

Marginal and Internal Adaptation of Cervical Restorations Using Direct, Direct–indirect, and Indirect Techniques

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Clinical Relevance

Cervical restorations using direct, direct–indirect, and indirect techniques with a flowable liner did not demonstrate advantages in terms of marginal and internal adaptation for the restoration of non-carious cervical lesions.

SUMMARY

Objective: This study aimed to evaluate the external and internal adaptations of cervical restorations using different restorative techniques.

Methods: Forty extracted and intact human premolars received standardized cervical preparations to simulate non-carious cervical lesions. The teeth were randomly divided into four groups (n=10) according to the restorative technique: D, direct composite restoration without

a base (Palfique LX5, Tokuyama Dental Corp Inc, Tokyo, Japan); DB, direct composite restoration with a flowable composite liner (Estelite Flow Quick - High Flow, Tokuyama Dental Corp Inc); DI, direct–indirect composite restoration bonded with flowable composite; and I, indirect restoration bonded with flowable composite. Marginal adaptation of the restorations was observed in different segments of the margins using a scanning electron microscope. Analyses of internal adaptation were performed using micro-computed tomography. The Kruskal–

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Wallis and Mann–Whitney tests were used for statistical analysis of the data ($\alpha=5\%$).

Results: No significant differences were found in the marginal adaptation of the groups ($p>0.05$), although a significantly higher percentage of continuous margin was found in the proximal segment than in the cervical segment ($p<0.05$). No significant differences were detected between the groups in terms of internal adaptation ($p>0.05$).

Conclusion: All the restorative techniques evaluated for the restoration of cervical lesions performed similarly in terms of marginal and internal adaptation.

INTRODUCTION

Non-carious cervical lesions (NCCLs) have been an issue for patients and clinicians because of their high prevalence. According to a recently published systematic review, the overall prevalence of NCCLs in the general population is 47%, with the elderly population being more affected than the young population.¹ The etiology of NCCLs is considered to be multifactorial and based on the interaction of various mechanisms such as biocorrosion (chemical erosion), friction (wear caused by abrasion), and occlusal stress (abfraction).^{2,3}

The decision to treat NCCLs depends on the progression of the lesions and the extent to which they compromise the vitality, function, and aesthetics of the teeth.⁴ Restorative treatments using glass ionomer cement, compomers, and composites have been advocated for the treatment of NCCLs.⁵ Based on their excellent aesthetic properties, there is a general trend toward the use of composite resins for the restoration of NCCLs.⁶ However, the clinical performance of composite resin restorations for NCCLs is considered to be highly material- and operator-dependent.^{4,6} Restorations performed within the cervical region of teeth have a high rate of loss of retention, discoloration, and marginal degradation.⁷ Adhesive failures are often attributed to inadequate moisture control during the restorative procedure, the presence of sclerotic dentin, and the high incidence of occlusal factors leading to cusp deflection and incidence of flexion forces within the cervical region.⁸ Since restorative materials with a high modulus are unable to flex when the tooth structure is deformed under eccentric oblique load, it was hypothesized that more flexible restorative materials with a lower elastic modulus may absorb tooth flexure stress and be compressed with reduced tensile/shear stress imposed to the tooth-restoration interface.⁹ Therefore, a flexible material with a low

elastic modulus applied in between the cavity wall and restoration could absorb the stress generated during the polymerization shrinkage of composites as well as the mechanical loading in which the teeth are subjected during function.¹⁰ Therefore, depending on the elastic modulus of the lining material, when used in a thin layer under a non-flowable composite, the consequences of polymerization shrinkage would be minimized and a reduction in stress could be expected.^{11,12}

Other methods have been suggested to restore NCCLs, aiming to reduce the drawbacks associated with the direct restorative technique, such as polymerization shrinkage and access to the gingival margin. Recently, the direct–indirect technique was introduced for the treatment of NCCLs, which comprises the bulk insertion of a composite directly into the cavity before the adhesive procedure, followed by light activation, removal of the restoration, extraoral finishing, and adhesive luting.¹³ Another approach, although more unusual for cervical restorations and more labor intensive and time consuming, is the indirect technique in which the restoration is built in a cast from a dental impression of the preparation.¹⁴ The claimed benefits of both techniques include extraoral construction, finishing and polishing, minimizing injuries to adjacent tissues, and additional composite polymerization, which may reduce polymerization shrinkage stress.¹³

Despite the vast literature on this topic, to date, only one clinical study has compared different restorative techniques for the treatment of NCCLs.¹⁵ Thus, more investigation is needed to assess the performance of adhesive materials associated with different restorative techniques in order to make the treatment of NCCLs more effective and long lasting.

The present study aimed to evaluate the marginal and internal adaptation of composite resin restorations using a direct (with and without a flowable lining), direct–indirect, and indirect technique in preparations that simulated NCCLs. The gap formation was analyzed using micro-computed tomography (μ CT) and scanning electronic microscopy (SEM). The hypotheses tested were as follows: (1) the restorative techniques would perform similarly in terms of marginal and internal adaptation, and (2) the external adaptation would be similar in different regions of the dentin/restoration margins, regardless of the restorative technique used.

METHODS AND MATERIALS

Preparation of Specimens

Forty intact human premolars were stored in a 0.5% chloramine-T solution at 4°C. All teeth were used within three months after extraction. Standardized

V-shaped Class V cavities were prepared on the buccal surface of each tooth using rounded and cylindrical diamond burs (801-012, 835-008, Komet USA, Rock Hill, SC, USA) under continuous water cooling. Each bur was replaced after five cavity preparations. The dimensions of the cavities were 5.0-mm high, 5.0-mm wide, and 2.0-mm deep, and they were checked with a periodontal probe and a digital caliper (Mitutoyo 500-173-30, Mitutoyo Corp, Kanagawa, Japan). The occlusal margins were located in enamel and cervical margins in dentin. The enamel margins were beveled with a small flame-shaped diamond bur (6889-010, Komet USA) and finished with a flexible disc (Sof-Lex Pop-On, 3M ESPE, St Paul, MN, USA). The teeth were randomly divided into four experimental groups, with ten teeth in each group, according to the restorative technique used (Table 1).

