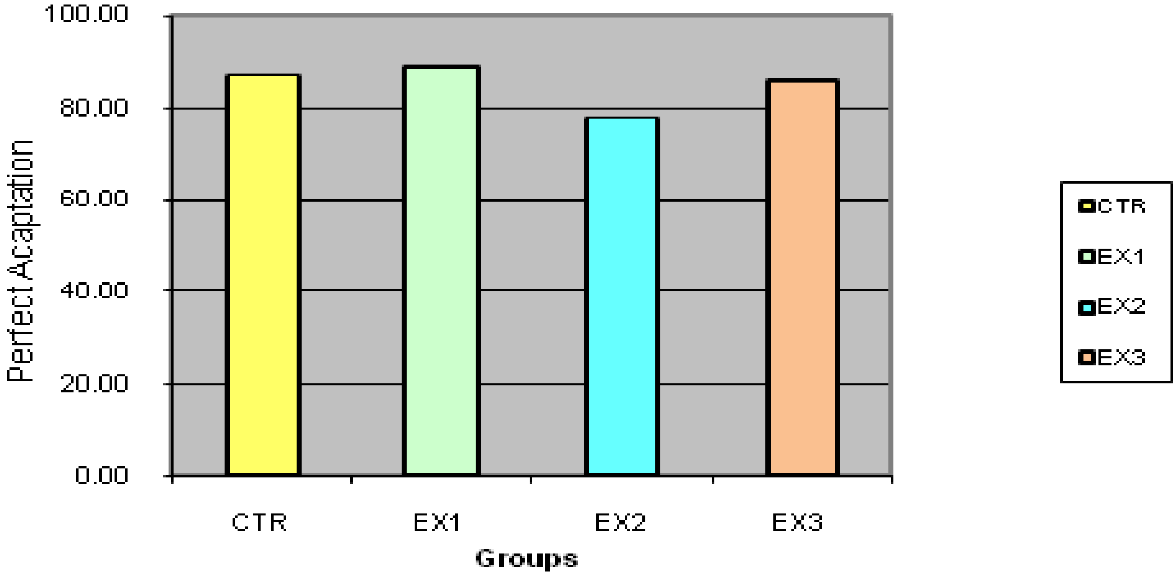


Figure 11: Percentages of internal adaptation for *cervical* dentin interface expressed as percentage of "perfect adaptation"

