

***In vitro* Comparative Study on the Marginal Adaptation of Direct, Semi-direct and Indirect Composite Resins Restorations to Dentine and Dental Cementum**

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The aim of the present study is to compare the marginal adaptation of direct, semi-direct and indirect restorations made with nanofill and microhybrid composite materials and ormocers materials bonded with SE adhesives at the dentin and cementum. 120 standardized class II cavities were prepared (40 for each techniques- RD, RSD, RI) with the gingival margin over and below to the cementum-enamel junction. The teeth (n= 20) were restored using one of three adhesive systems (OptiBond XTR, G-Premio Bond bottle refill, Futurabond U) with incrementally placed composite restorations and ormocers. After applying the various restorations, the teeth were prepared for SEM analysis to check the marginal adaptation by the presence of continuous margins or gaps. Comparative analysis of treatment methods and materials used was performed by statistical analysis of Chi-square test data, the statistical significance was $p < 0.05$ and Fisher's Exact Test for validation of results. It was found that among the three materials used for RD, RSD, RI both at the dentin and the cementum, there are no significant differences ($RD\ d = 0.661$, $RSD/d = 0.755$, $RSD/c = 0.942$; $RI/d = 0.739$; $RI/c = 0.985$). Comparison between the presence of continuous margins/gaps subgingivally and supragingivally at the three types of restorations shows that there are significant differences between the marginal adaptation at the cementum and dentin to all the restoration techniques used ($p < 0.05$). Direct and indirect restorations with nanocomposites and ormocers bonded with 1-step SE adhesive are the best solutions for restoring the posterior teeth.

Keywords: direct restorations, indirect restorations, semi-direct restorations, inlay, marginal adaptation

The use of aesthetic restorations in the posterior dental area is already a standard procedure. The materials used are composite and ceramic resins and the techniques used are direct (RD), semidirect (RSD) and indirect (RI) restorations.

The direct adhesive technique in the posterior area is used for restoring small and medium sized cavities, but for large sized cavities, indirect techniques are recommended.

Indirect techniques show a number of advantages in terms of reducing the polymerization shrinkage that occurs only at the cementing resin level, the ability to achieve an interdental contact point and a more accurate anatomical modeling, and thus a very rigorous marginal adaptation. Marginal adaptation is a criterion for appreciating the longevity of a restoration. This reduces the possibility of mikroleakage and, ultimately, marginal discolorations, secondary caries or postoperative sensitivity.

Other important advantages in using indirect restoration are increasing bond strength, increasing surface hardness and reducing the risk of fractures and cracks in the internal structure of the material [1].

Semidirect restorations are made by applying and curing the resin into the cavity, then they are subjected to heat treatment and light outside the oral cavity.

Direct inlays are achieved by lightcuring the composite in the prepared dental cavity, then extracuring outside the oral cavity, indirect inlays are obtained after an impression of the preparation.

Indirect composites represent an alternative to posterior teeth ceramic restorations, especially to prevent the occurrence of the abrasion phenomenon of the antagonist teeth determined by this material.

A new generation of composites is classified by Touati quoted by Torabzadeh H et al. 2013 as second-generation

laboratory composites or optimized ceramic polymers (Ceromeri) [2].

Manufacturers and research data claim that they offer improved bending strength, increased elasticity, and fracture resistance as compared to direct composites [2].

The aim of this study is to evaluate the marginal adaptation of direct, semidirect and indirect restorations made with nano composite filling materials (Premise™, Estelite Sigma Quick), microhybrid composite (Gradia direct), ceromers (Crea.ling Bredent, Ceramage Shofu ArtGlaze, Hereus) and ormocer (Admira Fusion) bonded with 2-step self-etch adhesive systems (OptiBond XTR) and 1-step self etch (G-Premio Bond bottle refill) and dual cure cement (Futurabond U) at the dentin and cementum.

Experimental part

The study included 60 extracted teeth collected from anonymous patients. Prior to the treatment, patients were informed about the use of teeth in research studies and gave their consent to the use of biological material for research purposes.

The teeth were cleaned and disinfected to a short sterilization cycle in the autoclave and then rehydrated for 48 hours in physiological saline solution. The teeth were divided into 3 groups of 20 teeth each which were prepared with standardized 2nd class cavities on both proximal surfaces, in order to be restored through direct restorations (group 1 RD) and semidirect (group 2 RSD) and indirect (group 3 RI) as follows: on the distal surfaces the gingival extension was 1 mm above the enamel-cementum junction, on the mesial surfaces, 1 mm below it.

