



# Influence of Bioactive Desensitizers on Bonding of Self-adhesive Resin Cement: A SEM/EDX Microanalysis Study

Alaa Turkistani<sup>1,\*</sup>  and Rasha R Basheer<sup>1,2</sup>

<sup>1</sup>Department of Restorative Dentistry, Faculty of Dentistry, King Abdul-Aziz University, Jeddah, Saudi Arabia

<sup>2</sup>Conservative Dentistry Department, Faculty of Dentistry, October University for Modern Sciences and Arts, Giza, Egypt

## Abstract:

**Introduction:** Bioactive desensitizing agents are increasingly used to alleviate dentin hypersensitivity; however, their impact on the bonding performance of self-adhesive resin cements remains unclear. This *in vitro* study evaluated the effect of bioactive desensitizers on the bond strength of a self-adhesive resin cement to dentin and examined elemental changes on the dentin surface using Energy-Dispersive X-ray (EDX) spectrometry.

**Methods:** Dentin surfaces of extracted molars were exposed and treated with a glutaraldehyde-based desensitizer (Dentin Desensitizer; DD), a calcium phosphate-based desensitizer (Teethmate Desensitizer; TM), a hydroxyapatite-based desensitizer (Predicta Bioactive; PB), or fluoride gel (APF Fluoride Gel; FL). The control group received no treatment. Self-adhesive resin cement (Panavia SA Cement Universal) was applied in cylindrical molds. After thermocycling, microshear bond strength was measured, and failure modes were analyzed. Scanning Electron Microscopy (SEM) combined with EDX analysis was performed to assess changes in the dentin surface.

**Results:** The DD group showed the highest bond strength ( $11.15 \pm 1.32$  MPa), followed by PB ( $5.98 \pm 1.79$ ), control group ( $5.08 \pm 1.17$ ), and FL ( $4.78 \pm 0.75$ ). TM showed the lowest value ( $4.09 \pm 0.52$  MPa). ANOVA with post-hoc comparisons confirmed significant differences, with DD outperforming all other groups ( $p < 0.001$ ). Adhesive failure was the most common, followed by mixed-type failures. EDX results indicated increased mineral and decreased carbon content across all treated groups, most notably in the PB group.

**Discussion:** Although bioactive desensitizers altered dentin composition, their inconsistent effect on bond strength may be attributed to the distinct microstructural changes each induces.

**Conclusion:** Clinicians must carefully consider the balance between enhancing patient comfort and preserving the long-term integrity of the restoration.

**Keywords:** Dentin desensitizing agents, Dentin hypersensitivity, Resin cements, Shear strength, Spectrometry, X-Ray emission.

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\*Address correspondence to this author at the Department of Restorative Dentistry, Faculty of Dentistry, King Abdulaziz University, Jeddah 21589, Saudi Arabia; Tel: +966-12-640-1000; Ext: 22322, Fax: +966-(0)12-640-4166; E-mail: [aturkistani1@kau.edu.sa](mailto:aturkistani1@kau.edu.sa)

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## 1. INTRODUCTION

Dentin hypersensitivity is a common issue that can occur after tooth preparation for indirect restorations. During preparation, millions of dentinal tubules are exposed, leading to increased dentin permeability and potential pulpal irritation. Several factors can elevate the temperature within the pulp chamber and exacerbate dentin hypersensitivity, including insufficient water cooling, excessive air pressure, or applying excessive cutting force [1]. Additionally, increased surface area of the preparation, a prolonged provisional phase, and inadequate sealing of temporary restorations can further contribute to hypersensitivity [2, 3]. This presents a clinical challenge, as managing dentin hypersensitivity is essential for patient comfort and the long-term success of restorative treatment.

According to the hydrodynamic theory, external stimuli, whether thermal, chemical, osmotic, or tactile, cause movement of intratubular dentinal fluid in exposed dentin, which activates underlying nerve fibers and triggers a pain response [4]. Emerging evidence suggests that odontoblasts may also contribute to dentin hypersensitivity by sensing stimuli and releasing pain mediators that signal nearby nerves [3, 5]. To alleviate dentin hypersensitivity, many dentists incorporate desensitizing agents into their protocol after tooth preparation for indirect restorations [5]. These agents function either by desensitizing the nerve fibers, reducing their responsiveness to external stimuli, or by occluding the dentinal tubules to prevent fluid movement [5, 6]. Glutaraldehyde/ Hydroxyethyl Methacrylate (HEMA), oxalates, and fluoride compounds are among the most commonly used formulations [3, 5]. Recently, bioactive desensitizers containing nano-hydroxyapatite and bioactive glass have gained attention for their dual function in managing dentin hypersensitivity and promoting remineralization of tooth structure [3, 7]. Clinical studies have shown that nano-hydroxyapatite may offer superior efficacy in reducing dentin hypersensitivity compared to traditional agents [8]. In addition to providing immediate relief, the deposition of Hydroxyapatite (HA) and other minerals by these bioactive desensitizers may enhance dentin resistance to secondary caries around the restorations [9, 10].

