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The Effect of Trichloracetic Acid as a Hemostatic and Etching Agent on the Morphological Characteristics and Shear Bond Strength of Resin Composite to Enamel

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Clinical Relevance

TCA gel etches enamel surfaces and produces surface morphological characteristics and bond strength similar to that produced by phosphoric acid. When TCA is used as a hemostatic agent on marginal gingiva, its inadvertent contact with enamel improves the immediate bond strength of resin composite to enamel. However, when using phosphoric acid and 50% TCA, an erosive enamel surface is produced.

SUMMARY

Introduction: Trichloracetic acid (TCA) is a soft tissue chemical cauterizing agent that is used on gingival margins prior to restoring cervical cavities with resin materials. This study evaluated the effect of TCA gel as an etchant, its use before etchant on the shear bond strength between resin composite and enamel and also its effect on enamel surface morphological characteristics.

Materials and Methods: Seventy-five sound, extracted human anterior maxillary teeth were selected for the purpose of this *in vitro* study. The teeth were equally divided into five groups prior to enamel surface preparation with silicone carbide papers. In Group 1, the enamel surfaces were etched with 35% phosphoric acid for 30 seconds. In Groups 2 and 3, a 35% TCA gel and 50% TCA gel, respectively, were used on the enamel surfaces for 30 seconds. The enamel surfaces were then rinsed with water for 10 seconds. In Groups 4 and 5, the specimens were prepared in the same manner as Groups 2 and 3 and the enamel surfaces were then

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etched with 35% phosphoric acid for 30 seconds. In all the experimental groups, after rinsing and drying the samples, Single Bond adhesive (3M ESPE) was used to bond Z250 composite cylinders onto the enamel surfaces. After 500 rounds of thermocycling, the composite cylinders were loaded to failure in shear in a DARTEC test machine and the data were analyzed using the ANOVA and Scheffé's tests (α=0.05). Two specimens from each group were prepared for surface morphology evaluation under SEM.

Results: The mean bond strengths and standard deviations in Groups 1 through 5 were 23.77±1.64, 22.43±3.02, 23.48±3.48, 25.31±1.42 and 28.68±1.28 MPa, respectively. Analysis of the variances demonstrated statistically significant differences in the study groups (*p*<0.05). Pairwise testing showed statistically higher bond strength in Group 5 than all the other groups (*p*<0.05). The morphology of surfaces etched with TCA in Groups 2 and 3 was similar to that of surfaces etched with phosphoric acid alone (Group 1).

Conclusion: TCA is capable of etching enamel surfaces in a manner similar to phosphoric acid. Although the inadvertent contact of TCA with enamel prior to conventional etching with phosphoric acid may have a positive effect on bond strength between enamel and resin composite, microscopical evaluations also show an overetching pattern that is more prominent with 50% TCA.

INTRODUCTION

Contamination with blood and moisture reduces bond strength between the adhesive and tooth structure,[1-2] necessitating rubber dam use during adhesive procedures. However, practitioners do not generally use a rubber dam as a routine procedure. Instead, they make use of other methods to prevent moisture and blood contamination. Moreover, it should be kept in mind that, in some instances, it is not possible to use a rubber dam. In restoring cervical cavities with direct techniques, control of sulcular fluids and hemorrhaging is of the utmost importance.[3-4] Gingival areas are subject to trauma and bleeding as a result of some restorative procedures; in addition, the seeping of sulcular fluid poses problems in some clinical situations.[1] When cavities are contaminated, visualization and accessibility are impaired and microleakage leads to less durable restorations.[5] Epinephrine, aluminum chloride and ferrous sulfate are frequently used to solve these problems. Additionally, electrosurgery and laser beams are also currently used to prevent cavity contamination with blood and sulcular fluids.[6-8]

The use of epinephrine is limited, because it causes hypertension and tachycardia.[4] Iron compounds can result in restoration margin discoloration in tooth-colored restorations if not completely removed with irrigation.[1] Since these agents come in contact with tooth structures when used on gingival margins, some studies have evaluated their effect on tooth structure and tooth-resin bonds. One such study evaluated the bond strength of a self-etch adhesive system to superficial dentin contaminated with ferric sulfate, or $AlC1_3$, and concluded that this kind of contamination markedly decreases bond strength in comparison with uncontaminated dentin.[9] Another study evaluated the bond strengths of a total-etch and a self-etch system to dentin contaminated with a hemostatic agent containing aluminum chloride. The self-etching bonding system had far lower bond strength to dentin contaminated with 25% aluminum chloride solution than it did to uncontaminated dentin.[1]