The restorations were made with composite resins and adhesive systems according to table 1.

Prior to application of the adhesive, the dental structures were treated with 37% phosphoric acid by total etching technique.

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Table 1
COMPONENT OF STUDY BATCHES

Batch 1 RD		Batch 2 RSD		Batch 3 RI	
Composite	Adhesive	Composite	Adhesive	Composite	Adhesive
Premise™	G-Premio Bond	Admira Fusion	Futurabond U	Ceramage Shofu	Adhese Universal viva Pen, Ivoclar
Gradia direct	OptiBond XTR	Premise	OptiBond XTR	Crea.ling Bredent	Adhese Universal viva Pen, Ivoclar
Admira Fusion	Futurabond U	ESTELITE	G-Premio Bond	Art Glass Hereus	Adhese Universal viva Pen, Ivoclar

The materials used for the study and their composition are presented in table 2.

After applying different restorations, by means of a high speed diamond bur and under cooling, mesial and distal aspects of the teeth were prepared such that flat surface exposure of the preparation, restorations and the area between restoration and dental structures could be seen and examined.

The exposed area was polished with plastic discs and soft discs for better exposure for SEM analysis.

The teeth were prepared for SEM analysis by exposing them to a gold spraying system. Using a mini-gold sprayer, gold is sprayed for 30 seconds at a pressure of ~70 mTorr. A different thickness of the gold layer may be required depending on the geometry of the sample. Coarser or porous surfaces require a longer spraying time (fig.1).

The analysis of the marginal adaptation was performed using the Quanta Inspect F electronic microscope equipped with field emission gun (FEM) with a resolution of 1.2 nm and an energy dispersive X-ray spectrometer (EDS) with a resolution of 133 eV MnK (fig. 2).

Material	Composition
Premise™, Kerr	Bis-GMA Filling 69%, 84% wt: Silica nanoparticles 0.02µ, prepolymerized filler 30-50µ, sticlă of barium of 0,4 microns
OptiBond XTR Kerr, universal	Ethyl alcohol 20-30% Alkyldimethacrylate 47-68% barium aluminoborosilicate glass 5-15% silicon dioxide (silicon dioxide) 3-10% sodium hexafluorosilicate 0.5-3%
Gradia direct, Denta Products Corp, Tokyo, Japan	Matrix: urethane dimethacrylate (UDMA) 20-25% Ethylene dimethacrylate Filling: 65% volume Silica, pre-polymerized particles, flour-alumino-silicate glass
Admira Fusion, Voco GmbH, Cuxhaven, Germany	Matrix: Ormocer resin Filling: silicon oxide nano filler, glass ceramics filler (1 µm)
Futurabond U Voco GmbH, Cuxhaven, Germany	Liquid 1: 2-hydroxyethyl methacrylate monomers (10-25%) (HEMA), BIS-GMA (10-25%), Urethanedimethacrylate (2.5-5%) (UDMA) Liquid 2: Ethanol (10-25%), initiator, catalyst, silicic pyrogenic acid (2.5-5%).
Variolink Esthetic DC Ivoclar Vivadent	Matrix: Bis-GMA, dimethacrylate urethane, glycidyl dimethacrylate Filler (0.04-3.0 µm, average particle size 0.7 µm.) -ytterbium trifluoride, barium glass, Ba-Al-fluorosilicate glass beads -catalysts, stabilizers and pigments.
G-Premio Bond bottle refill, GC, Japonia	Acetone (25-30%), 2-hydroxy-1,3-dimethacryloxyp propane (10-20%), methacryloyloxydecyl dihydrogen phosphate (5-10%), 2,2-ethylenedioxydiethyl dimethacrylate (1-5%), diphenyl (2,4,6-trimethylbenzoyl) phosphine oxide (1-5%), 2,6-di-tert-butyl-p-cresol (<0.5%).
Crea.ling Bredent GmbH & Co. KG	pure nano-composite which does not contain glass filling tetramethylene dimethacrylate 2-propenoic acid reaction products with pentaerythritol (PETIA / PETTA), diphenyl (2,4,6-trimethylbenzoyl) -phosphine oxide (TPO) 7,7,9(or7,9,9)-trimethyl-4,13-dioxo-3,14-dioxo-5,12-diazahexadecane-1,16-diyl bismethacrylate (25-50%) tetramethylene dimethacrylate (10-25%), inorganic fillers, initiators and colorants
Ceramage Shofu,	Matrix UDMA, 2-HEMA, urethane diacrylate Filling 73% zirconium silicate (PFS-progressive fine structured filler) pigment, photoinitiator, zirconium silicate.
ArtGlass Hereus	Matrix - 30% organic resin (bis DMA, TEGMA.) In addition to conventional bifunctional molecules, Artglass contains four to six functional groups which offer the possibility of multiple conversions with double photoinitiator bindings. Filling - filling of 70% by weight of siliconized barium-siliconized aluminum silicon 0.7 µm, silicon dioxide. [11]