Despite these potential advantages, the influence of newly introduced bioactive desensitizers on the bond strength of resin cements to dentin remains insufficiently studied. Previous reports have suggested that certain bioactive agents may improve the bonding interface by creating a more stable and mineralized surface, potentially leading to stronger and durable bonding [11]. However, the efficacy of these agents can vary depending on their composition, application protocols, and interactions with both dentin and the resin cement. Additionally, the composition and adhesion mechanism of the resin cement itself significantly affect bonding performance, as factors such as the acidity, hydrophilicity, and type of functional monomers influence the cement's interaction with dentin.

Self-adhesive resin cements simplify the bonding process by combining adhesive and cementing functions

into a single product, eliminating the need for separate etching, priming, and bonding steps. While these cements offer convenience and reduced technique sensitivity, concerns remain regarding long-term durability [12]. Furthermore, studies on crown retention when desensitizers are used prior to cementation have shown mixed results, with some reporting a reduction in retention, while others found no adverse effects [13, 14].

Therefore, this *in vitro* study was conducted to explore the influence of bioactive desensitizers on dentin bonding and surface composition, using Energy-Dispersive X-ray (EDX) analysis to quantify elemental changes and evaluate their effects on the bond strength of self-adhesive resin cement. The null hypothesis tested was that there is no significant effect of desensitizing agents on the bond strength of self-adhesive resin cement or on the elemental composition of the dentin surface.

## 2. MATERIALS AND METHODS

All procedures in this *in vitro* experimental study were conducted in compliance with relevant laws and institutional guidelines. The study protocol was reviewed and approved by the institution's Research Ethics Committee (Approval reference number: 88-09-24). Extracted human molars, free of caries and restorations, were collected with patients' informed consent and in accordance with the principles of the Declaration of Helsinki. Four different desensitizing agents were used: a fluoride gel (APF Fluoride Gel, FL; Keystone Industries, Gibbstown, NJ, USA), a glutaraldehyde-based desensitizer (Dentin Desensitizer, DD; Pulpdent, Watertown, MA, USA), a calcium phosphate-based desensitizer (Teethmate Desensitizer, TM; Kuraray Noritake Dental, Tokyo, Japan), and a hydroxyapatite-based desensitizer (Predicta Bioactive Desensitizer, PB; Parkell, Edgewood, NY, USA). The resin cement used was Panavia SA Cement Universal (Kuraray Noritake Dental, Tokyo, Japan). The composition and application method of each material are listed in Table 1.

### 2.1. Specimen Preparation

Molar teeth were sectioned below the cemento-enamel junction using a diamond saw under water cooling (IsoMet Low Speed Precision Cutter; Buehler, Lake Bluff, IL, USA) and mounted in acrylic resin blocks. The occlusal surfaces were ground perpendicular to the long axis of the tooth using a model trimmer (MT 10, Ray Foster, Huntington Beach, CA, USA) until the dentin was exposed. Dentin exposure was verified under a stereomicroscope (Eclipse MA100, Nikon, Tokyo, Japan) at 40× magnification. The dentin surfaces were then polished with 600-grit silicon carbide paper for 60 seconds to produce a standardized smear layer. The specimens were randomly divided into five groups, with eight specimens in each group (n = 8). Group 1 served as the control group and received no desensitizing treatment. In Groups 2 to 5, the respective desensitizing agents were applied to the dentin surfaces according to the manufacturer's guidelines and allowed to react for the recommended time.

**Table 1. Materials used in the study.**

Material (Abbreviation) Manufacturer	Composition	Manufacturer Application Instructions
APF gel (FI) Keystone Industries, Gibbstown, NJ, USA	1.23% fluoride, citric acid, phosphoric acid, magnesium aluminum silicate, sodium benzoate, titanium dioxide, water, xylitol	Apply on the surface for 60 s and remove excess
Dentin desensitizer (DD) Pulpdent, Watertown, MA, USA	5% Glutaraldehyde, fluoride, water	Apply to dentin for 20-30 s using a cotton pellet, blot or apply short blast of air to remove excess, but do not dry
Teethmate desensitizer (TM) Kuraray Noritake Dental, Tokyo, Japan	Powder: tetracalcium phosphate (TTCP) and dicalcium phosphate anhydrous (DCPA) Liquid: water	Mix the powder and water for 30 s to form a slurry, apply with a microapplicator for 15 s, rub for 60 s, rinse off with a water spray
Predicta bioactive desensitizer gel (PB) Parkell, Edgewood, NY, USA	Calcium, phosphate, nanohydroxyapatite	Rinse and dry surface with cotton pellet, apply a coat of the liquid and gently rub it in for 10-20 s. Wipe off the product with a cotton pellet before air blowing
Panavia SA Cement Universal Kuraray Noritake Dental, Tokyo, Japan	Paste A: MDP, Bis-GMA, TEGDMA, dimethacrylate, HEMA, fillers, photoinitiator, peroxide, catalysts, pigments Paste B: dimethacrylate, silane coupling agent, fillers, sodium fluoride, photoinitiator, accelerators, pigments	Dispense equal amounts of paste A & B, mix for 10 s. Apply and light cure for 10 s

**Abbreviations:** MDP; 10-methacryloyloxydecyl dihydrogen phosphate, Bis-GMA; bisphenol A diglycidyl methacrylate, TEGDMA; triethyleneglycol dimethacrylate, 2-HEMA; hydroxyethyl methacrylate.

