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Original Article

Evaluation of Microleakage of Two Nano Hybrid Composite Materials in Class II Cavities: A Stereomicroscopic Analysis

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Abstract

Aim: The aim of the study is to compare the microleakage of Tetric N-Ceram Bulk Fill and Spident EsCom100 composites in Class II cavities using a stereomicroscope.

Materials and Methods: A total of 66 extracted teeth were randomly divided into three groups. The teeth were mounted on putty, and standardized Class II cavities were prepared in each tooth. After cavity preparation, all cavities were etched and bonded. In Group 1, 22 teeth were restored with Spident EsCom100 composite with Spident EsBond Bonding agent. In Group 2, 22 teeth were restored with Spident EsCom100 with 3M ESPE Single Bond Universal Adhesive bonding agent. In Group 3, 22 teeth were restored with Tetric N-Ceram Bulk Fill composite using Tetric n-bond total etch bonding agent according to the manufacturer's instructions. The restored samples were subjected to thermocycling and then immersed in 1% methylene blue dye for 24 h. Subsequently, the teeth were sectioned mesiodistally into two halves using a low-speed diamond disc. All sections were examined under a stereomicroscope at ×20 magnification.

Results: A statistically significant difference in cervical microleakage was observed among the three groups (P = 0.037). Group 1 (EsCom100 + EsBond) exhibited significantly higher microleakage than Groups 2 and 3 (P < 0.05), while no significant difference was found between Groups 2 and 3 (P = 0.864).

Conclusion: Restorative technique and adhesive protocol significantly influenced cervical microleakage in Class II composite restorations. Group 1 (EsCom100/EsBond) exhibited the highest microleakage, whereas the use of a universal adhesive in Group 2 significantly improved marginal sealing, showing performance comparable to Group 3. Group 3 (Tetric N-Ceram Bulk Fill/Tetric N-Bond) demonstrated the lowest microleakage, confirming the effectiveness of bulk-fill composite technology.

Key words: Bulk-fill composite, Class II cavity, Microleakage, Nanohybrid composite, Stereomicroscopy, Universal adhesive

INTRODUCTION

Maintaining optimal dental health is essential for ensuring a high quality of life. In recent years, dentistry has undergone rapid advancements, with a significant shift toward minimally invasive techniques and preventive approaches. Adhesive dentistry, in particular, has revolutionized restorative procedures by enabling preservation of tooth structure while achieving superior functional and esthetic outcomes.[1]

Composite resins are the most widely used direct restorative materials for the management of dental caries, coronal fractures, and structural defects due to their excellent esthetic and mechanical properties. However, polymerization shrinkage remains a major drawback, generating stresses at the tooth–restoration interface. This can result in gap formation, marginal microleakage, post-operative sensitivity, and eventual restoration failure.[2]

Microleakage, defined as the passage of bacteria, fluids, molecules, and ions between the restorative material and cavity walls, is a critical factor influencing the longevity

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of restorations. It may lead to hypersensitivity, secondary caries, and pulpal damage.

Achieving a uniform and durable seal is particularly challenging in Class II restorations, especially at gingival margins, which are more susceptible to leakage due to their proximity to the gingival crevice.[3] To overcome these limitations, bulk-fill composite resins have been introduced, allowing placement in thicker increments with reduced polymerization shrinkage stress and adequate depth of cure. Tetric N-Ceram Bulk Fill, a nanohybrid composite incorporating Ivocerin® initiator technology, enables efficient polymerization with improved marginal integrity and reduced chair time.[4]

In addition, nanohybrid universal composites such as Spident EsCom100 have been developed to provide an optimal balance of strength, esthetics, and handling characteristics, with improved resistance to marginal leakage and post-operative sensitivity. Contemporary adhesive systems also play a crucial role in enhancing restoration longevity. Universal adhesives such as Tetric N-Bond total etch, Spident EsBond, and 3M ESPE Single Bond Universal offer simplified application protocols, compatibility with multiple etching strategies, and reliable bond strength to enamel and dentin, thereby improving marginal adaptation and reducing technique sensitivity.[5,6]

Dye penetration, dye diffusion, fluid filtration, radioisotope penetration, animal studies, and electrochemical or 3D evaluation are different methodologies used to assess microleakage. Still, the dye penetration method is the gold standard for checking microleakage in Class II restorations.[7]

Thus, to evaluate and compare cervical microleakage of bulk-fill and conventional nanohybrid composite resins using different universal adhesive systems in Class II cavities under stereomicroscopic evaluation.