Buonocore introduced phosphoric acid for etching enamel in 1955.[10] Since then, phosphoric acid has been widely used and is now also used for etching dentin. The phosphoric acid etching procedure leads to the successful bonding of resin to enamel.[11] Other acids have also been suggested and evaluated as dentin and enamel etchants.[12-13] Trichloracetic acid (TCA) is a chemical escarotic agent that has been used in medicine and dentistry for more than a century.[14] TCA is produced by the oxidation of chloral hydrate with nitric acid and is manufactured by the chlorination of acetic acid. Its aqueous solution is highly acidic, yielding a pH of 1.0. It is predominantly used for decalcification and fixation in microscopic studies and as a precipitating agent for proteins. It has been used as a cauterizing agent in medical procedures, especially for dermatologic and ophthalmologic purposes.[14]

Heithersay used a 90% aqueous solution of TCA in an attempt to remove hyperplastic gingival tissues to achieve a sound substrate in cervical defects with a resorptive nature. Three- and five-year follow-ups of cases demonstrated 100% success rates.[15]

A highly saturated solution of TCA has been recommended for its prompt hemostatic effect and control of gingival fluid seepage when restoring cervical defects.[16-17] This solution gives rise to a well-circumscribed area of coagulation necrosis of the involved soft tissues. This area of well-defined coagulation necrosis is separated from neighboring tissues in a few days.[14,16,18] When applying TCA to a cervical root resorption defect to exert its caustic effect, it inadvertently makes contact with dental hard tissues.[14]

Heithersay and Wilson applied TCA to soft tissues in rats; it did not exhibit any inflammatory reactions in neighboring tissues and healing was uneventful.[19] Subsequently, TCA was widely and successfully used in the treatment of resorptive cervical lesions and in the debridement of external root surface resorptive lesions involving gingival hyperplasia.[20-22] TCA was also used with electrosurgery, proving to be a very effective therapeutic procedure.[16]

Lewinstien and others evaluated the effect of TCA on human dentin and enamel microhardness and surface morphological characteristics. They concluded that the duration of TCA application progressively influences microhardness. Furthermore, the application of 90% TCA for 60 seconds results in an etched appearance on the enamel surface; after 90 seconds, the etched pattern disappears and an erosive enamel surface appears. Lewinstien and others also reported an etched appearance on dentin surfaces.[14] In 1994, Galun and others introduced TCA as an effective dentin conditioner, with proper shearing bond strengths for glass-ionomer restorations.[23] However, to date, no studies have evaluated the effect of TCA on prepared enamel surfaces and bonding to enamel.

TCA is an acid and may come in contact with cavity margins when used as a hemostatic agent, especially in cervical restorations that are in close proximity to marginal gingiva. Therefore, the current study treated enamel with 37% phosphoric acid alone, with 35% and 50% TCA gels alone as etching agents and with a combination of TCA gels and phosphoric acid to evaluate the surface morphological characteristics and shear bond strength of resin composite.

METHODS AND MATERIALS

Preparation of Specimens for Bond Strength Evaluation

Seventy-five sound, extracted human anterior maxillary teeth were selected for the purpose of this *in vitro* study. The teeth had been extracted for periodontal reasons and were cleaned and rinsed with brushes and slurry of pumice, then stored in 0.2% thymol solution before being used for the study. They were embedded in self-curing acrylic molds (Acropars, Marlic Medical Co, Tehran, Iran), then the enamel surfaces on the buccal aspect of all the specimens were prepared using 400- and 600-grit silicone carbide papers until a smooth surface was achieved for bonding composite. The teeth were randomly divided into five groups of 15 teeth each.