Restorative Procedures

The enamel margins of the teeth assigned to the D group were treated with 35% phosphoric acid (Ultra-Etch, Ultradent Products Inc, South Jordan, UT, USA) for 30 seconds, thoroughly rinsed with air/water spray, and then gently air-dried. Clearfil SE Primer (Kuraray Co, Osaka, Japan) was actively applied in the dentin for 20 seconds, followed by gentle air-blowing. The bond was applied and light cured for 10 seconds at a 1400 mW/cm² output (Led Valo, Ultradent Products Inc). The output of the light-curing unit was measured using a radiometer. Direct restorations were made in three increments using a micro-hybrid composite resin (Palfique LX5, Tokuyama Dental Corp Inc, Tokyo, Japan). The first and second direct restoration increments were inserted on the opposite walls of the cavity, starting with the cervical wall, and the third increment covered the first two increments to reconstruct the anatomic contour.¹⁶ Each increment was light cured for 10 seconds with the same curing unit. The restoration was covered with a thin layer of water-soluble gel (KY Jelly, Reckitt Benckiser Inc, Parsippany, NJ, USA) and light cured for an additional 10 seconds. Finishing and polishing were accomplished after 48 hours using medium, fine, and ultra-fine aluminum oxide discs (Sof-Lex Pop-On, 3M ESPE) and polishing cups (FlexiCups, Cosmedent Inc, Chicago, IL, USA) with 1.0- μ m and 0.5- μ m diamond polishing pastes (Diamond Polish Paste, Ultradent Products Inc), and followed by felt discs (FlexiBuff, Cosmedent Inc) with an aluminum oxide polishing paste (Enamelize, Cosmedent Inc).

Teeth in the DB group were treated with the same adhesive procedure as teeth in the D group, that is, with selective enamel acid etching and application of

Table 1: <i>Description of the Experimental Groups in the Study</i>	
Group	Description
D	Direct composite restoration without a base
DB	Direct composite restoration with a flowable composite base
DI	Direct-indirect composite restoration bonded with flowable composite
I	Indirect restoration bonded with flowable composite

the Clearfil SE Bond (Kuraray Co) adhesive system. A flowable composite (Estelite Flow Quick - High Flow, Tokuyama Dental Corp Inc) was used as an intermediary lining. A disposable tip was used to apply an approximately 0.5-mm thick layer of flowable composite to the axial wall up to the gingival margin, followed by 10 seconds of light curing. The restorative procedures were performed exactly as described for the D group.

Teeth in the DI group had their cavities restored with a bulk increment of the same composite resin (Palfique LX5) slightly larger than the actual cavity size, light cured for 10 seconds, and detached from the cavity with a fine instrument. The restorations were manipulated using an adhesive-tipped handling instrument (OpraStick, Ivoclar Vivadent AG, Schaan, Liechtenstein). The margins were outlined extraorally to facilitate finishing, and the excess composite was removed with aluminum oxide discs (Sof-Lex Pop-On). The restorations were submitted for additional light curing extraorally for 15 seconds on the external side and 15 seconds on the internal side using a high-irradiance unit (3200 mW/cm²).¹³ The intaglio surfaces were air-abraded with 50- μ m aluminum oxide particles, followed by water rinsing and air-drying. Acid etching with 35% phosphoric acid was performed for 5 seconds to clean the treated surface, followed by water rinsing and air-drying. An adhesive layer (Clearfil SE Bond adhesive system) was applied to the surface, followed by gentle air drying, and was not light cured. Selective enamel etching and adhesive system application were performed as described for the D and DB groups. The indirect composite restorations were bonded to the preparations using the same flowable composite used in the DB group (Estelite Flow Quick - High Flow). Once stabilized, a 2-mm diameter light tip attached to the curing unit was pressed at the center of the restoration for 5 seconds to allow the excess composite to flow out of the margins.¹³ Light curing was carried out for

2 seconds at 1400 mW/cm², and the excess composite was removed with a disposable brush. The margins of the restoration were covered with a water-soluble gel, and light curing was completed for an additional 20 seconds at 1400 mW/cm². Finishing and polishing were performed using the same cups, felt discs, and pastes used for the D and DB groups.

The cavity preparations of teeth assigned to the I group were subjected to alginate impressions, followed by the fabrication of addition-curing silicone casts (Die Silicone, VOCO GmbH, Cuxhaven, Germany). Indirect restorations were built with the same composite resin (Palfique LX5) using the restorative procedures described for the DI group. After finishing, light curing, and air abrasion of the intaglio surfaces, the restorations were bonded with a flowable composite (Estelite Flow Quick - High Flow), and finished and polished using the protocol previously described for the DI group. Table 2 lists all the materials used in this study.

