ORIGINAL RESEARCH

Comparative Evaluation of Microleakage and Fracture Resistance of Two Novel Nanoceramic-based Restorative Materials in Standardized Class II Cavities Subjected to Thermocycling: A Multiparametric *In Vitro* Study

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Abstract

Background: Resin composites vary in physical properties, leading to the development of nanoceramics such as Admira Fusion (AF) and Neo Spectra ST (NSST). This study evaluated their microleakage and fracture resistance in class II cavities.

Objectives: To compare the microleakage and fracture resistance of AF and NSST in standardized Class II cavities subjected to thermocycling.

Materials and methods: Sixteen extracted teeth were divided into two groups ($n = 8$) and restored with either test material. After thermal cycling (2000 cycles, 5–55°C), samples were subjected to a dye penetration test and assessed under a stereomicroscope. For fracture resistance, 45 teeth were divided into four groups: group I (AF), group II (NSST), group III (unrestored teeth), and group IV (unprepared intact teeth). Specimens were then tested using a universal testing machine.

Results: Admira Fusion showed lower microleakage than NSST (occlusal margins: $p = 0.048$; cervical margins: $p = 0.000$) and higher fracture resistance (714.47 N) than NSST (651.00 N). Both materials showed 73.3% mode I failure.

Conclusion: Admira Fusion and NSST demonstrated favorable properties; however, significant differences were observed in certain parameters (microleakage).

Clinical significance: According to the study's findings, AF may provide better marginal integrity and durability in class II restorations than NSST because of its lower microleakage and increased fracture resistance.

Keywords: Admira Fusion, Fracture resistance, Microleakage, Neo Spectra ST.

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Introduction

Resin-based composites (RBC) are the foundation of contemporary dental practice and are the preferred choice of clinicians for direct restorations of teeth. This is due to their exceptional biological, physiochemical, and aesthetic properties. Despite many advantages, polymerization shrinkage and poor marginal adaptation leading to marginal microleakage are lingering concerns.[1–3]

Microleakage is the clinically undetectable passage of bacteria, fluids, molecules, or ions between a cavity wall and the restorative material applied to it.[4] It remains a substantial contributing factor to the failure of restorations. It serves as a precursor to secondary caries, postoperative sensitivity, restoration staining, tooth discoloration, marginal deterioration, degradation of restorative materials, and pulpal injury, adversely affecting the clinical efficacy and durability of restorations in the oral cavity.[5]

To reduce polymerization shrinkage and its clinical effects, material composition is just as crucial as filling technique.[6] Hence, restorative materials with different compositions are being developed.

In the quest for finding better restorative materials, a new generation of materials, ORMOCERS, was developed.[5] ORMOCER, an acronym for organically modified ceramic, was introduced as a dental restorative for the first time in 1998. Since then, this pioneering technology has seen continued research and development to overcome the limitations of the first generation of ORMOCER materials.[5,6] A new development in the area of ORMOCER is the universal nanohybrid ORMOCER restorative product Admira Fusion (AF), produced by VOCO, GmbH. The manufacturer claims that it has a unique "Pure silicate technology" which makes it the world's first purely ceramic-based healing substance.[7]

Another nanoceramic-based material recently introduced into the market is the nanoceramic, Neo Spectra ST (NSST), DENTSPLY, which contains the new Sphere TEC technology.[8]

Fracture toughness (critical stress intensity) is a mechanical parameter that indicates a brittle material's resistance to the

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catastrophic propagation of flaws under applied stress. It determines the lifespan of the material in the oral cavity.[9]

Only a few studies have compared the performance of AF and NSST; no study has evaluated the microleakage and fracture resistance of these two novel nanoceramic resin-based restorative materials in standardized class II cavities. In view of the paucity of research, the present study was undertaken to evaluate and compare the microleakage and fracture resistance of AF and NSST universal composite.

Materials and Methods

The Institutional Ethics Committee-VIDS-IEC granted approval for the study (Ref No: VIDS-IEC/PG/APP/2023/63). Seventy-six noncarious extracted permanent mandibular molars were procured from the institute. After extraction, teeth were cleaned with an ultrasonic scaler, examined under a 2X stereomicroscope, and stored per ISO TS 11405:2015.[10]

Inclusion criteria:

- Caries-free permanent mandibular molars (10.5 ± 0.5 mm buccolingual width).
- Unprepared, Intact teeth.