MATERIALS AND METHODS

The present *in vitro* study was carried out in the Department of Conservative Dentistry and Endodontics, Government Dental College and Hospital, Jamnagar. Ethical approval for this study was obtained from the Institutional Ethics Committee, M.P. Shah Govt. Medical College and Guru Gobind Singh Hospital, Jamnagar (EC/NEW/INST/2021/1896, Ministry of Health and Family Welfare Department of Research) with ethical reference project no. January 01, 2026.

Study Design and Sample Size

This *in vitro* experimental study was conducted on 66 extracted human maxillary premolars. The data obtained from the samples were subjected to statistical analysis using the G*power software (Version 3.1.9.4) to evaluate microleakage in Class II restorations, with 22 specimens allocated to each group.

Specimen Selection and Storage

Freshly extracted non-carious permanent human premolars were included. Teeth with caries, cracks, restorations, or structural defects were excluded. All specimens were cleaned of debris and soft tissue remnants and stored in 0.1% thymol solution until use to ensure disinfection.

Cavity Preparation

Each tooth was mounted with an adjacent tooth in a putty index to simulate proximal contact. Standardized Class II proximal box cavities were prepared using ISO standard round diamond bur (size 2) (Mani, Japan) in a high-speed handpiece (NSK, PanaAir FX, Tokyo, Japan) at a speed of 3,00,000 RPM with water coolant. The cavity dimensions were standardized to 4 mm depth, 3 mm buccolingual width, and 1.5 mm gingival floor width from enamel because the magnitude of polymerization shrinkage depends on the configuration C-factor; in the present study, all the cavities prepared were of the same dimensions to ensure standardization.

A new bur was used after every five cavity preparations to maintain cutting efficiency. All cavity dimensions were verified using a Williams' graduated periodontal probe (GDC, Punjab). Saddle matrix system (TOR VM, Moscow, Russia) with wooden wedges (NMD, Mumbai) was applied to achieve proper proximal contour and contact.

Group Allocation

The specimens were randomly divided into three experimental groups ($n = 22$ each) based on the restorative material and bonding agent used:

- Group 1: Nanohybrid composite (Spident EsCom100) with fifth-generation adhesive (Spident EsBond, Incheon, South Korea), bulk-fill composite
- Group 2: Nanohybrid composite (Spident EsCom100, Incheon, South Korea) with Universal adhesive (3M ESPE Single Bond Universal, Bayern, Germany)
- Group 3: Bulk-fill composite (Tetric N-Ceram Bulk Fill, Ivoclar Vivadent, Schaan, Liechtenstein) with Universal adhesive (Tetric N-Bond, Ivoclar Vivadent, Schaan, Liechtenstein).

Restorative Procedure

All restorative procedures were performed under standardized conditions. The cavity surfaces were dried

using oil-free compressed air. A total-etch technique was employed using 37% phosphoric acid etchant (N-Etch, Ivoclar Vivadent, Schaan, Liechtenstein). Enamel was etched first, followed by dentin for 15 s, rinsed with water for 15 s, and gently air-dried for 5 s without desiccation.