Analysis of Initial External Adaptation by Scanning Electron Microscopy

Impressions of the restorations were performed using polyether impression material (Impregum F Polyether, 3M ESPE), and replicas were made using epoxy resin. The replicas were mounted on aluminum stubs and sputter-coated with gold-palladium alloy before being examined with an SEM (Vega Tescan 3, Tescan, Brno, Czech Republic). First, the restoration margins were observed under 45× magnification (Figure 1A) and then divided into three segments, namely mesial (T1), gingival (T2), and distal (T3), using the SEM

measurement tool (Figure 1B). Subsequently, each segment was analyzed at a magnification of 200× to 300× (Figure 1C), and when a gap was observed in the tooth/restoration interface, the magnification was increased to 500× to measure the length of the affected interface using the same measurement tool. If necessary, up to 3000× magnification was used to identify and distinguish a gap from an artifact. The results are expressed as a percentage of the continuous margin relative to the total length of each segment. The results of segments T1 and T3 were combined to obtain the percentage of adaptation at approximal margins, whereas the results of segment T2 were used to represent adaptation at the gingival margin.

Thermocycling Procedures

The teeth were submitted to 35,000 thermal cycles at 5°C and 55°C with a 15 second dwell time (OMC 250, Odeme Dental Research, Luzerna, SC, Brazil). Thereafter, the teeth were replicated in epoxy resin and subjected to the same microscopic analysis to assess the final marginal adaptation. After thermocycling, the samples were stored in water at room temperature until the microtomographic analysis.

Analysis of Internal Adaptation by Micro-computed Tomography

Analysis of the internal adaptation was carried out using a high-resolution three-dimensional X-ray microtomography system (SkyScan High Energy Model 1173, Bruker Belgium SA, Kontich, Belgium). The μ CT images were taken using a 70 kV acceleration voltage, 114 μ A current strength, 14.96 μ m resolution,

Table 2: Materials Used in This Study (Information Provided by the Manufacturers)

Material (Manufacturer)	Batch No.	Composition	Filler Content
Clearfil SE Bond (Kuraray Co)	114391286	Primer: MDP, HEMA, hydrophilic dimethacrylate, camphorquinone, NN-diethanol-p-toluidine water. Bond: MDP, HEMA, Bis-GMA, hydrophobic dimethacrylate, camphorquinone, NN-diethanol-p-toluidine, silanized colloidal silica	10 wt%
Palfique LX5 (Tokuyama Dental Corp Inc)	W9527	Bis-GMA, TEGDMA, silica-zirconia fillers (average 200 nm)	82 wt% 71 vol%
Estelite Flow Quick-High Flow (Tokuyama Dental Corp Inc)	W728	Bis-GMA, TEGDMA, silica-zirconia fillers (average 300 nm)	68 wt% 49 vol%

Abbreviations: Bis-GMA, bisphenol A bis(2-hydroxypropoxy) dimethacrylate; HEMA, 2-hydroxyethyl methacrylate; MDP, 10-methacryloyloxydecyl-dihydrogen phosphate; TEGDMA, triethylene-glycol dimethacrylate; vol%, volume percent; wt%, weight percent.

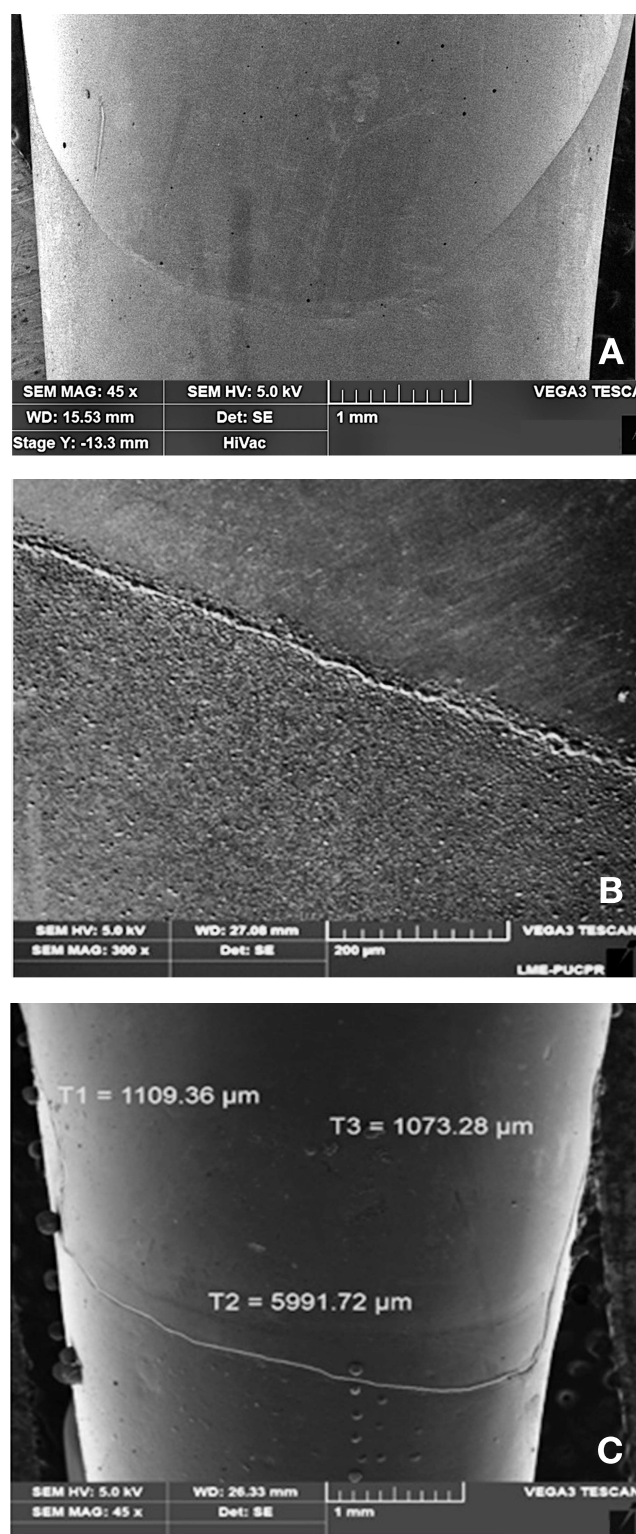


Figure 1. Scanning electronic microscopy images of samples showing the interface between the dentin margin and the adhesive restoration. (A): view of a cervical margin at 45× magnification; (B): division of the tooth/restoration interface into three segments (45×); (C): cervical margin showing 100% adaptation (300×).

and 360° rotation with slices taken every 0.5°, totaling 720 slices per sample. The average reading time for each sample was approximately 22 minutes.

