Original article

The Effect of Polymerization Technique on Marginal Index of Composite Fillings in Dentin

Stefan Dačić[1], Aleksandar Mitić[1], Marija Nikolić[1],

Milica Cenić[2], Nenad Stošić[3], Dragica Dačić-Simonović[1]

[1]*University of Niš, Faculty of Medicine, Clinic of Dentistry,*
Department for Restorative Dentistry and Endodontics, Niš, Serbia
[2]*Military Hospital of Niš, Serbia*
[3]*University of Niš, Faculty of Medicine, Niš, Serbia*

SUMMARY

Polymerization contraction of composite resins has been one of the most extensively studied phenomena in dentistry in recent years. Initial polymerization by low intensity light followed by polymerization high intensity light improves marginal adaptation of composite in tooth cavities. A number of studies have verified that less marginal leakage and lower marginal index (MI) exist in relation to standard polymerization (continuous high intensity light).

The aim of the study was to quantittively evaluate the bond of composite materials to dentin and determine the MI values in dentin after the application of two techniques of light polymerization in two composite systems.

Twenty V class cavities were restored on extracted teeth for scanning electron microscopic (SEM) analysis of composite to dentin junction. Adhesion to dentin was achieved using *Adper Single Bond 2-*ASB/ 3MESPE, that is, *Adper Easy One*-AEO/3MESPE. Light polymerization of composite materials *Filtek Ultimate*-FU/3MESPE was performed using standard halogen light (HIP) or *soft start* program (SOF).

Marginal index of dentin was determined by measuring the length and width of marginal gap at the junction of composite filling to dentin, using scanning mirographies and *Autodesk AutoCAD* program.

Two-way ANOVA test was used for statistical processing of the obtained results. Differences in MI index between different light polymerization techniques (HIP- 8,18 and SOF-7,12) were not statistically significant (p>0,05), while the differences between composite systems (ASB/FU- 3,67 i AEO/FU- 7,69) were statistically significant (p <0.05).

The polymerization technique showed no significant effect on the composite to dentin junction. Lower MI dentin was established in composite system with the application of adhesive etch and rinse procedure in both polymerization techniques.

Key words: composite resins, light polymerization, adhesives, dentin

Corresponding author:

Stefan Dačić

e-mail: stefandacic1978@yahoo.com

INTRODUCTION

Photopolymerization composites are nowadays most frequently used in restorative odontology. The main problem with placing composite restorations is the occurrence of marginal crack around the restoration induced by polymerization contraction of composite resins.

Polymerization represents a chemical reaction that occurs in the organic resin and causes conversion of monomers into polymers leading to molecule proximity and contraction. In this process the pressure created in the composite concentrate and on the adhesive contact between the teeth and restorative materials affects the integrity of the region and may lead to marginal defects, gap formation, cusp folding, and postoperative sensitivity (1).

In recent years, polymerization contraction of composite resins has been one of the most frequently studied phenomena in dentistry. It is well known that numerous factors influence the contraction, some of which include: chemical composition, polymerization rate, polymerization system, the elasticity module of restorative materials, cavity configuration factor (factor C) (2). Polymerization depends on the size of inorganic composite particles and their composition, color, transparency, light intensity, duration of illumination exposure, as well as the monomer composition and the polymerization initiator concentration (3).

Light polymerization is initiated by a ray of light that activates molecules of initiators (camphorquinone, Lucerin, phenylpropanedione). This leads to free radicals formation and initiation of composite resins polymerization.

The degree of polymerization or adhesion of composites depends on the power density of light device, exposition time, resin colour, the size of particle fillings, and loading level (3).

When light passes through the restoration its strength significantly decreases, which reduces the efficiency of polymerization and limits the depth of adhesion. The device power is of primary importance in providing the adequate polymerization depth. Inadequate polymerization reduces physical and biological properties of composite resins. Insufficiently polymerized resins could be cytotoxic (4).

