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Effect of Surface Conditioning methods on Resin Cement Tag Formation at The Porcelain Surface Between Composite and Porcelain Interface: A Quantitative SEM-Based Analysis

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KEYWORDS

Surface conditioning, resin cement, tag formation, composite, porcelain

ABSTRACT

Background: Dental porcelain restorations are widely used for their esthetics and biocompatibility but are prone to chipping. Composite resin repair offers a conservative alternative; however, the success of such repairs depends on optimal bonding at the porcelain–composite interface.

Objective: To evaluate the effect of different surface conditioning methods on resin cement tag formation at the porcelain surface between composite and porcelain interface using quantitative scanning electron microscopy (SEM) analysis.

Methods: This in-vitro comparative study was conducted at the Department of Prosthodontics, Bangladesh Medical University, from January to June 2025. Forty-eight porcelain–composite specimen pairs were divided into three groups (n=16): Group 1 – no conditioning, Group 2 – silane treatment, and Group 3 – phosphoric acid etching followed by silane. Specimens were bonded using Panavia V5 resin cement, cured, stored in distilled water at 37 °C for 7 days, sectioned, and examined under SEM (1000×) for resin tag formation. Data were analyzed using Kruskal–Wallis and Mann–Whitney U tests.

Results: Resin tag formation differed significantly among groups ($p < 0.001$). Group 1 showed minimal tag formation (mean rank = 9.44), Group 2 demonstrated moderate improvement (24.69), and Group 3 exhibited the highest tag density and uniformity (39.38). Pairwise comparisons revealed significant differences between all groups ($p < 0.001$).

Conclusion: Combined surface conditioning with phosphoric acid etching and silane application produced the most effective micromechanical and chemical bonding at the porcelain–composite interface. This dual treatment enhances resin tag formation and is recommended for achieving durable and esthetic porcelain repairs.

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INTRODUCTION

Ceramics are widely used in dentistry for metal-free restorations due to their esthetics, shade stability, biocompatibility, wear resistance, and low thermal conductivity.[1] Chipping remains a common cause of failure in aesthetic restorations, often requiring replacement.[2] Repairing chipped porcelain restorations with composite resin is important because it offers a minimally invasive, cost-effective alternative to full replacement, preserving the existing prosthesis and reducing patient treatment time.[3] Extraoral repairs risk tooth and tissue damage, and repeated firings may weaken the porcelain.[4] Repair success depends on strong composite–porcelain bonding to prevent debonding and maintain esthetics and function.[5]

Bonding between porcelain and composite occurs by creating both micromechanical bonding and chemical bonding, which is achieved by etching the porcelain surface with hydrofluoric acid followed by silane application, and it increases bond strength.[6] Primarily composite restorations bond to enamel or dentin by using adhesive systems, offering a more conservative but less durable alternative, and repairs of porcelain with composite require careful surface treatment and proper adhesive selection for optimal longevity.[7] Resin cement forms long, uniform tags in etched porcelain with silane for strong adhesion, while on composite, tags are shorter and rely mainly on mechanical retention, explaining porcelain's higher bond strength.[8] Several studies have shown that surface conditioning strongly influences resin cement bonding and tag formation. SEM analyses shows that well-formed resin tags on dentin and lithium disilicate ceramics, respectively, highlighting the role of etching and silanization.[9]

In Bangladesh, few studies have examined resin cement bonding at the composite–porcelain interface. Some related research has evaluated resin cement bond strength in crowns and sealants, highlighting the importance of surface treatment for durable adhesion.[10] The aim of this study is to investigate the effect of various surface conditioning techniques on the formation of resin cement tags at the composite–porcelain interface. Using scanning electron microscopy (SEM), the study seeks to quantitatively analyze how different treatments—such as etching, silanization, or mechanical roughening—affect the micromechanical interlocking of resin cement with the porcelain and composite surfaces. By evaluating tag length, density, and uniformity, the study aims to identify the surface conditioning method that provides optimal adhesion and bond strength, thereby improving the durability and clinical performance of porcelain–composite restorations.

MATERIALS AND METHODS

This cross-sectional, comparative in-vitro experimental study was conducted from January to June 2025 at the Department of Prosthodontics, Faculty of Dentistry, Bangladesh Medical University (BMU), Dhaka. A total of 48 porcelain–composite specimen pairs were prepared and equally divided into three groups (n = 16) according to surface treatment:

- Group 1 (Control): No conditioning
- Group 2 (Silane): Silane coupling agent application
- Group 3 (Phosphoric acid + Silane): Etching with 37% phosphoric acid followed by silane application

Feldspathic porcelain blocks (IPS Classic, Ivoclar Vivadent) and nano-hybrid composite resin (Filtek Z350 XT, 3M ESPE) were bonded using Panavia V5 dual-cure resin cement (Kuraray Noritake Dental Inc.). Porcelain surfaces were polished with 600-grit silicon carbide paper, ultrasonically cleaned, conditioned as per group, and bonded under a 1 kg load. Specimens were light-cured for 40 s from each side and stored in distilled water at 37 °C for 7 days.

After storage, specimens were sectioned perpendicularly through the bonded interface, gold-sputtered, and examined under Scanning Electron Microscope (SEM) at 1000× magnification to evaluate resin tag formation, scored as:

- 0 = No tag
- 1 = Mild (1–2)
- 2 = Moderate (3–4)
- 3 = Severe (5–6).

Data were analyzed using SPSS v30 (IBM Corp.). The Kruskal–Wallis test assessed group differences, and Mann–Whitney U tests were used for pairwise comparisons. A $p < 0.05$ was considered statistically significant. Ethical approval was obtained from the Institutional Review Board (IRB) of BMU.