After the acquisition, the images were transferred to a volumetric NRecon reconstruction software (version 1.7.0.4, Bruker, Kontich), which is used to reconstruct cross-sectional slices from acquired angular projections through the specimens. When a gap was observed in the inner tooth/restoration interface, the region of interest was selected, binarized, and segmented using the CT Analyzer software (Bruker Corporation). The regions of interest were added to each sample to provide a volume of interest per sample. The total volume of the gaps was expressed as mm³.¹⁷ Figure 2A–2D shows representative µCT images of axial slices of specimens from each experimental group.

Statistical Analysis

Data on the percentage of continuous margins (external adaptation) and volume of internal gaps were analyzed for normality and homogeneity of variances using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Owing to the non-normal distribution of the data, the Kruskal–Wallis and Mann–Whitney tests were used for the analysis of the external and internal adaptation of the tested variables and groups. All tests were performed at a 5% significance level using the SPSS 24.0 statistical package (IBM Corp, Armonk, NY, USA).

RESULTS

Marginal Adaptation

The initial marginal adaptation of all the specimens provided 100% adaptation. After thermocycling, no significant differences were found among the groups with different restorative techniques ($p > 0.05$, Table 3). However, significant differences were found between the gingival and proximal segments, regardless of the restorative technique ($p < 0.05$, Table 4).

Internal Adaptation

There were no significant differences in internal gap volume among the groups with different restorative techniques (Table 5).

DISCUSSION

This study compared different restorative strategies for wedge-shaped cervical lesions by analyzing the marginal and internal adaptations of the restorations. The first hypothesis tested was accepted, since no differences were found between the marginal and

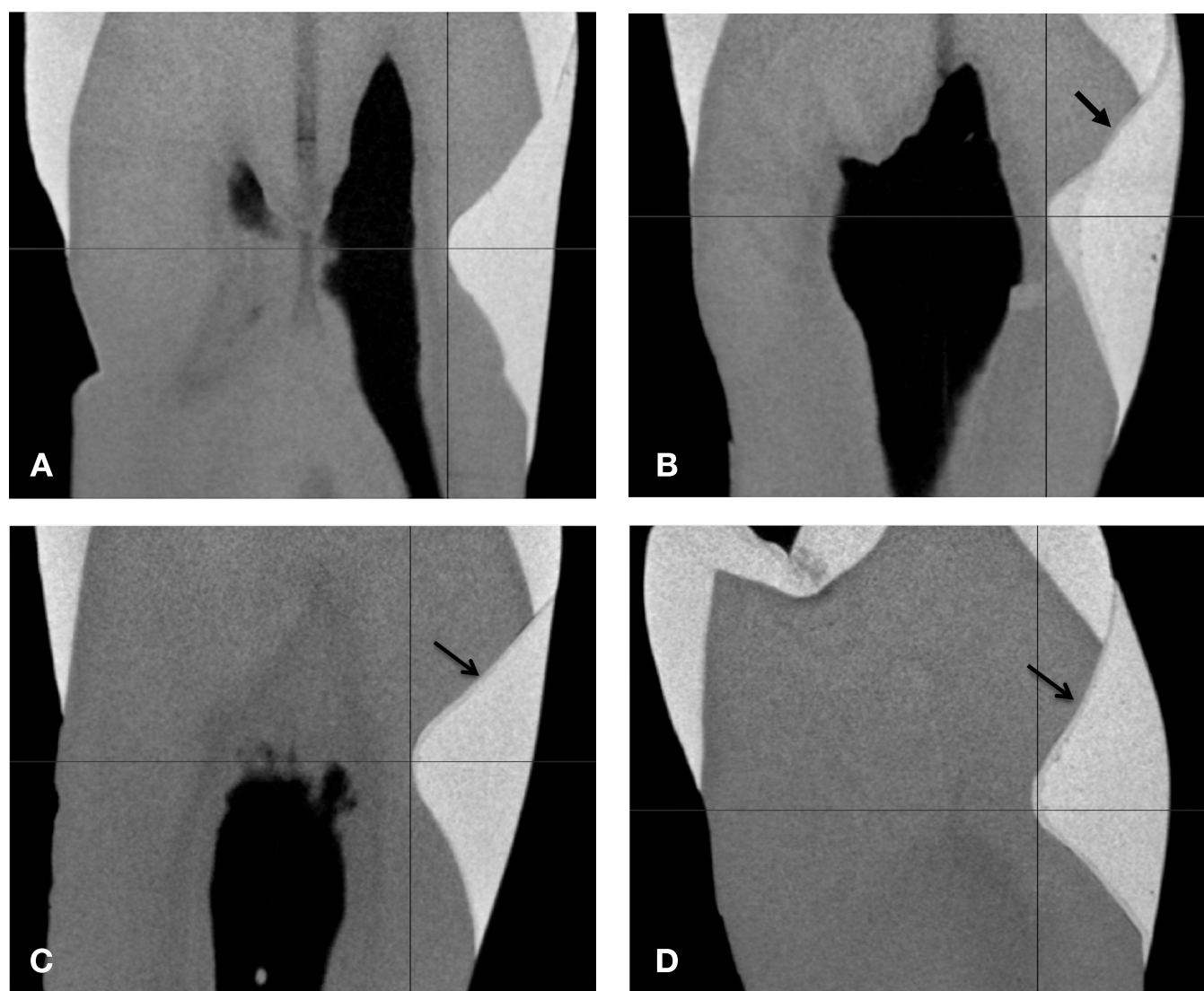


Figure 2. Images of axial slices by micro-computed tomography. (A): Specimen of Group D restored with direct technique; (B): specimen of Group DB restored with direct technique with a flowable liner (arrow); (C): specimen of Group DI restored using the direct-indirect technique and bonded with flowable composite (arrow); (D): specimen of Group I restored using the indirect technique and bonded with flowable composite (arrow).