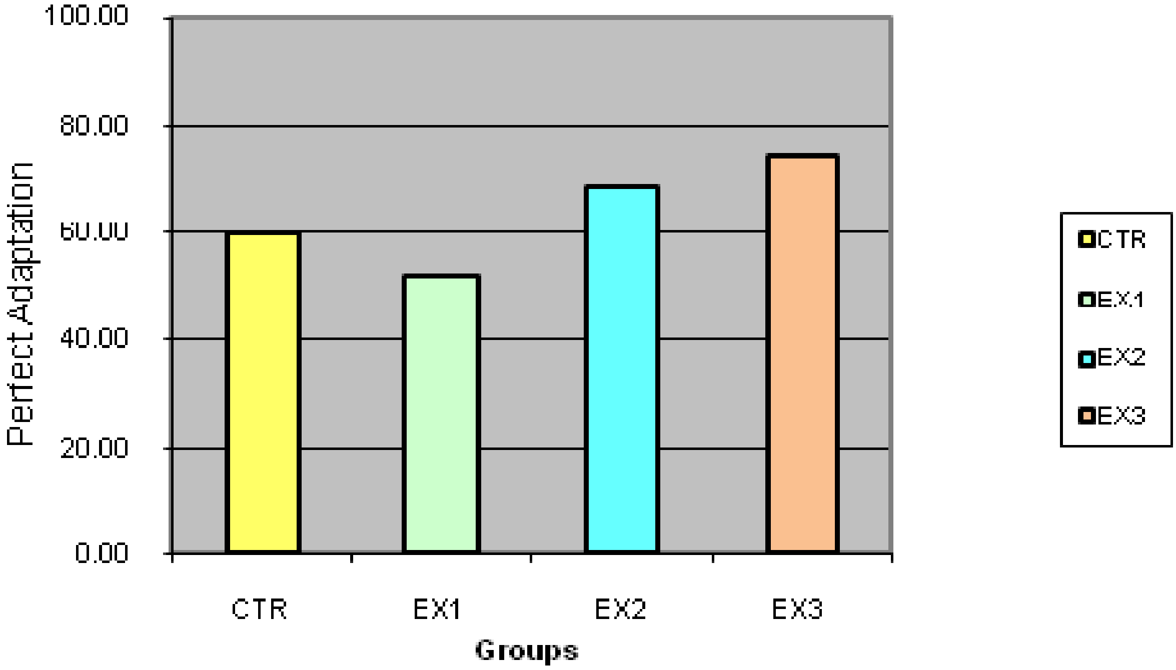


Figure 12A: Initial adaptation with enamel showing a perfect adaptation before loading

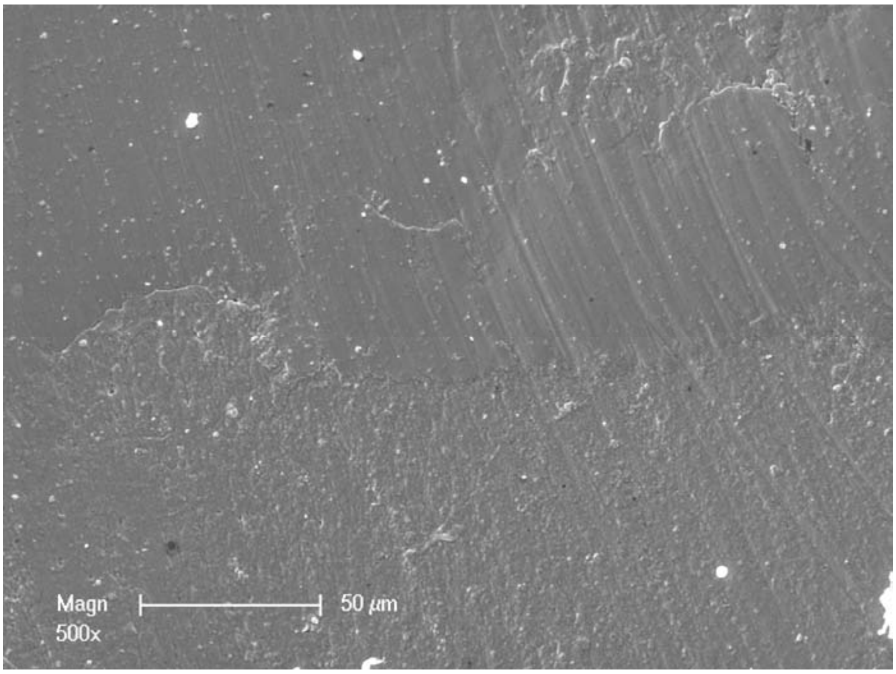


Figure 12B: Same restoration margin segment after loading showing marginal degradation; such defects were found in very small proportions of the entire enamel interface

