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Sustitutos de Amalgama para la obtención de un composite que nos permita obturar las cavidades de manera rápida y sencilla.

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SUSTITUTOS DE AMALGAMA PARA LA OBTENCIÓN DE UN COMPOSITE QUE NOS PERMITA OBTURAR LAS CAVIDADES DE MANERA RÁPIDA Y SENCILLA

Adhesive Dentistry, optimize the technique and preserve healthy tissue
Odontología Adhesiva para optimizar la técnica y conservar el tejido sano
PhD Thesis – with European Mention

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1. JUSTIFICATION

JUSTIFICATION

Conservative dentistry has encountered several substantial changes, the last started about 60 years ago, and it is called “adhesive dentistry”. Adhesion allows to preserve maximum healthy tissue by bonding to the remaining tooth, reproducing nature. Another important change in dentistry is the improvement in prevention and oral hygiene habits, resulting in caries decrease. As a consequence the concepts of traditional dentistry were progressively questioned giving rise to more conservative restorative techniques.

At the same time, an increased demand of the society for more esthetic restorations or metal-free restorations, together with the interest of dental profesionals in tooth-colored materials, made use of amalgam and other metals in the mouth increasingly controversial, despite the absence of definitive scientific proofs (1, 2).

The main challenge for dental adhesives is to provide an equally effective bond to two hard tissues of different nature, enamel and dentin. Bonding to enamel has been proven to be durable and rather simple. Bonding to dentin is far more intricate and can apparently only be achieved when more complicated and time-consuming application procedures are followed (3).

Composites have a number of advantages over old amalgams. They widely widespread for years among the population for its ease of use, acceptable adaptability and low cost, as they are most aesthetic, preserve healthy tooth tissue and exhibit better marginal seal, reducing microleakage and postoperative sensitivity (4- 6).

In the framework of this thesis four papers were written with the aim to: analyse the development of adhesive dentistry; describe the use of different adhesive systems, emphasize on the etch and rinse adhesive with technical variations in the use; quantitatively (SEM) and qualitatively (OCT) analyze the failure mode of adhesive interfaces; evaluate the performance of a dual-cure composite as an amalgam substitute for cavity restoration in a rapid and affordable way and describe the step -by- step of a full- mouth adhesive rehabilitation on a young patient with a minimally invasive approach, which allows for restoration of health, biomechanical function and esthetic appearance.

2. INTRODUCTION

INTRODUCTION

Advances in adhesive technology have simplified dental procedures. They have given a more aesthetic result to patients and a conservative alternative treatment to clinicians (1).

Adhesives

Adhesive systems can be classified according to their etching strategy into etch-and-rinse (E&R) and self-etch (SE) products. E&R adhesive systems were the first to be introduced into the market and are often considered as being the adhesive system of reference (7- 9). Both types of adhesive systems differ significantly in the manner they deal with tooth tissue.

The etch-and-rinse systems require a specific acid-etch procedure and may be performed in two or three steps, depending on whether primer and bonding are separated or combined in a single bottle. The adhesion strategy involves the application of the conditioner (acid etchant), followed by the primer (adhesion promoting agent), and bonding step (10, 11, 12).

OptiBond FL (OFL, Kerr, Orange, CA, USA) is a particle-filled, ethanol-based 3-step E&R adhesive that has played an important role in adhesion, reporting favorable and reliable bonding effectiveness (4, 5). The bonding effectiveness shown in-vitro (6, 10) and the resultant clinical performance (5, 7) have been attributed to optimal enamel inter-locking and dentin hybridization, as demonstrated in various ultra-morphologic interface analyses (6, 7, 8). Based on all these data, OFL is considered by some authors as the gold standard. (1)

Acid Conditioning

Buonocore (13) was the first to demonstrate that acid-etching enamel with phosphoric acid increased resin–enamel bond strengths by increasing the microscopic surface area available for resin retention. Later on, John Gwinnett reported that adhesive resins could penetrate into acid-etched enamel prisms where they could actually envelop apatite crystallites (14) rendering them acid-resistant (9).

Acid-etching of enamel is a widely accepted clinical procedure and has increased the life of composite resin restorations by decreasing the possibility of marginal staining, secondary caries and postoperative sensitivity (15).

Monomers

Hydrophilic and hydrophobic monomers are combined with solvent(s) in the same or different bottle depending on two or three bottle adhesive systems. When combined in the same bottle they may produce some chemical disorder during clinical application. Presence of unprotected dentin collagen fibrils may be explained by the presence of residual water that may prevent complete monomer infiltration in the deep demineralized zone, which compromises ideal adhesive infiltration and polymerization (16, 17). These factors could be responsible for the degradation of resin-dentin interfaces over short periods of time. The instability of bonds over longer time periods has been attributed to the degradation of both exposed collagen and resin monomers (15, 16, 18).

HEMA (2-hydroxymethyl methacrylate) is a very popular monomer employed both in three-step and two-step etch-and-rinse systems. Its hydrophilicity makes it an excellent adhesion promoter, enhancing bond strength (10, 19, 20).
One of the first chemical compounds that has been proposed to improve bonding to human dentin is the glycerol phosphate dimethacrylate (GPDM) (21), which is an acidic monomer containing methacrylated phosphoric acid esters and it is present within the composition of OptiBond FL (OFL) Primer.

Solvents

A very important component of the adhesive systems is the solvent such as water, ethanol or acetone. Solvents are important to assure the diffusion of monomers into the demineralized dentin. Water, ethanol and acetone are the most commonly used solvents. After diffusion the solvents must be eliminated from adhesive, otherwise remaining solvent in the adhesive may jeopardize polymerization due to the dilution of monomers and may result in voids and increase the permeability of the adhesive layer (22, 23).

Marginal integrity

The evaluations of restoration margins could be analysed rather in vitro or in vivo. Both methodologies try to indicate the effectiveness of a restorative material or technique.
In vitro evaluation of marginal adaptation identifies defects at the tooth-restoration interface. In vivo may follow the United States Public Health Service (USPHS) criteria, where marginal adaptation is one of the factors together with retention, staining, marginal discoloration, surface roughness and sensitivity that is used in most clinical studies to judge on the restoration's clinical success (24, 25). In a recent study, a high correlation was observed between clinical and laboratory data of marginal adaptation provided that the same restorative material is considered in both in vitro and in vivo studies (26).

However, the relationship between marginal integrity alone and the restorations' clinical outcome seems to be far more complicated to demonstrate.
In the context of marginal integrity, the width and depth of the marginal gap, rather than its solely presence, is claimed as a more significant factor to predict the restorations' clinical outcome (26).

Scanning electron microscope (SEM) quantitative analyses the presence of marginal gaps on the restorations surface, however, no additional knowledge can be obtained on how much this gap can propagate through the adhesive interface inside the cavity. The detection of a marginal gap is, very likely, the first sign of early failure at the restorations adhesive interface. In this sense, it might be of interest to qualitatively analyse restorations with marginal defects to see if the gaps that occur on the surface do propagate or not inside the cavity.

Optical coherence tomography (OCT) is an interferometry imaging technique that maps depth-wise reflections of near-infrared light from tissue to form cross-sectional images of morphological features at the micrometer scale (27). It is a high-resolution analysis that enables the visualization beyond the surface, without entering into contact with the tissue of interest.

Composites

Amalgam has been the material of choice worldwide for class I and class II restorations for more than a century due to its high strength, good wear resistance, low technique sensitivity and low cost (28). However, the lack of aesthetics, corrosion and difficult bonding to tooth structure, requiring the removal of sound structure to gain on macromechanical retention, resulted in the need to find an amalgam substitute for the aesthetic restoration of decayed teeth.

While the use of amalgam for posterior restorations is declining, composite resins are being more often used with almost no differences in terms of clinical longevity (29).

Dual-cured resin composites have been mainly used as a core material for the reconstruction of non-vital teeth (30), and as dentin substitute in the open sandwich filling technique (31, 32). Some advantages of using dual-cured composites as filling material would be the possibility of a bulk insertion, clinical time saving, the achievement of polymerization in deep areas due to chemical curing and the development of lower contraction stresses (33).

Oral rehabilitations

The development of new dental materials, in combination with considerable advances in dental adhesion in recent years (10), has enabled clinicians to adopt a more conservative approach involving the removal of minimal amounts of tooth structure and avoiding traditional retentive preparations that require important biologic sacrifices.

Many publications have focused on the treatment of dental erosion and attrition in the last years, using minimally invasive techniques that conserve as much sound tooth structure as possible (34-42).

Dental erosion and attrition have a relatively rapid impact on hard tooth structure (43). Dental erosion is defined as tooth substance loss resulting from a chemical process, and is mainly caused by the consumption of fruit juices or carbonated and sports drinks, or by digestive disorders (recurrent vomiting). Excessive attrition is often caused by bruxism, and many patients present a combined aetiology of erosion and attrition (44).

Most patients are aware of the problem but not its impact. Therefore, diagnosing the problem as early as possible, introducing preventive measures, and raising awareness of its importance among patients may help them to avoid the necessity of full-mouth rehabilitation. Ignoring the problem may lead to the loss of several teeth, the restoration of the health, biomechanical function, and aesthetic appearance of which may require the combined efforts of several different specialties (38,45,46).

3. OBJECTIVES

OBJETIVES

GENERAL OBJECTIVES:

1. To evaluate the marginal adaptation before and after a thermo-mechanical fatigue test of class V cavities restored with composite and an E&R adhesive system applied under 3 protocols that differ in the use of the phosphoric acid etching step.

2. To determine whether marginal adaptation is, or not, a superficial phenomenon without any influence of adaptation on depth of class V cavities.

3. To evaluate the marginal adaptation before and after thermo-mechanical loading of cavities entirely restored in bulk with a dual-cured resin composite with differences in the etching procedure.

4. To evaluate the marginal adaptation before and after thermo-mechanical loading of cavities entirely restored in bulk with a dual-cured resin composite with differences in the polymerization mode (chemical or dual-cure).

5. To describe the step-by-step procedure of a full-mouth adhesive composite rehabilitation of a young patient treated with V-shaped veneers and ultra- thin computer-aided design/ computer-assisted manufactured generated composite overlays.

OBJETIVES

SPECIFIC OBJECTIVES:

1.1 To evaluate the marginal adaptation before thermomechanical fatigue test on enamel, dentin and at the total margin length of class V cavities restored with composite and an E&R adhesive system applied following the manufacturer recommendation for use. The acid etching was used on enamel and dentin.

1.2 To evaluate the marginal adaptation before thermomechanical fatigue test on enamel, dentin and at the total margin length of class V cavities restored with composite and an E&R adhesive system. The acid etching was applied on enamel only.

1.3 To evaluate the marginal adaptation before thermomechanical fatigue test on enamel, dentin and at the total margin length of class V cavities restored with composite and an E&R adhesive system. No phosphoric acid on enamel or dentin was used.

1.4 To evaluate the marginal adaptation after thermomechanical fatigue test on enamel, dentin and at the total margin length of class V cavities restored with composite and an E&R adhesive system applied following the manufacturer recommendation for use. The acid etching was used on enamel and dentin

1.5 To evaluate the marginal adaptation after thermomechanical fatigue test on enamel, dentin and at the total margin length of class V cavities restored with composite and an E&R adhesive system. The acid etching was applied on enamel only.

1.6 To evaluate the marginal adaptation after thermomechanical fatigue test on enamel, dentin and at the total margin length of class V cavities restored with composite and an E&R adhesive system. No phosphoric acid on enamel or dentin was used.

OBJETIVES

2.1 To evaluate the gap propagation beneath the restoration of class V cavities restored with composite and an E&R adhesive system following thermomechanical fatigue test. The acid etching was applied only on enamel

2.2 To evaluate the gap propagation beneath the restoration of class V cavities restored with composite and an E&R adhesive system following thermomechanical fatigue test. No phosphoric acid on enamel or dentin was used.

3.1 To evaluate the marginal adaptation before thermo-mechanical loading on occlusal margins, on proximal margins, on cervical margins and at the total margin length of cavities entirely restored in bulk with a dual-cured resin composite. No acid etching was used and self-cured.

3.2 To evaluate the marginal adaptation before thermo-mechanical loading on occlusal margins, on proximal margins, on cervical margins and at the total margin length of cavities entirely restored in bulk with a dual-cured resin composite. No acid etching was used and dual-cured.

3.3 To evaluate the marginal adaptation before thermo-mechanical loading on occlusal margins, on proximal margins, on cervical margins and at the total margin length of cavities entirely restored in bulk with a dual-cured resin composite. The acid etching was used on enamel and self-cured.

3.4 To evaluate the marginal adaptation before thermo-mechanical loading on occlusal margins, on proximal margins, on cervical margins and at the total margin length of cavities entirely restored in bulk with a dual-cured resin composite. The acid etching was used on enamel and dual-cured.

3.5 To evaluate the marginal adaptation after thermo-mechanical loading on occlusal margins, on proximal margins, on cervical margins and at the total margin length of cavities entirely restored in bulk with a dual-cured resin composite. No acid etching was used and self-cured.

OBJETIVES

3.6 To evaluate the marginal adaptation after thermo-mechanical loading on occlusal margins, on proximal margins, on cervical margins and at the total margin length of cavities entirely restored in bulk with a dual-cured resin composite. No acid etching was used and dual-cured.

3.7 To evaluate the marginal adaptation after thermo-mechanical loading on occlusal margins, on proximal margins, on cervical margins and at the total margin length of cavities entirely restored in bulk with a dual-cured resin composite. The acid etching was used on enamel and self-cured.

3.8 To evaluate the marginal adaptation after thermo-mechanical loading on occlusal margins, on proximal margins, on cervical margins and at the total margin length of cavities entirely restored in bulk with a dual-cured resin composite. The acid etching was used on enamel and dual-cured.

OBJETIVES

OBJETIVOS GENERALES:

1. Evaluar la adaptación marginal antes y después de la carga termomecánica de cavidades de clase V restauradas con composite y un sistema adhesivo de grabado total aplicado con 3 protocolos que difieren en el uso del grabado con ácido fosfórico.

2. Determinar si la adaptación marginal es, o no, un fenómeno superficial sin ninguna influencia en la adaptación en profundidad de las cavidades clase V.

3. Evaluar la adaptación marginal antes y después de la carga termomecánica de cavidades restauradas en una sola capa con un composite de polimerización dual con diferencias en el procedimiento de grabado.

4. Evaluar la adaptación marginal antes y después de la carga termomecánica de cavidades restauradas en una sola capa con un composite de polimerización dual con diferencias en el procedimiento de polimerización (química/dual).

5. Describir el procedimiento paso a paso de una rehabilitación adhesiva completa de composite en un paciente joven tratado con carillas en forma de V e incrustaciones muy finas realizados por tecnología CAD/CAM.

OBJETIVES

OBJETIVOS ESPECÍFICOS:

1.1 Evaluar la adaptación marginal antes de la carga termomecánica en el esmalte, la dentina y en la longitud total del margen de cavidades clase V restauradas con composite y un sistema adhesivo de grabado total aplicado siguiendo las recomendaciones del fabricante. El grabado ácido se utilizó en el esmalte y la dentina.

1.2 Evaluar la adaptación marginal antes de la carga termomecánica en el esmalte, la dentina y en la longitud total del margen de cavidades clase V restauradas con composite y un sistema adhesivo de grabado total. El grabado ácido se utilizó solo en el esmalte.

1.3 Evaluar la adaptación marginal antes de la carga termomecánica en el esmalte, la dentina y en la longitud total del margen de cavidades clase V restauradas con composite y un sistema adhesivo de grabado total. No se realizó grabado ácido en esmalte o dentina.

1.4 Evaluar la adaptación marginal después de la carga termomecánica en el esmalte, la dentina y en la longitud total del margen de cavidades clase V restauradas con composite y un sistema adhesivo de grabado total aplicado siguiendo las recomendaciones del fabricante. El grabado ácido se utilizó en el esmalte y la dentina.

1.5 Evaluar la adaptación marginal después de la carga termomecánica en el esmalte, la dentina y en la longitud total del margen de cavidades clase V restauradas con composite y un sistema adhesivo de grabado total. El grabado ácido se utilizó solo en el esmalte.

1.6 Evaluar la adaptación marginal después de la carga termomecánica en el esmalte, la dentina y en la longitud total del margen de cavidades clase V restauradas con composite y un sistema adhesivo de grabado total. No se realizó grabado ácido en esmalte o dentina.

2.1 Evaluar la propagación de la grieta debajo de las restauraciones de clase V restauradas con composite y un sistema adhesivo de grabado total después de la carga termomecánica. El grabado ácido sólo se aplicó en el esmalte.

OBJETIVES

2.2 Evaluar la propagación de la grieta debajo de las restauraciones de clase V restauradas con composite y un sistema adhesivo de grabado total después de la carga termomecánica. No se utilizó ácido fosfórico en el esmalte o la dentina.

3.1 Evaluar la adaptación marginal antes de la carga termomecánica en los márgenes oclusales, en los márgenes proximales, en los márgenes cervicales y en la longitud total del margen de cavidades restauradas en una sola capa con un composite de polimerización dual. No se utilizó grabado ácido y con autopolimerización.

3.2 Evaluar la adaptación marginal antes de la carga termomecánica en los márgenes oclusales, en los márgenes proximales, en los márgenes cervicales y en la longitud total del margen de cavidades restauradas en una sola capa con un composite de polimerización dual. No se utilizó grabado ácido y con polimerización dual.

3.3 Evaluar la adaptación marginal antes de la carga termomecánica en los márgenes oclusales, en los márgenes proximales, en los márgenes cervicales y en la longitud total del margen de cavidades restauradas en una sola capa con un composite de polimerización dual. Se realizó grabado ácido en esmalte y autopolimerización.

3.4 Evaluar la adaptación marginal antes de la carga termomecánica en los márgenes oclusales, en los márgenes proximales, en los márgenes cervicales y en la longitud total del margen de cavidades restauradas en una sola capa con un composite de polimerización dual. Se realizó grabado ácido en esmalte y polimerización dual.

3.5 Evaluar la adaptación marginal después de la carga termomecánica en los márgenes oclusales, en los márgenes proximales, en los márgenes cervicales y en la longitud total del margen de cavidades restauradas en una sola capa con un composite de polimerización dual. No se utilizó grabado ácido y con autopolimerización.

3.6 Evaluar la adaptación marginal después de la carga termomecánica en los márgenes oclusales, en los márgenes proximales, en los márgenes cervicales y en la longitud total del margen de cavidades restauradas en una sola capa con un composite de polimerización dual. No se utilizó grabado ácido y con polimerización dual.

OBJETIVES

3.7 Evaluar la adaptación marginal después de la carga termomecánica en los márgenes oclusales, en los márgenes proximales, en los márgenes cervicales y en la longitud total del margen de cavidades restauradas en una sola capa con un composite de polimerización dual. Se realizó grabado ácido en esmalte y autopolimerización.

3.8 Evaluar la adaptación marginal después de la carga termomecánica en los márgenes oclusales, en los márgenes proximales, en los márgenes cervicales y en la longitud total del margen de cavidades restauradas en una sola capa con un composite de polimerización dual. Se realizó grabado ácido en esmalte y polimerización dual.

4. HYPOTHESES

HYPOTHESIS

The null hypotheses (N_0) were:

1. (H_0) There are no significant differences on the marginal adaptation of class V cavities restored with different application protocols of acid etching on enamel and dentin.

2. (H_0) SEM analysis is not able to detect differences in marginal gaps amongst groups.

3. (H_0) There are no gaps propagating inside the cavity, in cavities with non-continuous margins (or marginal gaps).

4. (H_0) There are no differences on the marginal adaptation of class II cavities restored in bulk with different etching procedures.

5. (H_0) There are no differences on the marginal adaptation of class II cavities restored in bulk with different polymerization modes, chemical and dual.

The alternative hypothesis (H_1) were:

1. (H_1) There are differences in the marginal adaptation of class V cavities restored with different application protocols of acid etching on enamel and dentin.

2. (H_1) SEM analysis is able to detect differences in marginal gaps amongst groups.

3. (H_1) There is a gap propagating inside the cavity, in cavities with non-continuous margins (or marginal gaps).

4. (H_1) There are differences on the marginal adaptation of class II cavities restored in bulk with different etching procedures.

5. (H_1) There are differences on the marginal adaptation of class II cavities restored in bulk with different polymerization modes, chemical and dual.

