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COMPARATIVE MICROLEAKAGE ASSESSMENT OF FIFTH, SEVENTH, AND EIGHTH-GENERATION DENTIN ADHESIVES IN CLASS II COMPOSITE RESTORATIONS: AN IN VITRO STUDY

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ABSTRACT
The problem of microleakage at the tooth repair junction in adhesive dentistry is of great concern as it may lead to a number of undesirable outcomes such as postoperative sensitivity, marginal discoloration, recurrent caries, pulpal irritation, and fiasco of the restoration. This in vitro investigation compared (SGA) of 5th, 7th and 8th generation dentin bonding agents (DBAs) in standard Class II box only composite (CO) restorations. A total of 90 (freshly extracted) human premolars were randomly subdivided into three groups of equal size. The restoration process for Group I was with Adper Single Bond 2, Group II with Coltene One Coat 7 Universal and Group III with G-Premio Bond. All cavities were filled with nanohybrid composite resin and exposed to 500 thermocycling from 5°C to 55°C. The specimens were placed in 2% methylene blue dye for 24 hours, longitudinally sectioned and observed under the stereomicroscope at a magnification of 40×. Microleakage was scored from 0 to 4 and analysed using the Kruskal–Wallis and Mann–Whitney U tests. The three groups were found to be significantly different ($p < 0.001$). The fifth-generation adhesive had the highest mean rank (74.97) for microleakage followed by the seventh-generation adhesive (46.03) while the eighth generation G-Premio Bond had the lowest mean rank (15.50). The 8th generation adhesive was therefore found to give the best marginal seal under the test conditions.

KEYWORDS: Microleakage; dentin bonding agents; Class II restoration; universal adhesive; marginal sealing.

INTRODUCTION
The field of restorative dentistry has evolved over the years to a biomimetic and minimally invasive approach that aims to maintain sound tooth structure with the goal of restoring function and aesthetics. A key change that has been facilitated by increases in adhesive dentistry is the ability to bond composite to enamel and dentin. The advancement of dental resin adhesives has been driven by several key areas, such as ease of use, enhancing bond durability, and extending the lifespan of restorations in clinical settings (Alomran et al., 2025). Dentin bonding is more difficult than enamel bonding due to its natural moisture, mineralization, collagen content, and tubule density and orientation. The smear layer and the presence of outward dentinal fluid movement could affect the penetration of the adhesive and the establishment of the hybrid layer (Migliau, 2017).

While modern composite materials offer excellent aesthetic properties, mechanical characteristics, and others, there is no complete achievement of the elimination of the marginal leakage yet (Sudhapalli et al., 2018). The clinically undetectable leaking of germs, fluids, ions, or chemicals between the curative material and the cavity wall is known as microleakage.The polymerization shrinkage of composite resin may create contraction stress at the interface where it is bonded and cause the formation of gaps at the adhesive interface if the bonding strength is not sufficient (Karaman & Ozgunaltay, 2014). Cavity configuration, light-curing technique, restorative placement and the location of the cavity margin (Zakavi et al., 2014) may also influence the magnitude of leakage. Clinical significance of microleakage is that it can cause marginal discoloration, postoperative sensitivity, recurrent caries, irritation of the pulp and early failure of the restoration (Waldman et al., 2008).

Dentin bonding agents have had multiple generations with the goal of increasing bond strength and decreasing procedures. In earlier etch-and-rinse systems, the bonding was generally found to be good, but moisture was required to be carefully controlled and the procedure carefully performed to execute multiple steps (Kallenos et al., 2005). Fifth generation adhesives include both of the primer and adhesive in one, while keeping a separate phosphoric acid etching stage, which provide reliable adhesion, but are still technique sensitive (Vinay & Shivanna, 2010). There is comparative evidence that some 5th generation systems achieve better marginal sealing than the simplified one-step adhesives (Tabari et al., 2016). Seventh-generation systems can be referred to as self-etching, as they allow print, priming and bonding to take place in a single application. They require less chairside time and are more hydrophilic, water sorption, and solvent retention, which may reduce the interfacial stability, though they may be still acceptable (Somani et al., 2016).

The 8th generation or nano-enhanced universal adhesives contain functional monomers with modified filler technology that are designed to increase the infiltration of the resin and strengthen the hybrid layer (Kamble et al., 2015). These materials have been shown to have good bonding performance compared to their previous generations (Sachdeva et al., 2018). G-Premio Bond has also been found to have greater shear bond strength when compared to other older adhesive systems (Ganesh, 2020). There is some evidence, but it is inconsistent, however. For fifth and eighth generation adhesives, similar performance (or worse in seventh generation systems (Shafigh et al., 2020)) has been reported for some investigations. Nano-adhesives have been proven to have lower microleakage than total-etch and universal self-etch systems (Singh et al., 2023).