- Group 1: Spident EsBond adhesive (Incheon, South Korea) was applied in two coats for 5 s, followed by gentle air drying and light curing (Blue phase, Ivoclar) with the light intensity of 1200 mW/cm^2 and a wavelength around 430–490 nm for 20 s. Restoration was completed using Spident EsCom100 composite (Incheon, South Korea) placed in 2 mm increments in the form of oblique layers with each increment cured at a light intensity of 1200 mW/cm^2 and wavelength around 430–490 nm for 20 s in accordance with manufacturing instructions.
- Group 2: 3M ESPE Single Bond Universal adhesive (Bayern, Germany) was applied in two coats for 5 s, followed by gentle air thinning and light curing for 20 s. The cavities were restored using Spident EsCom100 composite (Incheon, South Korea) placed in 2 mm increments in the form of oblique layers with each increment light-cured for 20 s at a light intensity of 1200 mW/cm^2 and wavelength around 430–490 nm in accordance with manufacturing instructions.
- Group 3: Tetric N-Bond total etch (Ivoclar Vivadent, Schaan, Liechtenstein) adhesive was applied in two consecutive coats for 5 s using a microbrush, followed by gentle air thinning for 5 s and light curing for 20 s using an LED curing unit (Bluephase, Ivoclar Vivadent) with a light intensity of 1200 mW/cm^2 and wavelength around 430–490 nm. The cavities were restored with Tetric N-Ceram Bulk Fill composite (Ivoclar Vivadent, Schaan, Liechtenstein) and cured with a light-curing unit (Bluephase–Ivoclar Vivadent) with the light intensity of 1200 mW/cm^2 and wavelength of 430–490 nm for 20 s in accordance with manufacturing instructions.
- Universal adhesives were intentionally used across different composite systems to evaluate their performance independent of manufacturer-specific bonding protocols.

Finishing, Storage, and Thermocycling

All restorations were finished using composite finishing burs (Shofu, Kyoto, Japan). The specimens were stored at 37°C in 100% relative humidity for 24 h. Thereafter, thermocycling was performed for 500 cycles between 5°C and 55°C with a dwell time of 30 s at each temperature.

Microleakage Evaluation

All tooth surfaces, except the restoration and a 1 mm margin surrounding it, were coated with two layers of nail varnish. Specimens were immersed in 1% methylene blue dye solution for 24 h at 37°C.

Following dye immersion, the teeth were rinsed under running water and sectioned longitudinally in a mesiodistal direction parallel to the long axis of the tooth. The sections were examined under a stereomicroscope at ×20 magnification.

Microleakage at the cervical margin was scored according to ISO/TS 11405:2003 criteria:

- Score 0: No dye penetration
- Score 1: Dye penetration up to half of the cervical floor
- Score 2: Dye penetration beyond half of the gingival floor without reaching the axial wall
- Score 3: Dye penetration extending to both cervical and axial walls.

Statistical Analysis

The data obtained from the specimens were compiled and subjected to statistical analysis using the Statistical Package for the Social Sciences statistics Software (Version 28.0; IBM Corp., Armonk, NY, USA). Because cervical microleakage was evaluated using ordinal scores (0–3) that did not follow a normal distribution, non-parametric statistical methods were performed. The Kruskal–Wallis H-test was utilized to evaluate overall statistically significant differences among the three independent experimental groups. *Post hoc* pairwise comparisons were subsequently carried out using the Mann–Whitney U-test to isolate specific differences between the restorative interfaces. Non-parametric effect sizes (r) were also calculated to determine the clinical relevance of the pairwise variations. For all tests, statistical significance was defined as $P < 0.05$.

RESULTS

The overall comparison using the Kruskal–Wallis test demonstrated a statistically significant difference in cervical microleakage scores across the three experimental groups ($Chi^2 = 6.593$, df = 2, $P = 0.037$). [Table 1] *Post hoc* pairwise analysis using the Mann–Whitney U - test revealed that Group 1 (Spident EsCom100 with Spident EsBond) exhibited significantly higher microleakage than both Group 2 (Spident EsCom100 with 3M ESPE Single Bond Universal) (U = 158.0, Z = −2.052, $P = 0.040$, effect size r = 0.309) and Group 3 (Tetric N-Ceram Bulk Fill with Tetric N-Bond) (U = 152.0, Z = −2.179, $P = 0.029$, effect size r = 0.328). No statistically significant difference in microleakage was observed between Group 2 and Group 3 (U = 234.5, Z = −0.171, $P = 0.864$, effect size r = 0.026).

