

Studies on Adhesion of Composite Resins and Glass-Ionomer Cements in Open-Sandwich Technique

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The aim of this study was to assess the quality of the interface between dental root cement and some restorative materials used in the open sandwich technique. Standardised cavities were prepared on the buccal and oral surfaces of 30 human molars with the gingival margin situated in root cement. The teeth were randomly divided in 3 groups. Different materials combinations were used in buccal and oral cavities. In the control group, the cavities were filled only with composite resins (Filtek Z250-3M ESPE and Zmack Comp-Zermack). In the test groups the cavities were restored using an open sandwich technique as follows: in group 1 Filtek Z250 in combination with Dyract, respectively Ketac Molar Easymix; in group 2 Zmack Comp in combination with Dyract, respectively Ketac Molar. The teeth were stored in 1% methylene blue solution, for 24 hours. The samples were longitudinally sectioned through the centre of restorations and the degree of dye penetration as well as the morphology of the interface between the root cement and the restorative material were evaluated by optical microscopy and SEM. The results showed less microleakage and adhesive failures in open sandwich restorations with Zmack Comp and Dyract combination.

Keywords: restorative materials, open-sandwich technique, compomer, cervical margin, SEM, OM.

The use of the adhesive materials is widespread for all types of dental restorative treatments. In cavities with the gingival margin located in the root cement, achieving the adhesion is challenging due to increased risk for cervical gap and microleakage and consequently secondary caries [1-5].

Many researchers tried to assess the ability of various restorative materials to seal the cervical margins. Most results showed that sealing of the cement or dentine margins is weaker comparing to the sealing of the enamel margins. There still exists a lot of controversies on which material is best suited for sealing the dentin and cement in cervical areas.

The sandwich technique, as an alternative to the restoration with composite resins, was proposed to solve this problem. In the conventional sandwich technique the glass-ionomer cement is used to replace the lost dentin while the composite resin is used as enamel substitute. The expectations from the lamination technique are to combine the advantages of both glass-ionomer cements and composite resins in order to enhance the clinical serviceability of the restoration [6, 7]. In the open sandwich technique, the glassionomer cement remains exposed to the oral environment in the cervical area [8-10].

The modern approaches have proposed the use of open sandwich restorations with resin-modified glassionomer cements and compomers in the cervical area instead of conventional glassionomer cements.

When using open-sandwich restorations, two interfaces should be considered: bonding of the laminated materials to each other and bonding of each material to the tooth structures. The loss of adhesion between the materials can determine discolorations, fractures and loss of composite resin restorations, failures that can be solved by the rehabilitation procedures. The adhesive failure of restorative materials at the cavity walls represents a higher risk associated to microleakage and infiltration of bacteria and their by-products in dentine, followed by recurrent dental caries and pulp inflammation.

The aim of this study was to assess the quality of the interface between dental root cement and two types of restorative materials (a compomer and a conventional glass ionomer cement) used with composite resins in the open sandwich technique.

Experimental part

Materials and methods

30 molars, extracted for orthodontic reasons, were cleaned and stored in distilled water. Standardised cavities (3mm x 2mm x 1.5mm) with gingival wall in root cement were prepared on the buccal and oral surfaces. The teeth were randomly divided in 3 groups. Different materials combinations were used in buccal and oral cavities (table 1). In the control group, the cavities were filled only with composite resins (Control F-Filtek Z250 - 3M ESPE for buccal surface, Control Z- Zmack Comp -Zermack for oral surface); in the test groups the cavities restorations were performed with the open sandwich technique as follows: in group 1 the composite resin Filtek Z250 was used in combination with Dyract (group 1 F-D), respectively Ketac Molar Easymix (group 1 F-KM); in group 2 the composite resin Zmack Comp was used in combination with Dyract (group 2 Z-D), respectively Ketac Molar (group 2 Z-KM).

For all the groups, the restoration were performed according to manufacturer's indications for each tested material. The light cured materials were polymerized using the lamp LEDidition - Ivoclaire Vivadent clinical, Austria.