Material contraction is focused mostly on the light source and the initial shrinkage of composites occurs exactly in the central part. This is more pronounced in classic (cuboidal) cavities by Black. It is therefore necessary to form adhesive cavity shape with rounded walls for composite fillings. In these cavities contraction of materials is decreased due to the synergism of the adhesion force and contraction as well as due to the use of lower amounts of composites. In adhesive cavities, a significantly lower amount of substance is removed in preparation so that a smaller amount of material for restoration is used. A smaller amount of material leads to reduced contraction (5-7).

Device with soft-start programs or the two-step polymerization and pulse-delayed polymerization allow an initial exposure of the composite to the low intensity light that was followed by the application of higher intensity light. The aim is to improve the marginal adaptation by extending the liquid phase of the composite resin, and thus to compensate polymerization contraction and stress (8-11).

These polymerization types are generally known as *soft start*, and use a reduced irradiation of light during the first few seconds of light activation by involving high irradiation for the remaining time of polymerization in order to provide sufficient exposure to the material. The efficiency of these polymerization methods has been shown by numerous studies that prove a significant contraction reduction in comparison with continuous high intensity photoactivation (12-15).

AIMS

The aim of this study was to determine the marginal adhesion of composite and marginal index value in dentin after the application of standard and soft start polymerization techniques in two composite systems.

MATERIAL AND METHODS

Twenty extracted molars of adult patients were used in the study. Adhesive cavities 3x2x3 mm of V class were prepared on the vestibular part. Round diamond drills (Meinsinger Germany) were used for the preparation of twenty cavities.

The first sample group consisted of ten teeth restored by composite system *Adper Singl Bond 2 + Filtek Ultimate - ASB/FU* (two-phase adhesive, etch and rinse technique and hybrid nano composite). The second group of samples included the remaining ten teeth restored by *Adper Easy One + Filtek Ultimate-*AEO/FU (one phase adhesive, self-etch technique and hybrid nano composite).

After the application of one layer of nanohybrid composite *Filtek Ultimate,* five restorations from the first group and five restorations from the second group were polymerized in a standard way (HIP–*High Intensity Power* - 800mW/cm2 for 40 seconds.), and the remaining five restorations from both groups were gradually polymerized by soft start technique for 10 seconds and then by using high intensity polymerization for 60 seconds, SOF - 400mW/cm2 for 10 sec + 800mW/cm2, total time 60 seconds).

Adhesives and composite materials were polymerized by halogen light *Elipar High light. 3MESPE* (Seria No 938020000257) with strict adherence to the manufacturer's instructions. The power light was controlled by external radiometer (Demetron CTUSA). After the composite fillings had been placed, the roots were cut first and then the crowns were cut longitudinally through composite fillings in order to expose the material and hard dental tissues. Sections were then polished by Soflex discs, conditioned by 37% phosphoricacid (60 seconds) and rinsed with water spray under air pressure. After that, the surface was drenched by 2% sodium hypochlorite solution for 60 seconds with the aim of dissolving the organic part of debris (16).

During the preparation of samples for scanning microscopy, a thin layer of gold (JFC- 1100 Ion Sputter JEOL) was applied on the surfaces of sections. Afterwards, scanning graphs of both complete sections of composite fillings on magnification x35 and segments of the marginal adhesion of the filling to tooth at x200 magnification were made using a scanning electron microscope-SEM(JSM-5300, JEOL).

Measuring the length and width of marginal gap

In order to show the total adhesion length of restoration to dentin on one scan, SEM micrographies at a magnification x35 were made for each sample. The parts of adhesion to the enamel dentin junction at x200 magnification were successively recorded in order to verify the existence of marginal gap, measure its length in micrometers and express it in percents in relation to the total adhesion length. In addition to the length, the width of gap on five adhesion spots was measured as well, using Autodesk AutoCAD.

The percentage of the gap length (GP) and average gap width (GW) were necessary parameters for measuring the marginal index (MI) of dentin, using formula MI= GPxGW/100 (17).