Newer adhesives have also been shown to have favourable bond strength and marginal sealing when applied using a selective technique (Hegde et al., 2021). Recent evidence, however, shows that some adhesive performance is product specific and is not completely dependent on generational classification (Gupta et al., 2025). Thus, it is necessary to have standardized comparative assessment to see if newer adhesive systems can offer better marginal sealing. The text is based on the thesis and the list of references.

Aim

To compare, in a controlled in vitro setting, the microleakage of Class II box-only complex restorations utilising dentin bonding agents of the fifth, seventh, and eighth generations.

Scope

The study is a comparison of the marginal sealing ability of Adper Single Bond 2, Coltene One Coat 7 Universal, and G-Premio Bond in standard class II cavities filled with a nanohybrid composite. Objectives

Objectives

- To compare the extent of microleakage among fifth-, seventh-, and eighth-generation dentin bonding agents.
- To assess their marginal sealing ability using dye penetration and stereomicroscopic evaluation at 40× magnification.
- To determine whether the eighth-generation adhesive reduces microleakage compared with older adhesive systems.
- To statistically analyse differences in microleakage scores among the three groups.

2. REVIEW OF LITERATURE

Numerous investigations have established that the routine of dentin bonding agents depends not only on the material's creation but also on its composition, dentin characteristics, moisture management, application method, and ageing conditions. Initial studies showed that the bond strength of materials tested in a laboratory setting could be higher than when tested in vivo due to pulpal pressure, moisture and oral environment (Gray & Burgess, 1991). Nakataki et al. (1999) did not observe any difference in overall microleakage between one-bottle and multi-step adhesive systems, but the sealing ability of the different adhesive and cavity margin substrates varied. The performance of the 5th generation adhesives is heavily dependent on their composition. The ethanol and acetone-based systems yielded higher shear bond strength than water based adhesives due to the ability of these solvents to remove water and allow resin penetration into dentin (Jonathan & Lakshminarayanan, 2001).

Excessively dried dentin also did not show as good bond as moist dentin due to the collapse of the collagen network when dentin is too dry (Ponnaappa & Rao, 2002). Kallenos et al. (2005) found that a fifth-generation adhesive had less microleakage in Class I restorations than 6th and 7th generation systems. In a similar fashion, Dhawan et al. (2013) reported higher tensile bond strength, and a thicker hybrid layer for a fifth-generation adhesive. There isn't a consistent record of evidence relating to 7th generation adhesives. Vinay, Shivanna (2010) reported that Clearfil S3 Bond showed the least microleakage among different 5th, 6th and 7th generation adhesives. However, under contaminated conditions, Kumar et al. (2012) found that leakage was less in Single Bond (fifth generation adhesive) compared to iBond (seventh generation adhesive). The same bond strengths were seen by Poptani et al. (2012) between most of the fifth and seventh generation adhesives after thermocycling, with Clearfil S3 having the best bond strength. In the study by Deepa et al. (2014), the bond strength of the 7th generation single-step adhesive was found to be less than multi-step adhesives, especially in deeper dentin. Tabari et al. (2016) also found that Single Bond 2 had better marginal sealing than two 7th generation systems. Eighth generation and universal adhesives were designed to increase resin infiltration and to improve the stability of the resin interface by using functional monomers and by adding the nano-sized components.

Kamble et al. (2015) reported the highest tensile bond strength with an eighth-generation adhesive, followed by sixth- and seventh-generation adhesives. Somani et al. (2016) reported that the eighth generation of the adhesive showed significantly less microleakage compared to the sixth and seventh generation of the adhesives. In addition, Taneja et al. (2017) noted that the eighth-generation material had the highest shear bond strength, despite saliva and blood contamination, which decreased the bond in each group. Sachdeva et al. (2018) concluded that the better bondability of the eighth-generation systems was due to the nanofillers and functional monomers and also attributed the role of reduced technique sensitivity. The effectiveness of 8th generation adhesives has been generally confirmed by more recent studies. Ganesh (2020) found that the shear bond strength of G-Premio Bond outperformed a seventh-generation agent. In the study, Shafigh et al. (2020) determined that the highest microshear bond strength occurred when an eighth-generation adhesive was used, followed by a fifth- and seventh-generation adhesive.

When combined with selective etching, Hegde et al. (2021) showed that G-Premio Bond has high bond strength and low microleakage. Singh et al. (2023) found that the nano-adhesive had the least leakage when compared to the total-etch and universal self-etch systems. The same finding was observed by Patel et al. (2023) which showed that G-Premio Bond had lower microleakage than G-Bond under contaminated conditions. However, Abedi et al. (2025) reported that a two-step self-etch adhesive performed better compared to one-step adhesive systems, indicating that the performance of the adhesive is not necessarily generation-dependent, but is still dependent on the product and protocol used.