HYPOTHESIS

Las hipótesis nulas (H_0) fueron:

1. (H_0) No existen diferencias en cuanto a la adaptación marginal en restauraciones de clase V con diferentes protocolos de aplicación de ácido fosfórico en esmalte y dentina.

2. (H_0) El análisis SEM no es capaz de detectar diferencias en grietas marginales entre los grupos.

3. (H_0) No hay propagación de una grieta en el interior de la cavidad, en cavidades con márgenes no continuos (o grietas marginales).

4. (H_0) No hay diferencias en cuanto a la adaptación marginal en restauraciones de clase II en una sola capa con diferentes protocolos de grabado ácido.

5. (H_0) No hay diferencias en cuanto a la adaptación marginal en restauraciones de clase II en una sola capa con polimerización, auto y dual.

Las hipótesis alternativas (H_1) fueron:

1. (H_1) Si que hay diferencias en cuanto a la adaptación marginal en restauraciones de clase V con diferentes protocolos de aplicación de ácido fosfórico en esmalte y dentina.

2. (H_1) El análisis SEM es capaz de detectar diferencias en grietas marginales entre los grupos.

3. (H_1) Hay propagación de grietas en el interior de la cavidad, en cavidades con márgenes no continuos (o grietas marginales).

4. (H_1) Si que hay diferencias en cuanto a la adaptación marginal en restauraciones de clase II en una sola capa con diferentes protocolos de grabado ácido.

5. (H_1) Si que hay diferencias en cuanto a la adaptación marginal en restauraciones de clase II en una sola capa con polimerización, auto y dual.

5. PUBLISHED PAPERS

PUBLISHED PAPER 1

Self-etching aspects of a three-step etch-and-rinse adhesive

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ORIGINAL ARTICLE

Self-etching aspects of a three-step etch-and-rinse adhesive

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Abstract
Purpose The purpose of this study is to assess the marginal adaptation of cavities restored with a three-step etch-and-rinse adhesive, OptiBond FL (OFL) under different application protocols.
Materials and methods Twenty-four class V cavities were prepared with half of the margins located in enamel and half in dentin. Cavities were restored with OFL and a micro-hybrid resin composite (Clearfil AP-X). Three groups (n=8) that differed in the etching technique were tested with thermomechanical loading, and specimens were subjected to quantitative marginal analysis before and after loading. Micromorphology of etching patters on enamel and dentin were observed with SEM. Data was evaluated with Kruskal–Wallis and Bonferroni post hoc test.
Results Significantly lower percent CM (46.9±19.5) were found after loading on enamel in group 3 compared to group 1 (96.5±5.1) and group 2 (93.1±8.1). However, no significant differences (p=0.30) were observed on dentin margins.
Conclusions Etching enamel with phosphoric acid but avoiding etching dentin before the application of OFL, optimal marginal adaptation could be obtained, evidencing a self-etching primer effect.
Clinical relevance A reliable adhesive interface was attained with the application of the three-step etch-and-rinse OFL adhesive with a selective enamel etching, representing an advantage on restoring deep cavities.

Key words Etch and rinse · OptiBond FL · Marginal adaptation · Class V · Etch pattern

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Introduction

Adhesive systems can be classified according to their etching technique into etch-and-rinse (E&R) and self-etch (SE) products. E&R adhesive systems were the first to be introduced in the market and are often considered as being the adhesive system of reference [1–3].

OptiBond FL (OFL, Kerr, Orange, CA, USA) is a particle-filled, ethanol-based three-step E&R adhesive that has played an important role in adhesion, reporting favorable and reliable bonding effectiveness [4, 5]. The superior bonding effectiveness shown in vitro [6, 7] and the resultant clinical performance [5, 8] has been attributed to optimal enamel inter-locking and dentin hybridization, as demonstrated in various ultramorphologic interface analyses [6, 7, 9]. Based on all these data, OFL is considered by some authors as the gold standard.

One of the first chemical compounds that have been proposed to improve bonding to human dentin is the glycerol phosphate dimethacrylate (GPDM) [10], which is an acidic monomer containing methacrylated phosphoric acid esters, and it is present within the composition of OFL Primer.

Due to the poor etching pattern observed on enamel when SE adhesives are used, several studies proposed to transform SE adhesives to E&R by adding a phosphoric acid conditioning step [11–16]. However, due to the presence of GPDM in the primer, OFL may be used as a self-etching system when the etching step with phosphoric acid is avoided on dentin.

Therefore, the purpose of the present study was to evaluate the marginal adaptation of class V cavities restored with composite and an E&R adhesive system applied under three protocols that differ in the use of the phosphoric acid etching step. The null hypothesis tested was that there would be no effect on the marginal adaptation with different application protocols on enamel and dentin.

Materials and methods

A universal restorative composite Clearfil AP-X (Kuraray, Okayama, Japan) and a three-step etch-and-rinse adhesive system Optibond FL were used for this study (Table 1). Twenty-four recently extracted sound molars were randomly assigned to three equal groups on the basis of the etching method used. After scaling and pumicing, the teeth were mounted on custom-made specimen holders with their roots at the center using a cold-polymerizing resin (Technovit 4071, Heraeus Kulzer GmbH, Wehrheim, Germany). Prior to the mounting procedure, the apices were sealed with two coats of nail varnish. To simulate dentinal fluid flow, a cylindrical hole was drilled into the pulpal chamber approximately in the middle third of the root, and a metal tube with a diameter of 1.4 mm was then adhesively luted using a dentinal adhesive (Syntac Classic, IvoclarVivadent AG, Schaan, Liechtenstein). The pulpal tissue was not removed. 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 (PAA Laboratories GmbH, Linz, Austria) and phosphate-buffered saline solution (PBS; Oxoid Ltd, Basingstoke, Hampshire, UK) diluted in a 1:3 ratio under a hydrostatic pressure of about 25 mm Hg. Twenty-four hours before starting the cavity preparations, using a three-way valve, the pulp chambers were evacuated with a vacuum pump and subsequently bubble-free filled with the above solution. As of this moment, the intrapulpal pressure was maintained at 25 mm Hg throughout the testing, i.e., during cavity preparation, restoration placement, finishing, and stressing.

In each tooth, a mixed class V, V-shaped cavity was prepared using fine diamond burs (Intensiv SA, Grancia, Switzerland), including both enamel and dentin margins. The dimensions of the V-shaped cavities were 3.0–3.5 mm in diameter, 2.5–3.0 mm in height, and 1.5 mm in depth. A slight enamel cavosuperficial margin was beveled to a crescent shape with a maximum width of 1.2 mm. using an extra-fine (15 μm) diamond bur (Intensiv SA) under ×12 magnification.

The teeth were divided into three groups (n=8) that differed in the application of phosphoric acid: group 1, enamel and dentin was etched with 37.5% phosphoric acid gel (Kerr, Scafati, Italy), applied for 30 s to enamel and 15 s to dentin; group 2, enamel was etched for 30 s and no phosphoric acid was applied on dentin; and group 3, no phosphoric acid was applied on either enamel or dentin. Then, OFL primer was applied on enamel and dentin using a microbrush with a continuous scrubbing motion for 15 s. Removal of excess solvent was done by drying the cavity with compressed air for 5 s, then OFL adhesive was applied with a microbrush to the primed surface for 15 s and spread with air for 5 s before a 20-s light curing. The cavity preparations were restored with a microhybrid resin composite Clearfil AP-X under ×12 magnification and light-cured for 40 s (L.E.D. Demetron II, serial number 792026758, Kerr, Orange, CA, USA) with a relative intensity of 800 mW/cm^2 (Curing Radiometer, Demetron Research, Danbury, CT, USA). The same operator performed the restoration of all groups.

Immediately after light polymerization, finishing and polishing of the restorations were carried out using flexible

Table 1 List of materials with composition, batch number and application mode

Material	Component (batch no.)	Application mode
OptiBond FL (Kerr, Orange, CA, USA), according to Mine et al. [9]	Primer (3271580): HEMA, GPDM, MMEP, water, ethanol, CQ, BHT (pH1.9)	Scrub for 15 s. Gently air dry 5 s
	Bond (3437447): Bis-GMA, HEMA, GDMA, CQ, ODMAB, Filler (fumed SiO_2, barium aluminoborosilicate, Na_2SiF_6), coupling factor A174 (approximately 48 wt% filled)	Apply thin coat for 15 s and gently air dry 5 s. Light-cure for 20 s
Clearfil AP-X (Kuraray, Okayama, Japan), according to manufacturer recommendations for use	Principle ingredients (1067BA) Silanated barium glass, silanated colloidal silica, silanated silica, Bis-GMA, TEGDMA, dl-Camphorquinone	Apply composite and light cure for 40 s

Bis-GMA bisphenol A diglycidyl ether dimethacrylate, *HEMA* 2-hydroxyethyl methacrylate, *GPDM* glycerol phosphate dimethacrylate, *MMEP* mono-2-methacryloyloxyethyl phthalate, *CQ* camphorquinone (photo-initiator), *BHT* butylhydroxytoluene or butylated hydroxytoluene or 2,6-di-(tert-butyl)-4-methylphenol (inhibitor), *GDMA* glycerol dimethacrylate, *ODMAB* 2-(ethylhexyl)-4-(dimethylamino)benzoate (coinitiator) discs (SofLex PopOn, 3 M ESPE AG, Seefeld, Germany). Then, impressions with a polyvinylsiloxane material (President light body, Coltène-Whaledent, Altstätten, Switzerland) were made of each restoration and poured with epoxy resin (Epofix Resin, Struers, Germany) and 24 h after gold sputtered to obtain replicas. They were subjected to the computer-assisted quantitative margin analysis in a scanning electron microscope (XL20, Philips, Eindhoven, The Netherlands) at ×200 magnification using a custom-made module programmed with an image processing software (Scion Image, Scion Corp, Frederik, MA, USA [17]. For the quantitative evaluation, a blinded and trained lab technician examined the specimens. The following criteria were considered for enamel and dentin margin analysis: percentages of perfect/continuous margins and percentages of noncontinuous margins due to the presence of: pure gaps, marginal enamel fractures, marginal dentin fractures, marginal restoration fractures, and overhang and underfilled margins, at each interval before and after loading.

After storage for 7 days at 37 °C in the dark, the teeth were loaded with simultaneous repeated thermal (×600 from 5 to 55 °C with a dwell time of 2 min) and mechanical stresses (240,000 chewing cycles at 1.7 Hz) by an antagonistic natural molar cusp with a maximum load of 49 N under the constant simulation of dentinal fluid flow according to a protocol described before by Krejci et al. [18]. After thermomechanical loading, the teeth were cleaned with toothpaste, rinsed with tap water, and impressions were taken again in order to perform the marginal replicas for SEM analysis after loading.

To qualitatively assess the self-etch pattern obtained with the different techniques, intact caries-free extracted human molars were selected. The crowns were sectioned perpendicular to their longitudinal axis above the roof of the pulp chamber using a precision slow-speed diamond saw (Isomet, Buehler Ltd., Evanston, IL, USA) under water cooling, to obtain a flat surface of dentin surrounded by enamel. Then, two grooves perpendicular to the flat surface were performed so that the surface could be divided into three sections. A metal matrix was fixed into each groove in order to achieve three separate flat surfaces that would not be contaminated by the different etching procedures. The first third was etched with 37.5 % phosphoric acid gel, applied 30 s to enamel and 15 s to dentin. After water rinsing and slight drying, OFL primer was applied to enamel and dentin for 15 s. On the second third, only OFL primer was applied, and the third control part was included without phosphoric acid or primer treatment. Fixation was performed by immersing the specimens in 2.5 % glutaraldehyde in 0.1 M sodium cacodylate buffer (pH7.4) for 12 h at 4 °C. After rinsing with sodium cacodylate for 1 h in three different baths and then in deonized water for 1 min, dehydration was performed by immersing the specimens in ethanol with increasing concentrations (50, 70, 90, and 100 %) and transferred to HMDS and allowed air-dry for 10 min [19].

Specimens were gold sputtered and observed in a scanning electron microscope at ×1,000 magnification (XL20, Philips, Eindhoven, The Netherlands).

Statistical analysis

In some groups, data of marginal adaptation was not normally distributed, as proved by Shapiro–Wilk test and therefore evaluated with Kruskal–Wallis and Bonferroni post hoc test. The level of confidence was set to 95 %. We used a one-way Bonferroni to assess whether there were significant differences between experimental groups both before and after loading on enamel and dentin margins.

Results

Percentages of continuous margins (%CM) before loading are shown in Table 2. No significant differences between groups were observed at dentin margins ($p=0.33$). However, on enamel margins, significantly lower %CM (80.2±10.1) were observed before loading in the group without phosphoric acid etching.

After loading (Table 3), significantly lower %CM on enamel margins (46.9±19.5) were observed in group 3, without phosphoric acid etching, in comparison to group 1 (96.5±5.1) and group 2 (93.1±8.1). Interestingly, the results on dentin were not statistically different ($p=0.30$) for the three groups.

Figure 1a and b represents the percentage of noncontinuous margins due to enamel fractures or pure gaps after loading. It can be observed that while the percentage of enamel fractures was similar in the three groups, a significantly higher percentage of pure open gaps was observed in the group in which phosphoric acid etching was avoided, indicating the absence of adhesion at this level.

Representative SEM images of enamel and dentin margins are presented in Figs. 2, 3 and 4 for the three groups.

The micromorphology of enamel and dentin surfaces after the different treatments is presented in Figs. 5 and 6. On enamel (Fig. 5), the best morphology was achieved when phosphoric acid was applied on the surface. On dentin (Fig. 6), while the morphology of the surface was quite similar for both OFL primer and H_3PO_4 treatment, we observed that in the surface treated with OFL primer, tubule openings were less evident, and some of them were still covered by smear layer, suggesting that the primer was less aggressive compared to phosphoric acid etching.

Table 2 Percentage of continuous margins (%CM, mean ± standard deviation) of each group before loading on enamel and dentin. Levels connected by the same letter are statistically similar and apply to each column

	%CM enamel before loading $p=0.012$	%CM dentin before loading $p=0.984$
Group 1 (H_3PO_4 E&D+OFL)	97.5±4.1 A	89.4±8.6 A
Group 2 (H_3PO_4 E+OFL)	89.9±14.5 AB	89±10.9 A
Group 3 (OFL no H_3PO_4)	80.2±10.1 B	90.1±16.6 A

Discussion

Based on recommendations of the American Dental Association for dentin and enamel adhesives, we performed class V restorations on noncarious teeth because of the following reasons [20]. The lesions do not have any macromechanical retention, and they have a small C-factor, which plays an important role in the performance of the adhesive system. Class V restorations may include margins on enamel and dentin with no major difficulties in cavity preparation, thus minimizing the operator factor variable and providing an appropriate location for the restorative and evaluation procedure.

One of the main objectives in adhesive restorative dentistry is to obtain a reliable and durable bonding interface creating restorations with clinical longevity, trying to avoid future leakage, recurrent caries, or pulpal irritation. Therefore, the simulation of oral conditions by thermomechanical loading, together with dentinal fluid simulation, assessing the marginal adaptation may serve as an appropriate model for the in vitro evaluation of adhesive systems [17, 18, 21]. Nevertheless, in vitro evaluations of marginal adaptation have been severely criticized in the last years, mainly due to the common belief that retention loss (and not the presence of marginal defects) is the most obvious sign of failure of an adhesive system [22]. However, it is known from the previous literature that clinical failure of restorations occurs most often due to inadequate sealing, with subsequent discoloration of the cavity margins, than due to restoration loss [23]. Moreover, the criterion marginal adaptation (together with cavosurface marginal discoloration, color match, anatomic form, and caries) is part of the US Public Health Service or Ryge guidelines to judge on the clinical performance of a restoration. These guidelines are by far the ones that had the greatest scientific impact in dentistry since their creation several decades ago [24]. Thus, it is difficult to explain the reason why marginal integrity is a widely accepted test when it is used in vivo and so criticized when it is used in vitro. Furthermore, Frankenberger et al. [25] reported that even if marginal integrity is only one among several factors, responsible for clinical success or clinical failure over time, thermomechanical loading and marginal analysis may be the in vitro test that is closest to the clinical situation. These authors reported that when high percentages of gap-free margins are observed in vitro, it could be assumed that the restoration's clinical behavior regarding marginal quality will not be problematic. This assumption was confirmed in a recent study [26], in which a correlation was observed between in vitro marginal adaptation and clinical outcome of class V restorations, when the same restorative composite was used in both in vitro and in vivo tests, justifying why in our study the primary criterion of evaluation was the percentages of continuous or gap-free margins, in class V cavities restored with the same composite resin.

Bond formation to enamel has proved reliable since Buonocore [27] demostrated that phosphoric acid etching increased resin-enamel bond strengths. Since then, several publications confirmed this assertion [11, 28–30]. Creation of a bond to dentin is more complicated due to the composition of the dentin substrate, presence of collagen, water, and smear layer deposition.

While several studies have transformed an SE adhesive to an E&R [11–16] by adding a phorphoric acid-etching step, there is not much literature evaluating a

Table 3 Percentage of continuous margins (%CM, mean±standard deviation) after loading on enamel and dentin

	%CM enamel after loading $p<0.001$	%CM dentin after loading $p=0.305$
Group 1 (H_3PO_4 E&D+OFL)	96.5±5.1 A	83.3±11.6 A
Group 2 (H_3PO_4 E+OFL)	93.1±8.1 A	68.7±25.1 A
Group 3 (OFL no H_3PO_4)	46.9±19.5 B	69.7±22.5 A

Levels connected by the same letter are statistically similar and apply to each column

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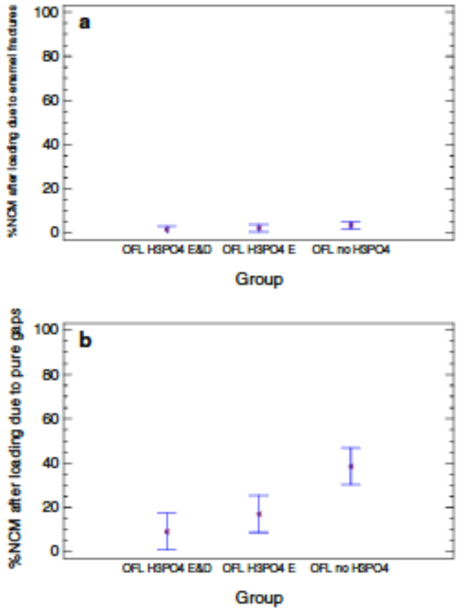

Fig. 1 Percentage of noncontinuous margins due to the presence of enamel fractures (**a**) and pure gaps (**b**). It can be observed that in the group in which H_3PO_4 was avoided, increased percentages of pure gaps were observed after loading, evidencing a lack of adhesion at the marginal level

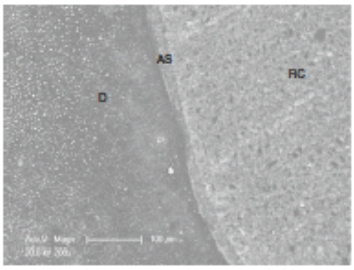

Fig. 3 SEM image of group 2 (H_3PO_4 E+OFL), showing a continuous margin between dentin (*D*), adhesive system (*AS*), and composite (*RC*) (magnification, ×200)

selective enamel etching for a three-step E&R adhesive system. The %CM after loading (Table 3) were significantly higher when enamel was conditioned with H_3PO_4 previous to the application of the primer (96.5 ±5.1 and 93.1±8.1) with respect to the group in which H_3PO_4 was avoided (46.9±19.5). This is in agreement with similar findings that have been reported in the literature [11, 31]. These better results on enamel were due to an enhanced mechanical interlocking resulting from the use of H_3PO_4 as shown on Fig. 5, which has a low pH. GPDM was probably not acidic enough to properly etch enamel, explaining why the %CM after loading on enamel was below 50 % (46.9±19.5). More, pure marginal gaps were observed when H_3PO_4 was avoided (Fig. 1b), showing a clear lack of adhesion at this level. Therefore, the null hypothesis was rejected for enamel margins.