Measured lengths and widths of gaps were then drawn in SEM micrographies x35 and x200 (Figure 1, 2).
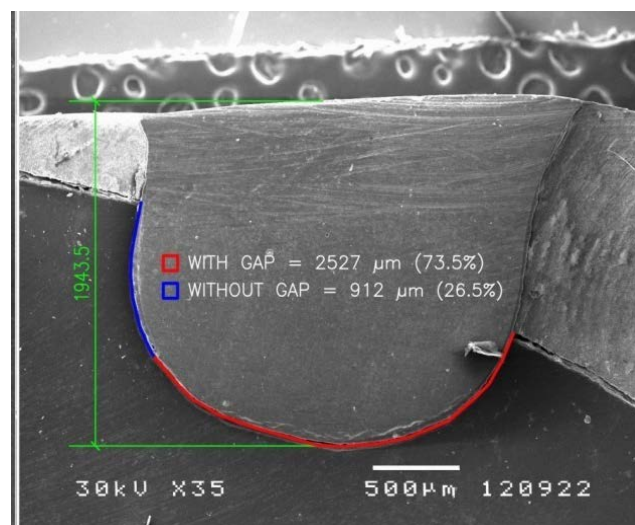

Figure 1. **The length of marginal gap in micrometers and percentages, measured by Autodesk AutoCAD for restoration by** *Adper Single Bond 2-Filtek Ultimate,* **polymerized using standard (HIP) technique**
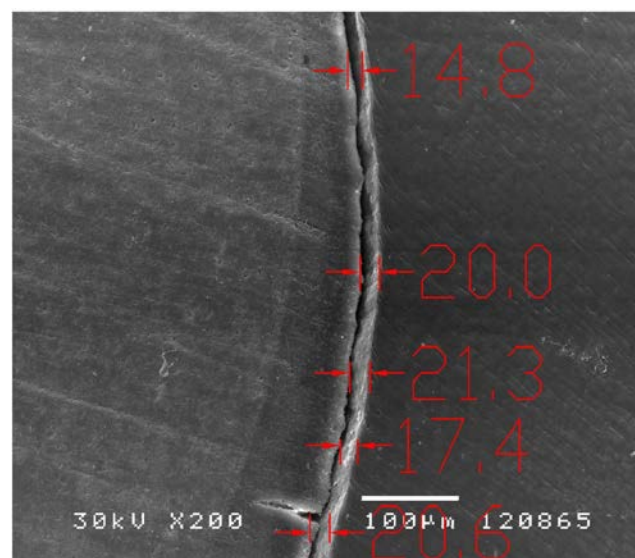

Figure 2. **SEM micrography of the segment of** *Adper Single Bond 2-Filtek Ultimate* **restoration polymerized by SOF technique with microgap (values of gap width in μm) x200**

Statistical analysis was done using descriptive and analytical statistical methodology, two-way ANOVA test (two-factor analysis of two lights and two composite systems). Statistical significance of the impact of polymerization technique and composite system on MI composite fillings in dentin was determined.

RESULTS

On the basis of the measured lenghts and widths of marginal gaps around composite fillings in dentin, the lowest index value MI=2,26±2,99 was determined after the application of SOF technique of photplolymerization and ASB/FU materials. The highest average MI =11,65± 8,09 was determined in standard photoplymerization (HIP) and application of AEO/ FU materials.