3. MATERIALS AND METHODS

3.1 Study Design and Setting

Assessing the microleakage of dentin bonding agents of the fifth, seventh, and eighth generations used by nanohybrid composite restorations in standardised Class II box only cavities was the goal of this in vitro experimental comparative investigation. Stereomicroscopic assessment was conducted in the Department of Oral Pathology and Conservative Dentistry and Endodontics.

3.2 Sample Size and Specimen Selection

The software G*Power version 3.1.9.2 was used to determine the sample size based on an effect size of 0.385, an alpha error probability of 0.05, and statistical power of 90%. Three experimental groups of thirty teeth each were given a total of ninety recently extracted human maxillary and mandibular premolars. In place of orthodontic or periodontal therapy, the teeth were taken out of the departments of oral and maxillofacial surgery, orthodontics, and periodontology. Intact, caries free premolars with fully formed apices and without cracks, fractures, restorations or developmental defects were included. Teeth with carious, restored, attrited, abraded, cracked or structurally defective teeth were excluded.

3.3 Materials

The main materials used were 37% phosphoric acid etchant, the fifth-generation adhesive, Adper Single Bond 2; the seventh-generation adhesive, Coltene One Coat 7 Universal; the eighth generation adhesive, G-Premio Bond; and the nanohybrid composite resin, Coltene NT Premium Universal. The other materials consisted of 5.25% sodium hypochlorite, normal saline, 2% methylene blue dye, microbrush applicators, nail varnish, sticky wax, diamond burs, a Tofflemire matrix system, a Shofu polishing kit, a light-curing unit, a thermocycling machine, a diamond disc, and a stereomicroscope. The main material and specimen-restoration methods in the experimental study are shown in Figure 1. (a) Adper Single Bond 2 (3M ESPE); (b) specific extracted human premolars used as test specimens; (c) Coltene One Coat 7 Universal dentin bonding agent (dentin bonding agent 7th generation, 3M ESPE); (d) Coltene NT Premium Universal nanohybrid composite resin used in cavity restoration; (e) LED light-curing unit used to polymerise the composite resin; and (f) G-Premio Bond (GC) dentin bonding agent (dentin bonding agent (8th generation, 3M ESPE). These materials formed the main materials for adhesive placement and/or restoration of the standard Class II cavities.

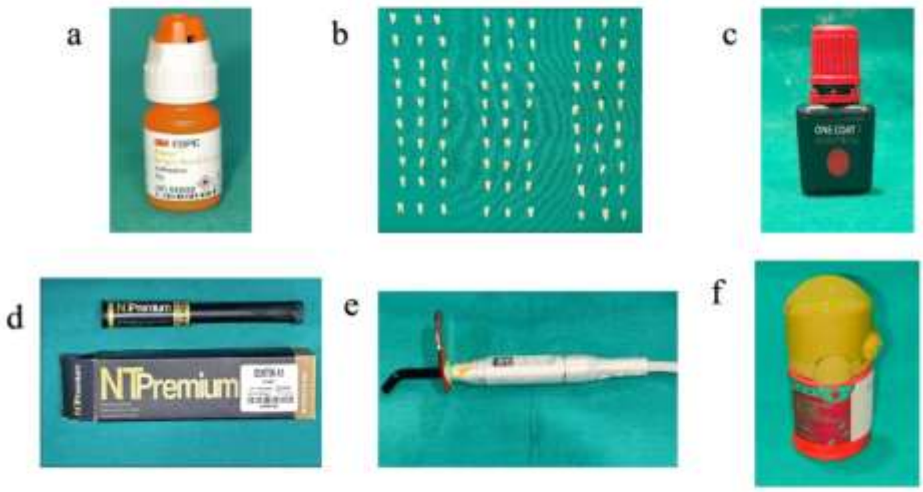

Figure 1. Materials and Specimens Used in the Study: (a) Adper Single Bond 2, (b) Extracted Human Premolars, (c) One Coat 7 Universal Bond, (d) NT Premium Universal Composite Resin, (e) LED Light-Curing Unit, and (f) G-Premio Bond

3.4 Tooth Preparation and Cavity Standardization

The teeth were obtained, and immediately after removal, cleaned of blood and other debris and placed in 5.25% sodium hypochlorite for 8 hours to remove organic remains. They were then well soaked under running water and kept in normal saline solution to avoid dehydration. All teeth were inspected at magnifications, and only specimens that fulfilled the eligibility criteria were chosen. Standardized class II box only cavities were equipped in each mesial and distal surfaces of the tooth with high-speed air-rotor handpiece and water-cooled diamond bur. The buccolingual width of each cavity was 4 mm and measured by a Williams graduated periodontal probe. Axial depth of each cavity was 1.5 mm. These cavities were then flushed with air water sprays and slightly air dried.