Etching dentin with phosphoric acid did not improve significantly marginal adaptation either before or after loading; indicating a self-etching effect most probably due to the presence of the acidic monomer (GPDM) within the composition of OFL primer. These findings led to accept the null hypothesis on dentin. Nevertheless,

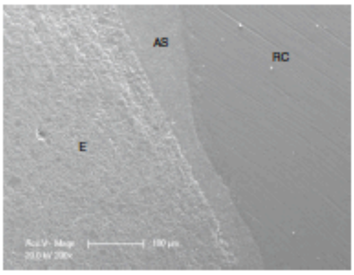

Fig. 2 SEM image of group 1 (H_3PO_4 E&D+OFL), showing continuous adhesive interface between enamel (*E*), adhesive system (*AS*), and composite (*RC*) (magnification, ×200)

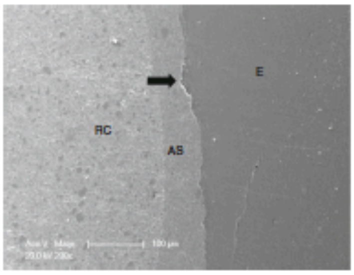

Fig. 4 Group 3 (OFL no H_3PO_4), SEM image with a noncontinuous margin observing a open gap (*arrow*) between enamel (*E*), adhesive system (*AS*), and composite (*RC*) (magnification, ×200)

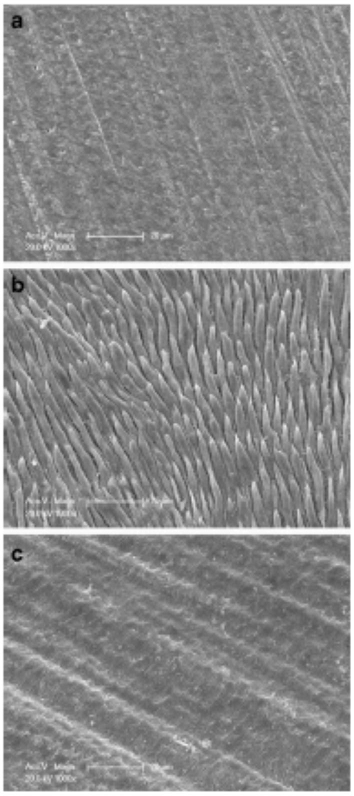

Fig. 5 SEM micrographs (×1,000) of enamel original surface without treatment (**a**), after H_3PO_4 etching (**b**), and after the application of OFL primer (**c**). See that micromorphology of enamel is clearly visible in **b**, that is, after acid conditioning with phosphoric acid

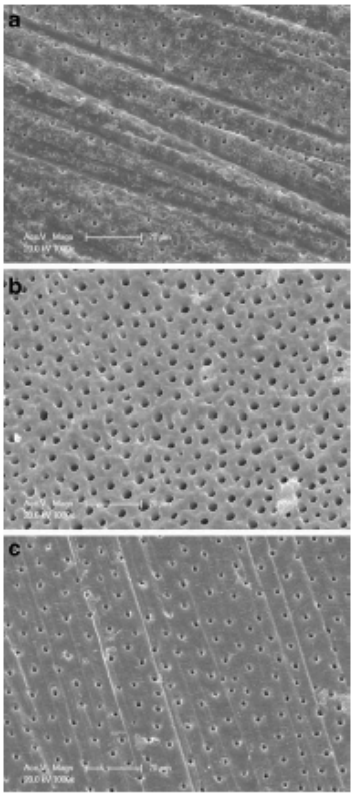

Fig. 6 SEM micrographs (×1,000) of dentin original surface without treatment (**a**), after H_3PO_4 etching (**b**), and after the application of OFL primer (**c**). Note that in **a** dentin is partially covered by smear layer; in **b**, dentinal tubules are completely opened, and in **c**, dentinal tubules are open due to the effect of the acidic monomer. However, the etching pattern looks less aggressive than the one obtained with H_3PO_4 etching

greater amount of variability in the bonding results were obtained in groups 2 and 3 compared to group 1. This may indicate that although there may be a self-etch effect from GPDM, it may not be as reliable as phosphoric acid. However, acid-etching deep dentin could have deleterious effects, justifying why some authors even recommend to avoid this procedure [32]. Phosphoric acid etching of cavities approaching the pulp may induce a moderate inflammatory response or pulpal irritation [33, 34]. Avoiding phosphoric acid etching of dentin thereby reduces the technique sensitivity of etch-and-rinse adhesives. Therefore, eliminating as many steps as possible in the bonding protocol could increase the efficiency of the procedure and would reduce technique sensitivity, as shown in the literature [35].

Because the effect of additional water storage was not assessed in the present study, it is not possible to know how these adhesive interfaces will behave when confronted by prolonged hydrolytic degradation. A previous study [36] tested the same adhesive system and found a significant decrease in bond strength from 1 to 6 months of water storage. These authors explained their findings by a combination of collagen and resin degradation within the hybrid layer. It is possible that due to the use of H_3PO_4 on dentin and then the application of the mentioned acidic primer,

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dentin was in fact etched "twice." The type of acid used to demineralize deep coronal dentin may significantly affect the quality of such bonding interface [37]. Phosphoric acid etching considerably increases dentin permeability as shown in the micromorphology in Fig. 6 and thus monomer diffusion into the pulp producing cytotoxicity. It is well known that inadequate etching procedures with a collapsed collagenous fibrillar network can decrease up to 90 % of the maximal level of bond strength values [38]. In this sense, additional studies are being performed by our research group in order to evaluate the hydrolytic degradation of these interfaces after long-term water storage.

Conclusions

Within the limitations of the present study, it can be concluded that when bur-prepared class V cavities were restored with the use of Optibond FL adhesive with selective enamel etching, high percentages of continuous margins were observed on dentin being not significantly different with the etch-and-rinse application procedure. These results might be due to a self-etching effect of the primer, owing to the presence of an acidic monomer within its composition. However, marginal adaptation on enamel was still enhanced by etching with phosphoric acid.

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Conflict of interest statement The authors declare that they have no conflict of interest.

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Failure analysis of adhesive restorations with SEM and OCT: from marginal gaps to restoration loss

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Failure analysis of adhesive restorations with SEM and OCT: from marginal gaps to restoration loss

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Abstract
Objective The objective of this study was to analyse the failure mode of adhesive interfaces by comparing OCT and scanning electron microscope (SEM) analysis of class V restoration margins located on enamel and dentin.
Materials and methods Three groups were tested that differed in the application of a 3-step etch-and-rinse adhesive system (OptiBond FL) prior to cavity filling with restorative composite resin (Clearfil AP-X). After tooth restoration and polishing, the samples were loaded in a fatigue machine, and adhesive interfaces were evaluated with OCT and SEM.
Results Important and complementary information could be obtained with OCT analysis in respect to how marginal defects can propagate inside the cavity, compromising the restoration's long-term performance. A self-etching effect was observed with OptiBond FL due to the presence of an acidic primer (GPDM) within its composition. Our results could show that areas of bonding and gaps coexisted within the same restoration.
Conclusions When marginal imperfections, or non-continuous margins, were detected by SEM, also imperfections beneath the surface could be observed at the tooth-restoration interface with OCT. Restoration loss occurred above the borderline of 50 % of marginal gaps on enamel and dentin.
Clinical relevance Marginal discrepancies of adhesive restorations can propagate inside the cavity and lead to restoration loss.

Keywords Quantitative margin analysis · Scanning electron microscope · Optical coherence tomography · Bond degradation

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Introduction

Both in vitro and in vivo evaluations of restoration margins, as an indicator of the effectiveness of a restorative material or technique, have been the subject of numerous publications [1–7]. In vitro evaluation of marginal adaptation is based on the fact that by identifying defects at the tooth-restoration interface, an early sign of adhesive failure is already affecting the restoration before catastrophic failures like restoration loss can occur. In vivo, marginal adaptation is one of the factors of the United States Public Health Service (USPHS) criteria together with retention, staining, marginal discoloration, surface roughness and sensitivity that is used in most clinical studies to judge on the restoration's clinical success [7, 8]. In a recent study, a high correlation was observed between clinical and laboratory data of marginal adaptation provided that the same restorative material is considered in both in vitro and in vivo studies [9]. Therefore, the clinical behaviour of restoration margins can be predicted on the basis of in vitro tests on marginal integrity, like shown by Frankenberger and co-workers [10].

However, the relationship between *marginal integrity* alone and the *restorations' clinical outcome* seems to be far

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more complicated to demonstrate. One reason may be that in clinical studies, frequent observation periods are of three years, which is too short if we consider that in most cases dentists replace existing class V restorations due to the diagnosis of secondary caries [11] and that failures due to secondary caries are usually observable after 5 years of the restoration's clinical service [12]. This is the main reason why some in vitro research methodologies have attempted to simulate a 5-year period of clinical function, to compare then the quality of the restoration immediately after placement and after these 5 years of "simulated clinical service" and be able to predict the fatigue resistance and long-term performance of that restoration [13–16].

In the context of marginal integrity, the width and depth of the marginal gap, rather than its solely presence, is claimed as a more significant factor to predict the restoration's clinical outcome [9]. One limitation of scanning electron microscope (SEM) *quantitative* margin analysis is that the presence of marginal gaps is detectable on the restorations' surface, with no additional knowledge on how much this gap can propagate through the adhesive interface inside the cavity. The detection of a marginal gap is, very likely, the first sign of early failure at the restoration's adhesive interface and in this sense, it might be of interest to *qualitatively* analyse restorations with marginal defects to see if the gaps that occur on the surface, propagate or not inside the cavity.

Optical coherence tomography (OCT) is an interferometry imaging technique that maps depth-wise reflections of near-infrared light from tissue to form cross-sectional images of morphological features at the micrometer scale [17]. It is a high-resolution analysis that enables the visualization beyond the surface, without entering into contact with the tissue of interest. Several studies have used this technology in the dental field to judge on the internal adaptation of fissure sealants, class I cavities, defects inside the mass of composite restorations and degree of demineralization of caries-affected dentin [18–22]. However, no study has assessed the effect of marginal gaps on gap depth, justifying why the present investigation can add interesting information to the existing literature.

Therefore, it was the purpose of this study to determine whether marginal adaptation is, or not, a superficial phenomenon without any influence of adaptation on depth of the cavity. The null hypotheses tested were that 1) SEM analysis would not be able to detect differences in marginal gaps amongst groups and that 2) In cavities with non-continuous margins (or marginal gaps), there would never be a gap propagating inside the cavity.

Materials and methods

The adhesive materials used in this study consisted of a 3-step etch-and-rinse adhesive (OFL: OptiBond FL, Kerr, Orange, CA, USA, batch numbers 3271580 and 3437447) and a microhybrid composite resin (Clearfil AP-X, Kuraray, Okayama, Japan, batch number 01067B). The application mode of the adhesive system determined the three testing groups: in *gr 1*, enamel and dentin were etched with 36 % phosphoric acid (H_3PO_4) prior to the application of the adhesive system, in *gr 2*, only enamel was etched with H_3PO_4 and in *gr 3*, no etching with H_3PO_4 neither on enamel nor on dentin was performed before the application of OFL primer and bond.

Twenty-four caries-free human molars stored in 0.1 % thymol solution after extractions were used for the experiment. After scaling and pumicing, the teeth were mounted on custom-made specimen holders with their roots in the centre using a cold-polymerizing resin (Technovit 4071, Heraeus Kulzer GmbH, Wehrheim, Germany) and then randomly assigned to the three above-mentioned experimental groups. Prior to the mounting procedure, the apices were sealed with two coats of nail varnish. To simulate dentinal fluid flow, a cylindrical hole was drilled into the pulpal chamber approximately in the middle third of the root and a metal tube with a diameter of 1.4 mm was then adhesively luted using a dentinal adhesive (Syntac Classic, IvoclarVivadent AG, Schaan, Liechtenstein). The pulpal tissue was not removed. 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 (PAA Laboratories GmbH, Linz, Austria) and phosphate-buffered saline solution (PBS; Oxoid Ltd, Basingstoke, Hampshire, England) diluted in a 1:3 ratio under a hydrostatic pressure of about 25 mm Hg. Twenty-four hours before starting the cavity preparations, by using a three-way valve, the pulp chambers were evacuated with a vacuum pump and subsequently bubble-free filled with the above solution. As of this moment, the intrapulpal pressure was maintained at 25 mm Hg throughout the testing, i.e. during cavity preparation, restoration placement, finishing and stressing.

One U-shaped standardized class V cavity was prepared on the buccal surface of each test tooth with half of the margins located on enamel and half on dentin. Fine diamond burs (Intensiv SA, Grancia, Switzerland) were used under continuous water-cooling. The dimensions of the V-shaped cavities were 3.0–3.5 mm in diameter, 2.5–3.0 mm in height and 1.5 mm in depth. The margin on enamel was bevelled to a crescent-shape with a maximum width of 1.2 mm. The entire cavity was finished using 15 μm finishing diamond burs (Intensiv SA). Then, the cavity preparations were checked for marginal imperfections such as fractures or chipping under an optical microscope (Wild M5, Wild AG, Heerbrugg, Switzerland) at ×12 magnification and corrected if necessary.

After the different etching protocols, OFL was applied in all groups following manufacturers' instructions. After placement and light-curing of the adhesive system by using a LED source (L.E.D. Demetron II, Serial No: 792026758, Kerr, Orange, CA, USA) with a relative intensity of 800 mW/cm^2 (Curing Radiometer, Demetron Research, Danbury, CT, USA) Clearfil AP-X was inserted into the cavity in two layers, the first layer being placed cervically up to one half of the cavity and the second layer occlusally, filling the other half of the cavity. Both layers were light-cured for 40 s each. Immediately after polymerization, the restorations were finished and polished by using flexible aluminium oxide discs with different grain sizes (SofLex PopOn, 3M ESPE AG, Seefeld, Germany). The final polishing was checked using an optical microscope under ×12 magnification and corrected if necessary. The same operator performed the restorations of all three groups.

After storage in the dark in a 0.9 % saline solution at 37 ° C for one week, the restored teeth were loaded in a computer-controlled chewing machine [23]. Thermal and mechanical loading was applied simultaneously. Thermal cycling was carried out in flushing water with temperatures changing 600× from 5 to 50 °C with a dwelling time of 2 min each. The mechanical stress comprised in total 240,000 load cycles transferred to the centre of the occlusal surface with a frequency of 1.7 Hz and a maximal load of 49 N applied by using a natural lingual cusp taken from an extracted human molar. The rationale for using 240,000 instead of 1.2 million load cycles was to diminish testing time; if 240,000 cycles were enough to induce a decrease of marginal adaptation, then the fatigue test was stopped and samples were removed from the chewing simulator. Simulation of dentinal fluid flow was permanently maintained throughout the loading procedure.

Immediately after loading, the teeth were cleaned with rotating brushes and toothpaste. Then impressions with a polyvinylsiloxane material (President light body, Coltène-Whaledent, Altstätten, Switzerland) were made of each restoration. Subsequently, gold-coated epoxy replicas were prepared for the computer-assisted quantitative margin analysis in a SEM (XL20, Philips, Eindhoven, Netherlands) at ×200 magnification [24]. The marginal quality, expressed in percentages of non-continuous margins (% NCM), was reported for enamel and dentin margins separately. SEM micrographs were procured from representative samples of each group.

Cirrus HD-OCT (Carl Zeiss Meditec AG, Jena, Germany) is mainly used in the ophthalmologic field for in-vivo viewing, axial cross-sectional and 3D imaging and measurement of anterior and posterior ocular structures. Specifications about this OCT are the following: Spectral domain OCT, Optical Source: super luminescent diode (SLD), 840 nm, optical power: less than 725 µW at the cornea, scan speed: 27,000 A-scans per second, A-scan depth: 2.0 mm (in tissue), axial resolution: 5 microns (in tissue), transverse resolution: 15 microns (in tissue), frame rate: more than 20 Hz. It is a computerized instrument that acquires and analyses cross-sectional and three-dimensional tomograms by using spectral domain optical coherence tomography (SD-OCT). The light source is an 840-nm super luminescent light emitting diode (SLD). Light returning from the sample is combined at the detector, which is a spectrometer in SD-OCT. The spectrometer resolves the interference signals throughout the depth of each A-scan immediately by means of a Fourier transform [25]. In order to analyse anterior ocular structures, the software proposes two techniques: Anterior Segment Cube 512×128 and Anterior Segment 5 Line Raster. To scan tooth structures, both scanning modes were tested in a pilot study and due to a superior quality of image; the first scanning mode was selected as tooth scanning method. This scan mode generates a volume of data through 4-mm square grid by acquiring a series of 128 horizontal scan lines each composed of 512 A-scans. It also acquires a pair of high definition scans through the centre of the cube in the vertical and horizontal directions that are composed of 1024 A-scans each. The additional advantage of this scanning mode is that it can create a 3-D image of the data. For data acquisition, each tooth sample was positioned on the right chin rest with a custom-made support, and the restoration was placed parallel to the imaging aperture so that the scanning beam could be oriented at about 90 ° in respect to the restorations' surface. By using the X–Y controls to move the chin rest, the tooth was displaced until the restoration was visible in the iris viewport (Fig. 1). Then, the distance between the restoration and the imaging aperture was adjusted with the mouse scroll until the tooth-restoration interface was seen in the OCT scan display. By clicking on the capture button, the data was acquired and the image saved. Cervico-occlusal images were obtained from each tooth sample, and a 3D reconstruction of the cavity was also possible. Five OCT images from each sample were selected and quantitative data of high scattering areas along the internal enamel-resin interface could be obtained by using a scoring system with the following scale: 0, no visible infiltration; 2, infiltration not reaching the enamel-dentin junction; 3, infiltration exceeding the enamel-dentin junction; and 4, restoration loss.

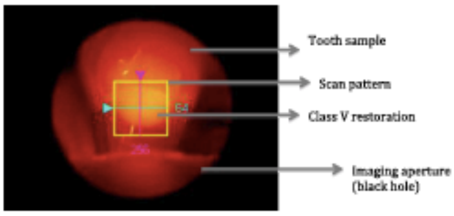


Fig. 1 Sample positioning in front to the imaging aperture of the OCT device. The scan pattern (*yellow box*) is positioned in front of the restoration before image acquisition. *Blue line* and *slice number* indicate current fast B-scan (X slice) seen in top scan viewport; *magenta line* and *slice number* indicate current slow B-scan (Y slice) seen in middle scan viewport

Statistical analysis

Statistical analysis was performed with SPSS 14.0 for Windows. Differences amongst the three groups on enamel and dentin margins were tested with nonparametric Kruskal-Wallis and post hoc test at a level of confidence of 95 %.

Results

The results of SEM margin analysis after thermo mechanical fatigue stress, expressed as the mean percentages of marginal gaps or non-continuous margins (%NCM) for each group, are detailed in Fig. 2. No significant differences on *dentin margins* were detected between the groups. On *enamel* margins, significant differences between groups were observed in percentages of marginal gaps. Significantly higher %NCM were observed at the resin-enamel interface of gr 3 (53.1±19.5, no etching with phosphoric acid on both enamel and dentin substrate) when compared to gr 2 (6.9±8.1 %NCM, enamel etching with phosphoric acid only on enamel) and to gr 1 (3.5±5.1 %NCM, standard application of OptiBond Fl, that is, phosphoric acid applied on both enamel and dentin).

The results (%NCM) of each sample (1 to 8) belonging to groups 1, 2 and 3 are detailed in Fig. 3a–c, respectively. Within the same group, results of marginal gaps on enamel and dentin were not homogeneous. Some samples presented high % of marginal gaps on enamel and low % of marginal gaps on dentin, and vice versa. In respect to restoration loss, one class V restoration (Fig. 3c, sample 3) was lost during the experiment; this restoration presented above 50 % of non continuous margins (NCM) on both enamel and dentin margins (Fig. 3c (sample 3) and Fig. 5).