Table 1: *Post hoc* pairwise comparisons and calculated effect sizes

Pairwise comparison	Mann–Whitney U	Standardized Z	*P*-value	Effect size (r)	Statistical significance
Group 1 versus Group 2	158.0	−2.052	0.040	0.309	Significant (strong effect)
Group 1 versus Group 3	152.0	−2.179	0.029	0.328	Significant (strong effect)
Group 2 versus Group 3	234.5	−0.171	0.864	0.026	Not significant (negligible)

DISCUSSION

The long-term durability and success of direct posterior resin composite restorations are heavily determined by their marginal adaptation and resistance to microleakage.[1,2] Microleakage is defined as the clinically undetectable passage of bacteria, fluids, oral molecules, and ions between the cavity wall and the restorative material.[2,3] This phenomenon is considered a primary factor leading to post-operative hypersensitivity, recurrent secondary caries, marginal discoloration, hybrid layer disintegration, and pulpal pathoses.[3,8,9] Achieving a stable and uniform seal at the restoration interface remains a complex task in Class II cavities, especially at the gingival/cervical margins, which are at a higher risk of microleakage due to their proximity to the gingival crevice, high fluid transudation through dentinal tubules, and the absence of a thick, reliable enamel border for bonding.[1,8,10,11]

The selection of human maxillary premolars for standardized Class II proximal box preparations in this study was highly deliberate. Maxillary premolars represent the most common posterior clinical scenario for proximal caries and subsequent direct composite interventions.[1,12] Anatomically, these teeth exhibit relatively consistent proximal crown morphology, flat proximal surfaces, and distinct cementoenamel junctions (CEJ), which facilitate standardized and reproducible cavity designs.[12] Furthermore, the proximity of the gingival seat to the CEJ in premolars simulates a highly demanding clinical zone where margins often terminate on thin cementum or dentin rather than robust enamel, testing the limits of contemporary adhesive protocols.[12,13]

To ensure standardization across all specimens, the prepared cavities were designed with identical dimensions to control the configuration factor (C-factor). The C-factor – defined as the ratio of bonded-to-unbonded dentinal walls – governs the development of internal contraction stresses.[13,14] In a Class II proximal box, the C-factor is unfavorably high (typically between 4.0 and 5.0), meaning that there is minimal free surface area available for the resin to flow and relieve stress during polymerization.[14,15] Consequently, any shrinkage-induced stress directly attacks the weakest link, which is the adhesive bond at the cervical floor, resulting in microgap formation and subsequent dye infiltration.[7,13,14]

To obtain correct anatomical contours and a tight cervical seal during restoration, the selection and application of a proper matricing and wedging system are paramount.[16] In this study, a saddle matrix system combined with wooden wedges was utilized. Unlike standard circumferential matrices, sectional or saddle matrix systems allow the restorative material to be compressed precisely into the proximal box without causing axial flattening, thereby establishing an anatomically correct proximal contact point.[16,17] Furthermore, the active insertion of wooden wedges is critical; the wedge acts to temporarily separate the adjacent teeth, compensating for the thickness of the matrix band, while simultaneously compressing the matrix band tightly against the gingival margin.[17] This snug seal prevents the extrusion of composite into the subgingival space, avoiding cervical overhangs that are highly prone to bacterial colonization and periodontal inflammation.[17,18]

Another pivotal protocol executed during the restorative phase was the active application ("rubbing" technique) of the bonding agents. Passive application of dental adhesives often results in inadequate hybrid layer formation.[19] In contrast, active rubbing of the universal adhesive (Group 2) and total-etch adhesive (Group 3) utilizing microbrushes serves multiple biomechanical purposes:

1. Smear layer dispersal: The mechanical rubbing action breaks down and disperses the smeared debris, allowing acidic monomers to gain intimate contact with the underlying dentin.[19]
2. Solvent evaporation: Solvents such as ethanol and water are highly volatile but must be completely evaporated prior to curing. Rubbing the adhesive thins the layer, facilitating the rapid release of these solvent carriers.[20] Residual solvent in the adhesive layer prevents complete polymerization, leading to resin-sparse, water-filled voids that degrade rapidly.[19,21]
3. Monomer infiltration: The mechanical rubbing force actively drives the hydrophilic monomers (such as HEMA and 10-MDP) deep into the acid-etched collagen meshwork and opened dentinal tubules, ensuring full tubule hybridization and a highly uniform, interlocking hybrid layer.[20,22]

Following the optimization of adhesive penetration, the photo-polymerization process (light curing) represents the absolute cornerstone of restorative stability.[23,24] Inadequate light curing is a major cause of clinical failure.