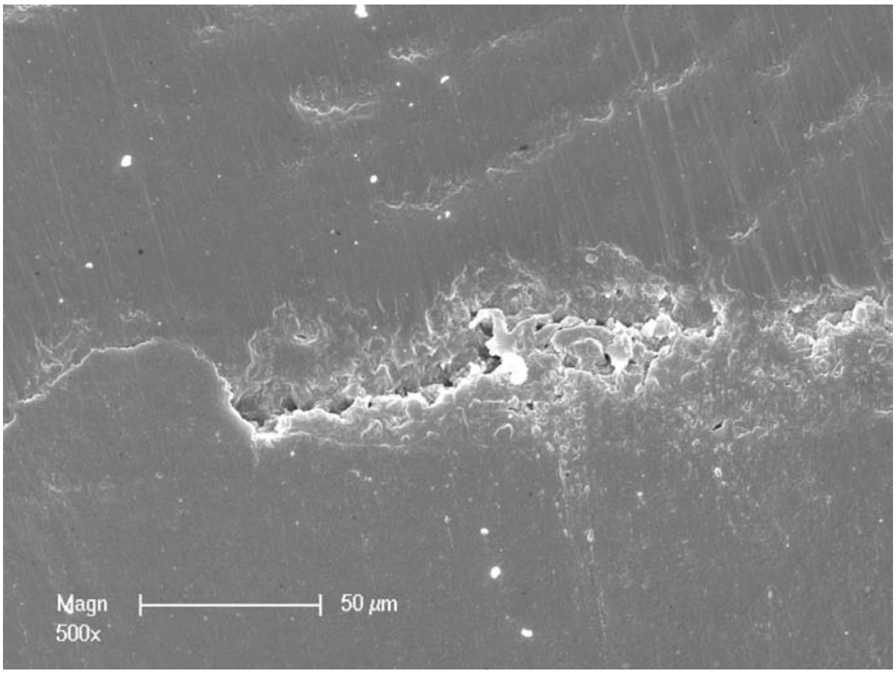


Figure 13A: Initial adaptation with enamel showing a perfect adaptation before loading

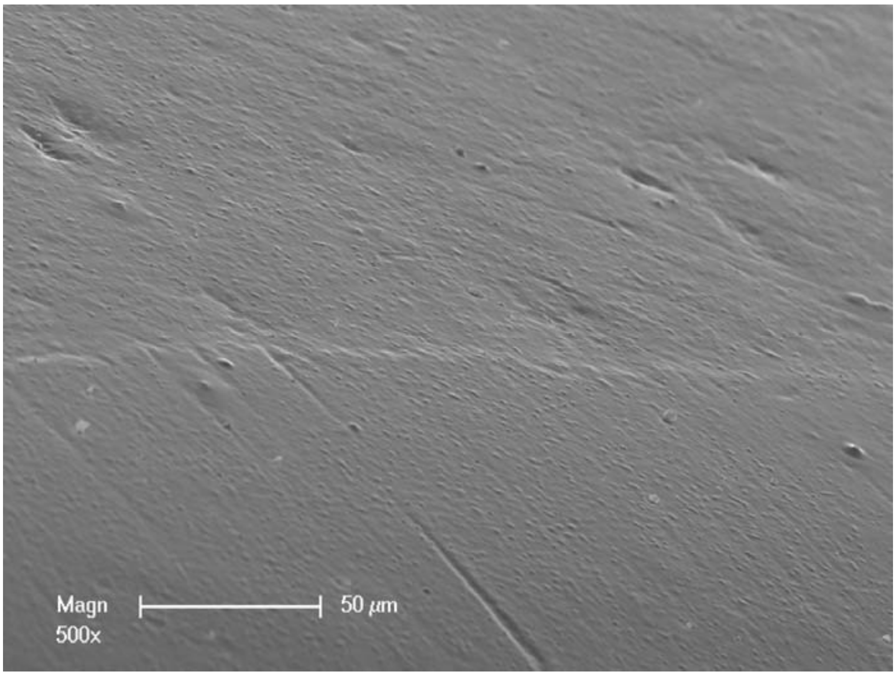


Figure 13B: Same restoration margin segment after loading showing perfect adaption and a stable margin quality, which was the most common observation in both occlusal and proximal enamel areas