The results of the OCT analysis are shown in Fig. 4 for enamel margins of the two test groups gr 2 and gr 3. The

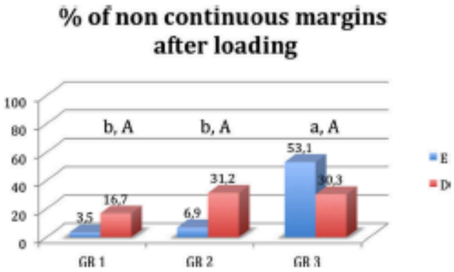


Fig. 2 Percentages of noncontinuous margins after thermomechanical loading in group 1 (H_3PO_4 etch on enamel and dentin before the application of OFL), gr 2 (H_3PO_4 etch only on enamel before the application of OFL and gr 3 (OFL applied on enamel and dentin without previous H_3PO_4 etch). Differences between groups on enamel are described in *lower case letters* (*a*, *b*), and differences between groups on dentin in *upper case letters* (*A*)

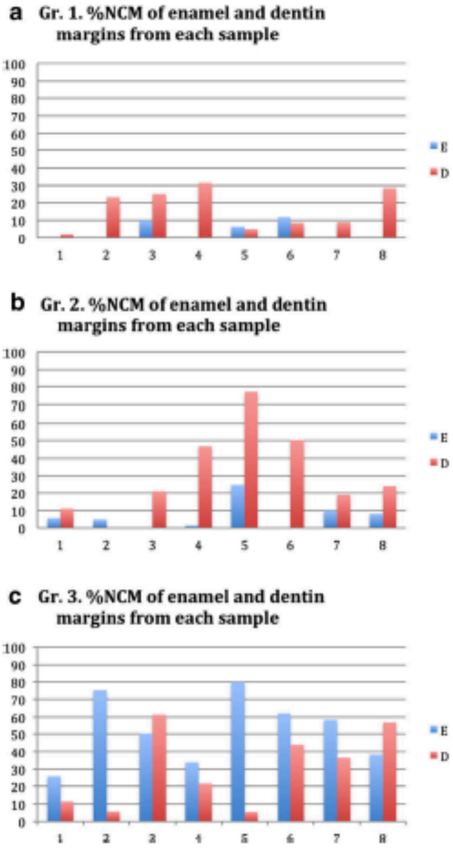
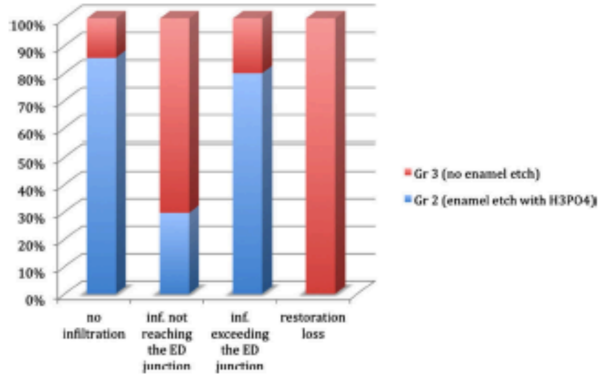


Fig. 3 Percentages of noncontinuous margins after thermomechanical loading of each sample in group 1 (**a**), gr 2 (**b**) and gr 3 (**c**). See the differences between samples from the same group, demonstrating the variability of the tooth substrate. Note sample 3 from gr 3 (**c**), percentages of non continuous margins were above 50 % on enamel and dentin; restoration loss was only observed on this sample

control group (gr 1) was excluded, as it was not significantly different from gr 2. The group with less % of marginal gaps on enamel (gr 2: 6.9±8.1) also presented significantly more percentages of "no infiltration" along the internal resin-enamel interface (Fig. 4, left bar, blue score), indicating that when less marginal gaps were observed on enamel margins, less infiltration was observed beneath the restoration as well.

Gaps that propagated inside the cavity were significantly more frequent in specimens that presented high percentages of marginal gaps. Said differently, gr 3 presented the lowest percentage of "no infiltration" beneath the margins (Fig. 4, left

Fig. 4 Gap propagation beneath the restorations of each group based on the scoring system. See that gr 2 presented the highest percentages of «no infiltration» beneath the margins (*left bar, blue score*), contrarily to gr 3 that presented the lowest percentages of non infiltrated margins (*left bar, red score*). It was in this last group where restoration loss occurred. *inf.* infiltration, *ED* enamel-dentin



bar, red score); at the marginal level, this group also presented the highest % of marginal gaps (53.1 ± 19.5), indicating that when more marginal gaps were observed on enamel margins, more infiltration was observed beneath the restoration as well.

The most negative factor influencing restoration survival was the presence of high percentages of non-continuous margins (Fig. 2) together with incipient infiltrations beneath the restoration, i.e. infiltrations not reaching the enamel-dentin junction, as it could be observed in gr 3 in respect to gr 2 (Fig. 4, 2nd bar from the left, red score). This was the only group in which restoration loss occurred (Fig. 4, right bar, and Fig. 5).

Important differences in micromorphology could be also observed between OCT scans from samples with low and high % of non-continuous margins. Continuous margins and low scattering areas were characteristic from gr 1 (Fig. 6). Figure 7a, b show how marginal and internal gaps were observed with SEM and 2D and 3D OCT scans, respectively.

Discussion

Under function, both chemical and mechanical stresses can result in an alteration of the tooth-restoration interface with time. Proliferation of surface and subsurface flaws may be one major mechanism involved in the mechanical property changes of this interface [26]. Both null hypotheses of the present study could be rejected; SEM analysis could detect differences in the percentage of marginal gaps between groups, and in cavities with non-continuous margins, also gaps propagating inside the cavity could be easily observed with OCT.

Scanning electron microscope margin analysis is a well-known method for the evaluation of adhesive restorations and considered the setup closest to the clinical situation [27]. Nevertheless, SEM diagnosis based on gold-coated replicas is an expensive and time-consuming way of evaluating dental restorations [27]. It also suffers from both sampling and inter observer variability. Interestingly, the medical field is also confronted to this problem; for instance, pathological diagnosis from histological sections has also a certain degree of uncertainty due to sampling variability. The analysis by itself is highly dependent on the pathologist's experience, and this is why the diagnosis process is expert-based, rather than evidence-based [17]. This has been one major reason why non-invasive optical diagnosis techniques are increasingly used in the medical field.

Optical coherence tomography (OCT), as an imaging method, is based on a classical measurement technique known as low-coherence interferometry that enables non-invasive, high-resolution, in vivo, two- or three-dimensional cross-sectional imaging of microstructural morphology in transparent and non-transparent biological tissue in situ [28]. The device used in the present study is basically conceived for ophthalmologic use. It acquires 27,000 scans per second with a resolution of around 5 microns for in-vivo viewing, axial cross-sectional, and 3-dimensional imaging and measurement of anterior and posterior ocular structures. Taking into consideration that the presence of a marginal or internal gap is a 3D phenomenon, the OCT used in this study enabled the 3D visualization analysis of the entire margin. This is an additional advantage because the entire tooth sample can be observed in a short amount of time without any additional preparation.

The same composite resin and adhesive system was used in the three groups. The same operator performed all restorations as well; therefore, the only variable was the application mode of OFL. This would enable us to see differences in gap formation that depended on how the adhesive system interacted with

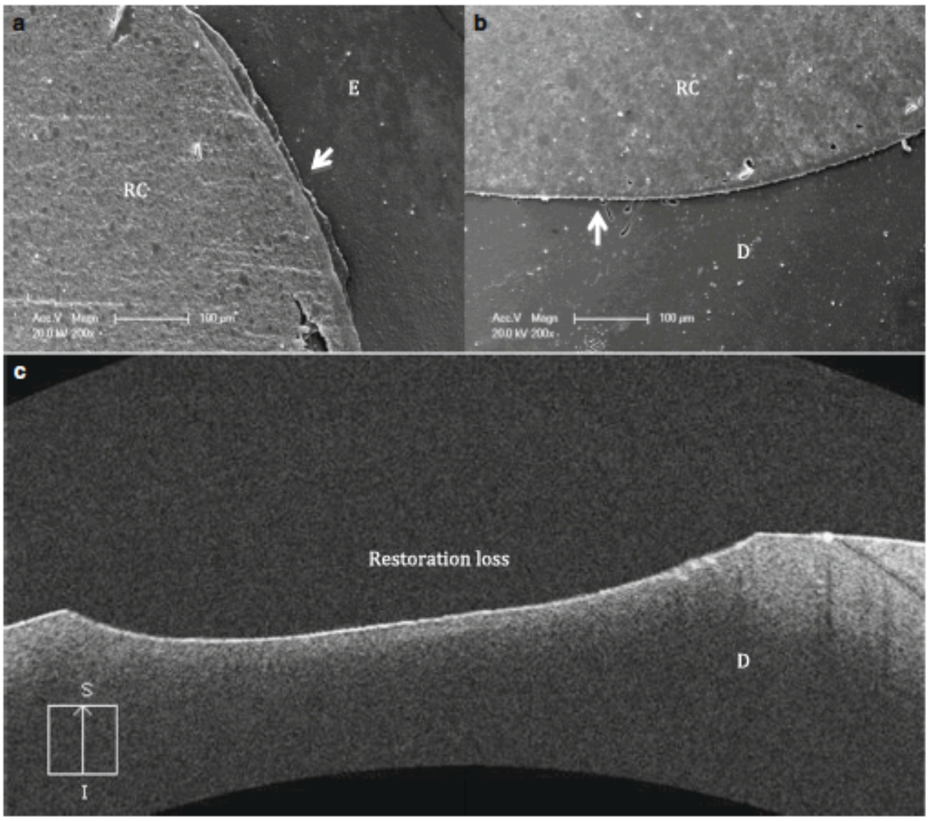


Fig. 5 Sample from gr 3. SEM micrographs of enamel (**a**) and dentin (**b**) margins after thermomechanical loading. See the presence of gaps along the margin length (*arrows*). OCT scan (**c**) of the same tooth sample confirming restoration loss before OCT analysis. *RC* resin composite, *E* enamel, *D* dentin

enamel and dentin. The finding that marginal gaps on enamel were significantly higher when phosphoric acid etch was avoided (gr 3) is confirmatory of those of other research groups [29] and might be due to a poor etch pattern on enamel. This was the group in which the maximum of marginal openings was observed. OCT analysis of the same margin showed high scattering areas that propagated inside the cavity and were interpreted as internal openings. The depth of the gap was variable and sample-dependent; however, the 3D visualization of the entire restoration permitted us to corroborate that with higher % of NCM; the depth of the gap also increased. Water uptake favoured by open margins may accelerate matrix degradation by abrading more the surface, increasing the surface area and allowing greater ingress of both water and enzymes [26].

However, marginal gaps on dentin were not increased as expected when phosphoric acid was avoided (gr 2 and 3). This might be due to the presence of an acidic monomer, glycerophosphoric acid methacrylate (GPDM), within the composition of the primer of OptiBond FL that favoured dentinal adhesion even without etching with phosphoric acid. This study could show, once again, that the performance of adhesive systems depend on their composition and not on their category (etch-and-rinse or

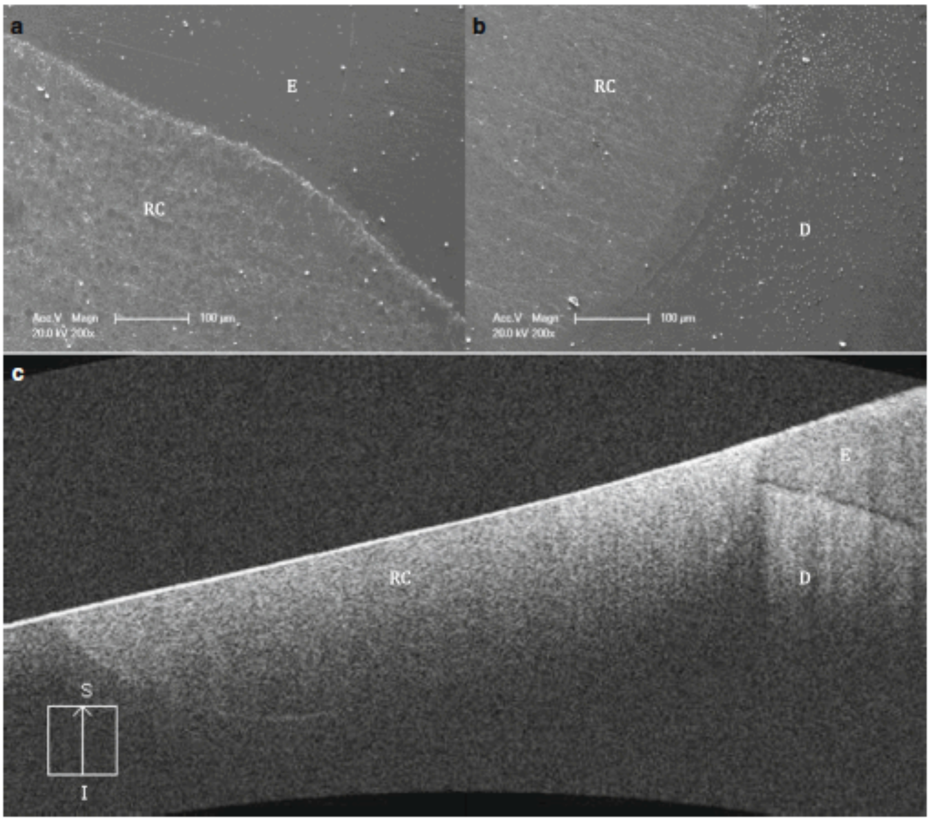
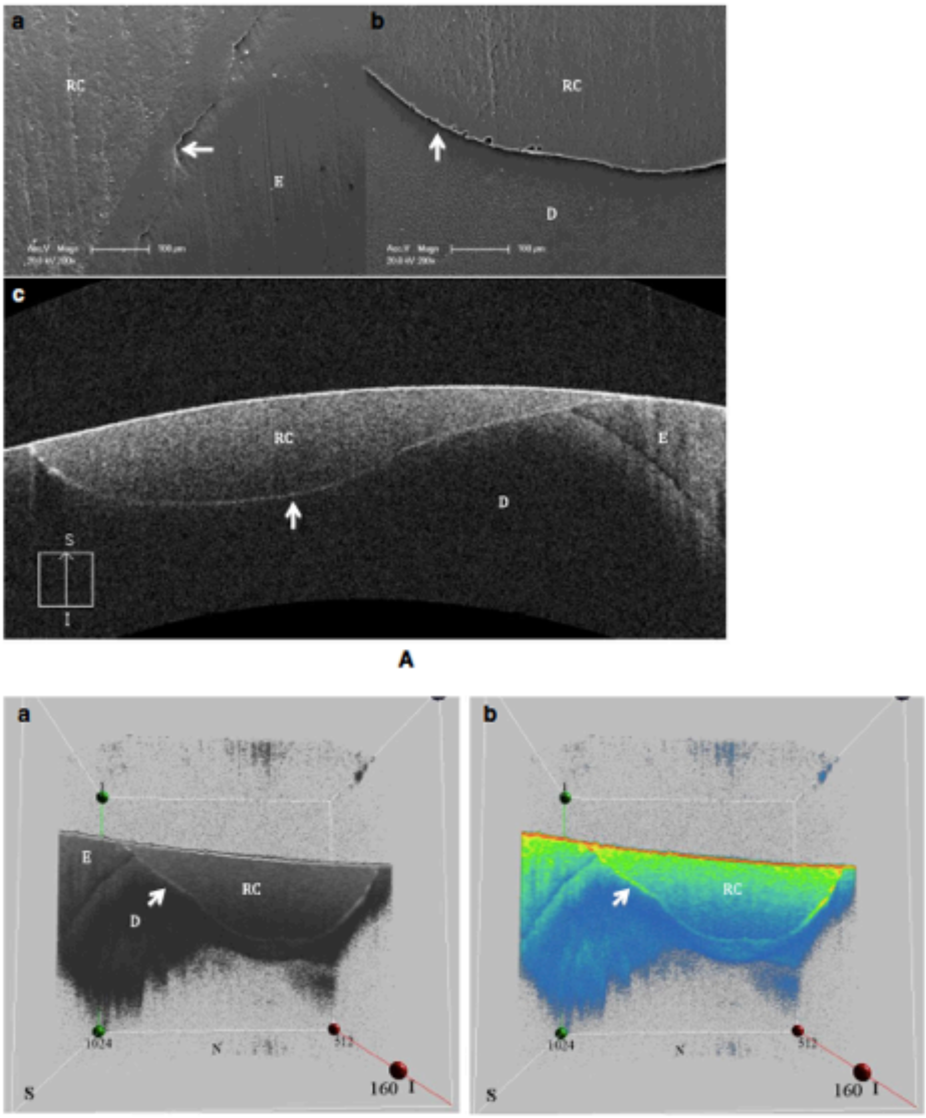


Fig. 6 Sample from gr 1. SEM micrographs of enamel (a) and dentin (b) margins. Continuous or gap-free margins can be observed along the margin length. OCT scan of the same tooth sample (c), see that high scattering areas are almost non existent at the tooth-restoration interface, which indicates that no gaps are detected inside the restoration as well. *RC* resin composite, *E* enamel, *D* dentin, *EDJ* enamel dentin junction

self-etch) or number of steps. The present findings showed that the so-called gold-standard 3-step etch and rinse adhesive, OptiBond FL, behaves also as a self-etching adhesive system [30].

To determine if high scattering areas that propagated from the composites surface inside the cavity were due to light distortion or to the real presence of gaps, samples with and without marginal gaps belonging to the same group were observed under OCT for comparison. Brighter and wider white lines could be observed along the resin-tooth interface of samples with high % of NCM (Fig. 7); these lines could be hardly observed or were even absent from the samples with gap-free margins (Fig. 6). Therefore, our OCT observations are in line with those of a recent study [22] and white areas at the adhesive interface did not represent reflection artefacts but the real presence of gaps inside the restoration.

Finally, the 3D scans showed that gap and gap-free adhesive interfaces coexisted within the same cavity, confirming the early findings of Shono and co-workers [31] in respect to how inhomogeneous enamel and dentin substrate and therefore, resin-dentin bonds, can be. This means that within the same cavity, areas of good bonding and adhesive gaps can coexist without compromising restorations' retention. The statement of Van Landuyt et al [32] that clinical failure of restorations occur more often due to inadequate sealing, with subsequent discoloration of the cavity margins, than due to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◀ **Fig. 7** a Sample from group 2. SEM micrographs of enamel (*a*) and dentin (*b*) margins. See that open margins (*arrow*) can be observed in several sites along the margin length. Lower: OCT scan of the same tooth sample (*c*), see that high scattering areas are present along the entire internal tooth-restoration interface, evidencing that the marginal gap propagated inside the whole cavity as well. b OCT 3D scan in grey (*a*) and color (*b*) scale of one sample from gr 2. See the high scattering areas along the interface (*arrow*) indicating the presence of a gap beneath the composite restoration. *RC* resin composite, *E* enamel, *D* dentin

restoration loss, could be confirmed in the present study as interface defects (marginal and internal gaps) were more frequently observed than lost restorations.

Marginal gaps could be interpreted as an early sign of restoration failure. Meanwhile, only one restoration was lost that presented above 50 % of marginal gaps on enamel and dentin (Fig. 5). Possibly, hydrolytic degradation is accelerated under the presence of more than 50 % of marginal openings on both enamel and dentin margins, increasing the probability of failure due to restoration loss. In addition, the OCT data of gr 3 confirmed that marginal openings also propagated beneath the restoration, evidencing that restoration loss strongly depends on the time needed for an infiltrated margin to propagate along the internal interface.

Nevertheless, and despite this evidence, the scientific literature has still not found an answer to the question of which is the minimum percentage of marginal adaptation necessary to ensure restorations' retention. The point is if this question provides with relevant information. According to the results of this study, the more the presence of marginal gaps, the more the presence of gaps beneath the restoration. Moreover, more than 50 % of open margins on enamel and dentin might compromise the restorations' retention on the long-term. But the best scenario a restoration can find is 100 % of continuous margins because then a perfect seal between tooth and restoration can be guaranteed. Therefore, attaining 100 % of continuous margins or 0 % of marginal gaps should be a better predictor of restorations' performance at an early stage of function before catastrophic failures like restoration loss occur. In the context of this study, the best results were attained by the group with a % of non infiltrated margins above 80 % (Fig. 4 left bar, blue score). Even so, only one brand of composite and adhesive system was tested in this study. Further evaluations are necessary before extending the present failure mode to all materials.

Conclusion

Quantitative OCT evaluation of adhesive interfaces provided with important complementary information to SEM *quantitative* analysis. Marginal gaps propagated from the margins beneath the restoration and degradation was sample-dependent. For class V restorations filled with OptiBond FL and Clearfil APX, the presence of marginal gaps could be considered as an early sign of adhesive failure that on the long term, led to restoration loss if more than 50 % of marginal openings were detected on enamel and dentin margins of class V restorations.

Conflict of interest The authors declare that they have no conflict on interest.