Table 2
MATERIALS AND
APPLICATION TECHNIQUE
USED IN THE STUDY

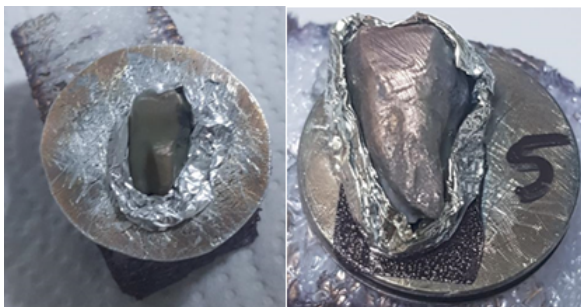


Fig.1 Exposure of the teeth to the mini-gold sprayer



Fig.2 Quanta Inspect F
Electronic scanning microscope

The final scheme of the study protocol is shown in figure 3.

SEM analysis of marginal adaptation was performed using the following criteria:

- Continuous margins when there is no space between the restoration material and the dental structures;
- The presence of voids/gaps when there is space between the restoration material and the dental structures.

Statistical analysis

The data were analyzed using the SPSS statistical program package (IBM SPSS 20.0, SPSS Inc., Chicago, IL, USA). Descriptive and of distributions frequency statistics were used to compare the incidence of gaps of dental structure (dentine, cementum) - restoration material interfaces for the three restoration techniques (RD, RSD, RI).

Comparative analysis of treatment methods and materials used was performed by statistical analysis of Chi-square test, the statistical significance was $p < 0.05$ and Fisher's Exact Test for validation of results.