Table 1. **Average values of MI index of dentin in relation to photopolymerization technique**

Light curing	Composite system	N	Marginal index			
			Mean	SD	Min	Max
HIP	ASB/FU	40	4,72	6,56	,00	25,09
	AEO/FU	40	11,65	8,09	,00	30,50
	Total	80	8,18	8,10	,00	30,50
SOF	ASB/FU	30	2,26	2,99	,00	9,65
	AEO/FU	40	10,76	11,88	,00	44,06
	Total	70	7,12	10,08	,00	44,06
Total	ASB/FU	70	3,67	5,44	,00	25,09
	AEO/FU	80	11,20	10,11	,00	44,06
	Total	150	7,69	9,06	,00	44,06

HIP – high intensity power of light (standard curing); SOF – soft start (two-step curing); N – number of samples; X – mean value; SD – standard deviation; Min – minimal value; Max – maximal value

Differences in MI between different photopolymerization techniques (HIP- 8,18 and SOF-7,12) were not statistically significant (p>0,05). However, the differences between the composite systems (ASB/FU- 3,67 and AEO/FU- 7,69) were statistically significant (p <0.05), determined by the two-way ANOVA test.

Table 1 shows the average index values in relation to the polymerization technique. The differences in average MI index values between different photopolymerization techniques (HIP-8,18i SOF-7,12) were not statistically significant (p>0,05), while the differences between composite systems (ASB/FU-3,67 i AEO/FU-11,20) were statistically significant (p<0,05).

Table 2. **The importance of differences between photopolymerization technique and composite systems**

Source	Marginal index			
	df	Mean Square	F	p
Corrected Model	3	746,17	10,09	,000
Intercept	1	7975,96	116,49	,000
Light curing	1	103,14	1,50	**,222**
Composite system	1	2194,81	32,05	**,000**
Light curing* Composite system	1	22,96	0,33	**,563**
Error	146	68,46		
Total	150			
Corrected Total	149			

Table 2 shows the significance of the obtained differences in MI index by means of ANOVA test. The differences in MI values due to the application of different photopolymerization techniques were not statistically significant (F=1.50 sig<0.222), while the differences in application of different composite systems (F=32,05 sig=0,0001) were significant.

DISCUSSION

The bond between composite and dental tissues is affected by numerous factors, among which adhesion and photoplymerization technique are of primary importance (18).

The contact between restorative materials and dental substrates must be morphologically perfect so that the following conditions could be avoided: accumulation of plaque, marginal leakage, discoloration of filling edges, secondary caries or pulp diseases.

In testing restorative materials or new adhesive technique, the quality of restoration edges is assessed by *in vitro* and *in vivo* studies. The majority of researchers use *in vitro* methods.

In vitro methods for estimating marginal leakage with penetrating colors include the use of 0.5-2% liquid solution of fuchsin, aniline blue, fluorescent colors, silver colors and radioactive isotopes (19).

SEM analysis and transmission electron microscopic (TEM) studies provided important information relating to the way in which adhesive systems bind to tooth enamel and dentin. Rouletet et al. (19) were the first to describe the method of quantitive analysis of marginal adhesion of restorations and dental tissues using special software connected to scanning electron microscope. The restoration edges were traced by means of digitizer on SEM monitor in order to quantitively assess the material-tooth adhesion. Apart from measuring the length of marginal adhesion, the way in which edges were categorized and simultaneous labeling of the length of characteristic adhesion in percents were described.

Van Meerbeek (20) describes computerized measurement of the length of marginal gaps on SEM micrographies as semi-quantitive measurement, while Frankenberger (21) defines the measurement of the adhesion length of composite restorations to enamel and dentin as qualitative analysis of adhesion. The restoration edges show numerous variations in their morphology. The quality quantification of marginal adhesion could be performed in different ways.

Luo et al. (17) determined the differences in marginal micromorphology between samples of three groups of compomer restorations. They performed quantitive measurement of contact using the image analysis (Quantimet 500+, Leica Imaging System Ltd, UK) and the gap level around the restoration was expressed in percents (gap percent /GP). The maximum gap width was recorded for the measurement of marginal index (MI) according to the formula MI= GPxMG/100.

They concluded that the quality of dentin-compomer contact was highly affected by the conditioning method, that is, the cavity treated with phosphoric acid significantly improved compomer-dentin adhesion (etch and rinse technique), which is in accordance with the results of our study.