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Bulk Filling of Class II Cavities with a Dual-Cure Composite: Effect of Curing Mode and Enamel Etching on Marginal Adaptation

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Bulk filling of Class II cavities with a dual-cure composite: Effect of curing mode and enamel etching on marginal adaptation

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Abstract

Objectives: This study attempted to find a simple adhesive restorative technique for class I and II cavities on posterior teeth.
Study Design: The tested materials were a self-etching adhesive (Parabond, Coltène/Whaledent) and a dual-cure composite (Paracore, Coltène/Whaledent) used in bulk to restore the cavities. Class II MO cavities were performed and assigned to 4 groups depending on the orthophosphoric acid (H_3PO_4) conditioning of enamel and polymerization method used (chemical or dual). Specimens were subjected to quantitative marginal analysis before and after thermo-mechanical loading.
Results: Higher percentages of marginal adaptation at the total margin length, both before and after thermo-mechanical loading, were found in groups in which enamel was etched with phosphoric acid, without significant differences between the chemically and dual-cured modes. The restorations performance was similar on enamel and dentin, obtaining low results of adaptation on occlusal enamel in the groups without enamel etching, the lowest scores were on cervical dentin in the group with no ortophosphoric acid and self-cured.
Conclusions: A dual-cure composite applied in bulk on acid etched enamel obtained acceptable marginal adaptation results, and may be an alternative technique for the restoration of class II cavities.

Key words: *Dual-cure composite, bulk technique, class II restoration, selective enamel etching, marginal adaptation.*

Introduction

Amalgam has been the material of choice worldwide for class I and class II restorations for more than a century due to its high strength, good wear resistance, low technique sensitivity and low cost (1). However, the lack of esthetics, corrosion and difficult bonding to tooth structure requiring the removal of sound structure to gain on macromechanical retention resulted in the need to find an amalgam substitute for the esthetic restoration of decayed teeth.

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Advances in adhesive technology made during the last 40 years have simplified dental procedures and given a more esthetic result to patients and a conservative alternative treatment to clinicians (2). While the use of amalgam for the restoration of posterior cavities is declining, composite resins are being more often used with almost no differences in terms of clinical longevity (3).

Previous studies of composite class II resin restorations have shown that their clinical longevity is adversely affected by several factors such as achieving a good proximal contact (1), lack of cervical enamel (4), difficulties for beveling proximal enamel margins, a limited wall flexibility to allow for a certain compensation of polymerization contraction (5), and poor composite adaptation at the gingival portion if margins are subgingivally located (6).

Polymerization contraction of dimethacrylate-based composites ranges from 2-6% of volumetric shrinkage (7). Various clinical methods have been proposed to reduce shrinkage stress. These methods include the regulation of curing light intensity (8), a flowable resin liner application (9), the elaboration of an indirect resin restoration (10), and the use of a sophisticated incremental layering technique (1). Another alternative has been the use of an open-sandwich technique restoration (11,12). In this procedure, a resin-modified glass-ionomer cement [RMGIC] or a glass ionomer is placed as a base covering the entire proximal box, to complete the restoration to full anatomic form and function, and then a top layer of a light-cured composite resin is placed. However, despite relatively good short-term clinical results, a noticeable dissolution of RMGIC has been reported after six years (12).

Dual-cured resin composites have been mainly used as a core material for the reconstruction of non-vital teeth (13), and as dentin substitute in the open sandwich filling technique (11,14). Some advantages of using dual-cured composites as filling material would be the possibility of a bulk insertion, clinical time saving, the achievement of polymerization in deep areas due to chemical curing and the development of lower contraction stresses (15).

A previous study reported that the tooth-restoration complex is more prone to fail at the interface rather than in the composite or tooth material (16). Therefore, assessing the integrity of the margins before and after a thermo-mechanical fatigue test would be discriminative enough to show differences among the different restorative techniques.

In an attempt to find a restorative material that could potentially be used as an amalgam substitute, i.e. an adhesive material that can be applied in bulk with a simple restorative technique, we evaluated the marginal integrity of cavities entirely restored with a dual-cured resin composite. The null hypotheses tested were that [i] The differences in the etching procedure would not affect the marginal adaptation before and after thermo-mechanical loading and [ii] Marginal adaptation would not be affected by the polymerization mode [chemical or dual-cure].

Material and Methods

The materials used for the study consisted of a chemically-cure self-etch adhesive system [Parabond, Coltène/Whaledent, Altstätten, Switzerland] composed by a non-rinse conditioner and 2 liquids [A and B] that need to be mixed before application, and a dual-cure radiopaque core material [Paracore, Coltène/Whaledent] (Table 1).

Thirty-two sound extracted human molars with complete apexification were selected for the study. After scaling and pumicing, the teeth were mounted on custom-made specimen holders with their roots in the centre using a cold-polymerizing resin [Technovit 4071, Heraeus Kulzer GmbH, Wehrheim, Germany]. Prior to the mounting procedure the apices were sealed with two coats of nail varnish. To simulate dentinal fluid flow, a cylindrical hole was drilled into the pulpal chamber approximately in the middle third of the root and a metal tube with a diameter of 1.4 mm was then adhesively luted using a dentinal adhesive [Syntac Classic, IvoclarVivadent AG, Schaan, Liechtenstein]. The pulpal tissue was not removed. 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 [PAA Laboratories GmbH, Linz, Austria] and phosphate-buffered saline solution [PBS; Oxoid Ltd, Basingstoke, Hampshire, England] diluted in a 1:3 ratio under a hydrostatic pressure of about 25 mm Hg. Twenty-four hours before starting the cavity preparations, by using a three-way valve, the pulp chambers were evacuated with a vacuum pump and subsequently bubble-free filled with the above solution. As of this moment, the intrapulpal pressure was maintained at 25 mm Hg throughout the testing, i.e. during cavity preparation, restoration placement, finishing and stressing (17,18).

Standardized box-shaped mesio-occlusal class II cavities with cervical margins located on dentin were prepared on each tooth using diamond burs with a grain size of 80 microns [Diatech Dental, Coltène/Whaledent] and finished with diamond burs with a grain size of 40 microns [Diatech Dental] under 12x magnification. The dimensions of the cavities were 4 mm height, 4 mm of bucco-lingual width, 2.5 mm mesio-distal depth and approximately 1.5 mm below the cemento-enamel junction.

In groups 1 and 2 the adhesive system was applied following manufacturer recommendations [that is, without previous acid etching of enamel] (Table 1). In groups 3 and 4 enamel was etched with 37.5% H_3PO_4 [Kerr, Scafati, Italy] for 30 s, rinsed and air-dried. The non-rinse conditioner was then applied on dentin [enamel was avoided because it had been previously etched with phosphoric acid]. After the application of the mixed A

Table 1. Materials, composition and manufacturer´s instructions.

Materials	Composition (Batch number)	Manufacturer´s instructions
Adhesive system: ParaBond (Coltène/Whaleden)	Chemical cured self-conditioning (A+B) adhesive system - Non- Rinse Conditioner Water Acrylamidosulfonic acid Methacrylate (Batch no. 0224294) - Adhesive A: Methacrylates Maleic acid Benzoyl peroxide (Batch no. 0224291) - Adhesive B: Ethanol Water Initiators (Batch no. 0224454)	Conditioner: - Apply Non-Rinse Conditioner on to the entire preparation/cavity using a brush. Massage for 30 s. - Dry excess Non-Rinse Conditioner using a gentle stream of air for 2 s. Adhesive A+B: - Mix one drop of Adhesive A together with one drop of Adhesive B into the mixing well. - Apply mixed adhesive components onto the contact surfaces (preparation/cavity) using a brush. Massage for 30 s. - Dry the adhesive bond layer using a gentle stream of air for 2 s.
Composite Resin: Paracore (Coltène/Whaleden)	Dual-cure radiopaque composite Methacrylates Fluoride Barium glass Amorphous silica (Batch no. 0226000)	2-component dual-cure composite 5 ml syringe supplied in an automix delivery system Chemical curing time: 4 min approximately Light curing time: 20s per side (occlusal, bucal and lingual)

and B adhesive components, cavities were filled with the build-up composite in one single layer. In groups 1 and 3 the restorations were left undisturbed for at least 4 min to enable the materials self-cure. In groups 2 and 4 they were immediately light cured with a curing device [L.E.D. Demetron II, Serial No: 792026758, Kerr, Orange, CA, USA] with a relative intensity of 800 mW/cm² [Curing Radiometer, Demetron Research, Danbury, CT, USA] 20 sec per side [occlusal, buccal and lingual]. The same operator performed the restoration of all groups.

One day after polymerization, finishing and polishing of the restorations was carried out using flexible discs [SofLex PopOn, 3M ESPE AG, Seefeld, Germany] for proximal and fine-grain diamond burs for the occlusal surface. Then, impressions with a polyvinylsiloxane material [President light body, Coltène/Whaledent] were made of each restoration and poured with epoxy resin [Epofix Resin, Struers, Willich, Germany] and 24 h after resin replicas were gold sputtered. They were subjected to a computer assisted quantitative margin analysis in a scanning electron microscope [XL20, Philips, Eindhoven, Netherlands] by using a custom made module programmed with an image processing software [Scion Image, Scion Corp, Frederik, USA]. For the quantitative evaluation, a blinded and trained lab technician examined the specimens (Fig. 1). The marginal quality was expressed in percentages of continuous margins [% CM] and reported for occlusal enamel margins, proximal enamel, cervical dentin and for the total marginal length [average value of enamel and dentin marginal adaptation], at each interval before and

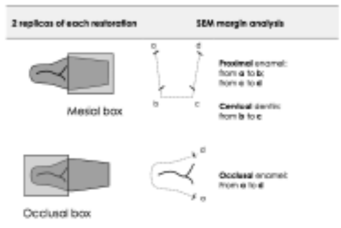

Fig. 1. Schematical representation of the quantitative evaluation for the SEM marginal analysis, assessing the % of continuous margins at the occlusal enamel proximal enamel and cervical dentin margins. The average value of enamel and dentin marginal adaptation was calculated and reported as the total marginal length (TML).

after loading. After storage for 7 days at 37°C in the dark, the teeth were loaded with simultaneous repeated thermal [600x from 5° to 55°C with a dwell time of 2 min] and mechanical stresses [240,000 chewing cycles at 1.7 Hz] by an antagonistic natural molar cusp with a maximum load of 49 Newtons under the constant simulation of dentinal fluid flow (19). After thermo-mechanical loading, the teeth were cleaned with toothpaste, rinsed with tap water and impressions were taken again in order to perform the marginal replicas for SEM analysis after loading (19).

Statistical Analysis

Analysis of data was performed by using an analysis of variance test (ANOVA) of variance [ANOVA] for each variable separately for two time points [before and after loading] in SPSS 19 for Windows. Significant differences were observed between groups with Tukey HSD post-hoc pairwise comparasion. In all analyses, the level of significance was set at 0.05.

Results

The scores of marginal adaptation expressed as percentages of continuous margins [% CM] attained by the different groups at the total margin length, occlusal, proximal and cervical margins are shown in table 2 [before load] and table 3 [after load].

- Quantitative margin analysis

Before loading (Table 2), higher % of CM were observed at the total margin length [TML] in the groups in which enamel margins were etched with phosphoric acid. At the different cavity segments [occlusal, proximal and cervical], lower % of CM were obtained at the occlusal margins in groups 1 and 2 where enamel was not etched with phosphoric acid, being statistically significant between group 2 with group 3 [p=0.001] and group 4 [p=0.004]. However, no significant differences between groups were seen at the proximal margins or cervical portion.

After loading, the highest scores of marginal adaptation at TML were attained, once again, by the groups that used H3PO4 (Table 3). Statistically significant differences were obtained between group 1 and group 3 [p=0.002] and with group 4 [p=0.013]. At the cavity segments, we obtained again lower % of CM at the occlusal side in groups in which phosphoric acid on enamel was not used. No differences between groups were observed at the proximal enamel margins. However, at the cervical portion, the lowest % of CM were obtained in group 1 being statistically different from group 2 [p=0.008] and group 3 [p=0.024].

Representative SEM images (Fig. 2) with margins on enamel and dentin after thermo-mechanical loading for the 4 groups [a, b, c, d]. In figure 2 section a, an open margin at the occlusal segment could be observed; this finding could be related to the fact that enamel was not etched with orthophosphoric acid. In group 2, a non-continuous dentin margin was detected at the cervical portion as shown in figure 2 section b. Continuous and intact margins could be seen in figure 2 section c for the group 3 at the CEJ, representing the high percentages of adhesion. Dentin continuous margins are shown in figure 2 section d, showing no differences between the self and dual-cured approach.

Table 2. Mean ± Standard Deviation scores of each group before thermo-mechanical loading on occlusal margins, on proximal margins, on cervical margins and at the total margin length (average of occlusal, proximal and cervical marginal adaptation). Abbreviations. % CM: percentages of continuous margins. Levels connected by the same letter are statistically similar and apply to each column.

	% CM occlusal enamel before loading	% CM proximal enamel before loading	% CM cervical dentin before loading	% CM total margin length before loading
Group 1 (No H_3PO_4 + self-cure)	60.07±18.05 B, C	78.89±12.60 A	67.62±23.42 A	68.86±15.44 B
Group 2 (No H_3PO_4 + dual-cure)	53.88±12.72 B, C	90.44±14.48 A	93.22±16.22 A	79.18±9.43 A, B
Group 3 (H_3PO_4 + self-cure)	88.38±13.71 A	86.28±14.04 A	87.04±20.26 A	87.23±10.19 A
Group 4 (H_3PO_4. + dual-cure)	84.02±15.19 A, B	85.93±11.24 A	90.12±20.45 A	86.69±10.50 A, B

Table 3. Mean ± Standard Deviation scores of each group after thermo-mechanical loading on occlusal margins, on proximal margins, on cervical margins and at the total margin length (average of occlusal, proximal and cervical marginal adaptation). Abbreviations. % CM: percentages of continuous margins. Levels connected by the same letter are statistically similar and apply to each column.

	% CM occlusal enamel after loading	% CM proximal enamel after loading	% CM cervical dentin after loading	% CM total margin length after loading
Group 1 (No H_3PO_4 + self-cure)	51.02±8.50 B, C	68.70±11.43 A	39.36±16.10 B	53.03±10.20 B
Group 2 (No H_3PO_4 + dual cure)	41.97±15.74 C	71.74±28.50 A	89.29±16.72 A	67.66±11.66 A, B
Group 3 (H_3PO_4 + self-cure)	80.86±15.20 A	72.99±20.52 A	81.71±26.41 A	78.52±12.30 A
Group 4 (H_3PO_4. + dual-cure)	69.98±14.95 A, B	76.85±17.82 A	75.10±30.52 A, B	73.98±7.02 A

J Clin Exp Dent. 2014;6(5):e502-8.   Bulk filling of Class II cavities with a dual-cure composite

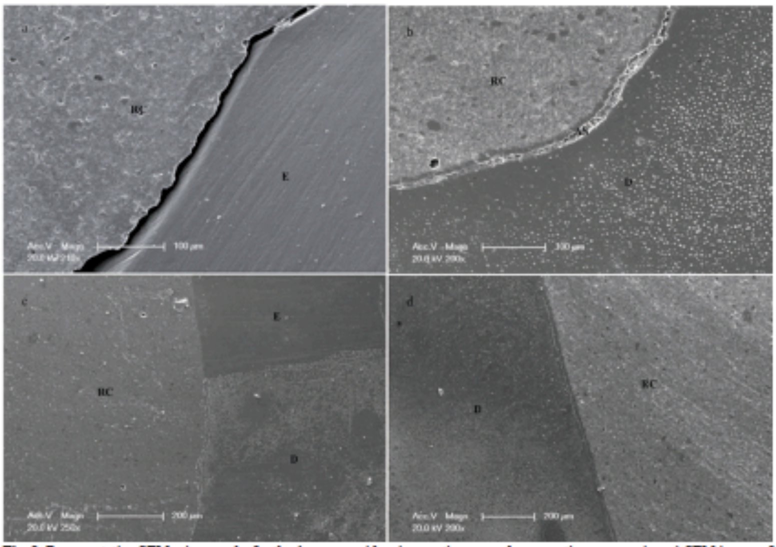

Fig. 2. Representative SEM micrographs for the 4 groups evidencing continuous and non-continuous margins; **a)** SEM image of group 1 (No H_3PO_4 + self-cure) showing a clear open margin between enamel (E) and composite material (RC), a no orthophosphoric acid etching enamel surface may be related with the lower % of marginal adaptation at the occlusal portion in this group; **b)** SEM image of group 2 (No H_3PO_4 + dual-cure) at the cervical bottom part of the cavity, despite the good results obtained in this group at this segment, a non-continuous margin can be observed between dentin (D), adhesive system (AS) and composite (RC); **c)** SEM image of group 3 (H_3PO_4 + self-cure) at the CEJ level with an intact continuous margin, no interruption of the adhesive interface between resin composite (RC) with enamel (E) and dentin (D) could be observed, representing the high percentage of continuous margins; **d)** SEM Image of group 4 (H_3PO_4 + dual-cure) evidencing a close margin between dentin (D) and resin composite (RC), showing no differences on marginal adaptation in comparison with the self-cured approach.

Discussion

The rationale for including the evaluation of marginal adaptation before and after thermo-mechanical loading relies on the fact that both methodologies constitute and adequate model to assess the performance of adhesive interfaces (19-21). In respect to the materials, a chemically-cured two-step self-etching adhesive system was used with a dual-cured build-up composite. To simplify the adhesive procedure we could have selected a 1-bottle or simplified self-etching adhesive system. However, the literature reported incompatibility problems due to the chemical interaction between simplified-step adhesives and chemical or dual-cured composites (22,23). This incompatibility is attributed to an adverse chemical interaction between the acidic monomer and the tertiary amines present within the composite. These features were absent when two-step self-etch adhesive are used (24), justifying why in the present study simplified adhesive systems were avoided.

It is known from previous studies that when etch and rinse adhesives are used on enamel, a reliable and favorable bonding interface is produced (25). However, when using dual-cured composites in conjunction with dual-cured dental adhesives, the self-etching approach has been proved to perform better on dentin (26). Therefore, a selective enamel etching would ensure a more adequate bonding effectiveness even when a self-etching system is selected (27). The results of the present study confirmed the precedent statement as we obtained the highest % of CM at the total margin length, both before and after loading, when enamel margins where etched with phosphoric acid, independently of the polymerization method used, leading to reject the first null hypothesis.

Marginal adaptation at the occlusal enamel margins were lower for the groups 1 and 2 where the self-etching primer was applied on enamel without previous conditioning with phosphoric acid. In addition, unsupported enamel prisms [margins were not beveled] may have resulted in enamel fractures at the marginal level especially after loading (10).

Gap formation or microleakage at the tooth-composite interface is related with polymerization shrinkage and shrinkage stresses. This issue may induce postoperative sensitivity and secondary caries, leading to restoration failure (28). Minimizing those determinant factors would improve marginal cavity adaptation (29). Light intensity was the highest at the restorations' surface de-

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creasing the pre-gel phase and leading to contraction forces and materials' shrinkage (8). This could explain the low results on occlusal enamel despite better scores of marginal adaptation on the proximal area.

Shrinkage strain rates of both self and light-curing modes would become almost identical after about 60 min for dual-cured core materials (8). In the present study, similar shrinkage stresses could have been developed on the self and dual-cured material at the late stages of polymerization, explaining why the percentages of continuous margins were similar in both groups, having to accepted the second null hypothesis.

Despite the similar marginal adaptation scores, when dual-cure composites are used, higher dentin bond strength are reported when light-cured as compared to self-curing (30). This could explain the lower results of marginal adaptation obtained at the cervical dentin in group 1, the self cured material would attain a lower degree of conversion and therefore, lower mechanical properties that would be evidenced at the marginal level in respect to the light cured ones.

In addition, final light polymerization would enhance significant mechanical properties, making the selection of a dual-cured composite an improvement over a self-cured or a light-cured at the gingival margin (11).

To conclude, materials insertion in one single layer, with the additional benefit of chemical cure in deep areas where light is attenuated has several clinical advantages in terms of handling, curing efficiency and time saving. Possibly, the restorative technique used in the present study could be a cost-effective alternative to traditional sophisticated adhesive restorative techniques, and a potential substitute to amalgam (31). Nevertheless, our methodology did not evaluate the wear resistance of such materials, which might be of clinical importance in intraoral conditions. In this perspective, future research should be also undertaken to assess if other dual-cured materials than the ones used in the present study experience a similar behavior in terms of marginal adaptation.