In Group 1, the enamel surface was etched using 35% phosphoric acid (3M ESPE, St Paul, MN, USA) for 30 seconds. In Groups 2 and 3, 35% and 50% TCA gels (Amin Pharm Co, Isfahan, Iran), respectively, prepared from TCA crystals (Merck KGaA, Darmstadt, Germany) were used for 30 seconds on the enamel surfaces and rinsed for 10 seconds. In Groups 4 and 5, the same procedure as described for Groups 2 and 3 was used, with Group 4 corresponding to Group 2 and Group 5 corresponding to Group 3; the enamel surfaces were further etched with 35% phosphoric acid (3M ESPE) for 30 seconds, then rinsed for 10 seconds and dried. Finally, Single Bond adhesive (3M ESPE) was applied in two layers according to the manufacturer's instructions. Each layer of the adhesive was applied for 30 seconds, dried with a gentle air current for five seconds, then cured for 20 seconds. A halogen light-curing unit (Coltolux 2.5, Coltene AG, Feldwiesenstrasse Altstätten/Switzerland) with 480 mW/cm^2 output was used for curing.

Plastic molds with an inner diameter of 3 mm and a length of 4 mm were used to bond cylinders filled with Z250 composite (3M ESPE) to the prepared enamel surfaces. The Z250 resin composite was placed and cured in two increments; each increment was 2 mm thick and light-cured for 40 seconds. The resin composite cylinders were then light-cured for an additional 120 seconds from all three directions. After 24 hours storage at 37°C, the specimens were placed under 500 rounds of thermocycling between 5°C and 55°C (Mp Based, KARA1000 Inc, Tehran, Iran) with a dwell time of 30 seconds and a transfer time of 10 seconds. To test the shear bond strength, the specimens were held in jaws that had been clamped to the base plate of a universal testing machine (Dartec, HC10, Dartec Ltd, Stourbridge, UK). Using a knife-edged metal rod, a shear load was applied vertically from the load cell to the base of the cylindrical mold. The crosshead speed was 1 mm/minute. In order to measure bond strength expressed in MPa, the resultant force in Newton was divided into the cross-section of the bonded area. The bond strength data were statistically analyzed by ANOVA and Scheffé's tests using SPSS version 10 at a significance level of 0.05.

Preparation of Specimens for SEM Evaluation

Two specimens from each group were prepared for analysis under SEM. The enamel surface of each specimen was freshened with silicone carbide papers. Subsequent to preparing each specimen according to the method described previously, each specimen was then fixed, dehydrated and dried. At this point, it was affixed to an aluminum mounting stub and sputter-coated with platinum-gold to a thickness of 10 nm for analysis under SEM. Different magnifications were used to provide SEM images at a distance of 19 mm. An accelerating voltage of 10.0 kV was used for the analysis.

RESULTS

Mean bond strengths and standard deviations in the groups are summarized in Table 1. A two-by-two comparison of the study groups using the Scheffé's test revealed statistically significant differences between Group 5, which showed the highest bond strength, and the other groups ($p<0.05$).

When viewed under SEM, enamel surfaces in the first group exhibited the characteristic pattern of etched enamel (Figure 1). The morphology of the sur-

Table 1: *Shear Bond Strength (SD) in MPa*

Groups	Mean (SD)
1. (35% H_3PO_4)	23.77 (1.64)[a]
2. (35% TCA)	22.43 (3.02)[a]
3. (50% TCA)	23.48 (3.48)[a]
4. (35% TCA & 35% H_3PO_4)	25.31 (1.42)[a]
5. (50% TCA & 35% H_3PO_4)	28.68 (1.28)[b]

Groups with the same superscript are not statistically different (p>0.05).