3.5 Group Allocation and Bonding Procedures

The 90 teeth were randomly allocated into three groups:

Group I: Adper Single Bond 2, fifth-generation adhesive

Group II: Coltene One Coat 7 Universal, seventh-generation adhesive

Group III: G-Premio Bond, eighth-generation adhesive

For Group I 37% phosphoric acid was smeared to enamel and dentin for 10-15 seconds, then rinsed for 20 seconds and blot dried. The 10sec application, air-thinning for 5sec and light-curing for 10sec were completed. In Group II, Coltene One Coat 7 Universal was applied directly to the cavity prepared and set for 20 seconds, air dried for 5 seconds and light cured for 10 seconds. In Group III, G-Premio Bond was applied using rubbing action for 20 seconds and then lightly air-dried for 5 seconds followed by light cure for 10 seconds.

3.6 Composite Restoration and Thermocycling

All the cavities were incrementally filled with Coltene NT Premium Universal nanohybrid composite resin. The Shofu polishing kit was used to complete and polish each increment after it had been light-cured for 20 seconds. Every restored one underwent 500 cycles of thermocycling between 5°C and 55°C. To simulate intraoral thermal stressors, each bath had a 30-second immersion period and a 30-second transfer period.

3.7 Dye Penetration and Microscopic Evaluation

Root apices were waxed and all tooth planes were varnished with the aid of three layers of nail varnish with a 1 mm clear space around the margins of the restoration. The specimens were placed in 2% methylene blue dye for 24 hours, rinsed and air dried. Tooth long sections were made in buccolingual direction with a diamond disc. The sections were observed using a stereomicroscope at 40× and dye penetration was scored: 0 = No dye penetration; 1 = dye penetration up to one-third of the depth of the cavity; 2 = dye penetration up to two-thirds of the cavity; 3 = dye penetration up to the whole cavity; and 4 = dye penetration up to the axial wall. The steps for the evaluation of microleakage after restoration of specimens are shown in Figure 2. (a) Thermocycling of restored teeth between 5°C and 55°C to simulate intraoral thermal stresses; (b) 24-hour dye immersion of the specimens; (c) sectioning of restored teeth in the longitudinal direction with a diamond disc to expose the tooth–restoration interface; and (d) evaluation of the dye-leakage at the tooth–restoration interface with 40× magnification stereomicroscopic examination and scoring.

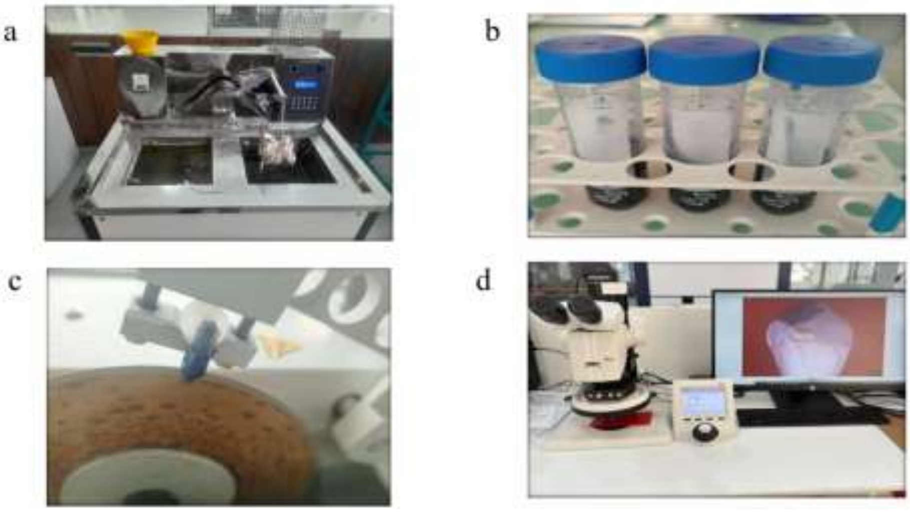

Figure 2. Experimental Procedures for Microleakage Assessment: (a) Thermocycling, (b) Dye Immersion, (c) Longitudinal Sectioning, and (d) Stereomicroscopic Evaluation

3.8 Statistical Analysis

Non-parametric statistics were used to show and interpret the data. The three groups' microleakage was compared using a Kruskal–Wallis test, and pairwise comparisons were accomplished using the Mann–Whitney U test. Statistical significance was defined as $p < 0.05$.. Only teeth extracted for therapeutic purposes were used and all samples were collected under institutional ethical standards.