After 24 hours of storage in artificial saliva (pH 6.5) at 37 °C, a polyethylene tube with an internal diameter of approximately 1.8 mm and a height of 2 mm was placed on the dentin surface, and the resin cement was injected into each tube. A glass slide was placed over the cement, gently pressed, and then light cured with an LED curing unit (Elipar, 3M ESPE, St. Paul, MN, USA) at 1200 mW/cm<sup>2</sup> for 20 seconds from both the top and sides to ensure complete polymerization. Specimens were then stored for 24 hours in 100% relative humidity at 37 °C. Afterwards, the plastic tubes were removed, and the specimens underwent thermocycling for 5000 cycles between 5 °C and 55 °C, with a dwell time of 20 seconds in each bath and a transfer time of 5 seconds between baths (Thermocycler 1100, SD Mechatronik, Feldkirchen-Westerham, Germany) [15].

## 2.2. Microshear Bond Strength Testing ( $\mu$ SBS) and Failure Mode Analysis

After thermocycling, each specimen was secured in the lower fixed head of a universal testing machine (Instron, Norwood, MA, USA). A 0.14-inch-diameter stainless steel wire was attached to the upper movable head of the testing apparatus and positioned as close as possible to the cement-dentin interface. The microshear bond strength ( $\mu$ SBS) test was conducted at a crosshead speed of 1 mm/min until bond failure occurred. The maximum load was recorded, and  $\mu$ SBS was calculated in MPa by dividing the load (N) by the bonded area (mm<sup>2</sup>). The fractured specimens were subsequently mounted on aluminum stubs using carbon adhesive tape and examined under a Scanning Electron Microscope (SEM; Quanta 3D 200i, FEI Company, Hillsboro, OR, USA). Failure modes were classified as adhesive, cohesive, or mixed. Adhesive failure refers to failure at the adhesive interface, cohesive failure indicates failure within the adhesive or dentin, and mixed failure represents a combination of adhesive and cohesive failure.

## 2.3. Energy-dispersive X-ray Spectrometry (EDX)

Elemental distribution on dentin surfaces from each test group was analyzed using EDX under SEM. The SEM was operated at an accelerating voltage of 20 kV, with a resolution of 1 nm, and magnifications of 90x and 250x. Initial EDX analysis provided a qualitative overview of elemental composition across the groups, identifying peaks corresponding to various elements and their relative intensities. Elemental quantification was then performed, and data were recorded as both weight percentages and atomic percentages to assess compositional changes on the dentin surface.