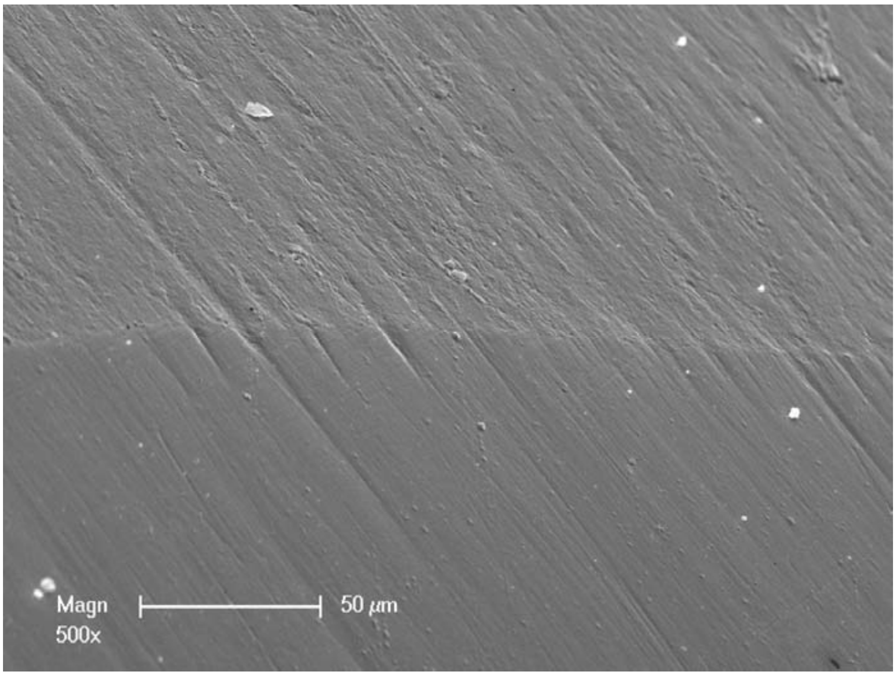


Figure 14A: Initial adaptation with cervical dentin showing a perfect adaptation before loading

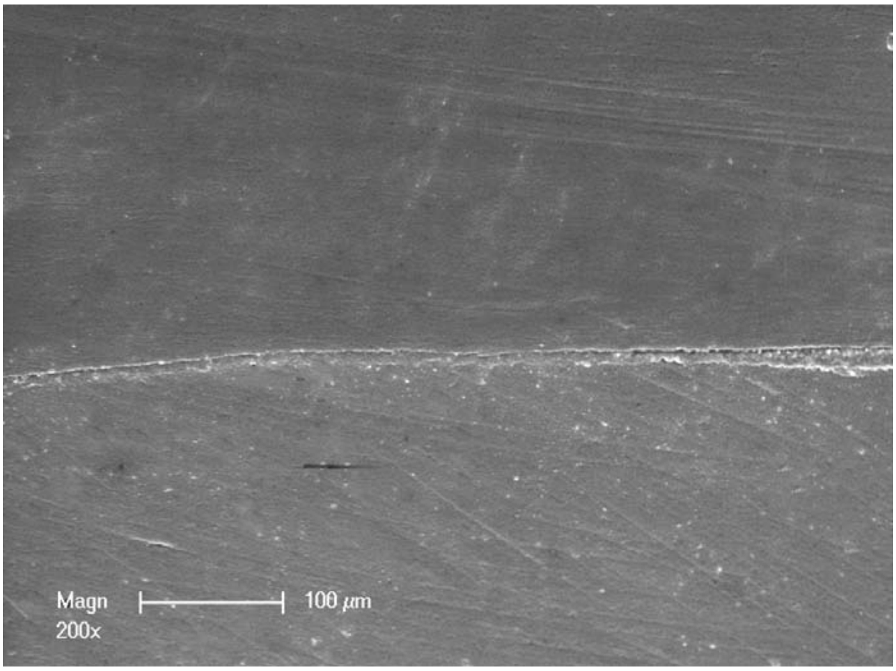


Figure 14B: Same restoration margin segment after loading showing defective adaption; such gap formation was observed in rather same proportions in all groups.