internal adaptations of the different restorative techniques. However, the second hypothesis was rejected, as a better marginal adaptation was observed in the proximal segment than in the gingival segment, regardless of the technique used.

To replicate natural NCCLs for this study, the gingival margins of the cavity preparations were located entirely on dentin. Our results showed that these margins exhibited more gaps than the proximal margins, which are partly located in enamel. The adhesive strategy used in this study might have affected the sealing ability of margins with enamel as opposed to the cervical margins, which are entirely located in

dentin. Recent systematic reviews concluded that the adhesive approach significantly influences the clinical effectiveness of restorations in NCCLs¹⁸ and that selective enamel etching prior to the application of self-etch adhesive systems can result in lower marginal discoloration rates and better marginal integrity.¹⁹

Based on the challenges and difficulties associated with the restorative treatment of NCCLs, different approaches have been suggested to improve the clinical effectiveness of these restorations, such as the use of different dental surface treatments, alternative restorative techniques, novel adhesive materials, and polymerization strategies.^{13,20-22}

Table 3: Mean $\pm$ Standard Deviation of Marginal Adaptation of the Segments (Proximal and Cervical) Expressed as a Percentage of Continuous Margin for Each Group ^a		
Group	Proximal (%)	Cervical (%)
D	99.77 $\pm$ 0.72 a	93.36 $\pm$ 8.40 a
DB	99.31 $\pm$ 2.17 a	96.03 $\pm$ 5.57 a
DI	98.51 $\pm$ 4.70 a	97.55 $\pm$ 3.66 a
I	98.82 $\pm$ 3.73 a	98.26 $\pm$ 4.28 a
Abbreviations: D, direct composite restoration without a base; DB, direct composite restoration with a flowable composite base; DI, direct-indirect composite restoration bonded with flowable composite; I, indirect restoration bonded with flowable composite. ^a Equal letters indicate the absence of a statistically significant difference between the groups ($p>0.05$).		

Composites are considered the material of choice for restoring NCCLs, as they have an elastic modulus similar to that of dentin, which leads to comparable tooth behavior in response to the occlusal load.²³ Another important factor is filler size and distribution of particles, which makes microfilled and nanofilled composites more recommended to restore cervical lesions.^{1,4} Because of their reduced mean filler size, these materials can provide a smooth surface texture after polishing,²⁴ directly influencing biofilm formation.²⁵ For this reason, nanofilled composites with supra-nanometric spherical particles (200–300 nm) were selected for this study.

Several clinical studies have investigated the use of flowable composites in NCCLs either as a restorative material^{15,26–28} or as a liner associated with a high-viscosity nanofilled or nanohybrid composite.^{29–31} Flowable composites have a lower viscosity due to either a reduction of filler content or an increased ratio of diluent monomers, which leads to a decrease in surface tension.³² Nevertheless, these materials have a sufficient filler load to ensure good mechanical properties and low polymerization shrinkage (at least when used in small amounts).³³ This is probably the reason why most

Table 4: Mean $\pm$ Standard Deviation of Marginal Adaptation Expressed as a Percentage of Continuous Margin for the Cervical and Proximal Segments ^a	
Segment	Marginal Adaptation (%)
Cervical	96.30 $\pm$ 5.86 a
Proximal	99.11 $\pm$ 3.12 b
^a Different letters represent a statistically significant difference between the segments ($p<0.05$).	

Table 5: Mean $\pm$ Standard Deviation of Internal Gap Volume for Each Group ^a	
Group	Internal Gap (mm ³)
D	0.015 $\pm$ 0.009 a
DB	0.014 $\pm$ 0.010 a
DI	0.010 $\pm$ 0.010 a
I	0.010 $\pm$ 0.008 a
Abbreviations: D, direct composite restoration without a base; DB, direct composite restoration with a flowable composite base; DI, direct-indirect composite restoration bonded with flowable composite; I, indirect restoration bonded with flowable composite. ^a Equal letters indicate the absence of a statistically significant difference between the groups ($p>0.05$).	

manufacturers of flowable composites recommend them for luting thin indirect restorations, as well as using them as a lining for composite restorations. Because of these features, this type of composite has a low modulus of elasticity, acting as an “elastic layer” that reduces the stress at the tooth/restoration interface and optimizing the adaptation of the restoration to the inner walls of the cavity.^{9,23}

Although the application of a low-viscosity composite liner for composite restorations has been suggested to overcome polymerization shrinkage stress and to improve bond strength,³⁴ the advantages of this approach for enhancing marginal and internal adaptation are still controversial. While some studies have demonstrated that the use of a 0.5- to 1.0-mm thick flowable liner improves internal adaptation relative to the use of conventional composite resin alone,^{30,35,36} other studies have shown that its use reduces internal adaptation and increases gap formation.^{37,38} This discrepancy might be related to the fact that while its low modulus of elasticity could relieve the induced stress caused by polymerization shrinkage,³⁵ the low filler content could cause higher polymerization shrinkage and gap formation at the cavity walls and margins.¹⁹ Thus, the effectiveness of flowable composites might be material dependent, with the type of adhesive system playing an important role in cavity adaptation.³⁹