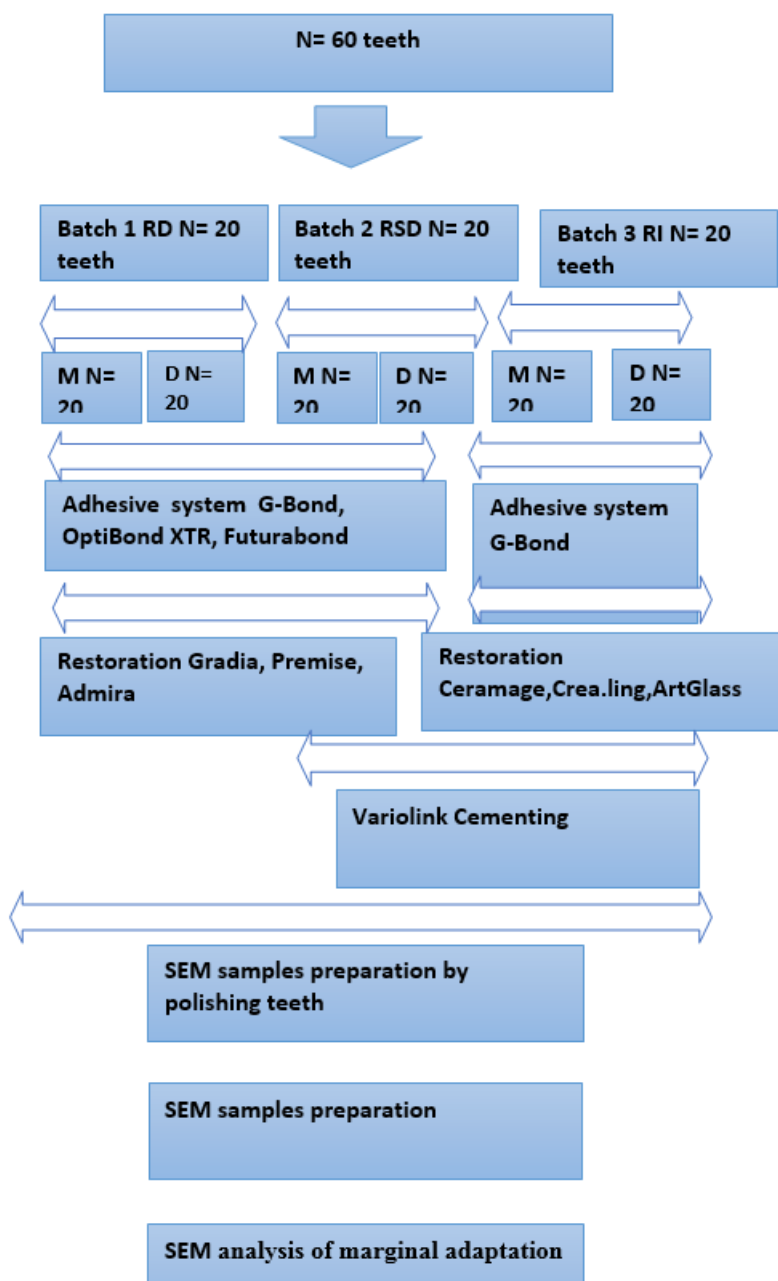


Fig. 3.

Results and discussions

According to the established criteria (continuous margins, gaps), the SEM analysis of the restoration/dentin/cementum interfaces of the three groups is presented in the following figures (figs. 4-9)

Group RD Below CEJ

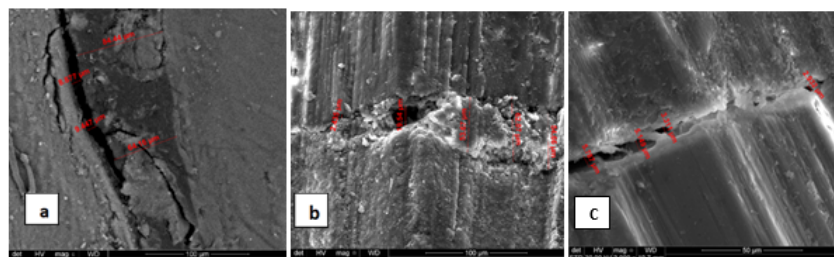


Fig.4a Premise Kerr/ G-Premio Bond; b. Gradia direct / OptiBond XTR; c. Admira Fusion/ Futurabond U

Above CEJ

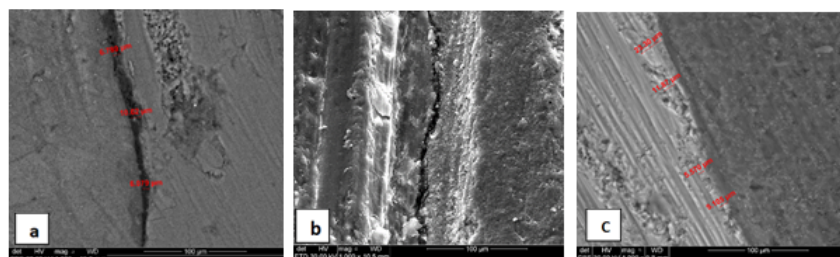


Fig.5. a. Premise Kerr/ G-Premio Bond; b. Gradia direct / OptiBond XTR; c. Admira Fusion/ Futurabond

Group 2 RSD Below CEJ

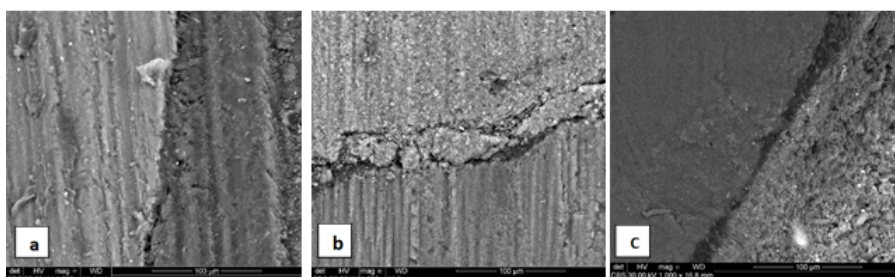


Fig. 6a. Estelite / G-Premio Bond/Variolink; b. Premise Kerr/ OptiBond XTR; c. Admira Fusion/ Futurabond U