In the control groups, 2 layers of composite were inserted and each layer was polymerised for 40 s. For the study groups, a layer of 1mm thickness of conventional glassionomer cement or compomer was used on the gingival floor and the rest of the cavity was filled with one layer of composite resin. Lightcuring for 40 s was used for the composite and for the compomer layers.

All restorations were polished with polishing system Sof-Lex (3M ESPE). The teeth were stored in distilled water at room temperature for 24 h. The teeth were isolated with a varnish resistant to acid, leaving a 2mm window around

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Table 1
THE COMPOSITION OF THE RESTORATIVE MATERIALS USED IN STUDY

MATERIALS	CATEGORY	COMPOSITIONS	MANUFACTURER
Filtek Z 250	Universal microhybrid composite	Bis-GMA, Bis-EMA, UDMA (0,01-3,5 µm zirconium/silica filler) 60% by volume	3M ESPE Dental Products, St.Paul, USA
Adper Single Bond 2	Adhesive system total etch	Bis-GMA, HEMA, dimethacrylates, ethanol, water, a novel photoinitiator system and a methacrylate functional copolymer of polyacrylic and polyitaconic acids (10 % by weight of 5nm diameter spherical silica filler)	3M ESPE Dental Products, St.Paul, USA
Zmack Comp	Universal microhybrid composite	Dymethacrylate resin (EBDADMA), TEGDMA, photo initiators, stabilizer, fillers: barium-aluminium-borosilicate <1,5 µm; highly dispersed silicon dioxide 0,04 µm; iron oxide pigments; titanium oxide (57%	Zermack SpA, Italy
Zmack bond total-etch adhesive	Adhesiv system total etch	Carboxylic acid modified dimethacrylate; phosphoric acid modified acrylate resin; UDMA: methacrylate resin; TEGDMA: methacrylate resin; HEMA; Camphorquinone: photoinitiator; Stabilizer: butylated benzenediol; Tertiary-butanol: solvent (< 25%)	Zermack SpA, Italy
Ketac Molar Easymix	Glass ionomer cement	Liquid: Water, copolymer of acrylic acid-maleic acid; tartaric acid Powder: oxide glass ; copolymer of acrylic acid-maleic acid; dichlorodimethylsilane reaction product with silica	3M ESPE, St.Paul, MN, USA
Dyract eXtra	Compomer	Ethoxylated Bisphenol-A dimethacrylate, urethane resin, triethylene glycol dimethacrylate (TEGDMA), and trimethylolpropane trimethacrylate (TMPTMA); strontium fluoride glass 0.8 µm	Dentsply De Trey GmbH Germany
Prime&Bond NT	adhesive	Di- and Trimethacrylate resins PENTA (dipentaerythritol penta acrylate monophosphate) Nanofillers-Amorphous Silicon Dioxide Photoinitiators Stabilizers Cetylamine hydrofluoride Acetone Caulk 34% Tooth Conditioner Gel: Phosphoric Acid Highly dispensed silicon dioxide Colorant Water	Dentsply De Trey GmbH Germany

restorations and then immersed in 1% methylene blue solution (Vitalia Pharma, Romania) for 24 h. The samples were longitudinally sectioned through centre of restorations using a diamond disc.

The sections were examined under optical digital microscopy, Leica CTR4000 (Leica Microsystems) and microscope SEMQUANTA 200 3D (FEI, USA), in mode ESEM(Enviromental SEM).

The dye penetration was assessed accordingly to the scores as follows (ISO/TS 11405-2003):

- 0 = no dye penetration;
- 1 = dye penetration into the enamel/cement part of the cavity wall;
- 2 = dye penetration into the dentine part of the cavity wall but not including the pulpal floor of the cavity;
- 3 = dye penetration including the pulpal floor of the cavity.

The tested hypothesis sustained the absence of significant statistically differences between microleakage scores of glass ionomer base and compomer base for both tested composite resins. The data were statistically analysed using Kruskal-Wallis and Mann-Whitney tests.

SEM microscopy was used to evaluate the interfaces between the gingival wall and the adjacent material and to detect the existence of the adaptation failures and their type as follows: cohesive (in the materials mass or dental tissues structure), adhesive (interface tooth/material) and combined.