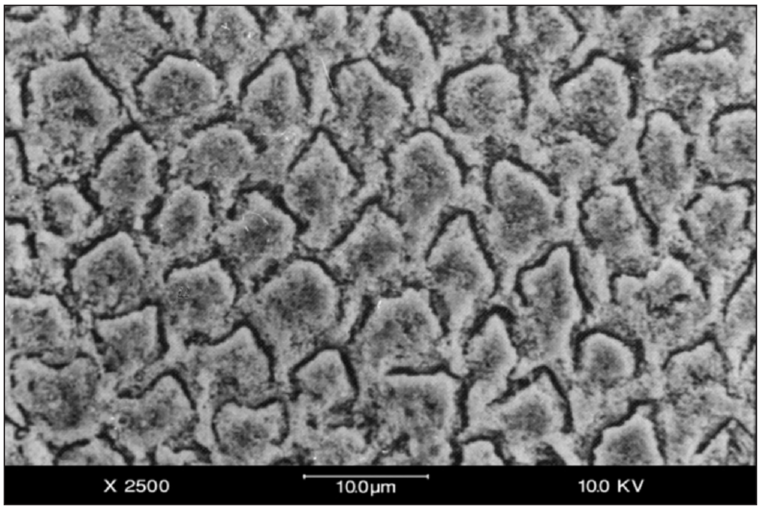

Figure 1: *Scanning electron micrograph of enamel surface after 30 seconds etching with 35% H_3PO_4. Original magnification 2500×.*

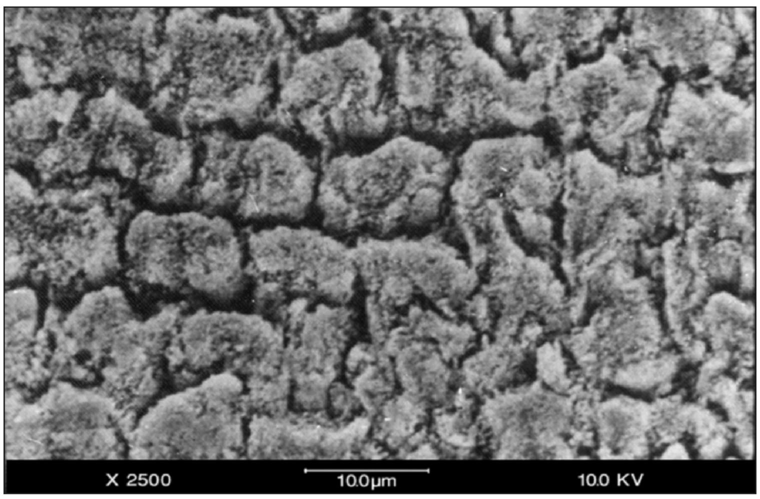

Figure 2: *Scanning electron micrograph of enamel surface after 30 seconds etching with 35% TCA. Original magnification 2500×.*

faces etched with TCA alone (Groups 2 and 3) was similar to that of surfaces solely etched with phosphoric acid (Group 1). Typical etched surfaces were observed in the TCA groups, with enamel. Enamel prisms were selectively removed (Figures 2 and 3). Additional changes were observed on surfaces etched with phosphoric acid and 35% TCA, Group 4 (Figure 4). An erosive enamel surface (over-etched surface) was observed on surfaces etched with phosphoric acid and 50% TCA, Group 5 (Figure 5). Surfaces etched with phosphoric acid (Group 1) and 50% TCA (Group 3) exhibited a more pronounced characteristic etching effect, with well-defined etched enamel prisms all over the surface (Figures 1 and 3).

DISCUSSION

In the current study, TCA gel was used to etch enamel surfaces in order to provide a comparison for etching enamel with phosphoric acid. In addition, since TCA is a cauterizing agent and results in the self-limiting necrotic effect on marginal gingiva,[14] its application for 30 seconds on gingival tissues seems sufficient. Nevertheless, further studies on the subject are required.

The results of bond strength tests on Groups 2 and 3 reveal favorable bond strengths with TCA as an etchant. This is consistent with the results of previous studies on the conditioning and etching effects of TCA.[14,23] However, some studies have reported that contact of other astringent agents on tooth structures resulted in decreased bond strength between a composite and tooth structures.[1,9] It is noteworthy that all materials with an acidic pH do not have the capacity to produce a proper bond with tooth structures, because they may leave deposits on the tooth structures that might interfere with bonding. Kuphasuk and others demonstrated through SEM evaluations decreased bond strength and remnants of aluminum chloride in tooth structures.[1] It may be possible to use TCA to condition enamel and dentin surfaces and to also control or decrease the bleeding of marginal gingiva in esthetic cervical restorations without the simultaneous application of phosphoric acid or other conditioners. However, it should be mentioned that TCA is an aggressive acid that can cause sloughing of the soft tissue if used improperly in the clinic. Additional research is needed to identify suitable concentrations and application times that are deemed safe for the above-mentioned uses.