In this study, a high-intensity LED curing unit operating at 1200 mW/cm^2 was utilized. High radiant exposure is mandatory to achieve an optimal degree of monomer-to-polymer conversion.[24] Under-cured resins exhibit poor mechanical properties, high solubility, and a high fraction of unreacted free monomers.[24,25] These unreacted monomers are highly cytotoxic, posing a threat to pulpal vitality if they transude through dentinal tubules.[5,25] Furthermore, high cross-linking density within the cured polymer network is necessary to resist hydrolytic degradation under oral thermal stresses, which explains why meticulous light curing is vital to maintain long-term marginal seals.[23,24]

For conventional nano-hybrid composites, such as Spident EsCom100 (Groups 1 and 2), utilizing an incremental layering technique is essential to manage polymerization contraction.[18,26] Conventional composites undergo significant volumetric shrinkage (up to 5%).[27] By placing the resin in horizontal or oblique increments restricted to 2 mm thickness, the volume of material undergoing contraction at any single time is minimized.[20,27] This incremental placement effectively lowers the C-factor during each curing cycle, distributing the contraction stress more evenly and allowing the resin to flow from the unbonded top surface to relieve stress.[14,20] This stands in contrast to Group 3 (Tetric N-Ceram Bulk Fill), which is uniquely formulated to be cured as a single 4mm bulk increment due to its built-in materials science modifications.[28]

Our statistical analysis revealed a significant overall difference in cervical microleakage scores across the three experimental cohorts ($Chi^2 = 6.593$, df = 2, $P = 0.037$), rejecting the null hypothesis. The most notable finding was the severe marginal seal failure observed in Group 1 (Spident EsCom100 paired with its proprietary 5th-generation EsBond), which recorded the highest mean rank of 43.11, with 59.1% of the specimens showing maximum dye penetration (Score 3) [Figure 1]. [Table 2] This failure is attributed to the combined challenges of a high C-factor, technique-sensitive wet bonding protocols, and the lack of stress-relieving monomers in conventional composites.[26,29]

However, when the same conventional composite (Spident EsCom100) was paired with 3M ESPE Single Bond Universal (Group 2), the cervical microleakage was significantly reduced ($P = 0.040$, effect size r = 0.309) [Table 1], resulting in a mean rank of 29.23, with 45.5% of the samples achieving complete seal integrity (Score 0) [Figure 2]. This highlights the superior clinical value of 10-MDP monomers present in 3M Universal Bond.[30] The phosphate groups of 10-MDP chemically bond to the calcium in hydroxyapatite, creating stable calcium-MDP salts that are highly resistant to hydrolytic degradation.[30,31] This chemical coupling, combined with active rubbing and optimized solvents, successfully withstood the polymerization stresses of the conventional nano-hybrid.[22,31,32]

Group 3 (Tetric N-Ceram Bulk Fill with Tetric N-Bond Total Etch) demonstrated excellent resistance to cervical microleakage, recording the lowest mean rank of 28.16, with only 18.2% of the specimens showing a Score 3 [Figure 3] level of leakage [Table 2]. Tetric Bulk Fill relies on Viscoelastic Shrinkage Stress Relievers that yield during polymer network cross-linking, reducing stress on the margins.[33,34] Furthermore, it utilizes Ivocerin® Photo-initiator Technology, a Germanium-based initiator with an extremely high absorption coefficient in the blue-light spectrum. Ivocerin triggers uniform, deep polymerization through increments up to 4 mm thick, preventing under-cured, weak resin interfaces at the cervical floor.[23,28]

The *post hoc* pairwise comparisons revealed no statistically significant difference in microleakage behavior between Group 2 and Group 3 ($P = 0.864$, r = 0.026). This statistical equivalence provides an important clinical insight: while using low-shrinkage bulk-fill resins (Group 3) is a highly reliable method to preserve marginal integrity,[35,36] a comparable marginal seal can be achieved with a conventional nano-hybrid composite if it is paired with a highly engineered, 10-MDP-containing universal adhesive system (Group 2).[37] This is consistent with findings in the European Journal of Dentistry and Journal of Conservative Dentistry and Endodontics, which concluded that modern universal adhesive chemistries can successfully compensate for the contraction stresses of conventional resin matrices.[38]