4. RESULTS

There were 90 specimens, 30 teeth per experimental group. Microleakage scores were considered as ordinal data and non-parametric statistical testing were used for analyzing the data. For comparison of the overall condition between the three groupings, the Mann-Whitney U test was used for group comparisons, and the Kruskal-Wallis test was used for group comparisons. The relationship between the adhesive group and the microleakage-score category was examined using a chi-square test. Statistical significance was defined as a p value of less than 0.05.

4.1 Overall Comparison of Microleakage

The microleakage of the three adhesive groups differed significantly (p<0.001), according to the Kruskal–Wallis analysis. Group I restored with the fifth generation of Adper Single Bond 2, which displayed the most microleakage, achieved the highest mean rank of 74.97. The seventh-generation Coltene One Coat 7 Universal (Group II) ranked in the middle at a mean rank of 46.03. The eighth-generation G-Premio Bond restored Group III showed the lowest mean rank of 15.50, which means that it exhibited the least microleakage and the best marginal sealing performance. Table 1 shows that the three adhesive groups differ statistically significantly (p < 0.001), with Group I having the greatest mean rank (74.97) and Group III having the lowest mean rank (15.50).

Table 1. Overall Comparison of Microleakage Among the Three Adhesive Groups

Experimental group	Adhesive system	n	Mean rank	Statistical result
Group I	Fifth generation Adper Single Bond 2	30	74.97	p < 0.001
Group II	Seventh generation Coltene One Coat 7 Universal	30	46.03	
Group III	Eighth generation G-Premio Bond	30	15.50	
Total		90		

Test used: Kruskal–Wallis test.
The descending order of microleakage was therefore:
Group I > Group II > Group III
This result demonstrates a gradual decrease in microleakage for the fifth generation to eighth generation adhesive.The highest mean rank (74.97) was achieved by Group I restored with the 5th-generation Adper Single Bond 2 while Group II restored with the 7th-generation Coltene One Coat 7 Universal achieved mean rank 46.03. (As seen in Figure 3) The mean rank (15.50) was lowest in Group III which was restored using the 8th-generation G-Premio Bond. The Kruskal-Wallis test revealed a significant difference (p < 0.001) across the three groups.

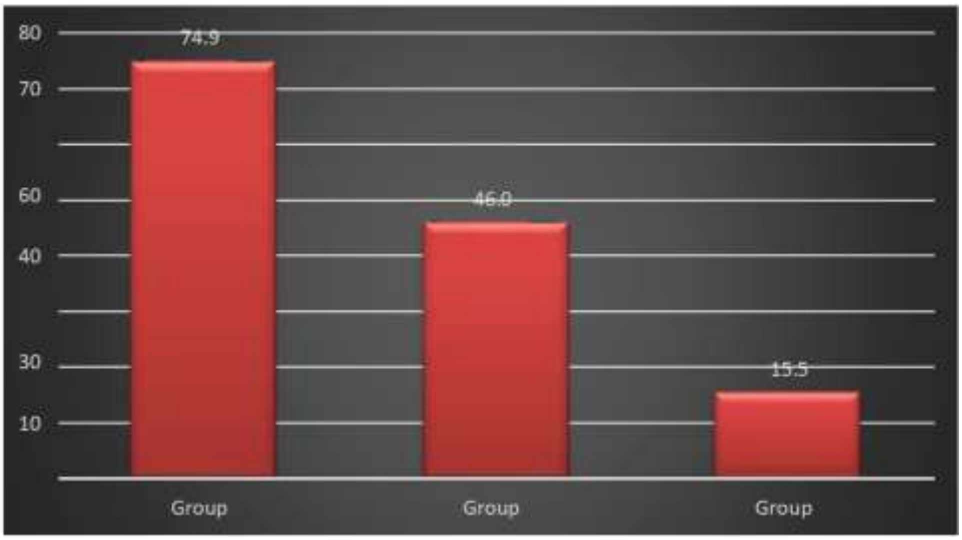

Figure 3. Comparison of Microleakage Mean Ranks Among the Three Adhesive Groups

4.2 Distribution of Microleakage Scores

There was wide variation in the distribution of microleakage scores in the groups. In Group I, 26 specimens (86.7%) had a score of 4 (dye penetration on the axial wall), and four specimens (13.3%) had a score of 3. The scores of 0, 1 and 2 were not observed in any Group I specimen. The majority of specimens in Group II (73.3%) had scored 2, indicating that the dye had penetrated two thirds of the way into the cavity, with 26.7% having scored 3. No one had a score of 0, 1, or 4. The distribution of scores was the most favourable for Group III. A total of 28 (93.3%) specimens gave a score of 0 (no dye penetration) and 2 (6.7%) specimens gave a score of 1. There were no Group III specimens with scores of 2, 3 or 4. The association between the distribution of adhesive group and microleakage-score was statistically significant (p < 0.001). Table 2 indicates that the majority of the Group I scores were the highest for microleakage while the majority of the Group III scores were the lowest with no dye penetration; there was a significant alteration between the score ranges of the groups (p < 0.001).