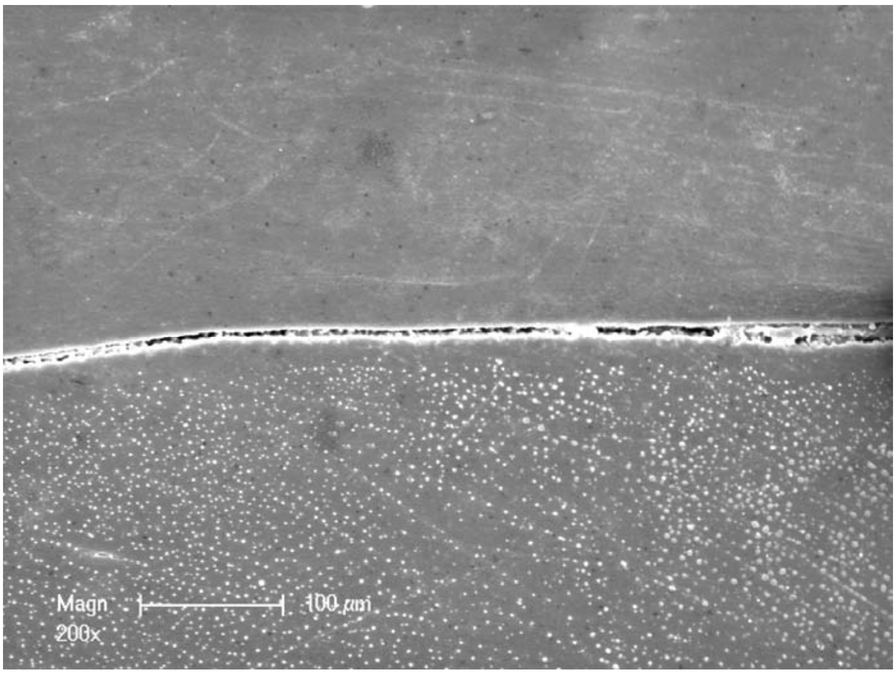


Figure 15A: Initial adaptation with cervical dentin showing a perfect adaptation before loading

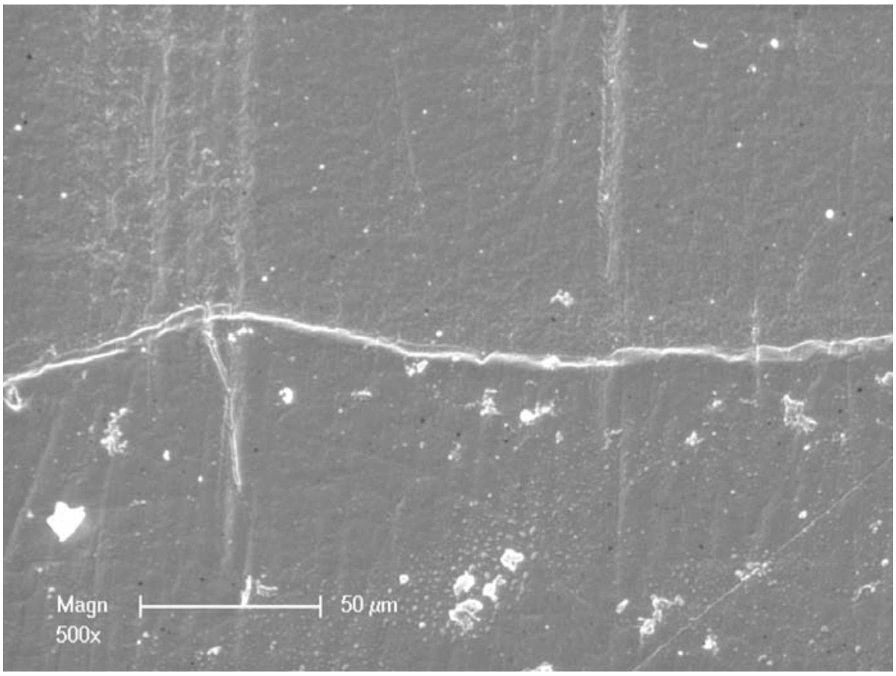


Figure 15B: Same restoration margin segment after loading showing a perfect adaptation and stable margin quality; after loading, perfect adaptation was reduced in significant proportions in all groups