Conversely, the use of conventional bonding protocols with standard nano-hybrids (Group 1) yields a higher risk of microgap formation.[38] While some classic studies suggest using flowable composites or resin-modified glass ionomer cements (RMGIC) as stress-absorbing intermediate liners to mitigate this issue,[3,33] newer clinical

Table 2: Frequency distribution of cervical microleakage scores and mean ranks

Group (*n*=22)	Score 0 (%)	Score 1 (%)	Score 2 (%)	Score 3 (%)	Mean rank
Group 1 (EsCom100+EsBond)	2 (9.1)	2 (9.1)	5 (22.7)	13 (59.1)	43.11
Group 2 (EsCom100+3M Universal)	10 (45.5)	1 (4.5)	4 (18.2)	7 (31.8)	29.23
Group 3 (Tetric Bulk+Tetric Bond)	9 (40.9)	3 (13.6)	6 (27.3)	4 (18.2)	28.16

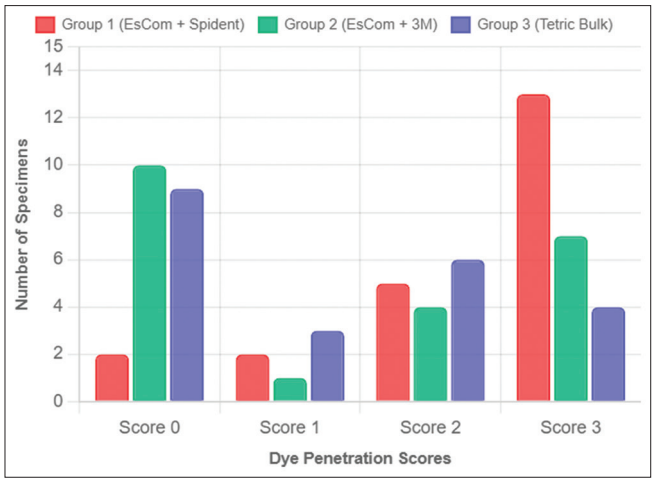

Figure 1: Frequency distribution of cervical microleakage scores across the three experimental groups (*n*=22 per group)