Exclusion criteria:

- Carious, restored, hypoplastic, or cracked teeth.

Sample Size Determination

I. To evaluate the microleakage of two novel nanoceramic-based restorative materials in standardized class II cavities

The sample size is calculated by using G*Power software for ANOVA

The formula is,

$$n = \frac{2\left[Z_{1-\frac{\alpha}{2^*\kappa}} + Z_{1-\beta}\right]^2}{\left(\frac{d}{\sigma}\right)^2}$$

Where,

$Z_{1-\frac{\alpha}{2^*\kappa}}$ = Standard normal score at 95% level of significance

$Z_{1-\beta}$ = Power

$\left(\frac{d}{\sigma}\right)$ = Effect size

At 95% level of confidence and 80% power, with a standard effect size of 0.4, the minimum sample size in each group is 15 (Rounded off to $N = 32$; $n = 16$ class II cavities/group).

II. To evaluate the fracture resistance of two novel nanoceramic-based restorative materials in standardized class II cavities

The sample size is calculated by using G*Power software for ANOVA

The formula is,

$$n = \frac{2\left[Z_{1-\frac{\alpha}{2^*\kappa}} + Z_{1-\beta}\right]^2}{\left(\frac{d}{\sigma}\right)^2}$$

Table 1: Material description, composition, and manufacturer details of the materials used in the study

Product	*Chemical composition as per the product brochure*	*Filler content, percentage*	*Manufacturer*	*Batch no.*
Admira Fusion (Nanohybrid ORMOCER)	Fillers (Nano-fillers as well as glass ceramics) and ORMOCER matrix based purely on silicon oxide.[7]	84 (w/w) 69 (v/v)	VOCO GmbH, Germany	2402064
Neo Spectra ST (Universal Composite Nanoceramic)	Modified methacrylate polysiloxane (organically modified ceramics) Dimethacrylate resins Fluorescent pigment UV stabilizer Stabilizer Camphoroquinones Ethyl-4(dimethylamino) benzoate Bis(4-methylphenyl) iodonium hexafluorophosphate Barium aluminum borosilicate crystals Ytterbium fluoride Titanium oxide and iron oxide pigments according to colour.[8]	78–80 (w/w) 60–62 (v/v)	DENTSPLY Sirona	2310000170
Scotchbond™ Universal Adhesive	MDP Phosphate Monomer Dimethacrylate resins HEMA Vitrebond™ Copolymer Filler Ethanol Water Initiators Silane		3M ESPE	30918C
Prime and Bond Universal™	PENTA (dipentaerythritol pentacrylate phosphate), 10-MDP (10-methacryloyloxydecyl 4-hydrogen phosphate), Active Guard™ Technology crosslinker, CQ/tertiary amine, 10–24.5% Isopropanol, 5–24.5% water		DENTSPLY Sirona	2309000225

Where,

$Z_{1-\frac{\alpha}{2*\kappa}}$ = Standard normal score at 95% level of significance

$Z_{1-\beta}$ = Power

$\left(\frac{d}{\sigma}\right)$ = Effect size

At 95% level of confidence and 80% power, with a standard effect size of 0.4, the minimum sample size in each group is 15 ($N = 60$, $n = 15$ test specimens/group) (Table 1).

Other materials:

- Ivoclar Vivadent N-Etch: 37% orthophosphoric acid, Ivoclar.
- Therapeutically extracted permanent mandibular molars.

Cavity Preparation for Microleakage Test

A total of sixteen teeth were subjected to 24-hour conditioning using distilled water at 23 ± 2°C. Mounted on acrylic blocks with wax spacer, two standardized class II (MO and DO) cavities [occlusal cavity depth: 2 mm, isthmus width (buccolingual): 2 mm, axial wall depth (mesiodistal): 2 mm, proximal box height: 4 mm, gingival floor width: 2 mm, occlusal width (mesiodistal): 4 mm, cavity depth (occlusal to base): 4 mm] were prepared per tooth (Fig. 1).[11,12] Dimensions were verified using a UNC-15 probe (SD ± 0.2 mm). Cervical margins were 1 mm above the CEJ, with 90° Cavo surface angles and no bevels. All preparations were done by a single operator using cylindrical diamond burs (changed after five uses) with a high-speed handpiece. Preparation accuracy was verified by a second investigator.