Within the limitations of the present study, the use of a dual-cure composite for the restoration of class II cavities, applied in bulk on phosphoric acid etched enamel, has provided the most reliable marginal adaptation.

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Conflict of Interest
The authors declare that they have no conflict of interest.

PUBLISHED PAPER 4

Full-mouth composite rehabilitation of a mixed erosion and attrition patient: a case report with v-shaped veneers and ultra-thin CAD/CAM composite overlays

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Jose Bahillo

Full-mouth composite rehabilitation of a mixed erosion and attrition patient: A case report with v-shaped veneers and ultra-thin CAD/CAM composite overlays

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Loss of tooth substance has become a common pathology in modern society. It is of multifactorial origin, may be induced by a chemical process or by excessive attrition, and frequently has a combined etiology. Particular care should be taken when diagnosing the cause of dental tissue loss, in order to minimize its impact. Several publications have proposed the use of minimally invasive procedures to treat such patients in preference to traditional full-crown rehabilitation. The use of composite resins, in combination with improvements in dental adhesion, allows a more conservative approach. In this paper, we describe the step-by-step procedure of full-mouth composite rehabilitation with v-shaped veneers and ultra-thin computer-aided design/computer-assisted manufacture (CAD/CAM)–generated composite overlays in a young patient with a combination of erosion and attrition disorder. *(doi: 10.3290/j.qi.a32439)*

Key words: attrition, CAD/CAM composite overlays, erosion, minimally invasive rehabilitation, v-shaped veneers

Recently, many publications have focused on the treatment of dental erosion and attrition using minimally invasive techniques that conserve as much sound tooth structure as possible.[1-9] While these publications have a common goal, each has adopted a different approach to clinical considerations and the development of new materials and technologies.

Dental erosion and attrition have a relatively rapid impact on hard tooth structure.[10] Dental erosion is defined as tooth substance loss resulting from a chemical process, and is mainly caused by the consumption of fruit juices or carbonated and sports drinks, or by digestive disorders (recurrent vomiting). Excessive attrition is often caused by bruxism, and many patients present a combined etiology of erosion and attrition.[11]

Most patients are aware of the problem but not its impact. Therefore, diagnosing the problem as early as possible, introducing preventive measures, and raising awareness of its importance among patients may help them to avoid the necessity of full-mouth rehabilitation. Ignoring the problem may lead to the loss of several teeth, and the restoration of the health, biomechanic function, and esthetic appearance, which may

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require the combined efforts of several different specialties.[5,12,13]

The development of new dental materials, in combination with considerable advances in dental adhesion in recent years,[14] have enabled clinicians to adopt a more conservative approach involving the removal of minimal amounts of tooth structure and eschewing traditional retentive preparations that require important biologic sacrifices.

In this paper, we present the case of a young patient with a combination of erosion and attrition disorder treated with full-mouth adhesive composite rehabilitation. A minimally invasive procedure was performed using v-shaped veneers and ultra-thin computer-aided design/computer-assisted manufacture (CAD/CAM)–generated composite overlays.

CASE PRESENTATION

A 34-year-old man presented to the School of Dentistry at the Universitat Internacional de Catalunya, Barcelona, Spain, suffering acute pain in his left maxillary first molar. Clinical and radiographic examinations revealed:

- irreversible pulpitis of the left maxillary first molar
- several caries lesions
- moderate and generalized dental erosion and attrition disorder, causing anterior and posterior tissue loss.

His medical history revealed that he was a keen sportsman and a consumer of carbonated drinks. On the second visit, his partner disclosed his habit of grinding his teeth at night (sleep bruxism). Although the patient was unconcerned about his esthetic and functional dental problems, a complete early diagnosis of his parafunctional habit was performed to minimize its impact. The anterior and canine guidance were absent, but the patient did not complain about tooth sensitivity or muscular or temporomandibular joint pain.

A treatment plan was designed around the reconstruction of the teeth affected by the combined pathology using composite resins. The treatment sequence was as follows:

- diagnosis (medical history, clinical and radiographic examinations, photographs, and study casts)
- production of a maxillary buccal wax-up, to define an adequate incisal edge and smile line position
- acquisition of facebow and centric relation records for the full-mouth wax-up
- provisionalization
- replacement of the provisionals with definitive direct or indirect composite restorations.

During the initial visits, the patient's chief complaint was addressed with endodontic treatment.

Diagnosis and wax-up

After treating the acute pain, photographs were taken, a radiographic analysis was performed, and full-arch impressions were obtained to construct a treatment plan (Figs 1, 2, and 3). Subsequently, laboratory work was performed to set the central incisors in the correct position,[15] taking into consideration the patient's sex and age. In the resting position, no dental exposure was visible. Hence, a maxillary buccal wax-up from first molar to first molar was prepared to determine the length of the anterior maxillary teeth and the related esthetic position of the occlusal plane using precise silicone keys.

At the next visit, a mock-up was fabricated using a self-curing resin (Protemp, 3M ESPE). A comprehensive clinical evaluation of the mock-up with the newly established resting incisal position was performed, with an appropriate occlusal scheme permitting restoration of a pleasing smile.

Once the mock-up was validated, facebow records were taken to mount the cast in centric relation on a semi-adjustable articulator (Artex, Amann Girrbach). In this position, the articulator pin was elevated by approximately 3 mm. This increase created about 1 mm of posterior space in each arch, which was sufficient to reestablish the full occlusal anatomy that had been lost with minimal tooth preparation (Fig 4). Duplication of the full wax-up was performed, and transparent silicone keys (Elite Transparent, Zhermack) were made.

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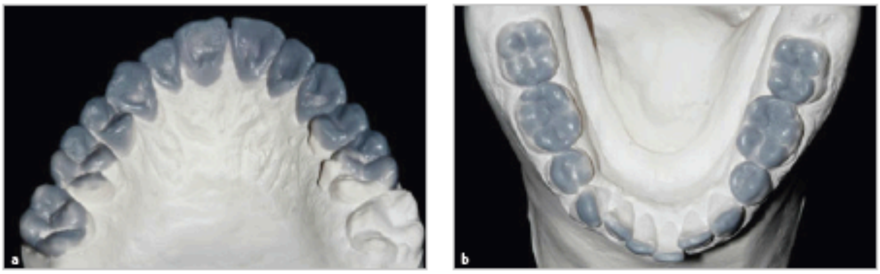
Fig 1 Preoperative view of a 34-year-old man who presented with moderate and generalized dental mixed erosion and attrition disorder.

Fig 2 Preoperative view of the maxillary arch with several caries lesions on the anterior teeth, wear facets, and a provisional restoration on the endodontically treated left first molar.

Fig 3 Preoperative occlusal view of the mandibular arch; note the mixed erosion and attrition, especially on the posterior teeth.



Figs 4a and 4b Full-mouth wax-up to reestablish the lost sound tooth structure, which served as a reference for the new vertical dimension of occlusion.

Provisionalization

The next clinical session involved a full oral provisionalization, lasting approximately 1 month, to confirm the new vertical dimension of occlusion (VDO; Fig 5). It was important that the patient felt comfortable and that no signs or symptoms of temporomandibular dysfunction developed.[3]

The materials used for the provisionalization were: acid for etching the enamel (37.5% phosphoric acid, Kerr Italia), an adhesive system (ExciTE F, Ivoclar Vivadent), and a preheated microhybrid composite (Enamel Plus HRi, Micerium) for the full-mouth replacement of missing tissue that allowed for higher-resistance material to be used in posterior segments.[8] We recommend use of a composite of a shade sufficiently contrasting to facilitate its differentiation from the tooth structure, thus allowing the eventual removal of the provisional material alone while preserving healthy tis-

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sue. An auto-polymerizing composite resin material (Telio, Ivoclar Vivadent) that was easy to remove was used on the anterior maxillary teeth.

One month later, the patient returned without any signs or symptoms of dysfunction as a result of the new augmented VDO, and he was pleased with the appearance of his new smile. At this stage, we began to carry out the definitive restorations, giving priority to the posterior teeth to achieve adequate posterior support. The selection of direct or indirect restorations should be based on the principle of maximum preservation of sound tooth structure. For this reason, each segment was treated differently.

Owing to the amount of tissue loss in the posterior mandibular and anterior maxillary segments, it was decided to perform indirect restorations to retain control of the anatomy and occlusion. On the anterior mandibular and posterior maxillary aspects, the teeth were restored directly, except for the left maxillary first molar, which was treated with an endocrown,[16] and the left maxillary second molar, which, being almost unaffected, was left unrestored.

Direct reconstruction of the posterior maxillary and anterior mandibular teeth

For the restoration of the posterior maxillary zone, a direct restoration technique was applied using a transparent silicone key (Elite Transparent) made from the wax-up. Each tooth was restored separately, and adjacent teeth were covered with "plumbers" tape, Teflon material (DuPont), to avoid splinting. The composite was heated to about 50°C on a composite heating conditioner (ENA HEAT, Micerium S) to decrease its viscosity and achieve a flowable consistency, thus allowing better adaptation and easier removal of any excess.

The anterior mandibular teeth were restored with a free-hand bonding technique using a palatal key to control the dimensions. The advantages of the direct option were that it allowed a more conservative approach, because no preparation was necessary, and the reparability of the composite material used. However, the high sensitivity of the technique, particularly for large restorations, is a major drawback. All adhesive procedures were performed under full rubber dam isolation. The OptiBond FL (OFL; Kerr) adhesive system was used according to the manufacturer's instructions, and a microhybrid composite (Enamel Plus HRi) served as the restorative material.

Indirect restoration of the posterior mandibular teeth

To reestablish the full occlusal anatomy of the posterior mandibular teeth, Lava Ultimate Blocks (3M ESPE) were selected and milled using a CAD/CAM system (CEREC 3, Sirona Dental Systems). The composite blocks were composed of nano-ceramic particles embedded in a highly converted resin matrix. The particularity of these restorations was their limited thickness, which was just 0.4 mm in some areas. They were designed using correlation software, which scanned the preparation and wax-up to reproduce the appropriate anatomy and occlusion. Once the six Lava Ultimate overlays were finished, the restorations were tried in place to allow adaptation to the six posterior mandibular teeth, contact point adjustment, and shade matching. Afterwards, the operator began to prepare the CAD/CAM occlusal composite overlays, following the method of Rocca and Krejci.[17]

Airborne-particle abrasion (CoJet, 3M ESPE) was used to condition the restoration surface, which was abundantly rinsed with water and dried. Organic silane was applied and, after a 60-second penetration time, was intensively dried with oil-free compressed air. Finally, a light-curing bonding resin (OFL bonding) was applied without precuring. The prepared restoration was left under a protective cover to avoid premature curing of the bond by ambient light.

The cavity was gently cleaned with 30 µm Al_2O_3 particles. Subsequently, the enamel and dentin were etched with 37.5% phosphoric acid gel, applied for 30 seconds to enamel and 15 seconds to dentin. OFL primer was applied to the dentin with a microbrush using a continuous scrubbing motion for 15 seconds. Excess solvent was removed by drying the cavity with compressed air for 5 seconds, following which, OFL adhesive was applied to the primed surface with a

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Fig 5a Provisional restorations on the maxillary arch made of composite of a different tooth shade. On the anterior teeth, the restoration was made with a self-curing resin to allow better adaptation and easy removal. On the posterior teeth, a preheated microhybrid composite and a transparent silicone key made from the wax-up were used.

Fig 5b The mandibular provisional restorations used heated composite and a transparent silicone key, splinted to the adjacent teeth to allow for better retention. The gingival embrasures were left open for hygiene purposes during the provisionalization phase.

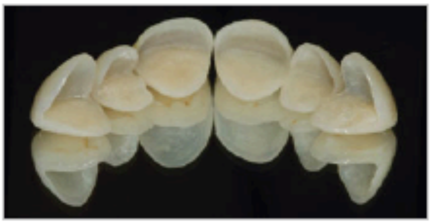

Fig 6 V-shaped composite veneers; note the v-shaped design of the restorations. Given that the contact point was not removed, an incisal path of insertion was required.

microbrush for 15 seconds and spread with air for 5 seconds without light curing. Next, a sufficient amount of heated restorative light-curing composite resin was placed in the cavity, the prepared composite overlay was set, and excess luting composite was removed with a microbrush or with Superfloss (Oral-B Superfloss, Procter & Gamble) in the interdental area. Full polymerization was achieved by light curing for at least 60 seconds per irradiated surface.

Finally, the rubber dam was removed, and occlusion was checked and corrected.

Indirect restoration of the anterior maxillary teeth

The anterior maxillary teeth were restored with indirect v-shaped composite veneers made of DEI Experience (DEI Italia; Fig 6). The purpose of using this type of restoration is to preserve as much sound tooth structure as possible. Minor preparation of the margin at the periphery is preferable, because it allows the technician to see the limits of the restoration and permits the clinician to ensure proper positioning of the restoration in the mouth. A small amount of preparation was necessary on the middle third of the maxillary central incisors to create the correct path of insertion. The preparations were checked by means of a silicone index in order to control the available space. The palatal dentin was cleaned with non-fluoride-containing pumice, and the angles were rounded.

The adhesive luting was performed, following the same protocol as for the indirect CAD/CAM composite occlusal overlays. Finally, an occlusal guard was pro-

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Fig 7 Postoperative view, 18 months after treatment, of the maxillary arch with posterior direct restorations, an indirect endocrown on the left first molar, and v-shaped indirect anterior composite veneers.

Fig 8 Postoperative view 18 months after treatment of the mandibular rehabilitation with posterior ultra-thin CAD/CAM-generated composite overlays and direct anterior restorations.

Fig 9 Intraoral view of the full-mouth adhesive composite rehabilitation at an 18-month follow-up, showing a successfully biologic, functional, and esthetic integration.

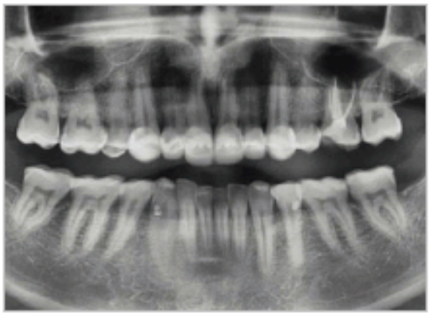

Fig 10 Final panoramic radiographic examination: pulp vitality was preserved in all teeth except for the left maxillary first molar, which showed irreversible pulpitis.

vided to the patient to protect the rehabilitation from mechanical stress through attrition, and advice was given on dietary habits with respect to carbonated drinks and their impact on erosion.

At an 18-month follow-up, both the direct and indirect restorations remained in situ without clear symptoms of wear (Figs 7, 8, and 9) and with no irregularities visible on radiographic examination (Fig 10). The patient continues to feel comfortable and is satisfied with the esthetic appearance.

DISCUSSION

There is a paucity of data on the appropriate material for tooth restoration; in particular, whether to choose ceramics or composites for non-retentive restorations. Reports on the clinical behaviors of composite and ceramic inlays and onlays have identified no major advantage of either material.[18] The longevity of dental restorations is dependent upon many factors involving the material, patient, and operator. The main reasons for failure in the long term are secondary caries, which

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relate to an individual's risk of caries, and fracture, which relates to patient factors, such as bruxism.[18,19]

However, when comparing composite and ceramic indirect restorations, composite resins have several advantages:[20]

- During the luting procedures, a wider range of shades is available for composite resin cementation. Given that minimal preparation is needed, preheated composite will fill the spaces of erosion/attrition concavities
- There is a lower risk of fracture during the luting, finishing, and polishing procedures
- The cost is lower, because the laboratory procedures are simpler; therefore, the treatment is affordable to more patients
- Intraoral repair with the same material is possible.

The main advantage of the v-shaped composite veneers used in this patient is that they facilitate a conservative approach in that they require only marginal preparation and a tiny correction in the middle third of the central maxillary incisors to achieve an adequate path of insertion.

Several treatment alternatives have been described for this type of patient, including, for example, the three-step technique.[2-4] A lesser degree of tooth preparation may be necessary using this technique. Nevertheless, some patients cannot afford a palatal veneer followed by a facial veneer to achieve an adequate esthetic result. More invasive retentive preparations, such as complete coverage crowns, can be used in combination with endodontic treatment in most patients, as well as with posts and cores. Porcelain-fused-to-metal (PFM) restorations function for a very long time, with survival rates of 74% after 15 years.[21] However, although the survival rate of PFM restorations is slightly superior to that of composite restorations, the former are associated with more severe complications, gingival inflammation, and secondary caries than bonded restorations.[22]

Moreover, clinical studies have shown that the performance of composite resins in the treatment of advanced tooth wear is adequate, and that partial fractures represent the most likely complication, which can be repaired or, in more severe cases, resolved by uncomplicated restoration replacement.[8,23,24] In contrast, PFM failures often lead to endodontic treatment or even extraction.

Although ceramic adhesive inlays and onlays have demonstrated long-term clinical reliability, with survival rates of 88.7% after 17 years[25] and 84% after 12 years,[26] long-term clinical studies of CAD/CAM ceramics are scarce. More conservative approaches, which take advantage of the development of stronger materials, should be considered in combination with CAD/CAM techniques and innovative adhesive technology, such as immediate dentin sealing.[27-29] A recent publication[29] showed that posterior occlusal veneers made of composite resin (Paradigm MZ100, 3M ESPE) exhibit significantly higher fatigue resistance than the leucite glass-ceramic IPS Empress CAD (Ivoclar Vivodent) and the lithium disilicate glass-ceramic IPS e.max CAD (Ivoclar Vivodent). The study also demonstrated the in vitro feasibility of a less invasive approach, using CAD/CAM ceramics and composite resins to fabricate thin occlusal veneers.

Furthermore, ultra-thin CAD/CAM composite resin occlusal veneers 0.6 mm thick demonstrated higher fatigue resistance than ceramics.[30] The use of composite resin blocks might have another advantage: the similarity of the E-modulus of the composite tested (16–20 MPa) with that of dentin (18.5 GPa)[31] may make a key contribution to the long-term performance of composite resin tooth restorations.[29]

CONCLUSION

An increasing number of patients visit dental offices with tooth wear caused by erosion, attrition, or a combined pathology. Correct diagnosis, followed by preventive and/or treatment strategies to arrest the progression of the disease, is essential.

In the past, treatment of such patients typically required full crown preparations, with significant sacrifice of sound dental tissue. The development of new dental materials, technologies, and adhesives has made

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alternative treatments possible while facilitating tissue preservation.

The use of adhesive techniques and composites in this patient demonstrate their potential in the treatment of moderate tooth wear. Modern composite resins are materials that should be taken into consideration in the direct or indirect restoration of anterior and posterior teeth.

The treatment described, which involved the use of ultra-thin CAD/CAM composite overlays and v-shaped veneers, allows the minimally invasive treatment of young patients, restoring the health, biomechanic function, and esthetic appearance of the teeth. Further study and long-term data are required to corroborate these findings and verify the performance of the full-mouth adhesive rehabilitation approach described in this report.

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6. DISCUSSION

DISCUSSION

The objectives of the present thesis were to evaluate the marginal adaptation of cavities restored with an adhesive system under different application protocols; qualitatively assess the marginal adaptation and the influence with the marginal adaptation on depth of class V cavities; find a simple adhesive restorative technique for the restoration of class I and II cavities on posterior teeth and a clinical application of the in-vitro adhesive investigations with a full mouth adhesive rehabilitation of a mixed erosion and attrition disorder on a young patient.

Evaluation of marginal adaptation

One of the main objectives in adhesive restorative dentistry is to obtain a reliable and durable bonding interface creating restorations with clinical longevity, trying to avoid future leakage, recurrent caries or pulpal irritation. On the first and third in vitro manuscripts we evaluate the marginal adaptation before and after thermomechanical loading as an indispensable prerequisite for clinical success.

Within the limitations of laboratory studies, quantitative analysis of marginal adaptation by SEM has been confirmed as an exact and reliable method of assessment for the evaluation of marginal adaptation of adhesive restorations (47).

Marginal adaptation has been severely criticized in the last years, mainly due to the common belief that retention loss (and not the presence of marginal defects) is the most obvious sign of failure of an adhesive system (48). However, clinically failure of restorations occurs most often due to inadequate sealing, with subsequent discoloration of the cavity margins, than to restoration loss (49). Moreover, the criterion marginal adaptation (together with cavosurface marginal discoloration, colour match, anatomic form and caries) is part of the USPHS or Ryge guidelines to judge on the clinical performance of a restoration. These guidelines are by far the ones that had the greatest scientific impact in dentistry since their creation several decades ago (50).