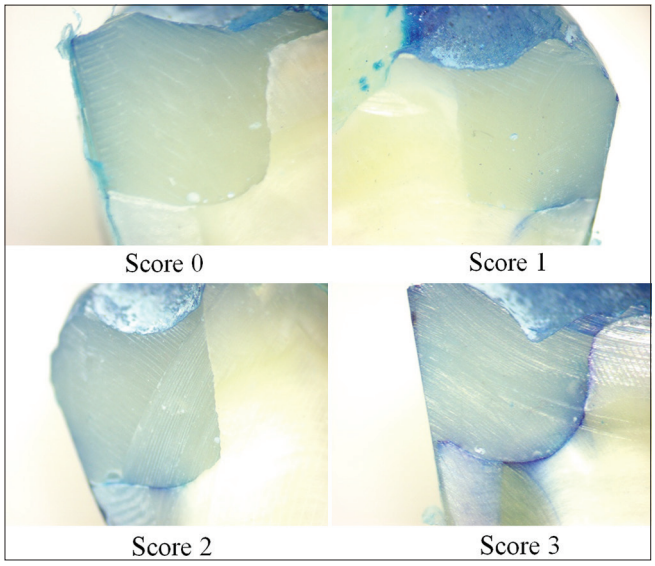

Figure 2: Microleakage scoring criteria

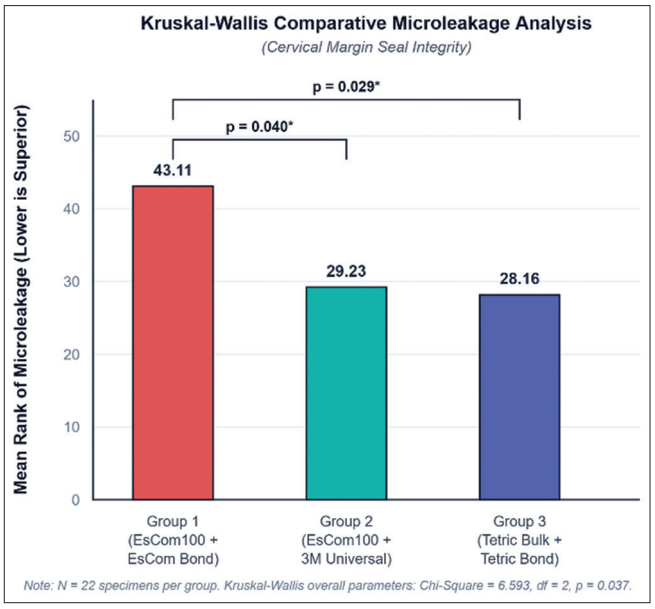

Figure 3: Kruskal–Wallis mean ranks of cervical microleakage for the evaluated restorative and adhesive interfaces

data published in the Journal of Conservative Dentistry and Endodontics indicate that these intermediate layers do not necessarily improve marginal sealing at sub-CEJ margins and may even increase interfacial stress due to mechanical and polymerization contraction mismatches.[18,39] Specifically, Ahirwal *et al.* demonstrated that Class II composite restorations placed with direct incremental or bulk-fill techniques exhibited significantly less cervical microleakage than those restored using RMGIC or flowable liners under thermal stress.[18] This is further corroborated by Mann *et al.*, who highlighted that while bioactive liners such as TheraCal LC and Biodentine show promising results, standard composite restorations without liners can still achieve comparable adaptation when modern universal adhesives are meticulously applied.[39]

Furthermore, Reddy *et al.* observed that while incorporating nanohydroxyapatite into GIC liners reduces microleakage at the dentin-liner interface, the interface integrity between the liner and the overlying composite remains a critical clinical challenge.[6] Thus, simplifying the adhesive interface by eliminating intermediary liners and instead utilizing universal bonding agents (Group 2) or bulk-fill composites (Group 3) minimizes the number of interfacial boundaries prone to adhesive failure, providing a more robust, long-term marginal seal.[6,18]

Ultimately, to optimize Class II restorative outcomes and ensure maximum restoration longevity, clinicians should focus on minimizing interface complexity by pairing conventional composites with advanced universal adhesives or utilizing specialized low-shrinkage bulk-fill materials.[18,28,35]

Limitations of the Study

Although this study provides valuable insights into marginal sealing, several limitations must be acknowledged. This *in vitro* model lacks dynamic oral simulations, such as vital pulpal pressure and salivary enzymatic activity, which accelerate hybrid layer degradation.[15,38] Specimens underwent hydrothermal stress (thermocycling) but not cyclic mechanical loading, which clinically acts synergistically with thermal changes to stress the adhesive interface.[38] Dye penetration microleakage assessment is a static, destructive, and cross-sectional method; three-dimensional, non-destructive techniques (e.g., micro-computed tomography or optical coherence tomography) would provide a more comprehensive, volumetric

assessment of marginal adaptation.[16] The 500-cycle thermocycling protocol represents only short-term aging, whereas long-term water storage (6–12 months) is required to verify the hydrolytic stability of the 10-MDP-calcium bond. Finally, these findings are material-specific and may not fully generalize to all commercial formulations with varying monomer chemistry and filler loads.

CONCLUSION

Within the limitations of this *in vitro* study, we conclude that restorative techniques and adhesive protocols significantly dictate the susceptibility of Class II composite restorations to cervical microleakage. Group 1 (Spident EsCom100/EsBond) exhibited the highest susceptibility to microleakage, showing comprehensive marginal sealing failure (Score 3). In contrast, active rubbing of a modern universal adhesive (Group 2, 3M ESPE Single Bond Universal) significantly improved the marginal seal of conventional nano-hybrid composite, achieving statistical equivalence to the bulk-fill gold standard ($P = 0.040$). Group 3 (Tetric N-Ceram Bulk Fill/Tetric N-Bond Total Etch) demonstrated the lowest overall mean rank of microleakage, confirming the reliability of stress-relieving bulk-fill composite technology.

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