## 2.4. Statistical Analysis

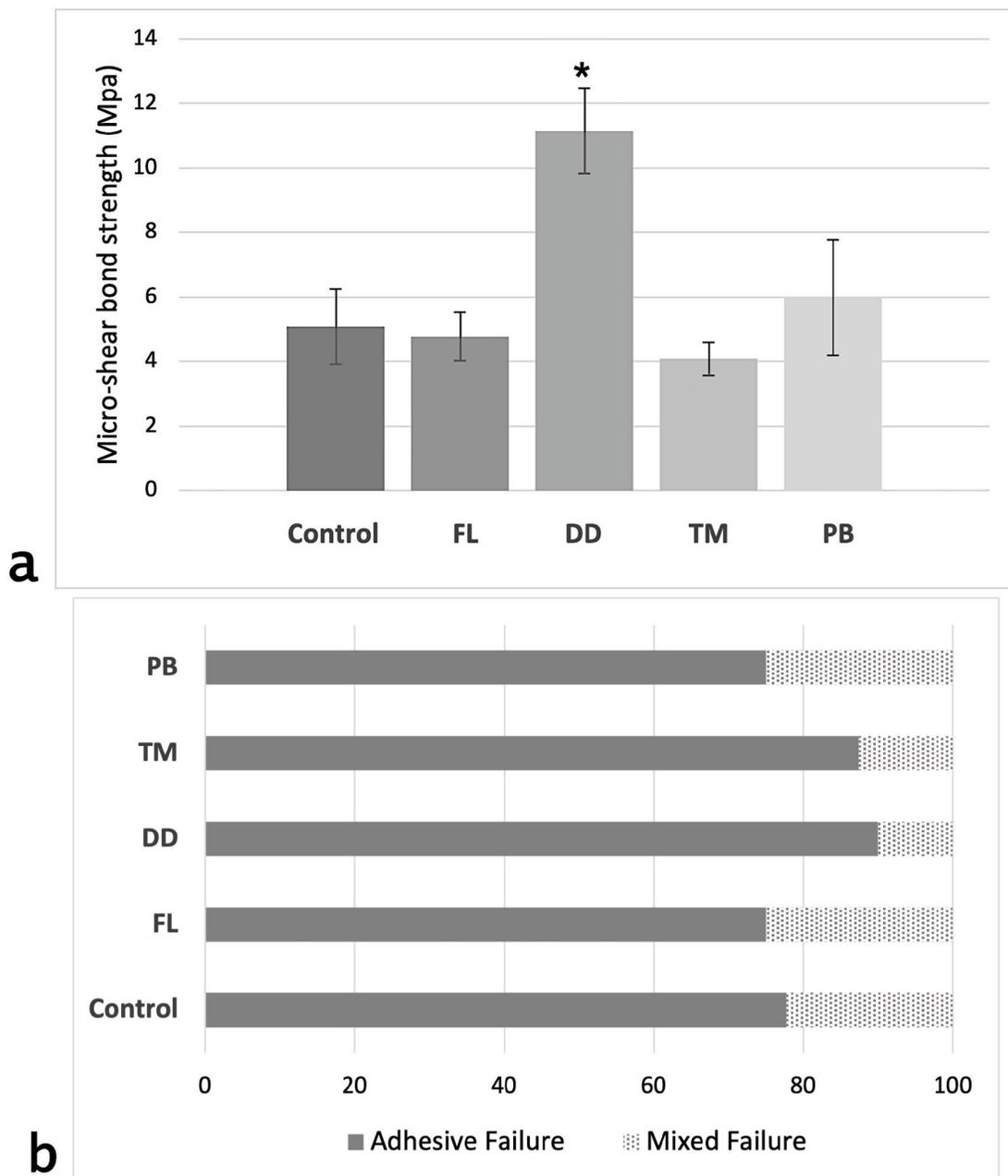
The  $\mu$ SBS data were expressed as mean values along with 95% Confidence Intervals (CI), Standard Deviation (SD), and the range, which included both the minimum (min.) and maximum (max.) values. To determine whether the data were suitable for parametric analysis, normality was tested using the Shapiro-Wilk test, and homogeneity of variances was assessed with Levene's test. Both assumptions were satisfied across all groups, allowing for further analysis using a one-way ANOVA, followed by Tukey's post hoc test for group comparisons with a significance level of  $p < 0.05$  (R software version 4.4.0, R Core Team, 2024, Vienna, Austria).

## 3. RESULTS

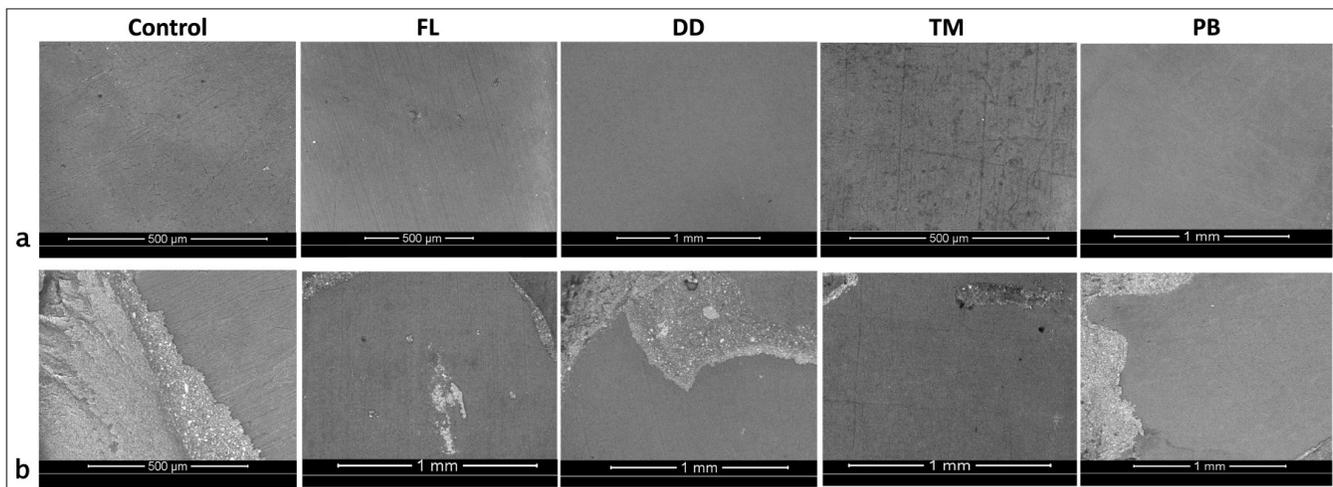
Mean with standard deviation values for  $\mu$ SBS are presented in Fig. (1a). Results showed a significant difference between the test groups ( $f = 28.28$ ,  $p < 0.001$ ). The highest  $\mu$ SBS (MPa) was measured in DD ( $11.15 \pm 1.32$ ), followed by PB ( $5.98 \pm 1.79$ ), then the control group ( $5.08 \pm 1.17$ ), and FL ( $4.78 \pm 0.75$ ), while the lowest bond strength was measured in TM ( $4.09 \pm 0.52$ ). Post hoc pairwise comparisons revealed that the DD group had significantly higher bond strength values than the other groups ( $p < 0.001$ ). No statistically significant differences were detected among the other groups ( $p > 0.05$ ).