Results and discussions

Optical microscopy and SEM are frequently used for the assessment of the interface between the restorative materials and dental tissues [11, 12].

Leakage has long been recognized as a problem in restorative dentistry [13]. In cavities with margins located in the root cement, the marginal leakage represents a more complicated problem due to the features of dental tissues involved and to the higher risk of contamination.

Microleakage evaluations are used to estimate the resistance of tooth-restoration interface to the passage of bacteria, fluids, chemical substances, molecules and ions [14-16]. In this study we used methylene blue for microleakage evaluation because it had been previously demonstrated that the capacity of the dyeing solution to

penetrate glass ionomer cement did not influence the validity of the results [17].

There are studies that found no significant differences in the microleakage between compomers and traditional glass ionomers [18]. Most of the studies concluded however that no material was able to completely eliminate microleakage.

In our study the recorded images proved the existence of samples where the percolation was absent (fig. 1.a). The scores 1 and 2 were frequently recorded for all groups (fig. 1.b), and score 3 was rarely recorded (fig. 1.c).

The mean values of ranks and penetration scores, recorded in optical microscopy, on study groups, are presented in table 2. The order of these data is as follows: Group 2 Z-D (0.30) < Control Z(0.50) < Group 1 F-D(0.60) < Control F (1.00) = Group 2 Z-KM(1.00) < Group 1 F-KM (1.70). Accordingly to the standard deviation the order is as follows: Group 2 Z-D (0.483) < Control F (0.667) < Group 1 F-D (0.699) < Control Z (0.707) < Group 2 Z-KM(1.054) < Group 1 F-KM (1.160).

Table 3 shows the results of Wallis test, which showed statistically significant differences of the microleakage between the groups ($p < 0.05$).

Mann-Whitney test showed the significant statistical differences only for Group 1 F-KM comparing to Group 1 F-D ($p < 0.05$). The differences were not statistically significant for the other investigated groups (table 4).

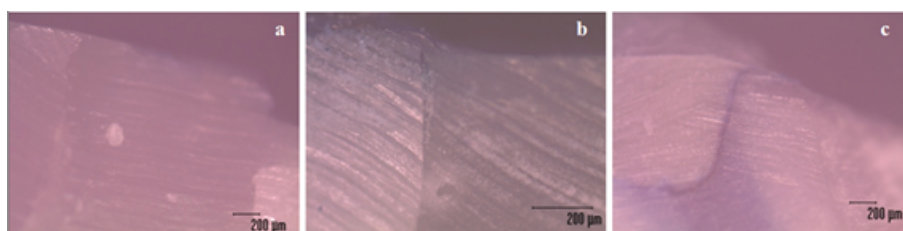


Fig. 1. Optical microscopy image of the interface between the gingival wall and the restoration material (a. Group 2 Zmack Comp-Dyract; b. Control group Zmack Comp ; c. Group 1 Filtek Z250-Ketac Molar Easymix)

	N	0	1	2	3	Mean	Mean Rank	Std. Deviation
CONTROL F	10	2	6	2	0	1.00	35.30	.667
CONTROL Z	10	6	3	1	0	.50	24.40	.707
GROUP 1 F-KM	10	2	2	3	3	1.70	43.25	1.160
GROUP 1 F-D	10	5	4	1	0	.60	26.75	.699
GROUP 2 Z-KM	10	4	3	2	1	1.00	32.75	1.054
GROUP 2 Z-D	10	7	3	0	0	.30	20.55	.483
Valid N (listwise)	10							

Table 2
MEAN SCORES, RANKS AND STANDARD DEVIATIONS FOR DYE PENETRATION OF CONTROL AND STUDY GROUPS

Table 3
THE RESULTS OF KRUSKAL WALLIS TEST FOR DYE PENETRATION OF CONTROL AND STUDY GROUPS

Test Statistics ^{a,b}	DYE PENETRATION
Chi-Square	12.814
df	5
Asymp. Sig.	0.025

a. Kruskal Wallis Test

b. Grouping Variable: LOT

	P Value
CONTROL F	0.100
CONTROL Z	
CONTROL F	0.132
GROUP 1 F-KM	
CONTROL F	0.185
GROUP 1 F-D	
CONTROL Z	0.267
GROUP 2 Z-KM	
CONTROL Z	0.557
GROUP 2 Z-D	
GROUP 1 F-KM	0.030
GROUP 1 F-D	
GROUP 2 Z-KM	0.101
GROUP 2 Z-D	