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RESULTS

Table 1: Resin cement tag formation scores at the Composite–Porcelain interface (n=48)

Groups	n	Score 0	Score 1	Score 2	Score 3	Mean Rank
Group-1	16	13	3	0	0	9.44
Group-2	16	0	10	6	0	24.69
Group-3	16	0	0	6	10	39.38

Non-parametric Kruskal- Wallis test was done, N= sample size

Score 0 = No resin tag; Score 1 = Mild resin tags (1-2) Score 2 = Moderate resin tags (3-4) Score 3 = Severe resin tags (5-6)

Group-1= Sample without Conditioning

Group-2= Sample conditioned with Silane coupling agent

Group-3= Sample conditioned with Phosphoric acid combined with silane coupling agent.

Table-1 shows that the categorical scoring distribution of sample on the basis of resin cement tagging visible under SEM among the three groups. Group-1 predominantly exhibited the lowest scores, with 13/16 of samples scoring 0 and the remainder scoring 1, indicating minimal effect of the applied treatment. In contrast, Group-2 showed a marked improvement, with 10/16 scoring 1 and 6/16 scoring 2, suggesting a moderate enhancement in the measured property. Group-3 samples achieved the highest scores, with 10/16 scoring the maximum value of 3 and 6/16 scoring 2, reflecting the greatest efficacy among groups. The mean rank values obtained from non-parametric testing (e.g., Kruskal-Wallis) further support these findings. Group-1 had the lowest mean rank (9.44), followed by Group-2 (24.69), and Group-3 had the highest mean rank (39.38). This statistically significant trend suggests that the surface conditioning method used in Group-3 was the most effective in enhancing the bond strength, while Group-1 performed the poorest.

Table 2: Pairwise comparison of resin tag scores by surface conditioning (Mann-Whitney U Test)

Comparison Groups	U Statistic	Z Value	p-Value
Group 1 vs Group 2	15.000	−4.592	< 0.001 **
Group 1 vs Group 3	0.000	−5.097	< 0.001 **
Group 2 vs Group 3	18.000	−4.402	< 0.001 **

*P-value obtained by Mann-Whitney U-test, P<0.001 was considered as a level of *significant*

Mann-Whitney U-test was done; N= sample size; P = Probability value

Group-1= Sample Without Conditioning

Group-2= Sample conditioned with Silane coupling agent

Group-3= Sample conditioned with Phosphoric acid combined with silane coupling agent.

Table-2 shows, pairwise comparisons using the Mann-Whitney U non-parametric test demonstrated significant differences in resin tag scores among all groups. Specifically, Group-2 showed significantly higher scores than the control Group-1 (U = 15.000, Z = -4.592, p < 0.001), indicating that surface conditioning improved resin tag formation. Group-3 exhibited the highest scores, significantly outperforming both Group-1 (U = 0.000, Z = -5.097, p < 0.001) and Group-2 (U = 18.000, Z = -4.402, p <0.001). These results suggest that the combined

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surface conditioning method used in Group-3 produced the most effective bonding interface.

DISCUSSION

Table 1 shows that the resin–porcelain bond interface is strongly influenced by surface conditioning protocols. Untreated porcelain (Group-1) exhibited minimal resin penetration and poor micromechanical retention (mean rank 9.44). Application of silane alone (Group-2) enhanced chemical bonding and resin infiltration (mean rank 24.69). The combination of phosphoric acid etching and silane (Group-3) produced the highest resin penetration and micromechanical interlocking (mean rank 39.38), demonstrating a robust and continuous bond interface. These findings emphasize the critical role of synergistic mechanical and chemical surface conditioning in achieving optimal resin–ceramic adhesion, consistent with previous studies.[11,12]

Table 2 shows that the Mann-Whitney U test showing significant differences in resin tag scores among all groups, highlighting the impact of surface conditioning. Group-2 (silane) scored higher than untreated porcelain (Group-1) ($U = 15.000$, $Z = -4.592$, $p < 0.001$), indicating improved chemical adhesion. [13] Group-3 (phosphoric acid + silane) achieved the highest scores ($U = 0.000$, $Z = -5.097$, $p < 0.001$), reflecting enhanced micromechanical retention and chemical bonding. [11,14] Comparison of Group-2 and Group-3 ($U = 18.000$, $Z = -4.402$, $p < 0.001$) confirmed the superiority of combined treatment. Overall, dual mechanical and chemical conditioning significantly improves resin–ceramic bond quality, with the combined protocol providing the most durable and clinically relevant outcome.[15]

CONCLUSION

The present study clearly demonstrates that surface conditioning plays a crucial role in enhancing resin cement adhesion at the composite–porcelain interface. Samples that received no surface treatment (Group-1) exhibited minimal resin tag formation, indicating poor micromechanical retention and weak bonding potential. Application of silane coupling agent alone (Group-2) significantly improved resin tag formation, reflecting moderate enhancement of the bond. However, the combination of phosphoric acid etching followed by silane application (Group-3) produced the highest number and most uniform resin tags, suggesting optimal micromechanical interlocking and chemical bonding. Statistical analyses using Kruskal-Wallis and Mann-Whitney U tests confirmed these differences to be highly significant ($p < 0.001$). These results underscore that effective surface conditioning not only enhances the formation of resin tags but also contributes directly to stronger and more durable adhesion between composite and porcelain surfaces, which is critical for the long-term success and clinical performance of repaired porcelain restorations.

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