The effect of flowable composite liners in marginal adaptation compared to restorations without lining has been doubted.^{40–42} According to a systematic review based on clinical trials, flowable composite liners have no significant effect on marginal adaptation and cannot improve the clinical performance of composite resin restorations.⁴³ In fact, marginal adaptation can be affected by several factors related to the adhesive system and the stress developed during composite polymerization. These factors include volume, cavity size and geometry,

configuration factor (C-factor), restorative placement, and curing technique.⁴⁴ In general, NCCLs have a low C-factor compared to other cavity configurations (eg, Class I cavities). However, deeper and larger cervical cavities have higher C-factors, increasing polymerization stress with a consequent increase in gap formation and microleakage.²² Although the incremental technique may be important for the control of polymerization shrinkage, it increases the possibility of trapping air between the layers and increases the time required to place and cure each layer.⁴⁴ In the present study, no differences were observed between the direct restorative technique alone and those techniques using a flowable composite as a liner or luting agent. However, irrespective of the restorative technique, the gingival margins showed more marginal gaps than the proximal margins, which might be attributed to the presence of enamel in the upper part of the proximal margins, which provides better sealing than in the gingival margins located in dentin.

Direct–indirect and indirect composite restorations can be built with the same materials originally claimed for direct use or with specific materials for laboratory use, both equally submitted to supplemental polymerization carried out by a single or combined action of high-irradiance light, high pressure, or heat.⁴⁵ The main advantages are based on the fact that extraoral restorations allow for ideal anatomic form, contour, and approximal contact, as well as improved physical–mechanical properties due to the higher degree of monomer conversion without polymerization stress.^{46,47} Additional curing also neutralizes the problems associated with an insufficient degree of polymerization at the bottom of thicker restorations and allows for prolonged exposure to light without concerns of potential pulp damage due to the increase in temperature.⁴⁸

To date, there have been no reports of studies aiming to investigate the use of flowable composites as luting agents for cervical restorations. Previous studies have demonstrated that the use of flowable composites as luting agents for porcelain veneers can retrieve better or similar mechanical properties compared with resin cements.^{49,50} Flowable composites also produce markedly lower film thicknesses than conventional composites at room temperature or after preheating.⁵¹

Although the direct–indirect and indirect techniques are associated with a more accurate anatomic form and marginal contour, minimal injuries to adjacent tissues during finishing/polishing, and a higher degree of polymerization, the mean time for the indirect technique was reported as more than 50% greater than for the direct technique, and had a similar success rate

after two years.¹⁵ The direct restorative technique is a simple, accessible, and universally used protocol for the treatment of NCCLs.⁵²

It is important to emphasize that, as a laboratory study, all the restorations were performed on extracted teeth and by a well-trained operator. The finishing/polishing procedures were carried out extraorally even for the direct restorations in which a clinician would have difficulties due to the proximity of the gingival tissues to the cervical margins. Although *in vitro* studies can provide useful information on the performance of restorative materials, long-term clinical studies are the best source of scientific evidence to determine the clinical success rates and longevity of restorative protocols for NCCLs.

The volume of internal gaps and the percentage of continuous margins reported in this study could be considered within the acceptable range for all the evaluated groups, indicating that direct, direct–indirect, and indirect techniques performed equally. Therefore, both direct–indirect and indirect techniques have no extra advantages when used to restore NCCLs, especially since they require extra equipment to perform secondary polymerization and are more time consuming and less cost effective than direct techniques used under similar clinical conditions. Therefore, these techniques do not represent an advantage over the conventional one.

CONCLUSIONS

Direct–indirect and indirect restorative techniques, as well as the use of a flowable liner in the direct technique, showed similar marginal and internal adaptation when compared to the conventional direct technique for the restorative treatment of NCCLs.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the human subjects oversight committee guidelines and policies of the Institutional Tooth Bank. The approval code issued for this study is 2.838.853.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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REFERENCES