Table 4
THE RESULTS OF MANN-WHITNEY STATISTICAL TEST FOR DYE PENETRATION OF CONTROL AND STUDY GROUPS

The higher mean values of microleakage scores for glass ionomer base than compomer base might be a consequence of the weaker adhesion to dentine and cement of Ketac Molar Easymix. However these differences were significant only for composite resin Filtek Z250 and the mean values of microleakage were higher for all the groups restored with Filtek Z250 comparing to the homologous group restored with Zmack Comp. These results suggests that the covering material can influence the sealing ability of the base material at the gingival margins in open sandwich restorations. The simplest explanation would be related to the polymerization shrinkages of the composite resins which might "pull out" the base if the bonding between the materials overpass the adhesion to the gingival wall. However for the tested materials, volumetric shrinkage during polymerization does not seem to play a significant role: 2.46% for Zmack Comp according to the brochure and 1.99% for Filtek Z250 according to Nagem at all [19]. Therefore some other mechanisms like the bond strength between composite and the base material, elastic modulus of composite resin or water sorption should be investigated to explain the phenomenon.

SEM images supported the results related to the microleakage study. The samples with the compomer as base showed a better adhesion to dental structures (fig. 2a) comparing to the glassionomer groups. The adhesive failures were associated to the interface between compomer and composite resin and not to the cavity walls and not to the cavity walls (fig. 2b and c).

The glass ionomer bases showed frequent voids and fractures at the interface with gingival wall as well as cohesive fractures (fig. 3a and b).

Glass ionomer cement has been recommended as a filling material for restoring cervical lesions because of its ability to chemically bond to dental tissues, biocompatibility, cariostatic effect and good dimensional stability. There are also several disadvantages related to the difficulty to obtain the ideal consistency, the prolonged setting time, the sensitivity to humid environment during primary setting and the surface roughness. A major deficiency of glass ionomer cements is represented by the presence of voids in their mass, due to the incorporation of air during material preparation. In addition GIC have been shown to be less able to seal margins and can dissolve over time [20, 21].

In our study, the conventional glass ionomer cement (Ketac Molar Easymix) was associated with all types of failures. The most frequent failures were observed when this material was used as base for restorations performed

with composite resin Filtek Z 250. Less frequent failures were observed when Ketac Molar Easymix was used in combination with composite resin Zmack Comp.

A higher percent of proper cervical sealing was observed for samples with compomer Dyract used in the area of gingival wall. Dyract, as a compomer material, is a polyacid-modified composite resin containing either or both of the essential components (basic glass and acidic polymer) of a GIC but at levels insufficient to promote the acid base cure reaction in the absence of light [22]. After initial light-activated polymerization, the traditional glass-ionomer reaction slowly emerges through the uptake of water, activation of carboxylic groups of the dimethacrylate monomer, and the establishment of an acid-base reaction [23, 24]. Due to its structure, Dyract has better mechanic properties than traditional glass ionomer and the adhesion to dental tissues is improved as a result of using bonding systems.

Our findings were consistent with the results of previous studies. Burrow et al found numerous air inclusions within the cement [25]. They believed that these air inclusions acted as stress points, thus giving rise to the increased likelihood of cohesive failure within the cement. When comparing bond strength and microleakage of composite, compomer and glass ionomer cement, Xie et al suggested that according to the failure mode analysis, the glass ionomer cement specimens exhibited cohesive failures more often [20]. They found that the bond of glass ionomer to dentin was much stronger than its cohesive strength. Such defect were rarely observed for compomer and composite resin and better adaptation at the dentine-composite and dentine-compomer interfaces were observed which is also consistent with our results. In case of both composites and compomers the bonding systems counteracts the polymerization shrinkage and contributes significantly to create a better sealing to dentin and cement than glass ionomer [26, 27]. The lower flexural modulus of elasticity of compomers might also contribute to prevent separation of the restoration from the cavity walls.