The failure mode analysis results indicate that adhesive failure between dentin and cement was the predominant failure type across all groups (Fig. 1b). The second most common failure mode observed was mixed failure. No cohesive failures were observed within either the cement or dentin in any group. Representative SEM images of adhesive and mixed failures from each group

are presented in Fig. (2). Adhesive failures, as seen in group (a) images, were characterized by smooth dentin surfaces with no resin residue, indicating superficial and insufficient bonding. In contrast, mixed failures (group b images) revealed localized areas with resin cement remnants and partially exposed dentin, suggesting partial resin infiltration and interfacial interaction.



**Fig. (1).** (a) Bar chart illustrating the mean micro-shear bond strength values along with standard deviations for each test group. The x-axis represents the experimental groups, while the y-axis shows the bond strength in megapascals (MPa). An asterisk (\*) denotes a statistically significant difference compared to all other groups ( $p < 0.001$ ). (b) Percentage distribution of failure modes across all experimental groups. The y-axis lists the test groups, and the x-axis indicates the percentage (%) of specimens exhibiting each failure mode.



**Fig. (2).** Representative Scanning Electron Microscope (SEM) images showing failure modes across experimental groups. Adhesive failure is illustrated in group (a) images, whereas (b) represent mixed type of failure.

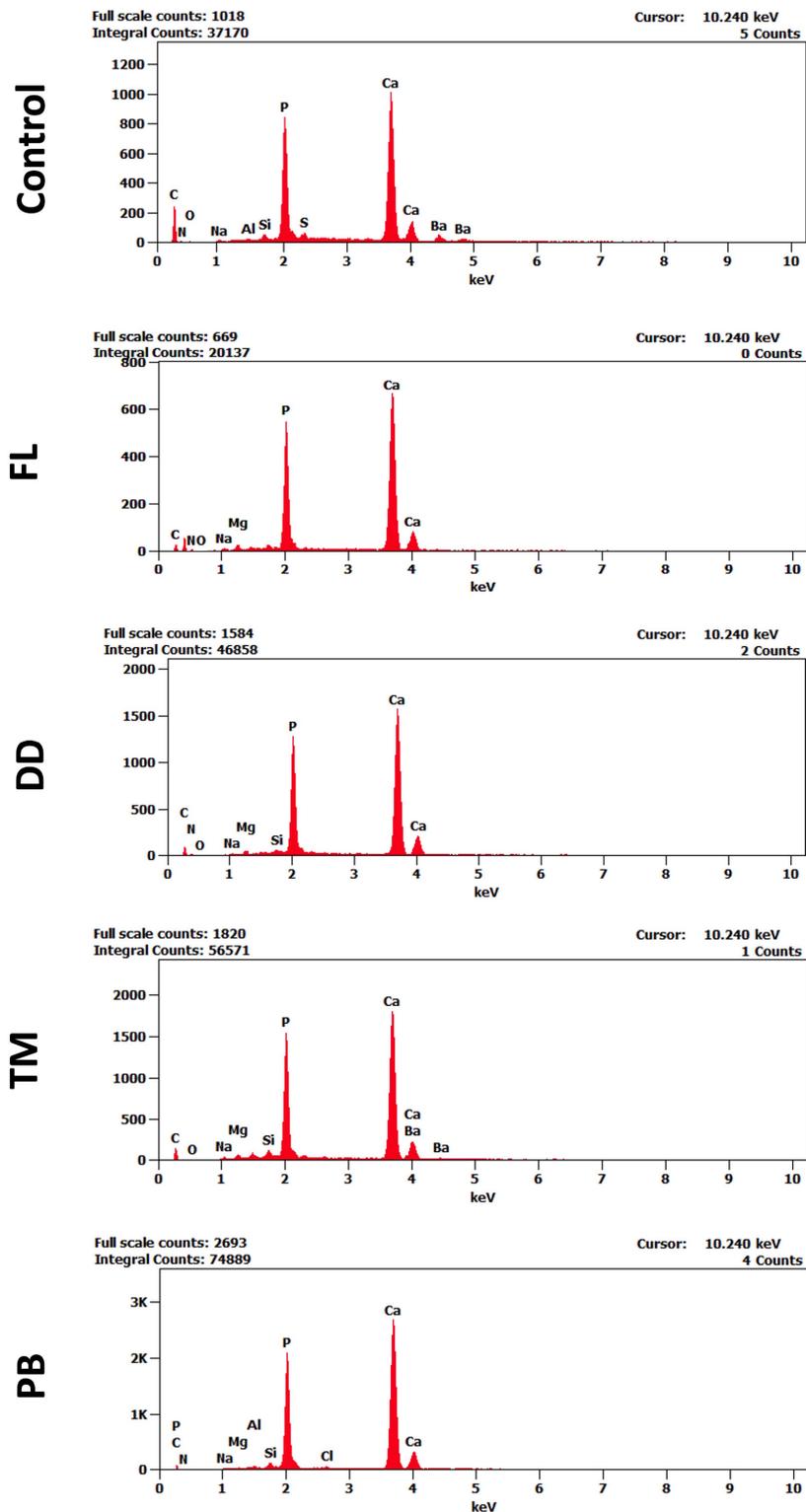
The EDX analysis showed a notable shift in the elemental composition of dentin after applying different desensitizers. In the control group, the spectra exhibited strong peaks for Calcium (Ca) and Phosphorus (P), with Ca making up 44.97% by weight and P 19.92%. Carbon (C) percentage was 15.41%, representing the organic matrix in dentin.