Mechanical tests

In attempt to simulate in-vitro with in-vivo conditions reaching a degree of clinical relevance, we tried to simulate oral conditions by performing the thermomechanical loading, together with dentinal fluid simulation, assessing the marginal adaptation to serve as an appropriate model for the in-vitro evaluation of adhesive systems (51, 52, 53). The teeth were loaded with simultaneous repeated thermal (600 x from 5° to 55°C with a dwell time of 2 min) and mechanical stresses (240,000 chewing

cycles at 1.7 Hz) by an antagonistic natural molar cusp with a maximum load of 49 newtons under the constant simulation of dentinal fluid flow according to a protocol described before by Krejci et al. (52).

Adhesives

Based on recommendations of the American Dental Association (ADA) for dentin and enamel adhesives, we performed Class V restorations on non-carious teeth for the following reasons (54):

1. The lesions do not have any macromechanical retention, and they have a small C-factor, which plays an important role in the performance of the adhesive system.

2. Class V restorations may include margins on enamel and dentin with no major difficulties in cavity preparation, thus minimizing the operator factor variable, and provides an appropriate location for the restorative and evaluation procedure.

Bond formation to enamel has proved reliable since Buonocore (55) demostrated that phosphoric acid etching increased resin-enamel bond strength. Since then, several publications confirmed this assertion (56- 59). Creation of a bond to dentin is more complicated due to the composition of the dentin substrate, presence of collagen, water and smear layer deposition.

While several studies have transformed a SE adhesive to a E&R (3, 56, 60- 62) by adding a phosphoric acid-etching step, there is not much literature evaluating a selective enamel-etching for a 3 steps E&R adhesive system.

The self-etch approach is an alternative based on the use of non-rinse acidic monomers that simultaneously condition and prime tooth tissues.

DISCUSSION

A lower technique-sensitivity of this approach is reported in the literature, since it eliminates the rinsing phase, which not only reduces clinical application time, but significantly decreases technique sensitivity or the possibility of making errors during application (11, 63).

Another important characteristic of the self-etch approach is that infiltration of monomers occurs simultaneously with the self-etch process; therefore, the possibility of discrepancies between both processes (10) and consequently the presence of an unprotected collagen fibres area is significantly reduced as the nanoleakage (11, 12, 15).

The findings of our first study, **Self-etching Aspects of a 3-step Etch-and-Rinse Adhesive,** indicate that etching dentin with phosphoric acid did not improve significantly marginal adaptation either before or after loading; indicating a self-etching effect most probably due to the presence of the acidic monomer (GPDM) within the composition of OFL primer. This finding could have several clinical implications as phosphoric acid etching of cavities approaching the pulp may induce a moderate inflammatory response, or pulpal irritation (64, 65) Avoiding phosphoric acid-etching of dentin, thereby, reduces the technique sensitivity of etch-and-rinse adhesives. Therefore, eliminating as many steps as possible in the bonding protocol could increase the efficiency of the procedure and would reduce technique sensitivity.

Qualitatively assessment of the self-etching pattern was performed, in order to obtain the micromorphology of enamel and dentin surfaces following the different phosphoric acid etching techniques. We could also observe that acid etching considerably increases dentin permeability and thus monomer diffusion into the pulp, which may result in an increased cytotoxicity.

Failure analysis of adhesive restorations

Marginal discrepancies of adhesive restorations can propagate inside the cavity and lead to restoration loss. Therefore, on our second manuscript: **Failure analysis of adhesive restorations with SEM and OCT: from marginal gaps to restoration loss,** tried to

DISCUSSION

evaluate the tooth restoration interface. Scanning electron microscope margin analysis is a well-known method for the evaluation of adhesive restorations and considered the setup

closest to the clinical situation (66). Nevertheless, SEM diagnosis based on gold-coated replicas is an expensive and time-consuming way of evaluating dental restorations (66). It also suffers from both sampling and inter observer variability.

Optical coherence tomography (OCT), as an imaging method, is based on a classical measurement technique known as low-coherence interferometry that enables non-invasive, high-resolution, in vivo, two- or three-dimensional cross-sectional imaging of microstructural morphology in transparent and non-transparent biological tissue in situ (67).

The OCT used in this study enabled the 3D visualization analysis of the entire margin. This is an advantage because the entire tooth sample can be observed in a short amount of time without any additional preparation. The 3D visualization of the entire restoration permitted us to corroborate that with higher % of NCM; the depth of the gap also increased.

To determine if high scattering areas that propagated from the composites surface inside the cavity were due to light distortion or to the real presence of gaps, samples with and without marginal gaps belonging to the same group were observed under OCT for comparison. Brighter and wider white lines could be observed along the resin-tooth interface of samples with high % of NCM; these lines could be hardly observed or were even absent from the samples with gap-free margins. Therefore, our

OCT observations are in line with those of a recent study (68) and white areas at the adhesive interface did not represent reflection artefacts but the real presence of gaps inside the restoration.

Finally, the 3D scans showed that gap and gap-free adhesive interfaces coexisted within the same cavity, confirming the early findings of Shono and co-workers (69) in respect to how areas of good bonding and adhesive gaps can coexist without compromising restorations' retention.

DISCUSSION

Marginal gaps could be interpreted as an early sign of restoration failure. Meanwhile, only one restoration was lost that presented above 50 % of marginal gaps on enamel and dentin. Possibly, hydrolytic degradation is accelerated under the presence of more than 50 %

of marginal openings on both enamel and dentin margins, increasing the probability of failure due to restoration loss. In addition, the OCT data of gr 3 confirmed that marginal openings also propagated beneath the restoration, evidencing that restoration loss strongly depends on the time needed for an infiltrated margin to propagate along the internal interface.

Composites

In the third publication, **Bulk Filling of Class II Cavities with a Dual-Cure Composite: Effect of Curing Mode and Enamel Etching on Marginal Adaptation**, we attempt to find a restorative material that could potentially be used as an amalgam substitute, i.e. an adhesive material that can be applied in bulk with a simple restorative technique. For that purpose the marginal integrity of cavities entirely restored with a dual-cured resin composite were evaluated.

We used a chemically-cured two-step self-etching adhesive system and a dual-cured build-up composite with different protocols in the etching procedure and polymerization mode (chemical or dual-cure).

When using dual-cured composites in conjunction with dual-cured dental adhesives, the self-etching approach has been proved to perform better on dentin (70). However, phosphoric acid etching on enamel has proved reliable and favorable bonding interfaces (71). Therefore, a selective enamel etching would ensure a more adequate bonding effectiveness even when a self-etching system is selected (72). The results of the present study confirmed the precedent statement as we obtained the highest % of CM at the total margin length, both before and after loading, when enamel margins where etched with phosphoric acid, independently of the polymerization method used.

The marginal quality was expressed in percentages of continuous margins (% CM) and reported for occlusal enamel margins, proximal enamel, cervical dentin and for the total marginal length (average value of enamel and dentin marginal adaptation), at each interval before and after loading.

Marginal adaptation at the occlusal enamel margins were lower for the groups 1 and 2 where the self-etching primer was applied on enamel without previous conditioning with phosphoric acid.

Gap formation or microleakage at the tooth-composite interface is related with polymerization shrinkage and shrinkage stresses. Light intensity was the highest at the restorations surface decreasing the pre-gel phase and leading to contraction forces and materials shrinkage (73). This could explain the low results on occlusal enamel despite better scores of marginal adaptation on the proximal area.

In the present study, similar shrinkage stresses could have been developed on the self and dual-cured material at the late stages of polymerization, explaining why the percentages of continuous margins were similar in both groups. Shrinkage strain rates of both self and light-curing modes would become almost identical after about 60 min for dual-cured core materials (73).

Despite the similar marginal adaptation scores, when dual-cure composites are used, higher dentin bond strength are reported when light-cured as compared to self-curing (74). This could explain the lower results of marginal adaptation obtained at the cervical dentin in group 1, the self cured material would attain a lower degree of conversion and therefore, lower mechanical properties that would be evidenced at the marginal level in respect to the light cured ones.

In addition, final light polymerization would enhance significant mechanical properties, making the selection of a dual-cured composite an improvement over a self-cured or a light-cured at the gingival margin (35).

DISCUSSION

Oral Rehabilitation

Loss of tooth substance has become a common pathology in modern society. Several publications have proposed the use of minimally invasive procedures to treat such patients in preference to traditional full-crown rehabilitation. The use of composite resins, in combination with improvements in dental adhesion, allows a more conservative approach.

In our fourth manuscript, **Full mouth composite rehabilitation of a mixed erosion and attrition patient. A case report with v-shaped veneers and ultra-thin CAD/CAM composite overlays,** we describe the step-by-step procedure of full-mouth composite rehabilitation in a young patient with a combination of erosion and attrition disorder.

There is a paucity of data on the appropriate material for tooth restoration; in particular, whether to choose ceramics or composites for non-retentive restorations. Reports on the clinical behaviors of composite and ceramic inlays and onlays have identified no major advantage of either material (75). The longevity of dental restorations is dependent upon many factors involving the material, patient, and operator. The main reasons for failure in the long term are secondary caries, which relate to an individual's risk of caries, and fracture, which relates to patient factors, such as bruxism (75, 76). However, when comparing composite and ceramic indirect restorations, composite resins have several advantages (77):

- During the luting procedures, a wider range of shades is available for composite resin cementation. Given that minimal preparation is needed, preheated composite will fill the spaces of erosion/attrition concavities.

- There is a lower risk of fracture during the luting, finishing, and polishing procedures.

- The cost is lower, because the laboratory procedures are simpler; therefore, the treatment is affordable to more patients.

- Intraoral repair with the same material is possible.

DISCUSSION

The main advantage of the v-shaped composite veneers used in this patient is that they facilitate a conservative approach in that they require only marginal preparation and a tiny correction in the middle third of the central upper incisors to achieve an adequate path of insertion.

Several treatment alternatives have been described for this type of patient, including, for example, the three-step technique (35- 37). Nevertheless, some patients cannot afford a palatal veneer followed by a facial veneer to achieve an adequate esthetic result.

More conservative approaches, which take advantage of the development of stronger materials, should be considered in combination with CAD/CAM techniques and innovative adhesive technology, such as immediate dentin sealing (78- 80). A recent publication (80) showed that posterior occlusal veneers made of composite resin (Paradigm™ MZ100; 3M ESPE) exhibit significantly higher fatigue resistance than the leucite glass-ceramic IPS Empress CAD (Ivoclar Vivodent) and the lithium disilicate glass-ceramic IPS e.max CAD (Ivoclar Vivodent).

The use of composite resin blocks might have another advantage: the similarity of the E-modulus, which may make a key contribution to the long-term performance of composite resin tooth restorations (80).

7. CONCLUSIONS

CONCLUSIONS

1. No significant differences in marginal adaptation at dentin margins were found between groups before and after loading. However, differences in continuous margins were observed before and after loading on enamel in the group without phosphoric acid-etching. Therefore, the null hypothesis was accepted for dentin and rejected for enamel margins.

The micromorphology of dentin and enamel surfaces after different treatments suggested that on dentin the acidic primer, was less aggressive in its etching effect compared to phosphoric acid, with tubule still covered by smear layer. On enamel the best etching pattern was achieved when phosphoric acid was applied to the surface. The application of the 3-step etch&rinse OFL adhesive with selective enamel etching may represent an advantage on restoring deep cavities because overetching dentin may become almost impossible with the application of the acidic primer only.

2. When marginal imperfections or marginal gaps, were detected by the SEM analysis on the surface of the tooth restoration interface, they could be confirmed beneath the surface with OCT. The depth of the gap was variable and sample-dependent; however, the 3D visualization of the entire restoration with OCT allowed for corroboration that with higher % of NCM; the depth of the gap also increased. This is why the null hypothesis was rejected.

3. We found higher percentages of continuous margins at the total margin length, both before and after thermo-mechanical loading, in groups where enamel was etched with phosphoric acid. The null hypothesis was thus rejected.

A dual-cured composite applied in bulk on acid etched enamel led to acceptable marginal adaptation results, and may thus be an alternative technique for the restoration of class II cavities.

4. We found no significant differences in marginal adaptation between the chemically and dual-cured modes. Therefore, the null hypothesis was accepted.

CONCLUSIONS

Materials' insertion in one single layer, with the additional benefit of chemical cure in deep areas where light is attenuated gives several clinical advantages in terms of handling, curing efficiency and time saving.

5. The development of new dental materials, in combination with considerable advances in dental adhesion in recent years, have enabled clinicians to adopt a more conservative restorative approach. Minimally invasive procedures should be taken into consideration in order to treat patients with erosion and/or attrition disorders. In this respect, a correct diagnosis is essential, followed by preventive and/or treatment strategies to arrest the progression of the disease.

The treatment described, which involved the use of ultra-thin CAD/CAM composite overlays and v-shaped veneers, allowed for a conservative approach to restore the health, biomechanic function, and esthetic appearance of the teeth.

CONCLUSIONES

1. No se encontraron diferencias en la adaptación marginal en dentina entre los grupos antes y después de la carga. Sin embargo, si se observaron diferencias antes y después de la carga en esmalte en el grupo sin grabado con ácido fosfórico. Teniendo que rechazar la hipótesis nula.

La micromorfología de superficie en dentina y esmalte después de diferentes tratamientos sugirió que en la dentina el primer era menos agresivo en comparación con el grabado con ácido fosfórico dejando el tubulo todavía cubierto por barrillo dentinario. En esmalte se logró la mejor morfología de superficie cuando se aplicó ácido fosfórico. La aplicación del adhesivo de grabado total OFL con grabado del esmalte selectivo puede representar una ventaja en la restauración de cavidades profundas.

2. Sí hemos encontrado que cuando las imperfecciones marginales o márgenes no continuos, fueron detectados por SEM, también se podían observar imperfecciones debajo de la superficie en la interfase de la restauración dental con OCT. La profundidad de la brecha

era variable y dependiente de la muestra; sin embargo, la visualización en 3D de toda la restauración con OCT nos permitió corroborar que con mayor % de márgenes no continuos la profundidad de la brecha también aumenta. Por lo tanto, la hipótesis nula fue rechazada.

3. Sí encontramos porcentajes más altos de adaptación marginal en la longitud total del margen, tanto antes como después de la carga termomecánica en los grupos en los que el esmalte fue grabado con ácido fosfórico, teniendo que rechazar la hipótesis nula.

Un composite de polimerización dual aplicado en una sola capa en esmalte grabado con ácido fosfórico obtuvo resultados de adaptación marginal aceptables, pudiendo ser una técnica alternativa para la restauración de cavidades de clase II.

4. No encontramos diferencias en la adaptación marginal entre los modos de polimerización dual y química. Por lo tanto, se aceptó la hipótesis nula.

La inserción de materiales en una sola capa, con el beneficio adicional de la polimerización química en las zonas profundas donde la luz es atenuada nos aporta varias ventajas clínicas en términos de manejo, eficiencia en la polimerización y ahorro de tiempo.

5. El desarrollo de nuevos materiales dentales, en combinación con considerables avances en la adhesión dental en los últimos años, han permitido a los clínicos adoptar un enfoque más conservador. Los procedimientos mínimamente invasivos deben tenerse en consideración con el fin de tratar a pacientes con erosión y / o atricción. Es esencial un correcto diagnóstico, seguido de las estrategias de prevención y / o tratamiento para detener la progresión de la enfermedad.

El tratamiento descrito, se realizó mediante el uso de incrustaciones CAD / CAM muy delgadas de composite y carillas en forma de v, permitiendo con un enfoque conservador restablecer la salud, la función biomecánica, y el aspecto estético de los dientes.

8. RESUMEN

RESUMEN

La Odontología conservadora ha dado varios cambios sustanciales, el ultimo se llama "odontología adhesiva". Los avances en la tecnología adhesiva han simplificado los procedimientos dentales, ofreciendo un resultado más estético a los pacientes y un tratamiento más conservador a los clínicos (1).

Estás mejoras en la adhesion, el aumento de la demanda de la sociedad hacia restauraciones más estéticas o restauraciones libres de metal, junto con el interés de profesionales dentales por materiales del color del diente, hizo que el uso de la amalgama y otros metales utilizados en boca cada vez más controvertido, a pesar de la ausencia de pruebas científicas definitivas (1, 2).

El objetivo de esta tesis se centró en analizar el desarrollo de la odontología adhesiva; se evaluó la adaptación marginal, analizando cuantitativamente mediante microscopía electrónica la cantidad de márgenes continuos y no continuos en restauraciones de clase V empleando un adhesivo de grabado total con diferencias en la aplicación del ácido ortofosfórico. Cualitativamente mediante el OCT, se analizó la posible propagación de las grietas o márgenes no continuos. Se evaluó también la adaptación marginal de un composite de polimerización dual como un sustituto de amalgama con diferencias en el grabado de ácido ortofosfórico en esmalte y diferentes modos de polimerización química y dual, con el objetivo de obtener la restauración de cavidades de una forma rápida y sencilla. Por último se describió el paso a paso de una rehabilitación adhesiva de composite en un paciente joven con un enfoque mínimamente invasivo, restaurando la salud, la función biomecánica y la apariencia estética.

En la primera publicación se realizaron 3 grupos de 8 dientes con diferencias en los modos de aplicación del grabado con ácido ortofosfórico realizando obturaciones de clase V. Se sometieron a carga termomecánica durante 240.000 ciclos mecánicos a una fuerza de 49 N y 600 ciclos termales entre 5 y 55ºC.

Antes y después del test de fatiga se realizaron réplicas de cada muestra para analizar las dos interfases adhesivas externas (esmalte- restauración y dentina- restauración) mediante Microsopio Electrónico de Barrido (SEM, Philips XL 20, Eindhoven, The Netherlands) a 200x de magnificación con la ayuda del programa informático evaluando así la “continuidad”

RESUMEN

(C) o "márgen abierto" (MO) de cada interfase. Se observó también la micromorfología del patrón de grabado que se produjo en esmalte y dentina con SEM.

En cuanto a los resultados que obtuvimos, encontramos diferencias significativas en la adaptación marginal en los margenes en esmalte. Por el contrario, no se obtuvieron diferencias en los margenes en dentina (p=0.30). El patron de grabado reveló un grabado más agresivo en las muestras que se aplicó ácido ortofosfórico.

El segundo artículo analizó el tipo de fracaso adhesivo de las restauraciones de clase V con los diferentes modos de grabado con ácido ortofosfórico, comparando el SEM con el OCT (Optical Coherence Tomography). El OCT permitió analizar cualitativamente los margenes no continuos del articulo anterior y ver la propagación de las grietas dentro de la cavidad. Obteniendo información complementaria del funcionamiento de las restauraciones a largo plazo.

La siguiente investigación trató de encontrar una técnica restauradora adhesiva simple y eficiente para cavidades de clase I y II. Se utilizó un composite de fraguado dual con diferencias en la aplicación del ácido ortofosfórico en el esmalte y el modo de polimerización (auto y dual). Las muestras fueron sujetas a análisis cuantitativo marginal mediante SEM antes y después de la carga termomecánica descrita previamente.

Los porcentajes más altos de adaptación marginal en la longitud total del margen, tanto antes como después de la carga termomecánica, se encontraron en los grupos en los que el esmalte fue grabado con ácido ortofosfórico, sin diferencias significativas entre los modos de polimerización auto y dual.

La última publicación es un artículo clínico que pone en práctica los conceptos de odontología adhesiva para rehabilitar a un paciente joven afectado por una sintomatología común de erosion y atricción. El artículo describe el paso a paso llevado a cabo para diagnosticar, realizar el plan de tratamiento y la ejecución de la rehabilitación adhesiva mediante el uso de restauraciones directas e indirectas de composite utilizando carillas en V e incrustaciones de espesor reducido de CAD/CAM.

RESUMEN

De acuerdo con los resultados obtenidos, la primera hipótesis nula en cuanto a que no habrá diferencias en la adaptación marginal con diferentes protocolos de aplicación de ácido ortofosfórico en esmalte y dentina debe ser rechazada. Se encontraron diferencias significativas en los márgenes de esmalte en el grupo en el que no se aplicó ácido ortofosfórico, sin embargo no se encontraron diferencias en dentina. Encontramos un efecto de autograbado en dentina pudiendo beneficiar la restauración de cavidades profundas.