Above CEJ

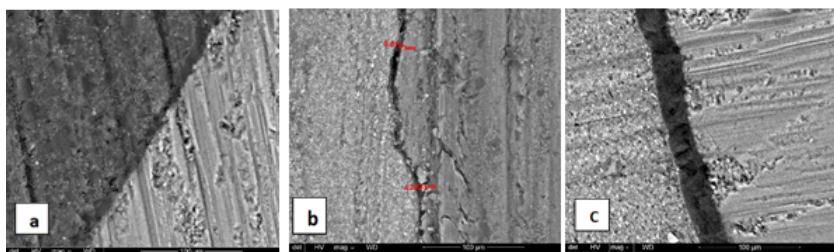


Fig.7a. Estelite / G-Premio Bond/ Variolink; b. Premise Kerr/ OptiBond XTR; c. Admira Fusion/ Futurabond U

Group RI

Below CEJ

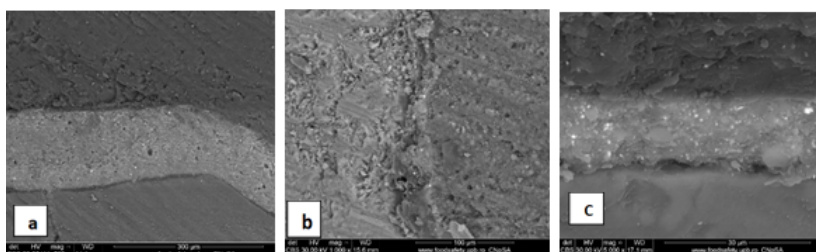


Fig. 8a. Artglass; b. Ceramag; c. Bredent

Above CEJ

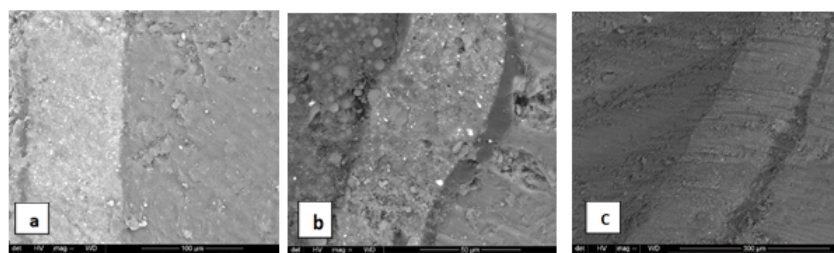


Fig.9a. Artglass; b. Ceramag; c. Bredent

We calculated the mean and standard deviation to compare the materials used according to established criteria (continuous margins, presence of gaps). It was found that among the three materials used for RD, RSD, RI at both the dentin and the cementum, there are no significant differences (RD/d = 0.661, RSD/d = 0.755, RSD/c = 0.942; RI/d = 0.739; RI/c = 0.985).

We then used mean and standard deviation to compare the restoration techniques used.

Below CEJ

	Mean	Std. Deviation	Std. Error	p-value
RD	10%	0.308	0.069	0.116
RSD	15%	0.366	0.082	
RI	35%	0.489	0.109	

Above CEJ

	Mean	Std. Deviation	Std. Error	p-value
RD	65%	0.489	0.109	0.428
RSD	55%	0.510	0.114	
RI	75%	0.444	0.099	

$p > 0.05$ there are no significant differences among the three restoration techniques.

Comparing the media among the restoration techniques, it has been pointed out the absence of significant differences. Comparison of areas with gaps was done with the Pearson Chi-Square test and for validation, Fisher's Exact Test.

Below CEJ

Batch * Material1 Crosstabulation									
Count									
		Material1							Total
		Gradia direct + G-Premino	Premise + OtiBond	Admira Fusion + Futurbond	Estelite	Ceramage	Crealing	Art glas	
Batch	RD	7 _a	6 _b	5 _b	0 _b	0 _b	0 _b	0 _b	18
	RSD	0 _a	7 _{b, c}	6 _{b, c}	4 _c	0 _a	0 _{a, b}	0 _{a, b}	17
	RI	0 _a	0 _a	0 _a	0 _a	5 _b	4 _b	4 _b	13
Total		7	13	11	4	5	4	4	48

Each subscript letter denotes a subset of Material1 categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests						
	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	63.289 ^a	12	.000	.000		
Likelihood Ratio	71.461	12	.000	.000		
Fisher's Exact Test	49.560			.000		
Linear-by-Linear Association	34.125 ^b	1	.000	.000	.000	.000
N of Valid Cases	48					

a. 21 cells (100.0%) have expected count less than 5. The minimum expected count is 1.08.

b. The standardized statistic is 5.842.