Teeth were divided into two groups ($n = 8$ each):

- Group I: Admira Fusion, adhesive—single bond.
- Group II: Neo Spectra ST, adhesive—prime and bond universal.

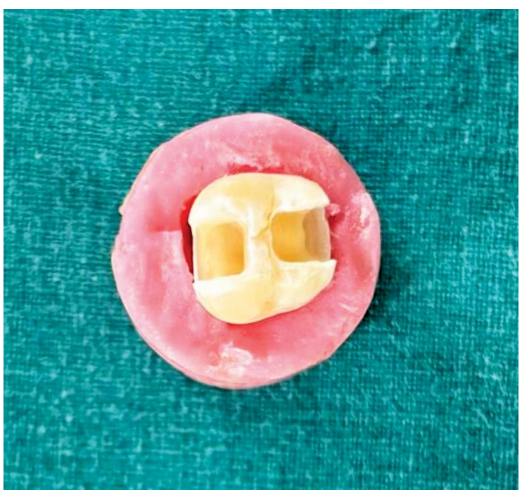


Fig. 1: Standardized class II cavities prepared (MO and DO)

Cavity Preparation for Fracture Resistance Evaluation

Acrylic resin (without wax spacer) was used to mount teeth using a custom metal mold with 1 mm of tooth above CEJ. After setting, they were removed. A single class II cavity was prepared in 45 teeth, then distributed to:

- Group I: Admira Fusion + single bond.
- Group II: Neo Spectra ST.
- Group III: Prepared but unrestored.
- Group IV: Intact, unprepared.

Cavity Conditioning and Restoration

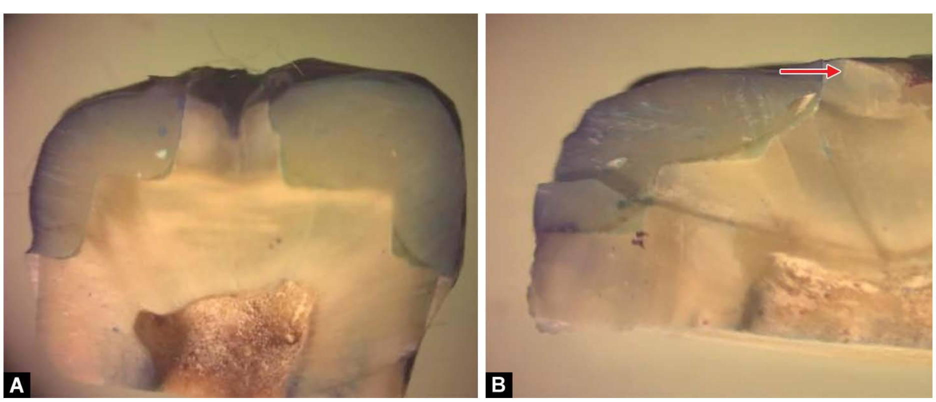
Cavities were etched with 37% phosphoric acid gel (Ivoclar)–enamel: 20–30 seconds, dentine: 15 seconds, rinsed 20 seconds. Moisture was removed with a 3-way syringe. Then the adhesives were applied: group I (Scotchbond Universal) for 20 seconds, group II (prime and bond universal) for 15 seconds, dispersed with air, and light-cured for 10 seconds. Restorations were done with AF (group I) and NSST (group II) using ≤ 2 mm increments, light-cured for 20 seconds (group I) and 15 seconds (group II) using LED (min. 500 mW/cm^2). A circumferential metal matrix was used for the restoration.

After restoration, the samples were kept in distilled water at a temperature of 37 ± 2°C for 24 hours and then polished with abrasive disks (Nexus Medodent). With a duration of 30 seconds, 2,000 repetitions of thermal cycling were performed within a temperature range of 5–55°C.[12]