TCA is an acid with a pH of 1.0 and has drawn much attention in previous studies as a hemostatic agent. The current study evaluated its etching effect on enamel surfaces. Previously, Galun and others introduced TCA as an effective dentin conditioner that increases shearing and tensile bond strengths of glass-ionomer to dentin. They attributed the results to removal of the smear layer, patency of the orifices of dentinal tubules and deeper penetration of TCA into dentinal tubules.[23] Other chemicals, including aluminum chloride, aluminum sulfate and ferric sulfate, which are commonly used to control bleeding and gingival fluids, are highly acidic, with pH values of 0.7 to 3.0. Dentin surfaces treated with $AlCl_3$ demonstrate varying degrees and patterns of demineralization.[24] The effects of TCA and other chemical hemostatic agents with different times and concentrations on dental tissues need further investigation.

The results of the current study show increases in bond strength between composite and enamel as a result of TCA application prior to etching enamel (Group 5). It seems that TCA is a chemical hemostatic agent that not only does not decrease composite bond strength, but it also increases composite bond strength if it comes in contact with tooth structures. While this phenomenon can be attributed to the acidity of the material, it also seems plausible that, after irrigation with water, the material itself does not leave any deposits to interfere with the bonding procedure. This is similar to phosphoric acid.

The effects of various application times of 90% TCA on the surface morphology of unprepared enamel are rough enamel surfaces after 30 seconds, exposure of enamel prisms after 60 seconds and overall changes in enamel surfaces after 90 seconds.[14] Although typical etched surface morphology on prepared enamel surfaces was readily visible in the current study, the effects of TCA on the unprepared enamel surface for bonding and the type and extent of enamel demineralization and remineralization need further investigation.

In the current study, 35% and 50% TCA gels were prepared and used. This selection was based on the results of a pilot study carried out by the authors on 35%, 50% and 90% concentrations of TCA gel. The results of the pilot study indicated that preparation of 90% TCA gel is unnecessary, because the hemostatic effect of the three concentrations was similar. The preparation of highly concentrated solutions of TCA from its crystals to control gingival bleeding has been previously recommended.[16]

In the current study, scanning electron micrographs for Groups 2 and 3 revealed Type 2 and Type 4 etch patterns,[25] with a cobblestone appearance and flat, smooth surfaces as the most prevalent patterns. Previously, similar etch patterns were observed under SEM.[25] Enamel surfaces exposed to phosphoric acid and 35% TCA, Groups 1 and 2, respectively, exhibited sharp etched surfaces with selective conditioning (Figures 1 and 2). More changes in enamel surfaces were observed on surfaces etched with 35% TCA and phosphoric acid, Group 4 (Figure 4). An erosive enamel surface (over-etched surface) was observed with 50% TCA and phosphoric acid, Group 5 (Figure 5). Of all the

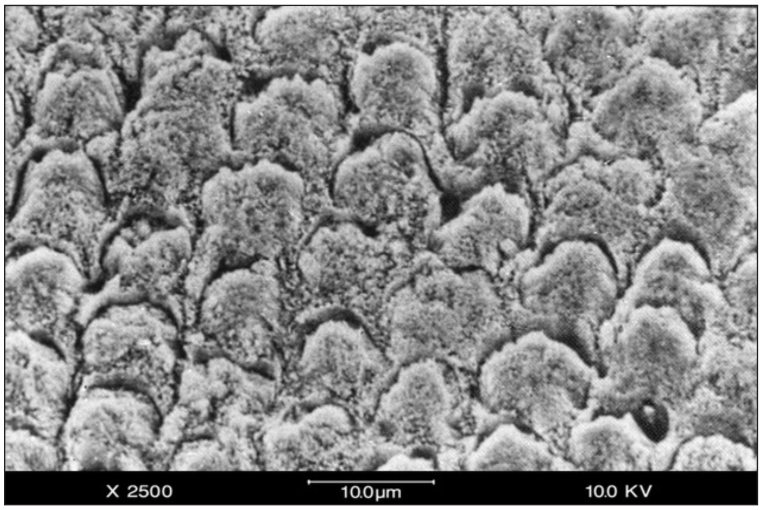

Figure 3: *Scanning electron micrograph of enamel surface after 30 seconds etching with 50% TCA. Original magnification 2500×.*