In the FL group, both calcium and phosphorus levels increased, with Ca reaching 54.30% and P 22.45% by weight, while carbon levels dropped to 7.11%. In comparison, the DD group exhibited Ca and P levels of 48.88% and 23.92% by weight, respectively, and an organic profile that closely matched that of the control group.

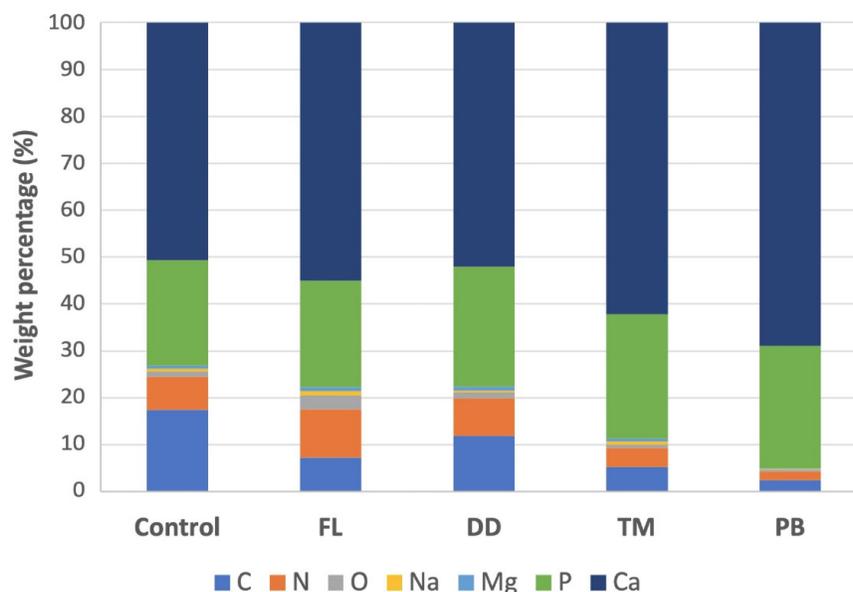
The TM group showed a Ca content of 60.56% by weight and P at 25.79%, with a relatively lower C content at 5.15%. In the PB group, Ca levels were the highest among all groups, demonstrating a significant increase in intensity in the corresponding spectra, reaching 68.06% by weight, with a *p*-value of 25.81%. The C-level was the lowest compared to other groups (2.41%). Representative EDX spectra for each group are presented in Fig. (3), while the weight and atomic percentage of key elements are summarized in Table 2. To facilitate comparison of elemental composition across groups, the weight percentage data are also presented as a bar graph in Fig. (4).