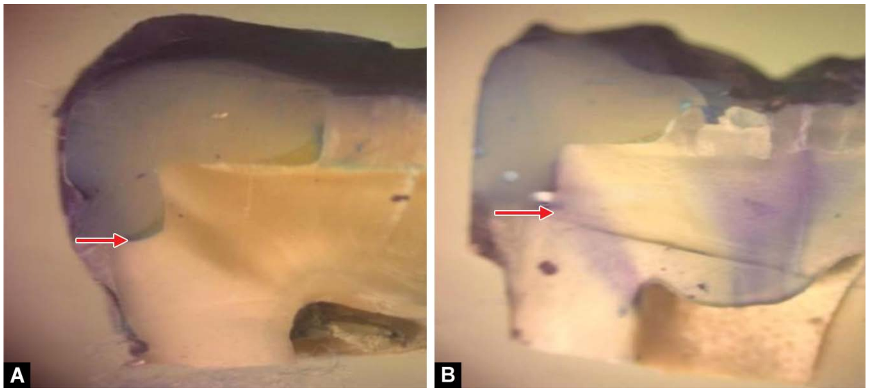
Microleakage Evaluation

Teeth were coated with two layers of nail polish, ensuring that there was a 1 mm border around the restoration. The root tips were closed using self-curing acrylic resin (DPI). After rinsing and 48 hours of immersion in 1% methylene blue at 37°C, samples had their roots sectioned 3 mm below CEJ. Crowns were mesiodistally sectioned and polished. Two blinded investigators assessed microleakage under a stereomicroscope (Leica EZ4, 40×). Disagreements resolved by the worst score. Images analyzed for dye penetration scoring:

- Score 0: No penetration (Fig. 2A).
- Score 1: Penetration into enamel (Fig. 2B).
- Score 2: Penetration into dentin, not pulpal wall (Fig. 3A).
- Score 3: Penetration including pulpal wall of the cavity (Fig. 3B).



Figs 2A and B: Microleakage test—representative test specimen of under stereomicroscope (40x): (A) Score 0; (B) Score 1



Figs 3A and B: Microleakage test—representative test specimen under stereomicroscope (40x): (A) Score 2; (B) Score 3

Figs 4A to C: Representative sample showing different modes of failure encountered: (A) Mode I; (B) Mode II; (C) Mode IV

Table 2: Group-wise frequency distribution of microleakage scores (occlusal and cervical margins)

			Frequency distribution							
			Score 0		*Score 1*		*Score 2*		*Score 3*	
Test group	*Restoration margin*	*N*	*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*
Group I (Admira Fusion)	Occlusal score	16	6	37.5	4	25	00	00	6	37.5
	Cervical score	16	2	12.5	3	18.8	7	43.8	4	25.0
Group II (Neo Spectra ST)	Occlusal score	16	2	12.5	00	00	4	25	10	62.5
	Cervical score	16	00	00	00	00	00	00	16	100

Mechanical Testing and Fracture Analysis

After removing the teeth from the distilled water, a Universal Testing Machine (Shimadzu, Tokyo, Japan) was used to perform fracture testing. In the center of the restoration's occlusal surface, a stainless-steel ball-shaped plunger (6 mm in diameter) was positioned parallel to the tooth's long axis and made contact with the buccal and lingual cuspal inclines of the teeth. A crosshead speed of 1 mm/min was used to apply the load, and the highest load before failure occurred was recorded in Newtons. The samples were also examined to identify the mode of failure, which was categorized as follows:[13]

- Mode I: Fracture in restorative material (Fig. 4A).
- Mode II: Fracture in the tooth and restoration (Fig. 4B).
- Mode III: Fracture of one cusp (intact restoration).
- Mode IV: Longitudinal fracture, unrestorable (Fig. 4C).

Statistical Analysis

Data were analyzed using IBM SPSS Statistics v23.0 (IBM Corp., Armonk, NY). Descriptive statistics (frequency, percentage for categorical variables; mean, SD for continuous variables) were applied. One-way ANOVA with Tukey's *post hoc* test was used for multivariate analysis. Mann–Whitney *U* and Wilcoxon signed-rank tests were used for intergroup and intragroup comparisons, respectively. A p-value < 0.05 was considered significant.

Results

Intergroup Comparison of Microleakage Score (Tables 2 to 4)

For occlusal margins of AF, scores 0 and 3 were each observed in 37.5% of samples, while score 1 was 25%. For cervical margins, score

Table 3: Intergroup comparison of microleakage scores for occlusal and cervical margins of group I vs group II

Microleakage score	*Group I—occlusal (n = 16)*		*Group II—occlusal (n = 16)*		*Group I—cervical (n = 16)*		*Group II—cervical (n = 16)*	
Scoring for the cavity margin	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
0	6	37.5	2	12.5	2	12.5	00	00
1	4	25	00	00	3	18.8	00	00
2	00	00	4	25	7	43.8	00	00
3	6	37.5	10	62.5	4	25.0	16	100
Median	1		3		2		3	
Range	3		3		3		0	
Min–max	0–3		0–3		0–3		3–3	
Mean ± SD	1.38 ± 1.360		2.37 ± 1.025		1.81 ± 0.981		3.00 ± 0.00	
Percentiles								
25	0.00		2.00		1.00		3.00	
50	1.00		3.00		2.00		3.00	
75	3.00		3.00		2.75		3.00	