On the contrary Recka et al found more microleakage when using a compomer -Compoglass than a traditional glass ionomer - Fuji IX [28]. This could be related with the wear phenomena which affect also the resin-based materials and involve complex degradation processes. Our study did not evaluate the interface when subjected to corrosive, abrasive, thermal and fatigue challenges. Even storage in slight acid or alkaline solutions might result in micro-pores formation in resin-based materials [29]. Further research is necessary to evaluate the influence of

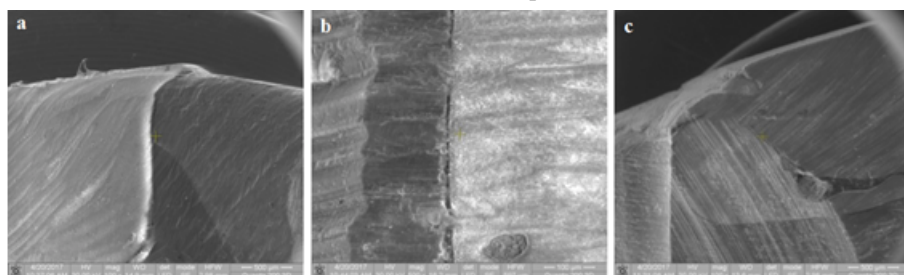


Fig.2. SEM evaluation of the interface between gingival margin and compomer (a, b- group 2 Z-D; c- group 1 F-D)

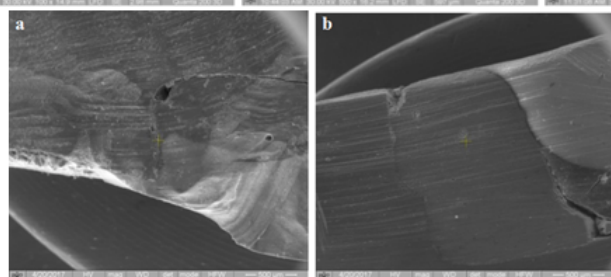


Fig.3. SEM evaluation of the interface between gingival margin and glass ionomer cement (a- group 2 Z-KM; b- group 1 F-KM)

the ageing processes on laminated restorations in simulated oral environment.

Fourie and Smit also found that the open-sandwich technique significantly reduced the microleakage when Ketac molar set with ultrasound was used as a base for Filtek Z250 [30]. These results might be explained by reducing the air bubbles within the material and improved cohesive strength of the material as a result of using ultrasounds for setting.

On the other hand, Moazzami et al founded that none of the four sandwich technique composite restorations used in the study, one of them being the compomer-Compoglass didn't reduce gingival microleakage to a greater degree than the incremental technique [31].

These controversial results are due to the differences in experimental designs, testing methods and tested materials.

In sandwich restorations the adhesive bond strength of the material to dentin cannot be used as the only criterion of success. In fact good adhesion can in certain cases to promote cracking of the dentin due to the stress developed within the material [32, 33]. Also a good adhesion between the two materials might debond not only the composite material but also the underlying base, resulting in increased microleakage between the cavity wall and the adjacent materials [34]. Several characteristics of the coating material should be considered when deciding to use such technique. Polymerization shrinkage, elastic modulus, water sorption are some of the characteristics that might influence the ability of underlying material to seal the margin. Also, microleakage and secondary caries can also be influenced by the existence of gingival secretions in periodontal disease [35]. More investigation is necessary to address the question of the most suited combination of materials for sandwich restorations.

Conclusions

The optical microscopy showed more dye penetration when the conventional glassionomer was applied on gingival wall in the open sandwich technique comparing to the compomer used in the same technique. The best results regarding the ability of open sandwich restoration to seal the cement margin, highlighted both by optical microscopy and SEM, were recorded when the compomer Dyract eXtra was used in combination with the composite resin Zmack Comp. Considering that the marginal sealing represents a challenge for dental practitioner, the proper combination of materials must be selected accordingly to the clinical situation.

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