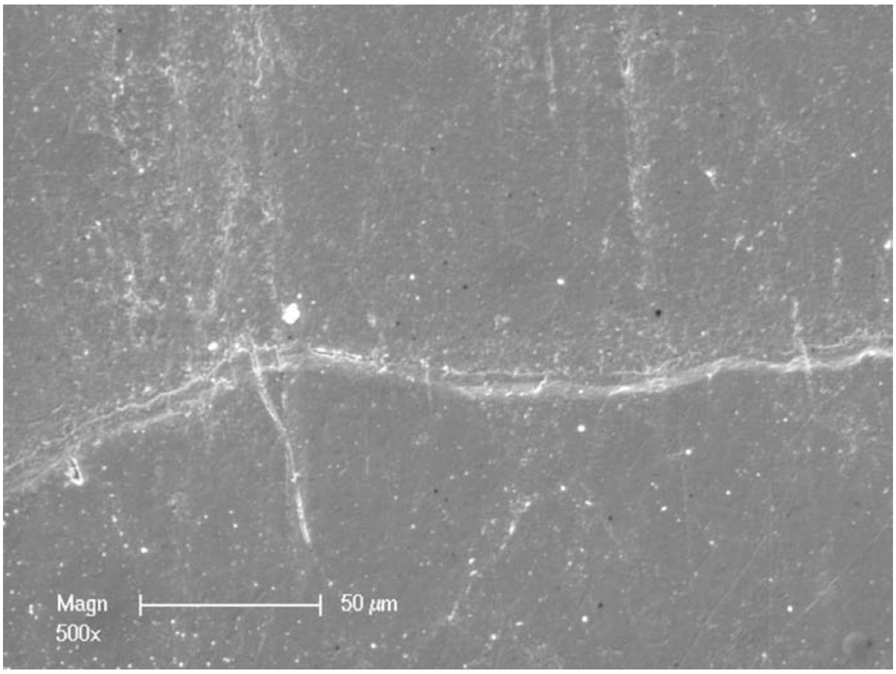


Figure 16A: Sample with failing interface in cervical dentin; when present, debonding did occur above the hybrid layer

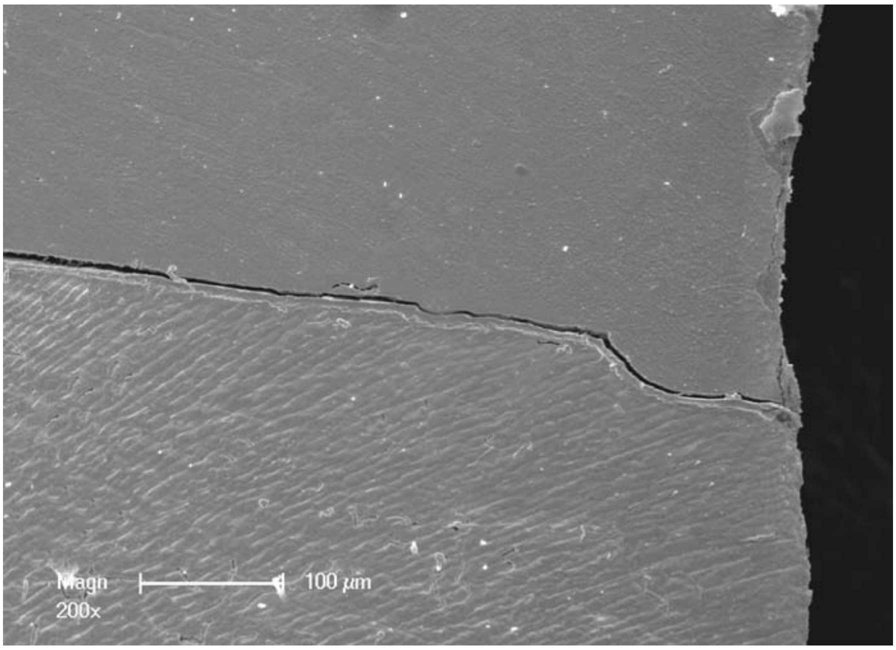


Figure 16B: Sample with stable interface in cervical dentin; however, the presence of a composite base/liner could not grant such perfect adaption in all samples or groups