Table 4: Intergroup comparison of mean ranks of microleakage scores for occlusal and cervical margins of group I vs group II (Mann–Whitney test)

Cavity margin	*Groups*	*N*	*Mean rank*	*Sum of ranks*	*Mann–Whitney U*	*p-value*
Occlusal score	Group I (Admira Fusion)	16	13.50	216.00	80.00	0.048
	Group II (Neo Spectra ST)	16	19.50	312.00		
Cervical score	Group I (Admira Fusion)	16	10.50	168.00	32.00*	0.000*
	Group II (Neo Spectra ST)	16	22.50	360.00		

*The *p*-value is less than 0.05, which indicates that there is a statistically significant difference in occlusal score and cervical score between group I and group II

Table 5: Intragroup comparison of mean ranks microleakage scores for occlusal and cervical margins of group I and group II (Wilcoxon signed-rank test)

Groups		*N*	*Mean Rank*	*Sum of Ranks*	*Z*	*p-value*
Group I (Admira Fusion) (Occlusal vs cervical scores)	Negative Ranks	2a	4.00	8.00	−1.811	0.70
	Positive Ranks	7b	5.29	37.00		
	Ties	7c				
	Total	16				
Group II (Neo Spectra ST) (Occlusal vs cervical scores)	Negative ranks	0d	0.00	0.00	−2.271	0.023*
	Positive ranks	6e	3.50	21.00		
	Ties	10f				
	Total	16				

*The *p*-value is less than 0.05. This indicates that there is a statistically significant difference between occlusal and cervical microleakage scores for group II

2 (43.8%) was most frequent, followed by score 3 (25%), score 1 (18.8%), and score 0 (12.5%).

In NSST, occlusal margins predominantly showed score 3 (62.5%), followed by score 2 (25%) and score 0 (12.5%). All cervical margins (100%) exhibited a score of 3. AF demonstrated better sealing at occlusal margins (score 0 in 37.5%) compared to NSST (12.5%).

A statistically significant difference in occlusal microleakage scores was observed between groups ($p = 0.048$), with a highly significant difference in cervical margins ($p = 0.000$), indicating superior marginal integrity in AF.

Intragroup Comparison of Microleakage Scores (Table 5)

In AF, score 0 was more frequent in occlusal (37.5%) than cervical (12.5%) margins. Score 3 appeared in 37.5% (occlusal) and 25% (cervical), while score 2 was more common in cervical (43.8%). In NSST, cervical margins uniformly showed a score of 3 (100%), while occlusal margins showed a score of 3 in 62.5%.

Intragroup comparison of the mean ranks of the microleakage scores revealed no statistically significant difference in microleakage scores between occlusal and cervical margins of AF ($p = 0.070$), whereas NSST exhibited a highly significant difference ($p = 0.023$).

Table 6: Group-wise mean values of fracture resistance in Newton (N)

Test groups	*N*	*Mean*	*Std deviation*	*95% Confidence interval for mean*		*Minimum*	*Maximum*
				Lower bound	*Upper bound*		
Group I (Admira Fusion)	15	714.467	145.0364	634.148	794.785	497.0	1010.0
Group II (Neo Spectra ST Universal)	15	651.000	147.5577	569.285	732.715	276.0	839.0
Group III (Prepared but unrestored teeth)	15	244.667	49.4638	217.275	272.059	139.0	292.0
Group IV (Intact teeth with no preparations)	15	1352.533	217.2141	1232.244	1472.823	1101.0	1793.0

Table 7: Overall comparison of Fracture resistance of all test groups using ANOVA

	Sum of squares	*df*	*Mean square*	*F*	*Sig*
Between groups	9436850.533	3	3145616.844	136.119	0.000
Within groups	1294124.800	56	23109.371		
Total	10730975.333	59			

Here p-value < 0.05 (0. 000 < 0.05). There is a statistically significant difference between the test groups

Table 8: Inter-group comparison of Fracture resistance of all test groups using *post hoc* test (Tukey HSD)