- Teixeira DNR, Thomas RZ, Soares PV, Cune MS, Gresnigt MMM, & Slot DE (2020) Prevalence of noncarious cervical lesions among adults: A systematic review *Journal of Dentistry* **95** 103285.
- Grippio JO, Simring M, & Coleman TA (2012) Abfraction, abrasion, biocorrosion, and the enigma of noncarious cervical lesions: A 20-year perspective *Journal of Esthetic and Restorative Dentistry* **24**(1) 10-23.
- Alvarez-Arenal A, Alvarez-Menendez L, Gonzalez-Gonzalez I, Alvarez-Riesgo JA, Brizuela-Velasco A, & DeLlanos-Lanchares H (2019) Non-carious cervical lesions and risk factors: A case-control study *Journal of Oral Rehabilitation* **46**(1) 65-75.
- Peumans M, Politano G, & Van Meerbeek B (2020) Treatment of noncarious cervical lesions: When, why, and how *International Journal of Esthetic Dentistry* **15**(1) 16-42.
- Cieplik F, Scholz KJ, Tabenski I, May S, Hiller KA, Schmalz G, Buchalla W, & Federlin M (2017) Flowable composites for restoration of non-carious cervical lesions: Results after five years *Dental Materials* **33**(12) e428-e437.
- Pecie R, Krejci I, García-Godoy F, & Bortolotto T (2011) Noncarious cervical lesions (NCCCL)—a clinical concept based on the literature review. Part 2: Restoration *American Journal of Dentistry* **24**(3) 183-192.
- Mahn E, Rousson V, & Heintze S (2015) Meta-analysis of the influence of bonding parameters on the clinical outcome of tooth-colored cervical restorations *Journal of Adhesive Dentistry* **17**(5) 391-403.
- Perez CDR, Gonzalez MR, Prado NAS, De Miranda MSF, Macedo MDA, & Fernandes BMP (2012) Restoration of noncarious cervical lesions: When, why, and how *International Journal of Dentistry* **2012** 687058.
- Peumans M, De Munck J, Van Landuyt KL, Kanumilli P, Yoshida Y, Inoue S, Lambrechts P, & Van Meerbeek B (2007) Restoring cervical lesions with flexible composites *Dental Materials* **23**(6) 749-754.
- Reis A & Loguercio AD (2006) A 24-month follow-up of flowable resin composite as an intermediate layer in non-carious cervical lesions *Operative Dentistry* **31**(5) 523-529.
- Braga RR, Hilton TJ, & Ferracane JL (2003) Contraction stress of flowable composite materials and their efficacy as stress-relieving layers *Journal of the American Dental Association* **134**(6) 721-728.
- Baroudi K & Rodrigues JC (2015) Flowable resin composites: A systematic review and clinical considerations *Journal of Clinical and Diagnostic Research* **9**(6) ZE18-24.
- Fahl N (2015) Direct-indirect class V restorations: A novel approach for treating noncarious cervical lesions *Journal of Esthetic and Restorative Dentistry* **27**(5) 267-284.
- Chee H, Wan Bakar W, Ghani Z, & Amaechi B (2018) Comparison of composite resin and porcelain inlays for restoration of noncarious cervical lesions: An *in vitro* study *Dentistry Research Journal (Isfahan)* **15**(3) 215-219.
- Caneppele TMF, Meirelles LCF, Rocha RS, Gonçalves LL, Ávila DMS, Gonçalves SE de P, & Bresciani E (2020) A 2-year clinical evaluation of direct and semi-direct resin composite restorations in non-carious cervical lesions: A randomized clinical study *Clinical Oral Investigations* **24**(3) 1321-1331.
- Owens BM & Johnson WW (2005) Effect of insertion technique and adhesive system on microleakage of Class V resin composite restorations *Journal of Adhesive Dentistry* **7**(4) 303-308.
- Rengo C, Goracci C, Ametrano G, Chieffi N, Spagnuolo G, Rengo S, & Ferrari M (2015) Marginal leakage of class V composite restorations assessed using microcomputed tomography and scanning electron microscope *Operative Dentistry* **40**(4) 440-448.
- Peumans M, De Munck J, Mine A, & Van Meerbeek B (2014) Clinical effectiveness of contemporary adhesives for the restoration of non-carious cervical lesions. A systematic review *Dental Materials* **30**(10) 1089-1103.
- Szesz A, Parreiras S, Reis A, & Loguercio A (2016) Selective enamel etching in cervical lesions for self-etch adhesives: A systematic review and meta-analysis *Journal of Dentistry* **53** 1-11.
- Atoui JA, Chinelatti MA, Palma-Dibb RG, & Corona SAM (2010) Microleakage in conservative cavities varying the preparation method and surface treatment *Journal of Applied Oral Science* **18**(4) 421-425.
- Salman Km, Naik S, Kumar Nk, Merwade S, Brigit B, & Jalan R (2019) Comparative evaluation of microleakage in Class V cavities restored with giomer, resin-modified glass ionomer, zirconomer and nano-ionomer: An *in vitro* study *Journal of the International Clinical Dental Research Organization* **11**(1) 20-25.
- Alomari QD, Barrieshi-Nusair K, & Ali M (2011) Effect of C-factor and LED curing mode on microleakage of class V resin composite restorations *European Journal of Dentistry* **5**(4) 400-408.
- Senawongse P, Pongprueksa P, & Tagami J (2010) The effect of the elastic modulus of low-viscosity resins on the microleakage of class V resin composite restorations under occlusal loading *Dental Materials Journal* **29**(3) 324-329.
- Hosoya Y, Shiraishi T, Odatsu T, Nagafuji J, Kotaku M, Miyazaki M, & Powers JM (2011) Effects of polishing on surface roughness, gloss, and color of resin composites *Journal of Oral Sciences* **53**(3) 283-291.
- Flausino JS, Soares PBF, Carvalho VF, Magalhães D, Da Silva WM, Costa HL, & Soares CJ (2014) Biofilm formation on different materials for tooth restoration: Analysis of surface characteristics *Journal of Materials Science* **49**(19) 6820-6829.
- Oz FD, Kutuk ZB, Ozturk C, Soleimani R, & Gurgan S (2019) An 18-month clinical evaluation of three different universal adhesives used with a universal flowable composite resin in the restoration of non-carious cervical lesions *Clinical Oral Investigations* **23**(3) 1443-1452.
- Canali GD, Ignácio SA, Rached RN, & Souza EM (2019) One-year clinical evaluation of bulk-fill flowable vs regular nanofilled composite in non-carious cervical lesions *Clinical Oral Investigations* **23**(2) 889-897.
- Kemaloğlu H, Atalayin C, Ergucu Z, & Onal B (2020) Follow-up of flowable resin composites performed with a universal adhesive system in non-carious cervical lesions: A randomized, controlled 24-month clinical trial *American Journal of Dentistry* **33**(1) 39-42.
- Reis A & Loguercio AD (2006) A 24-month follow-up of flowable resin composite as an intermediate layer in non-carious cervical lesions *Operative Dentistry* **31**(5) 523-529.