Table 2. Distribution of Microleakage Scores Across the Study Groups

Group	Score 0, n (%)	Score 1, n (%)	Score 2, n (%)	Score 3, n (%)	Score 4, n (%)
Group I Adper Single Bond 2	0 (0.0)	0 (0.0)	0 (0.0)	4 (13.3)	26 (86.7)
Group II One Coat 7 Universal	0 (0.0)	0 (0.0)	22 (73.3)	8 (26.7)	0 (0.0)
Group III G-	28 (93.3)	2 (6.7)	0 (0.0)	0 (0.0)	0 (0.0)

Premio Bond					

Chi-square test: p < 0.001.

4.3 Distribution Relative to the Median

All 30 specimens in Group I were found to have microleakage values greater than the overall median value. Eight specimens were greater than the median and 22 specimens were equal to or less than the median in Group II. All 30 specimens in Group III had values equal to or less than the median. The difference between the groups was statistically significant ($p < 0.001$) and further confirmed the gradual improvement in the marginal sealing of the three groups, with Group III having the highest value.

4.4 Pairwise Comparisons

The mean ranks of the two groups were found to be 44.97 for Group I and 16.03 for Group II with the Mann–Whitney U comparison revealing significant distinction between the values ($p < 0.001$). This finding suggests that the 5th generation adhesive was significantly more microleakage than the 7th generation adhesive. There was also a statistically meaningful difference between the comparison of Group II and III. The mean rank of group II was 45.50 and group III was 15.50 ($p < 0.001$), which indicated that microleakage was significantly higher in the seventh generation adhesive compared to the eighth generation adhesive. The results presented in Table 3 indicate that there was a significant difference between Groups I and II and between Groups II and III with both comparisons having p value < 0.001.

Table 3. Pairwise Comparison of Microleakage Between the Adhesive Groups

Pairwise comparison	Group	n	Mean rank	Sum of ranks	p-value
Group I vs Group II	Group I Adper Single Bond 2	30	44.97	1349.00	<0.001
	Group II One Coat 7 Universal	30	16.03	481.00	
Group II vs Group III	Group II One Coat 7 Universal	30	45.50	1365.00	<0.001
	Group III G-Premio Bond	30	15.50	465.00	

Test used: Mann–Whitney U test.

The numerical results comparing group I with group III using the Mann–Whitney test are not given in the document. So, if a t test has not been performed between two of the three comparisons, don't cite the significance of the third pair of comparisons unless that comparison is projected from the SPSS output.

4.5 Stereomicroscopic Findings

The statistical results were supported by representative stereomicroscopic images. Group I exhibited high dye penetration that extended to axial wall, Group II exhibited moderate dye penetration to cavity depth, and Group III exhibited no dye penetration or low dye penetration to cavity depth. The visual confirmation with these images shows that G-Premio Bond was the most effective adhesive system at the margin. Figure 4. Representative stereomicroscopic pictures showing the penetration of dye at the tooth-restoration contact are shown: (a) Group I (5th generation Adper Single Bond 2); (b) Group II (7th generation Coltene One Coat 7 Universal); and (c) Group III (8th generation G-Premio Bond).