Test groups		*Mean difference (between the groups)*	*Std. error*	*p-value*	*95% Confidence Interval*	
					Lower bound	*Upper bound*
I (Admira Fusion)	II	63.4667	55.5090	0.665	−83.515	210.448
	III	469.8000*	55.5090	0.000*	322.818	616.782
	IV	−638.0667*	55.5090	0.000*	−785.048	−491.085
II (Neo Spectra ST Universal)	III	406.3333*	55.5090	0.000*	259.352	553.315
	IV	−701.5333*	55.5090	0.000*	−848.515	−554.552
III (Prepared but unrestored teeth)	I	−469.8000*	55.5090	0.000*	−616.782	−322.818
	II	−406.3333*	55.5090	0.000*	−553.315	−259.352
	IV	−1107.8667*	55.5090	0.000*	−1254.848	−960.885

*Represents there is a significant difference between the groups

Table 9: Intergroup comparison of frequency distribution of mode of failure (group I vs group II)

Test group	*N*	*Frequency distribution*								
		Mode I		*Mode II*		*Mode III*		*Mode IV*		*Total*
		Frequency	*%*	*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*	*%*
Group I (Admira Fusion)	15	11	73.3	3	20.0	00	00	1	6.7	100%
Group II (Neo Spectra ST Universal Composite)	15	11	73.3	2	13.3	00	00	2	13.3	100%

Intergroup Comparison of Fracture Resistance (Tables 6 to 8)

Group I (AF) ranged from 497.0 to 1010.0 N, with a mean of 714.47 ± 145.04. Group II (NSST) ranged from 276.0 to 839.0 N, with a mean of 651.00 ± 147.56. Group III (prepared but unrestored teeth) showed the lowest values, ranging from 139.0 to 292.0 N (mean 244.67 ± 49.46). Group IV (intact teeth) exhibited the highest resistance, ranging from 1101.0 to 1793.0 N (mean 1352.53 ± 217.21). The descending order of mean fracture resistance was: group IV > group I > group II > group III. Statistical analysis revealed a highly significant difference in fracture resistance among all groups ($p = 0.000$), except between group I and group II, where no significant difference was observed ($p = 0.665$).

Intergroup Comparison of Mode of Failure (Table 9)

Failure modes were assessed post-fracture. Both AF and NSST predominantly showed mode I failure (fracture limited to the restorative material) in 73.3% of samples.

Admira Fusion also showed mode II (tooth and restoration fracture) in 20% and mode IV (longitudinal fracture, unrestorable) in 6.7%. NSST showed mode II in 13.3% and mode IV in 13.3%. No statistically significant difference in failure mode was observed between the two groups ($p = 0.315$).

Discussion

The advancement of resin-based composites has been propelled by esthetic requirements and the pursuit of alternatives to amalgam restorations owing to mercury apprehensions.[14,15] Notwithstanding advancements in filler technology and adhesive methodologies, polymerization shrinkage continues to pose a significant obstacle that undermines the marginal integrity of restorations.[14,16] This contraction induces internal stresses that may surpass bond strengths, leading to marginal gaps, microleakage, postoperative sensitivity, recurrent caries, and eventually, restoration failure.[2,11,15,16]

Alternative monomer systems and filler technologies have been devised to address these constraints. Nonetheless, significant alterations to the resin matrix have been minimal since the advent of Bis-GMA and other dimethacrylates.[17]

ORMOCER-based materials (organically modified ceramics) present an innovative methodology featuring an inorganic-organic hybrid matrix that establishes a three-dimensional crosslinked network prior to curing.[18] These materials demonstrate enhanced polymerization characteristics and less volumetric shrinkage owing to their prepolymerized siloxane framework.[17,18] The creation of AF by VOCO marked a substantial advancement in this domain. This is the inaugural restorative composite that entirely replaces traditional methacrylates such as Bis-GMA, TEGDMA, and HEMA with a pure ORMOCER matrix derived from silicate technology.[7,14,18] The second material evaluated in this study, NSST, is a sophisticated nano-hybrid composite using SphereTEC® technology. It includes methacrylic polysiloxane nanofillers that improve adaptability, handling, and mechanical performance. The spherical microstructure and elevated filler loading (78–80 wt%) of NSST are designed to minimize shrinkage and enhance physical strength.[8,19]

Methylene blue was used due to its diminutive molecular weight (319.9 Da), enabling it to replicate the infiltration of microbial toxins and providing enhanced sensitivity compared to alternative dyes, such as silver nitrate.[20]

The findings demonstrated that AF displayed markedly reduced microleakage at both the test surfaces compared to NSST ($p = 0.048$ and $p = 0.000$, respectively). These findings align with other studies indicating enhanced marginal integrity for ORMOCER-based composites compared to methacrylate-based alternatives.[18,21,22] Kalra et al.[17] and Sudhapalli et al.[5] both observed less microleakage in ORMOCER materials relative to hybrid and nanohybrid composites. Civelek et al.[22] and Politi et al.[21] similarly stated that AF exhibited superior marginal sealing compared to Tetric EvoCeram and other hybrid composites following thermocycling.