30. Li Q, Jepsen S, Albers HK, & Eberhard J (2006) Flowable materials as an intermediate layer could improve the marginal and internal adaptation of composite restorations in Class-V-cavities *Dental Materials* **22**(3) 250-257.
31. Loguercio AD, Zago C, Leal K, Ribeiro NR, & Reis A (2005) One-year clinical evaluation of a flowable resin liner associated with a microhybrid resin in noncarious cervical lesions *Clinical Oral Investigations* **9**(1) 18-20.
32. El-Safty S, Akhtar R, Silikas N, & Watts DC (2012) Nanomechanical properties of dental resin-composites *Dental Materials* **28**(12) 1292-1300.
33. Prieto LT, José Souza-Junior E, Pimenta Araújo CT, Lima AF, dos Santos Dias CT, & Maffei Sartini Paulillo LA (2013) Knoop hardness and effectiveness of dual-cured luting systems and flowable resin to bond leucite-reinforced ceramic to enamel *Journal of Prosthodontics* **22**(1) 54-58.
34. Cho E, Chikawa H, Kishikawa R, Inai N, Otsuki M, Foxton RM, & Tagami J (2006) Influence of elasticity on gap formation in a lining technique with flowable composite *Dental Materials Journal* **25**(3) 538-544.
35. Han SH, Sadr A, Shimada Y, Tagami J, & Park SH (2019) Internal adaptation of composite restorations with or without an intermediate layer: Effect of polymerization shrinkage parameters of the layer material *Journal of Dentistry* **80** 41-48.
36. Dionysopoulos D, Papadopoulos C, & Koliniotou-Koumpia E (2014) The evaluation of various restoration techniques on internal adaptation of composites in class V cavities *International Journal of Biomaterials* (2014) 148057.
37. Soubhagya M, Goud KM, Deepak BS, Thakur S, Nandini TN, & Arun J (2015) Comparative *in vitro* evaluation of internal adaptation of resin-modified glass ionomer, flowable composite and bonding agent applied as a liner under composite restoration: A scanning electron microscope study *Journal of International Oral Health* **7**(4) 27-31.
38. Bakhsh TA, Sadr A, Shimada Y, Mandurah MM, Hariri I, Alsayed EZ, Tagami J, & Sumi Y (2013) Concurrent evaluation of composite internal adaptation and bond strength in a class-I cavity *Journal of Dentistry* **41**(1) 60-70.
39. Yahagi C, Takagaki T, Sadr A, Ikeda M, Nikaido T, & Tagami J (2012) Effect of lining with a flowable composite on internal adaptation of direct composite restorations using all-in-one adhesive systems *Dental Materials Journal* **31**(3) 481-488.
40. Korkmaz Y, Ozel E, & Attar N (2007) Effect of flowable composite lining on microleakage and internal voids in class II composite restorations *Journal of Adhesive Dentistry* **9**(2) 189-194.
41. Aggarwal V, Singla M, Yadav S, & Yadav H (2014) Effect of flowable composite liner and glass ionomer liner on class II gingival marginal adaptation of direct composite restorations with different bonding strategies *Journal of Dentistry* **42**(5) 619-625.
42. Pedram P, Hooshmand T, & Heidari S (2018) Effect of different cavity lining techniques on marginal sealing of class II resin composite restorations *in vitro International Journal of Periodontics and Restorative Dentistry* **38**(6) 895-901.
43. Boruziniat A, Gharaee S, Sarraf Shirazi A, Majidinia S, & Vatanpour M (2016) Evaluation of the efficacy of flowable composite as lining material on microleakage of composite resin restorations: A systematic review and meta-analysis *Quintessence International* **47**(2) 93-101.
44. Borges ALS, Borges AB, Xavier TA, Bottino MC, & Platt JA (2014) Impact of quantity of resin, C-factor, and geometry on resin composite polymerization shrinkage stress in Class V restorations *Operative Dentistry* **39**(2) 144-151.
45. Malta DAMP, Magne P, & Monteiro-Junior S (2014) Bond strength and monomer conversion of indirect composite resin restorations, part 1: Light vs heat polymerization *Journal of Adhesive Dentistry* **16**(6) 517-522.
46. Almeida-Chetti VA, Macchi RL, & Iglesias ME (2014) Effect of post-curing treatment on mechanical properties of composite resins *Acta Odontológica Latinoamericana* **27**(2) 72-76.
47. Grazioli G, Francia A, Cuevas-Suárez CE, Zanchi CH, & De Moraes RR (2019) Simple and low-cost thermal treatments on direct resin composites for indirect use *Brazilian Dental Journal* **30**(3) 279-284.
48. Oberholzer TG, Makofane ME, du Preez IC, & George R (2012) Modern high powered led curing lights and their effect on pulp chamber temperature of bulk and incrementally cured composite resin *European Journal of Prosthodontics and Restorative Dentistry* **20**(2) 50-55.
49. Barceleiro MO, Miranda MS, Dias KRHC, & Sekito T (2003) Shear bond strength of porcelain laminate veneer bonded with flowable composite *Operative Dentistry* **28**(4) 423-428.
50. Bragança GF de, Mazão JD, Versluis A, & Soares CJ (2020) Effect of luting materials, presence of tooth preparation, and functional loading on stress distribution on ceramic laminate veneers: A finite element analysis *Journal of Prosthetic Dentistry* **125**(5) 778-787.
51. Blalock JS, Holmes RG, & Rueggeberg FA (2006) Effect of temperature on unpolymerized composite resin film thickness *Journal of Prosthetic Dentistry* **96**(6) 424-432.
52. Peumans M, De Munck J, Van Landuyt K, & Van Meerbeek B (2015) Thirteen-year randomized controlled clinical trial of a two-step self-etch adhesive in non-carious cervical lesions *Dental Materials* **31**(3) 308-314.