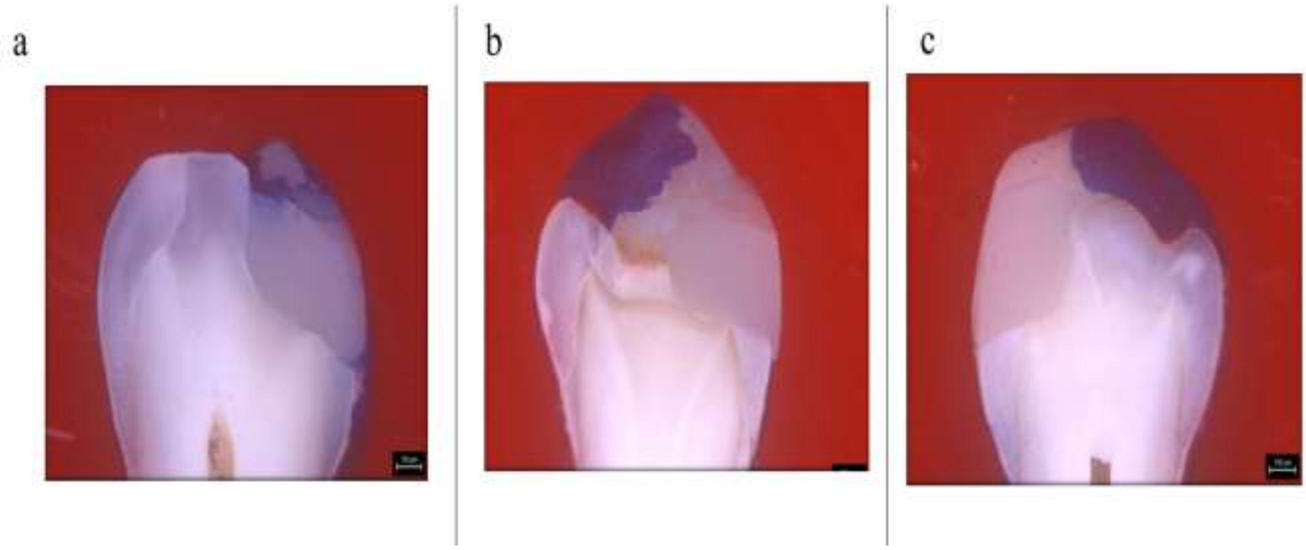

Figure 4. Representative Stereomicroscopic Images of Microleakage in the Three Adhesive Groups

4.6 Summary of Findings

The 5th generation adhesive had the highest degree of microleakage, the 7th generation had an intermediate degree and the 8th generation had the lowest degree. The variations between the three groups were statistically significant and the G-Premio Bond of the eighth generation showed the best marginal sealing.

5. DISCUSSION

Comparing the microleakage of fifth, seventh, and eighth generation dentin bonding agents in standardised class II composite reinstatements was the aim of the current in vitro investigation. The three adhesives were found to differ significantly from one another. Adper Single Bond 2, the fifth-generation adhesive, had the highest mean rank (74.97) followed by Coltene One Coat 7 Universal (the seventh generation) (46.03). The eighth-generation G-Premio Bond had the lowest mean rank (15.50). This null hypothesis was thus rejected, and it was concluded that the type of bonding agent had a significant effect on marginal sealing. This was also confirmed in the distribution of microleakage scores. The dye penetrated into the axial wall in most fifth-generation specimens while the seventh-generation group had mostly dye penetration up to two-thirds of the cavity. Most eighth generation specimens had no dye penetration, however. These results suggest that the 8th generation adhesive system is the least microleaky system. The functional monomers, the better solvent system, the lower technique sensitivity and the better interaction with hydroxyapatite of G-Premio Bond might be responsible for the better performance.

The use of nano-reinforced or universal adhesive could enhance resin infiltration, polymerization, hybrid-layer stability, and resistance to the generation of interfacial gaps. Similar results have indicated the potential higher tensile bond strength and bonding efficiency of the 8th generation of adhesive systems over previous ones (Kamble et al., 2015). The bonding effectiveness of the eighth-generation adhesives has also been credited to the nanofilled formulation, functional monomers, and the ease of use of their application processes (Sachdeva et al., 2018). Other in vitro studies have also reported superior bonding with 8th generation systems. Shear bond strength of eighth-generation adhesive systems has also been shown to be superior to that of the seventh and sixth generation systems (Jalannavar et al., 2024). The present results are similar to the past study which demonstrated that eight generation adhesives have the least microleakage (Somani et al., 2016). Microleakage resistance has also been documented to be better with the 8th generation universal adhesives as compared to 5th and 7th generation.

Nano-adhesive systems have also shown to have reduced microleakage compared to total-etch and universal self-etch systems (Singh et al., 2023). G-Premio Bond has also shown to be more effective at reducing leakage than a 7th generation adhesive when contaminated (Patel et al., 2023). Potential in reducing the marginal gap formation may also be due to better interfacial integrity and bond strength with 8th generation systems (Meshki et al., 2023). But, the adhesive performance is not solely determined by the generation. A few of the 7th generation product has demonstrated good sealing property, and Clearfil S3 Bond exhibited the minimum leakage when compared with various test adhesives (Vinay & Shivanna, 2010).

A seventh-generation adhesive system has also been found to have lower microleakage compared to a fifth generation system (Varma et al., 2019). These variations could be due to variations in the chemistry and composition of the solvents, acidity, application time, cavity design, thermocycling protocol, and restorative material, which may differ from brand to brand. Previous research has also shown that newer generations of adhesive do not necessarily have to be better than older ones. A lower microleakage has been reported for the fifth generation adhesive than for the sixth and seventh generation (Kallenos et al., 2005). Single Bond 2 has also been found to have the superior marginal seal among the selected 7th generation products (Tabari et al., 2016). Solvent composition also plays a role in the effectiveness of the bonding of 5th generation adhesives (Jonathan & Lakshminarayanan, 2001). Particularly, moisture control is important as the extra drying can lead to collapse in the collagen network and will also decrease resin infiltration (Ponnaappa & Rao, 2002).