**Table 2. Elemental composition of dentin surfaces in different study groups based on EDX analysis.**

-	-	C	N	O	Na	Mg	P	Ca
Control	Weight %	15.41	6.26	1.13	0.42	0.59	19.92	44.97
	Error (+/-1 Sigma)	±0.34	±1.22	±0.36	±0.08	±0.08	±0.35	±0.60
FL	Atom %	33.56	11.68	1.85	0.47	0.64	16.82	29.34
	Error (+/-1 Sigma)	±0.74	±2.29	±0.58	±0.09	±0.09	±0.30	±0.39
DD	Weight %	7.12	10.15	3.04	0.82	0.84	22.45	54.30
	Error (+/-1 Sigma)	±0.38	±1.97	±0.66	±0.15	±0.12	±0.46	±0.94
TM	Atom %	16.03	19.60	5.14	1.21	0.93	19.60	36.64
	Error (+/-1 Sigma)	±0.84	±3.79	±1.11	±0.21	±0.13	±0.40	±0.63
PB	Weight %	11.18	7.48	1.25	0.36	0.78	23.92	48.88
	Error (+/-1 Sigma)	±0.983	±1.08	±0.38	±0.08	±0.07	±0.31	±0.62
TM	Atom %	31.084	15.76	2.30	0.46	0.95	22.78	38.39
	Error (+/-1 Sigma)	±2.73	±2.27	±0.71	±0.10	±0.09	±0.29	±0.46
PB	Weight %	5.15	3.89	0.73	0.66	0.59	25.79	60.56
	Error (+/-1 Sigma)	±0.20	±0.83	±0.27	±0.09	±0.13	±0.31	±0.59
PB	Atom %	19.76	7.53	1.45	0.91	0.77	26.46	48.02
	Error (+/-1 Sigma)	±0.53	±1.61	±0.54	±0.12	±0.17	±0.32	±0.47
PB	Weight %	2.41	1.82	0.40	0.15	0.15	25.81	68.06
	Error (+/-1 Sigma)	±0.13	±0.58	±0.09	±0.06	±0.05	±0.28	±0.55
PB	Atom %	6.84	4.43	0.59	0.21	0.18	28.42	57.92
	Error (+/-1 Sigma)	±0.37	±1.41	±0.13	±0.08	±0.07	±0.30	±0.45



**Fig. (3).** Representative EDX spectra of dentin surfaces in different study groups, showing labeled elemental peaks. Variations in peak intensities indicate changes in surface elemental composition among the treatment groups. The x-axis represents the energy levels in kiloelectronvolts (keV), corresponding to specific elemental peaks, while the y-axis indicates the intensity of detected X-ray signals.



**Fig. (4).** Bar graph showing the relative weight percentages of selected elements detected on dentin surfaces in each experimental group, based on EDX analysis. The x-axis represents the experimental groups (Control, FL, DD, TM, PB), and the y-axis indicates the mean weight percentage (%) of each element.

#### 4. DISCUSSION

This study compared the influence of bioactive-based desensitizers on dentin surface composition and bonding performance, using EDX analysis to detect elemental changes and to elucidate the effects on the bond strength of self-adhesive resin cement. The findings suggest that the desensitizers did not significantly affect the bond strength of self-adhesive resin cements to dentin, except in DD, where a significant increase in the bond strength was observed. EDX analysis revealed that all desensitizers increased mineralization on the dentin surface, as evidenced by increases in Ca and P, along with a reduction in C. Therefore, the null hypothesis was rejected.

In the present study, a self-adhesive resin cement was utilized, which primes the dentin surface without requiring separate etching or bonding steps. To ensure consistency, only one commonly used resin cement was selected. Self-adhesive resin cements are popular due to their straightforward application and reduced postoperative sensitivity, making them a preferred choice for a range of indirect restorations [16]. The bond strength of self-adhesive resin cements primarily depends on the interaction between acidic functional monomers, such as 10-MDP, and the calcium in the HA of dental tissues [12]. However, previous studies have indicated that the long-term performance of self-adhesive resin cements is generally low and have suggested using self-etching adhesives immediately after preparation to seal the dentinal tubules, prevent postoperative sensitivity, and enhance bonding through the formation of a stable hybrid layer [17, 18].

In this study, the predominance of adhesive-type failure across all test groups potentially indicates the limi-

tations of self-adhesive resin cements in bonding to dentin. Additionally, the modification of dentin surface by different desensitizers might interfere with resin infiltration, resulting in surface-level adhesion rather than a stable hybrid layer. Self-adhesive resin cements generally lack aggressive demineralization capability and therefore may not fully compensate for the dense mineral layers formed by certain desensitizers [12, 17].

When comparing the bond strength results, specimens treated with DD showed the highest bond strength values. This suggests that DD application may have promoted favorable modification to the dentin surface, allowing for improved interaction with the resin cement. EDX analysis revealed elevated carbon content in this group, along with quantities of oxygen and nitrogen, suggesting preservation of the organic composition of the dentin. DD is a HEMA-free formulation containing 5% glutaraldehyde, fluoride, and water [19]. Glutaraldehyde cross-links with dentinal fluid protein and promotes their coagulation, effectively plugging the tubules [20]. Previous SEM analyses have demonstrated that glutaraldehyde-based desensitizers result in semi-closed dentinal tubules without forming a thick surface coating, thereby preserving surface receptivity to resin penetration and contributing to improved bond strength [21]. In addition, the interaction between glutaraldehyde and phosphate in resin cement may have contributed to improved and durable bonding [22]. These findings support previous studies, which have shown that glutaraldehyde-based desensitizers enhance bond strength by forming a stable bond interface [19, 22-24].