Above CEJ

Batch* Material1 Crosstabulation									
Count									
		Material1							Total
		Gradia direct + G-Premino	Premise + OtiBond	Admira Fusion + Futurbond	Estelite	Ceramage	Crealing	Mat x	
Lot	RD	3	2	2	0	0	0	0	7
	RSD	0	2	4	3	0	0	0	9
	RI	0	0	0	0	1	2	2	5
Total		3	4	6	3	1	2	2	21

Chi-Square Tests						
	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	29.556 ^a	12	.003	.000		
Likelihood Ratio	31.799	12	.001	.001		
Fisher's Exact Test	20.329			.001		
Linear-by-Linear Association	15.134 ^b	1	.000	.000	.000	.000
N of Valid Cases	21					

a. 21 cells (100.0%) have expected count less than 5. The minimum expected count is .24.

b. The standardized statistic is 3.890.

Both at dentine and cementum level, there are significant differences among the materials used ($p < 0.05$).

The comparison between the continuous margins/gaps supra and subgingivally at the three types of restoration

used shows that there is no association among them, so there are significant differences among the marginal adaptation at cementum and dentine level in all the restoration techniques used.

Chi-Square Tests							
Lot		Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
RD	Pearson Chi-Square	12.907 ^d	1	0.000	0.001	0.000	
	Continuity Correction ^b	10.667	1	0.001			
	Likelihood Ratio	14.024	1	0.000	0.001	0.000	
	Fisher's Exact Test				0.001	0.000	
	Linear-by-Linear Association	12.584 ^e	1	0.000	0.001	0.000	0.000
	N of Valid Cases	40					
RSD	Pearson Chi-Square	6.833 ^f	1	0.008	0.019	0.009	
	Continuity Correction ^b	5.385	1	0.020			
	Likelihood Ratio	7.362	1	0.007	0.019	0.009	
	Fisher's Exact Test				0.019	0.009	
	Linear-by-Linear Association	6.857 ^g	1	0.009	0.019	0.009	0.008
	N of Valid Cases	40					
RI	Pearson Chi-Square	6.465 ^h	1	0.011	0.025	0.012	
	Continuity Correction ^b	4.949	1	0.026			
	Likelihood Ratio	6.660	1	0.010	0.025	0.012	
	Fisher's Exact Test				0.025	0.012	
	Linear-by-Linear Association	6.303 ⁱ	1	0.012	0.025	0.012	0.011
	N of Valid Cases	40					
Total	Pearson Chi-Square	24.859 ^a	1	0.000	0.000	0.000	
	Continuity Correction ^b	23.052	1	0.000			
	Likelihood Ratio	25.903	1	0.000	0.000	0.000	
	Fisher's Exact Test				0.000	0.000	
	Linear-by-Linear Association	24.652 ^c	1	0.000	0.000	0.000	0.000
	N of Valid Cases	120					

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 25.50; b. Computed only for a 2x2 table;

c. The standardized statistic is 4.965; d. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.50; e. The standardized statistic is 3.547; f. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.00; g. The standardized statistic is 2.619; h. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.00; i. The standardized statistic is 2.511.

In this study we analyzed through SEM the integrity and marginal adaptation of some restorations made with composite resins by direct, semi-direct and indirect techniques. SEM analysis is the most efficient method for determining gaps and, therefore, appreciating the continuity of tooth - restoration material interfaces.

The root cementum has so far been much less studied than other dental structures in terms of adhesion. Perhaps for this reason, at least nowadays, not only are there fewer things known about this subject, but the results obtained are not so clear. Root cementum has properties closer to dentin, but with a different physico-chemical structure [3].

Correa Netto et al. [4] and Shim et al. [5] reported in their studies that the success of direct and indirect restorations depends on several factors, one of the most important being marginal adaptation.

In this study, a significant difference was observed between the marginal adaptation for gingival limit restorations in cementum/dentin as compared to dentinal gingival restorations. ($p < 0.005$).