Simplified self-etch systems require fewer application steps, but could still be susceptible to contamination and hydrolysis. Comparable performance has been measured in the controlled laboratory setting for total-etch and self-etch systems (Stalin & Varma, 2005). But, there is also increased leakage under contaminated conditions with a 7th generation adhesive (Kumar et al., 2012). The simplified application of some universal adhesives has been shown to have reduced fatigue longevity compared with the well established two-step self-etch systems, indicating that easy application may not provide long-term stability (Tsujimoto et al., 2017). But, even newer adhesive products are known to yield contradictory results. In one study, the shear bond strength of a sixth generation adhesive was found to be higher than seventh and eighth generation adhesives (Gazal et al., 2024). Additionally, the bonding ability of the two-step approach has been reported to produce superior bonding with primary dentin, when compared with one-step universal adhesives (Abedi et al., 2025).

The lack of uniformity in the results might explainable by the different kind of substrates used, adhesive materials used, the experimental procedure and the measurement of the outcome as bond strength does not necessarily correlate with microleakage. In the present study, standardized cavity dimensions, equal group allocation, thermocycling, dye penetration and stereomicroscopic evaluation were all advantages. However, it is not valid for clinical extrapolation due to its in vitro design, use of only one product per generation, lack of mechanical loading and the semi-quantitative leakage scoring. In vivo performance of an adhesive is likely to be poorer than that obtained under laboratory conditions due to factors such as pulpal pressure, oral moisture, occlusal loading, and biological factors (Gray & Burgess, 1991). Thus, long-term clinical studies that include mechanical fatigue, pulpal pressure, contamination, and 3D leakage evaluation are needed. Based on the limitations of this study, there were significantly different amounts of microleakage associated with the three different adhesive systems. Adper Single Bond 2 recorded the highest leakage while Coltene One Coat 7 had an intermediate leakage rate with G-Premio Bond the lowest dye penetration and the best marginal sealing properties.

None of the tested systems were able to absolutely stop the formation of microleakage, although the 8th generation adhesive was the best result. The lack of perfect fit of the tooth–restoration interface remains a challenge due to polymerisation contraction, thermal stresses and structural complexity of dentin. The performance of G-Premio Bond can be improved with functional monomers, advanced solvent system, improved resin infiltration, and improved stability of the hybrid layers. The results of this study indicate that newer universal dentin bonding agents may yield improved marginal adaptation and offer enhanced longevity of composite restorations. Adhesive selection should not be based exclusively upon the generational classification as product composition, substrate, moisture control and application methods also play a role in the performance of the adhesive. These results need to be confirmed by further studies through additional aging periods, mechanical loading, 3D leakage evaluation and randomized clinical trials.

6. CONCLUSION

The present in vitro study showed that there were considerable differences in the ability of the three dentin bonding systems to inhibit microleakage in standard Class II composite restorations. The fifth generation adhesive, Adper Single Bond 2 exhibited the highest microleakage, and the seventh generation Coltene One Coat 7 Universal had intermediate microleakage. The eighth generation G-Premio Bond showed the lowest degree of dye penetration and the best marginal sealing ability. Overall differences between groups was statistically significant. None of the tested adhesive systems completely eliminated microleakage although there was a preference for the 8th generation adhesive. Even though several techniques have been developed to reduce the polymerization reduction and thermal stresses, the structural complexity of dentin remains a challenge for the creation of a fully sealed tooth–restoration interface. The sealing was better at enamel margins than dentin and cementum margins, which was attributed to the more predictable bonding properties of highly mineralized enamel and hydrated and tubular dentin. The functionality of the monomers, advanced solvent system, improved resin infiltration, and improved stability of the hybrid layers may be associated with the improved performance of G-Premio Bond. These research' findings indicate that more recent universal adhesives may show better marginal adaptation and be more resilient for composite restorations. But it is not all about the generation that determines which adhesive to use - product composition, substrate characteristics, moisture control and application technique are also important considerations. Pulpal pressure, occlusal loading, bacterial activity and saliva, and long term hydrolytic degradation should be kept in mind, as they cannot be reproduced in the laboratory, and caution should be exercised in clinical interpretation. Additional research should include mechanical fatigue testing, extended aging procedures, three dimensional leakage testing, and randomized clinical testing. In general, the eighth-generation adhesive performed best in terms of creating marginal sealant for the composite restorations and could be a good choice for Class II composite restorations.

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