While DD functions through the coagulation of dentin, the other desensitizers act via mineral precipitation. In this study, FL and TM appeared to reduce the bond str-

length when applied to dentin before cementation. Fluoride is known to form a Calcium Fluoride ( $\text{CaF}_2$ ) layer on the surface of dentin [25]. The precipitated  $\text{CaF}_2$  can create a barrier that reduces the resin's ability to infiltrate and bond with dentin, leading to weaker bonding. Previous studies have reported mixed results on the influence of fluoride on bond strength. Some research indicates that the use of fluoride-containing solutions prior to bonding can reduce bond strength by interfering with hybrid layer formation and micromechanical retention. This effect was attributed to a thicker crystal layer formed on the dentin surface, as noted by Saraç *et al.*, who concluded that higher fluoride concentrations resulted in reduced bond strength [26]. In contrast, other studies have shown that applying fluoride to demineralized dentin either increased or had no significant effect on bond strength [27, 28]. However, more recent research has consistently reported a reduction in bond strength with fluoride application [25]. In the present study, the absence of phosphoric acid etching prior to bonding may have compounded the issue, allowing  $\text{CaF}_2$  deposits and desensitizer residues to persist on the dentin surface.

Similarly, TM desensitizer demonstrated reduced bond strength. TM desensitizer stimulates the formation of HA through the reaction of its Tetracalcium Phosphate (TTCP) and Dicalcium Phosphate Anhydrous (DCPA) components. This process involves the dissolution of calcium and phosphate ions from the desensitizer, followed by re-precipitation as HA crystals [9]. Previous studies observed substantial deposit formation and tag structures in the dentinal tubules after TM treatment, with these tags primarily composed of Ca and P, indicating HA deposition within the tubules [29, 30]. While this bioactivity is effective for reducing sensitivity, it may pose a challenge for bonding [20, 29, 31]. Therefore, the reduced bond strength may be attributed to desensitizer deposition, which could obstruct dentinal tubule orifices and hinder intertubular diffusion, thereby interfering with the cement's ability to interact and form a strong interlocking hybrid layer. This finding is consistent with the results of previous studies, which indicate that calcium phosphate desensitizers can reduce bonding efficacy by creating a physical barrier [31, 32]. However, earlier work has shown that calcium phosphate-based desensitizers did not affect bond strength when etch-and-rinse adhesives were used [33].

The EDX analysis indicated that the PB desensitizer induced the highest degree of mineralization on the dentin surface. However, this increased mineral content did not result in the highest bond strength, similar to the TM group. On the other hand, PB-treated specimens exhibited fewer adhesive failures than TM and a higher incidence of mixed failures, suggesting improved interfacial bonding. Unlike TM, PB employs a bioactive gel matrix containing Ca, P, and preformed HA. This inclusion of HA may enhance remineralization while maintaining a surface that supports bonding and chemical interaction at the interface [11, 34].

## 5. STUDY LIMITATIONS

This *in vitro* study has limitations that should be considered when interpreting the results. The controlled laboratory setting may not fully replicate the complex conditions of the oral environment. Additionally, only one self-adhesive resin cement was tested, and solely in self-etch mode, potentially limiting the generalizability of the findings. Further clinical studies and investigations involving a broader range of materials are needed to confirm and extend these findings.

## CONCLUSION

Within the limitations of this *in vitro* study, desensitizing agents altered the dentin surface but did not consistently improve the bond strength of self-adhesive resin cement. These findings suggest that surface modifications induced by desensitizers may not uniformly benefit adhesive performance and should be considered in material selection and clinical protocols.

## AUTHORS' CONTRIBUTIONS

The authors confirm contribution to the paper as follows: A.T., R.R.B.: Study conception and design; A.T., R.R.B.: Data collection; A.T., R.R.B.: Analysis and interpretation of results; A.T., R.R.B.: Draft manuscript. All authors reviewed the results and approved the final version of the manuscript.

## LIST OF ABBREVIATIONS

C	=	Carbon
Ca	=	Calcium
$\text{CaF}_2$	=	Calcium fluoride
DCPA	=	Dicalcium phosphate anhydrous
DD	=	Dentin Desensitizer
EDX	=	Energy-dispersive X-ray
FL	=	APF Fluoride Gel
HA	=	Hydroxyapatite
HEMA	=	Hydroxyethyl methacrylate
$\mu\text{SBS}$	=	Microshear bond strength
P	=	Phosphorus
PB	=	Predicta Bioactive Desensitizer
SEM	=	Scanning electron microscopy
TM	=	Teethmate Desensitizer
TTCP	=	Tetracalcium phosphate

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Research Ethics Committee of the Faculty of Dentistry, King Abdul-Aziz University, under reference number 88-09-24.

## HUMAN AND ANIMAL RIGHTS

All human research procedures followed were in accordance with the ethical standards of the committee responsible for human experimentation (institutional and

national), and with the Helsinki Declaration of 1975, as revised in 2013.

### CONSENT FOR PUBLICATION

Informed consent was obtained from the patients.

### STANDARDS OF REPORTING

STROBE guidelines were followed.

### AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article will be available from the corresponding author upon reasonable request.

### FUNDING

None.

### CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

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