Luo et al. also determined the MI marginal compomer-dentin adaptation (17) and found a significantly lower MI in the group of teeth where the etch and rinse technique was used 0,3±0,6 as compared to the group of teeth where self-etch technique was used 3,8±4,0

The studies by Mehl et al. (22) established that the initial regimen of polymerization by low intensity light with final polymerization of composite by high intensity light produced significantly better marginal adhesion as compared with continuous high intensity light.

However, a certain number of researchers determined the differences in the quality of marginal adaptation of composites by means of successive or SOF polymerization technique (23-27), which is in accordance with the results of our study. The results of other researchers may be connected with the application of other methodologies of examining marginal closing, other composite systems and different light sources.

CONCLUSION

The obtained results of ANOVA test in our study suggest that differences in MI index in different polymerization techniques of two composite systems were not statistically significant. Lower MI dentin was determined in the composite system with the application of adhesion etch and rinse technique in both polymerization techniques.

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Uticaj tehnike osvetljavanja na marginalni indeks kompozitnih ispuna u dentinu

Stefan Dačić[1], Aleksandar Mitić[1], Marija Nikolić[1],
Milica Cenić[2], Nenad Stošić[3] Dragica Dačić-Simonović[1]

[1]Univerzitet u Nišu, Medicinski fakultet, Klinika za stomatologiju,
Departman za restorativnu stomatologiju i endodonciju Niš, Serbia
[2]Vojna bolnica u Nišu, Srbija
[3]Univerzitet u Nišu, Medicinski fakultet Niš, Srbija

SAŽETAK

Jedan od najproučavanijih fenomena u stomatologiji poslednjih godina je polimerizaciona kontrakcija kompozitnih smola. Početno osvetljavanje svetlom niskog intenziteta praćeno osvetljavanjem svetlom visokog intenziteta, poboljšava marginalnu adaptaciju kompozita u kavitetima zuba. Kroz više studija je dokazano da kod postepenog osvetljavana kompozitnih ispuna postoji manje marginalno propuštanje i manji marginalni indeks (MI) u odnosu na standardno osvetljavanje (kontinuirano svetlo visokog intenziteta).

Cilj ovog rada bio je da se kvantitativno proceni veza kompozitnih materijala za dentin i utvrde vrednosti MI u dentinu, nakon primene dve tehnike svetlosne polimerizacije kod dva kompozitna sistema.

Na ekstrahovanim zubima je restaurisano 20 kaviteta V klase za skenirajuću elektronsko-mikroskopsku (SEM) analizu pripoja kompozita za dentin. Adhezija za dentin je obezbeđivana primenom AdperSingleBond2-ASB/3MESPE, odnosno, primenom AdperEasyOne-AEO/3MESPE. Svetlosna polimerizacija kompozitnog materijala (FiltekUltimate-FU/3MESPE) vršena je standardnim halogenim svetlom (HIP) ili soft start programom (SOF).

Marginalni indeks dentina je utvrđivan merenjem dužine i širine marginalne pukotine na spoju kompozitnog ispuna sa dentinom, korišćenjem skening mikrografija i Autodesk AutoCAD programa.

Za statističku obradu dobijenih rezultata korišćen je dveosmerni ANOVA test. Razlike u MI ideksu između različitih svetlosno-polimerizujućih tehnika (HIP- 8,18 and SOF-7,12) nisu bile statistički značajne ((p>0,05), dok su razlike između kompozitnih sistema (ASB/FU- 3,67 i AEO/FU- 7,69) bile statistički značajne (p <0,05).

Tehnika osvetljavanja nije pokazala značajan uticaj na pripoj kompozita za dentin. Manji MI dentina utvrđen je kod kompozitnog sistema sa primenom adhezivnog postupka nagrizanja i ispiranja kod obe tehnike osvetljavanja.

Ključne reči: kompozitne smole, svetlosna polimerizacija, adhezivi, dentin