Nonetheless, some researchers, such as Yazici et al.[23] and Al-Harbi et al.[14] observed no substantial difference in microleakage between ORMOCERs and traditional composites. These inconsistencies may be ascribed to variations in adhesive systems, cavity design, thermocycling techniques, and aging processes. Furthermore, Bedran de Castro et al.[24] and Hooshmand et al.[15] observed increased microleakage in ORMOCERs compared to hybrid composites under particular bonding conditions, suggesting that material efficacy may be affected by method sensitivity and adhesive compatibility. This study's intragroup comparisons indicated that microleakage was more significant at the cervical edges compared to occlusal sites for NSST, corroborating other findings.[11,15,18,20] Cervical margins, especially those situated in dentin or cementum, pose bonding difficulties owing to reduced mineral content, increased moisture, and a scarcity of enamel prisms for micromechanical retention.[22] Enamel provides a more solid substrate for adhesion compared to dentin or cementum because of its elevated inorganic composition (95%).

The reduced microleakage of AF can be ascribed to its prepolymerized polysiloxane matrix, which experiences negligible volumetric shrinkage during the curing process.[17,18] The elevated filler loading (84 wt%) and modulus of elasticity enhance the material's stability during the setting process.[7] Furthermore, the diminished presence of residual monomers improves biocompatibility and mitigates interfacial deterioration.[14,17]

The fracture resistance test indicated no meaningful difference between AF and NSST; nevertheless, AF exhibited a little greater mean resistance (714.47 N compared to 651.0 N). Both materials exhibited markedly superior fracture resistance compared to unrestored prepared teeth (244.66 N) and endured loads surpassing ordinary masticatory forces (200–540 N). The results correspond with earlier studies by Hamouda et al.,[25] which indicated superior fracture resistance in teeth treated with ORMOCERs relative to those restored with other composites.[20–25]

In contrast, research conducted by Taha et al.[26] indicated diminished fracture resistance of ORMOCERs relative to packable or nanoceramic composites. This variance is probably attributable to differences in cavity design, restorative methods, and loading regimes. Taha et al.[26] employed MOD cavities with increased isthmus widths, which intrinsically compromise the tooth structure and may influence outcomes variably based on the restorative material utilized.[27]

The failure analysis revealed that both materials predominantly displayed Mode I failures—fractures limited to the restorative material—indicating cohesive failure without affecting the tooth structure. This result indicates advantageous stress distribution and mechanical characteristics, including flexural strength and compressive resistance, in both materials.[15] Keskin et al.[13] and Aboelnagga et al.[27] showed analogous failure patterns, hence validating the structural integrity of ORMOCERs under stress.

In our investigation, incremental implantation was utilized to alleviate polymerization pressure, which could have contributed to the positive outcomes of the study. This study highlights the possible effectiveness of both materials *in vitro*, although their clinical significance should be evaluated with caution. Laboratory testing, while beneficial for comparative study, fails to emulate the dynamic conditions of the oral environment. This study has limitations due to the lack of load cycling and dynamic fatigue testing. Although static load testing yields significant insights, masticatory forces are characterized by cyclicality and intermittence. Future research should incorporate thermomechanical cycling and simulate pH and salivary interactions to more accurately replicate intraoral environments. Furthermore, evaluating the effects of different adhesive systems, curing methods, and elastic liners may enhance the therapeutic application of these materials.

Clinical Significance

Compared to NSST, AF showed improved marginal sealing and greater fracture resistance, indicating longer-lasting Class II restorations. Both materials showed fracture resistance above normal masticatory load, confirming their clinical applicability. AF may lessen the chance of secondary caries and restoration failure by reducing microleakage. As a result, ORMOCER-based composites are a dependable option for long-lasting posterior restorations.

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