La segunda y tercera hipótesis nula en la que el análisis SEM no sería capaz de detectar diferencias en las grietas marginales entre los grupos y que no hay propagación de una grieta en el interior de la cavidad, en cavidades con márgenes no continuos (o grietas marginales) deben ser rechazadas. Cuando se detectaron imperfecciones marginales, o márgenes no continuo mediante SEM, también se podían apreciar imperfecciones debajo de la superficie con OCT.

La cuarta y quinta hipótesis nula en la que no hay diferencias en cuanto a la adaptación marginal en restauraciones de clase II en una sola capa con diferentes protocolos de grabado ácido y polimerización auto y dual debe ser rehusada para las diferencias en el protocolo de grabado, y aceptada para los modos de polimerización. El grabado con ácido ortofosfórico en esmalte tuvo ventajas en la adaptación marginal sin diferencias en cuanto al modo de polimerización. La utilización de un composite dual en una capa para restaurar cavidades de clase II, es una técnica económica, alternativa a técnicas de restauración adhesivas sofisticadas por capas y un sustituto potencial a la amalgama.

Pese a las limitaciones de esta tesis, podemos decir que la odontología adhesiva nos ayuda a respetar al máximo la estructura dental sana, alargar la vida de la dentición al adherirse al diente y reproducir la naturaleza. De todas maneras se necesitan más artículos que corroboren estos hallazgos y verifiquen el funcionamiento de la odontología adhesiva a largo plazo.

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10. APPENDIX

APROVACIÓN DEL PROYECTO DE TESIS

APPENDIX

Universitat Internacional de Catalunya

FACULTAD DE ODONTOLOGÍA
Comisión científica

La comisión de doctorado del Departamento de Odontología de la Universitat Internacional de Catalunya, CERTIFICA que

El presente proyecto de Tesis Doctoral titulado: "**Sustitutos de amalgama para la obtención de un composite que nos permita obturar las cavidades de manera ràpida y sencilla**", cuyos directores son el Dr. Ivo Krejci y el Dr. Miguel Roig Cayón y cuyo investigador principal es el doctorando **José Bahillo Varela**

ha sido evaluado satisfactoriamente y es apto para entrar en el programa de doctorado.

Firmado en Sant Cugat del Vallès, a 23 de febrero del 2011.

Universitat Internacional de Catalunya
Facultat d'Odontologia

Dr Lluís Giner Tarrida
Director de la comisión de doctorado de Odontología

Título:	**Sustitutos de amalgama para la obtención de un composite que nos permita obturar las cavidades de manera ràpida y sencilla**
Investigador principal:	**José Bahillo Varela**
Director de la tesis:	**Dr. Ivo Krejci; Dr. Miguel Roig Cayón**
Número de estudio:	**EST-ELM-2011-04-NF**

APPENDIX

CARTA APROVACIÓN CER

APPENDIX

Comitè d'Ètica de Recerca | Universitat Internacional de Catalunya

CARTA APROVACIÓ PROJECTE PEL CER

Codi de l'estudi: EST-ELM-2011-04-NF
Versió del protocol: 1.1
Data de la versió: 02/04/13
Títol: "Sustitutos de amalgama para la obtención de un composite que nos permita obturar las cavidades de manera rápida y sencilla"

Sant Cugat del Vallès, 02 d'abril de 2013

Investigador: José Bahillo Varela

Títol de l'estudi: "Sustitutos de amalgama para la obtención de un composite que nos permita obturar las cavidades de manera rápida y sencilla"

Benvolgut(da),

Valorat el projecte presentat, el CER de la Universitat Internacional de Catalunya, considera que, des del punt de vista ètic, reuneix els criteris exigits per aquesta institució i, per tant, ha

RESOLT FAVORABLEMENT

emetre aquest CERTIFICAT D'APROVACIÓ per part del Comitè d'Ètica de la Recerca, per que pugui ser presentat a les instàncies que així ho requereixin.

Em permeto recordar-li que si en el procés d'execució es produís algun canvi significatiu en els seus plantejaments, hauria de ser sotmès novament a la revisió i aprovació del CER.

Atentament,

Dr. Josep Argemí
President CER-UIC

1

APPENDIX

CARTA DE APROVACIÓN CAD

APPENDIX

JOSÉ BAHILLO VARELA
44846509M
C/ MONTERO RIOS 34, 3º
15701 SANTIAGO DE COMPOSTELA

Sr. José Bahillo,

Por la presente, le comunicamos que la Comisión Académica del Doctorado en Salud en la pasada edición del 9 de junio de 2015, aprobó su tesis doctoral para la defensa " SUSTITUTOS DE AMALGAMA PARA LA OBTENCIÓN DE UN COMPOSITE QUE NOS PERMITA OBTURAR LAS CAVIDADES DE MANERA RÁPIDA Y SENCILLA ".

Atentamente,

Universitat Internacional de Catalunya | Escola de Doctorat

Esther Belvis
Secretaria Técnica de l' Escola de Doctorat

Barcelona, 15 de junio de 2015

APPENDIX

CERTIFICADO ESTANCIA EN LA UNIVERSITÉ DE GENÈVE

APPENDIX

UNIVERSITÉ DE GENÈVE
FACULTÉ DE MÉDECINE
Clinique universitaire de médecine dentaire

Pr. Ivo KREJCI
Président de la CUMD
Ligne directe: 022 379 41 00
Ivo.Krejci@unige.ch

A qui de droit

Genève, 25 mars 2015

Attestation

Je soussigné, Professeur Ivo KREJCI, Président de la Clinique universitaire de médecine dentaire, Chef de la Division de Cariologie et d'Endodontie, certifie que Monsieur José Bahillo Varella, né le 02 janvier 1985, domicilié c/ Montero Rios 34-3ºC. C.P: 15701, Santiago de Compostela, Espagne, a travaillé en qualité d'étudiant libre du 17 novembre 2010 au 23 février 2011 dans ma division.

Professeur Ivo Krejci
Président de la Clinique universitaire de médecine dentaire

19 rue Barthélemy-Menn - CH-1205 Genève
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APPENDIX

INFORME DE LA UNIVERSITÉ DE GENÈVE

APPENDIX

UNIVERSITÉ DE GENÈVE
FACULTÉ DE MÉDECINE
Clinique universitaire de médecine dentaire

Pr. Ivo KREJCI
Président de la CUMD
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Ivo.Krejci@unige.ch

To whom it may concern

Geneva, 24th March 2015

Recommendation

I, hereby Professor Ivo Krejci, Head of Cariology and Endodonty Division, President of the Dental School of Geneva University, is aware and positive about the PhD work of Jose Bahillo on "Sustitutos de amalgama para la obtencion de un composite que nos permita obturar las cavidades de manera rapida y sencilla". He has performed his research project very well, and we hereby confirm that her works fullfills the requirements to obtain a European Doctorate.

Professor Ivo Krejci
President of the Dental School

19 rue Barthélemy-Menn - CH-1205 Genève
Tél. 022 379 40 16 - Fax 022 379 41 02 - www.smd.unige.ch

APPENDIX

UNIVERSITÉ DE GENÈVE
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Clinique universitaire de médecine dentaire

Giovanni Tommaso Rocca
Chargé d'enseignement
Ligne directe: 022 379 41 00
Giovanni.rocca@unige.ch

To whom it may concern

Geneva, 25th March 2015

Attestation

I, hereby Doctor Giovanni Tommaso Rocca, Cariology and Endodonty Division, Dental School of Geneva University, is aware and positive about the PhD work of Jose Bahillo Varela on "Sustitutos de amalgama para la obtención de un composite que nos permita obturar las cavidades de manera rápida y sencilla". He has performed his research project very well, and we hereby confirm that her works fullfills the requirements to obtain a European Doctorate.

Doctor Giovanni Tommaso Rocca
Cariology and Endodonty Division

19 rue Barthélemy-Menn - CH-1205 Genève
Tél. 022 379 40 16 - Fax 022 379 41 02 - www.smd.unige.ch

APPENDIX

PÓSTER PRESENTADO EN CONSEURO 2011, ESTAMBUL

(1er PREMIO)

APPENDIX

Self-etching Aspects of a Classic Etch & Rinse Adhesive

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ID 115

OBJECTIVES

Evaluate the self-etching properties of a classic 3-step etch&rinse adhesive, OptiBond FL (OFL).

MATHERIAL & METHODS

Class V cavities with margins located in enamel and dentin. Restored with OFL and a micro-hybrid resin composite (Clearfil AP-X). The specimens were randomly assigned to three groups: 1.enamel (E) and dentin (D) etching with 37% H_3PO_4 followed by Primer (P) and Adhesive (A) application, 2. Only E etching with H_3PO_4 followed by P and A application and 3. P and A with no previous etching with H_3PO_4.

Fig 1. Class V cavity

Fig 2. Restoration

Fig 3. Vinyl polysiloxane impression

Fig 4. Gold sputtered replica

Thermo-mechanical loading was performed and specimens were subjected to quantitative marginal analysis before and after loading. Data was evaluated with ANOVA and DUNCAN post hoc test.

RESULTS

GROUPS	% CM E before loading	% CM D before loading	%CM TML before loading	% CM E after loading	% CM D after loading	% CM TML after loading
1. OFL H3PO4 E&D+P+A	97.5± 4.1A	89.4± 8.6A	93.5± 5.1A	96.5± 5.1A	83.3± 11.6A	89.5± 6.4A
2. OFL H3PO4 E+P+A	89.9± 14.5AB	89± 10.9A	90± 9.2A	93.1± 8.1A	68.7± 25.1A	80.8± 16.3A
3. OFL P+A (no H3PO4)	**80.2± 10.1B**	90.1± 16.6A	85.5± 9.8A	**46.9±19.5B**	69.7± 22.5A	**58± 12.4B**

No significant differences in the % of continuous margins (CM)at TML were observed before loading. Interestingly, after loading no significant differences were observed on dentin margins, evidencing a self-etching effect on dentin. However, significantly lower % CM were observed on enamel in group 3.

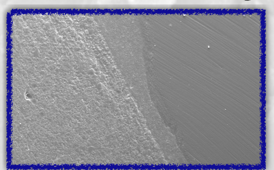

Fig 5. SEM image group 1

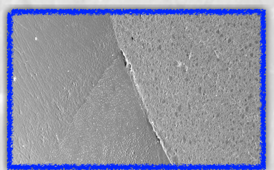

Fig 6. SEM image group 2

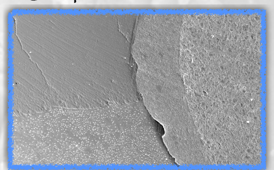

Fig 7. SEM image group 3

CONCLUSIONS

A self-etching behaviour was observed due to the presence of the acidic monomer GPDM within the composition of OFL.

CLINICAL RELEVANCE

OFL, a classic 3-step etch&rinse adhesive, behaves as a self-etching adhesive.

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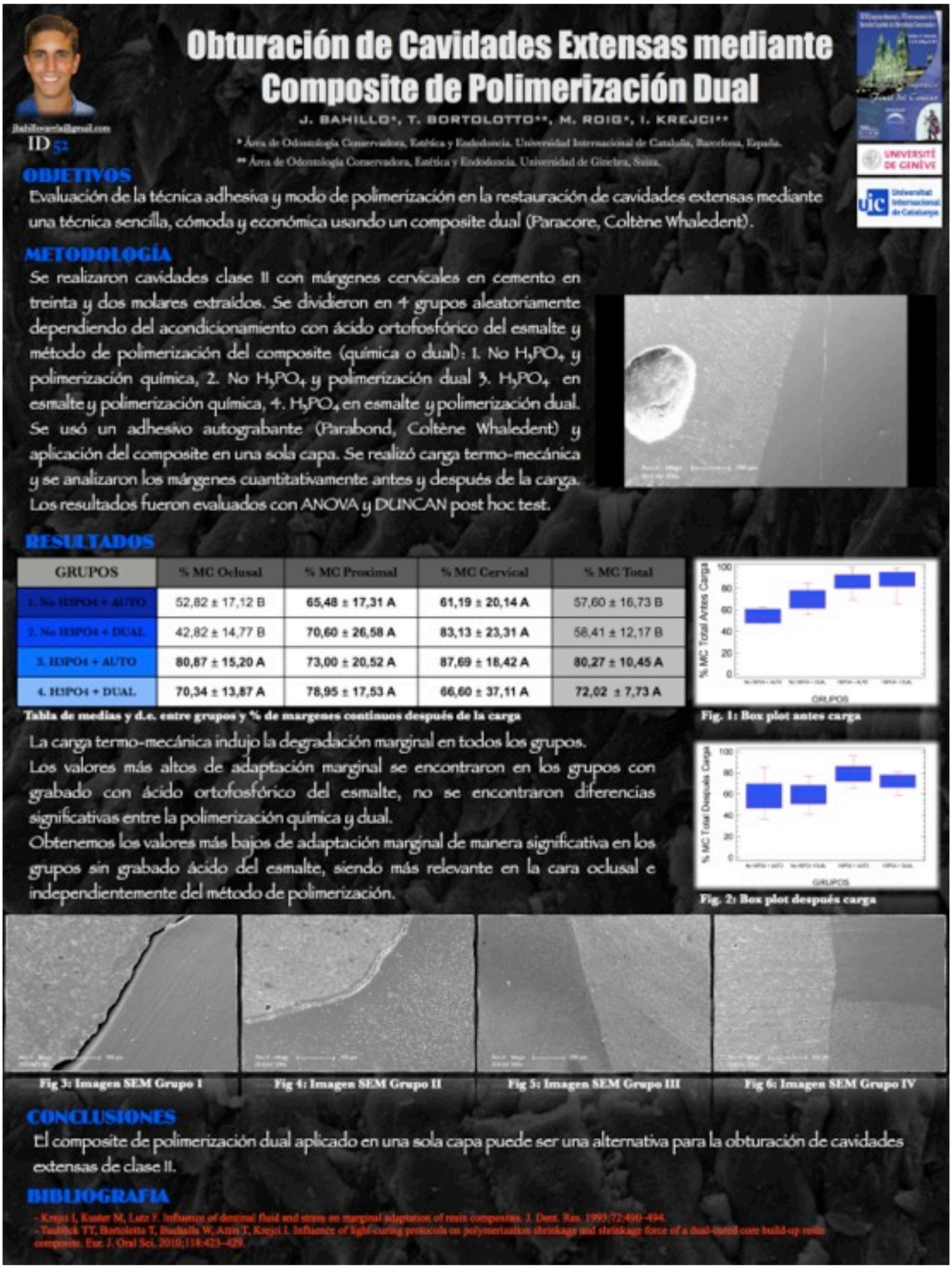
APPENDIX

PÓSTER PRESENTADO EN SEOC 2012, SANTIAGO

APPENDIX



Obturación de Cavidades Extensas mediante Composite de Polimerización Dual

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ID 52

UNIVERSITÉ DE GENÈVE

Universitat Internacional de Catalunya

OBJETIVOS

Evaluación de la técnica adhesiva y modo de polimerización en la restauración de cavidades extensas mediante una técnica sencilla, cómoda y económica usando un composite dual (Paracore, Coltène Whaledent).

METODOLOGÍA

Se realizaron cavidades clase II con márgenes cervicales en cemento en treinta y dos molares extraídos. Se dividieron en 4 grupos aleatoriamente dependiendo del acondicionamiento con ácido ortofosfórico del esmalte y método de polimerización del composite (química o dual): 1. No H_3PO_4 y polimerización química, 2. No H_3PO_4 y polimerización dual 3. H_3PO_4 en esmalte y polimerización química, 4. H_3PO_4 en esmalte y polimerización dual. Se usó un adhesivo autograbante (Parabond, Coltène Whaledent) y aplicación del composite en una sola capa. Se realizó carga termo-mecánica y se analizaron los márgenes cuantitativamente antes y después de la carga. Los resultados fueron evaluados con ANOVA y DUNCAN post hoc test.

RESULTADOS

GRUPOS	% MC Oclusal	% MC Proximal	% MC Cervical	% MC Total
1. No H3PO4 + AUTO	52,82 ± 17,12 B	65,48 ± 17,31 A	61,19 ± 20,14 A	57,60 ± 16,73 B
2. No H3PO4 + DUAL	42,82 ± 14,77 B	70,60 ± 26,58 A	83,13 ± 23,31 A	58,41 ± 12,17 B
3. H3PO4 + AUTO	80,87 ± 15,20 A	73,00 ± 20,52 A	87,69 ± 18,42 A	80,27 ± 10,45 A
4. H3PO4 + DUAL	70,34 ± 13,87 A	78,95 ± 17,53 A	66,60 ± 37,11 A	72,02 ± 7,73 A

Tabla de medias y d.e. entre grupos y % de margenes continuos después de la carga

% MC Total Antes Carga; GRUPOS

Fig. 1: Box plot antes carga

% MC Total Después Carga; GRUPOS

Fig. 2: Box plot después carga

La carga termo-mecánica indujo la degradación marginal en todos los grupos.

Los valores más altos de adaptación marginal se encontraron en los grupos con grabado con ácido ortofosfórico del esmalte, no se encontraron diferencias significativas entre la polimerización química y dual.

Obtenemos los valores más bajos de adaptación marginal de manera significativa en los grupos sin grabado ácido del esmalte, siendo más relevante en la cara oclusal e independientemente del método de polimerización.

Fig 3: Imagen SEM Grupo I **Fig 4: Imagen SEM Grupo II** **Fig 5: Imagen SEM Grupo III** **Fig 6: Imagen SEM Grupo IV**

CONCLUSIONES

El composite de polimerización dual aplicado en una sola capa puede ser una alternativa para la obturación de cavidades extensas de clase II.

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APPENDIX

PÓSTER PRESENTADO EN SPED 2012, OPORTO

APPENDIX

MINIMAL INVASIVE COMPOSITE REHABILITATION IN A YOUNG PATIENT

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** Professor of the Department of Operative Dentistry and Endodontics. International University of Catalonia, Barcelona , Spain.

Universitat Internacional de Catalunya

Fig. 1: Initial superior occlusal view

Fig. 2: Initial situation. Frontal view

Fig. 3: Initial inferior occlusal view

OBJECTIVES

To reestablish anatomy and function in young patients, based on minimal invasive procedures in order to achieve a proper occlusal scheme and a pleasing smile.

Fig. 4: Superior Wax up

Fig. 5: Mounted study casts in CR

Fig. 6: Inferior Wax up

Fig. 7: V-shape veneers

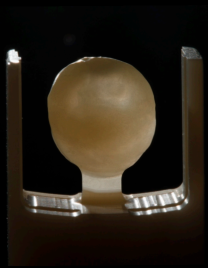

Fig. 8: Lava Ultimate Blocks

Fig. 9: Cerec CAD/CAM Overlays

Fig. 4: Final superior occlusal view

Fig. 5: Final Situation. Frontal view

Fig. 6: Final inferior occlusal view

CONCLUSIONS

The use of adhesive techniques and resin composites in combination with moderate tooth wear has demostrated its potential. Intercepting this patients at the initial stages and the use of minimal invasive procedures helps to avoid significant irreversible teeth damages giving back biology, function and esthetics.

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sábado 13 de diciembre de 14

APPENDIX

COMUNICACIÓN ORAL EN SEPES 2013, OVIEDO

APPENDIX

SEPES OVIEDO 2013
43 Reunión Anual

El Comité Organizador de la 43 Reunión Anual de SEPES

CERTIFICA que

Bahillo Varela, J., Tarazón Visús, I., Castelo Baz, P., Ruiz Piñón, M., Bahillo Varela, M., Roig Cayón, M.

Ha/han presentado la Comunicación Oral titulada

ABORDAJE MINIMAMENTE INVASIVO EN LA REHABILITACIÓN DE PACIENTES CON EROSIÓN Y ATRICCIÓN

Código de presentación: O-035

durante la 43 Reunión Anual de SEPES celebrado en Oviedo del 11 al 13 de Octubre de 2013. Y para que así conste a todos los efectos, firmamos la presente Certificación, en Oviedo, a 11 de Octubre de 2013.

Dr. José Mª Suárez Feito
Presidente de la 43 Reunión anual

Dr. Juan Ignacio Rodríguez Ruiz
Presidente de SEPES

Secretaría Técnica: Grupo Pacifico.
sepes2013@pacifico-meetings.com