Araujo et al. and Tredwin et al. quoted by Dhingra V. [6] reported that cementum/dentine edge restorations have significantly microleakage than those with enamel location. This difference can be explained by the structure of substrates, dentin and cementum have a greater proportion of water and organic material than enamel, which makes it difficult to obtain an adhesive capable of resisting the adverse effects of polymerization shrinkage, thermal stress.

In this study we used self-etching adhesive systems, one step G-Premio BOND and self-etch, 2 steps OptiBond XTR. Compared to ER adhesive systems, SE adhesive systems have some advantages over the lack of acid scaling as a separate step, so washing and drying after demineralization is eliminated, and clinical efficiency is improved by reducing working time. Elimination of washing and drying phases presents another advantage related to the elimination of *postoperative sensitivity* associated with adhesion to demineralized dehydrated dentine [7].

These properties may explain, at least in part, the result that SE adhesive systems produce a larger *continuous* interface. Self-etching systems use different acid primers to alter and/or solubilize the smear layer, and although it does not wash, as in the case of total etch systems, direct interaction of the dentine substrate adhesive is achieved [8].

To enhance the wetting, spreading and penetration of the polymerizable monomers in the dentine, different solvents are used as *thinning agents*. These solvents are typically water, ethyl alcohol, butyl alcohol or acetone. The first three are very hydrophilic and thus increase the interaction of monomers with surface water, while acetone assures the displacement of water inside the dentin. Thus, this solvent is incorporated into the hybrid layer and can be a contamination factor that can cause the adhesion to weaken. The monomers in dental adhesives are similar to those used in dental composites, thus ensuring a strong interaction between the adhesive and the composite [8].

In this study we used an adhesive system containing ethanol (G-Premio Bond bottle refill) and one with acetone as solvent (Optibond XTR). The results obtained showed that RD made with Premise (universal nanoparticles with trimodal and prepolymerized particles) and G-Premio Bond bottle refill showed at the level of the cement a relatively uneven adhesive layer with an average thickness of 70 μm and the presence of the gaps of approx. 9 μm , while the combination of Gradia and Optibond XTR showed larger gaps, of approx. 20 μm . Kurtzman GM shows that Premise

Restoration through G-Premio Bond forms a thin layer of adhesive which reduces the number of gaps [9]. At the dentine level there were no gaps and the thickness of the adhesive layer was on average 8 μm .

Recently, some manufacturers have introduced universal adhesives that can be used with self-etching and etch and rinse techniques, selective or total etch techniques [10]. In this study, the association between Admira Fusion and Futurabond U (Voco) (8th generation universal bonding agent containing nanomaterials) determined the presence of small sized gap areas (2.93-5.78 μm) and at the level of the dentin the presence of a very good adhesion without gaps.

Most of the internal gaps in the current study were observed at axiopulpal line angles. This finding agrees with those of Souza-Junior et al. [11].

Teeth with indirect restorations are potentially less susceptible to deterioration than those with direct restorations.

Composite inlays provide better sealing compared to direct restorations [12].

The polymerization shrinkage determines the level of stress in teeth with direct restorations, while its impact on adherence to indirectly restored teeth is insignificant.

At RSD and RI, the larger the marginal gaps, the higher the dissolution rate of the cement. Although rarely clinically achieved, the ideal size of marginal gaps should be 25-40 μm [13].

However, the statistical analysis showed that among the three materials used for RD, RSD, RI at both the dentine and the cement level, there are no significant differences ($RD/d = 0.661$; $RD/c = 0.586$; $RSD/d = 0.755$; $RSD/c = 0.942$; $RI/d = 0.739$; $RI/c = 0.985$).

Calculation of mean and standard deviation to compare the restoration techniques used showed with no significant difference among the analyzed restoring techniques ($p > 0.05$).

They are in agreement with da Veiga et al. which showed that there was no difference in the longevity of direct and indirect composite restorations, regardless of the type of material and type of restored teeth [14].

Another analysis, in which the clinical performances of different types of direct and indirect composite restorations in the posterior teeth were compared, concluded that there was no significant difference between direct and indirect techniques [15,16].

Conclusions

In order to restore the posterior dental segment, combining nanofilled resin composites for RD and RI with 1-step SE adhesive systems seem to be the best solution/option.

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