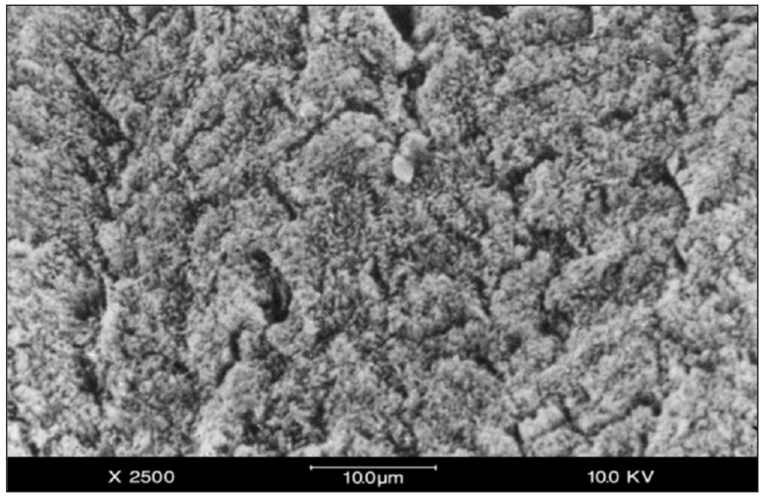

Figure 4: *Scanning electron micrograph of enamel surface after etching with 35% TCA and then 35% H_3PO_4. Original magnification 2500×.*

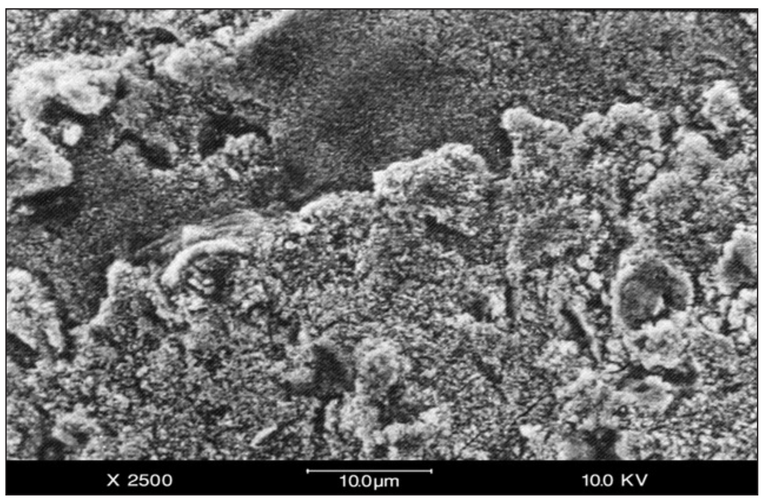

Figure 5: *Scanning electron micrograph of enamel surface after etching with 50% TCA and then 35% H_3PO_4. Original magnification 2500×.*

groups, Group 5 demonstrated the highest bond strength. This group may have had an adequate microretentive etch pattern for bonding. Recently, a study reported a lack of relationship between the etch pattern and the total surface area of enamel.[26] A previous study showed no correlation between less well-defined enamel-etching patterns and shear bond strength.[27] Another study inferred that high bond strength does not depend on an ideal etch pattern.[28]

The contact of acidic agents with mineralized surfaces, such as enamel and dentin, leads to the demineralization of these structures. Although no studies have evaluated the mechanical effects of routine hemostatic agents on dental hard tissues, a decrease in enamel and dentin hardness subsequent to contact with TCA has been reported.[14] What is of most importance is the use of the material as a cauterizing agent, astringent or hemostatic agent in cases in which procedures are carried out adjacent to gingival margins but bonding is not involved, such as when taking impressions. Therefore, it seems logical to limit the use of TCA as a hemostatic agent to cases in which the bonding procedure will be carried out in the area next to the TCA contact area, such as cervical resin restorations, until there is sufficient data on the remineralization of dental tissues after contact with TCA. Further studies on the application of TCA alone are required, without phosphoric acid as an etchant and as a hemostatic agent for bonded restorations on dental tissues. Other bonding agents, such as self-etch and self-adhesive systems, also need to be studied. Additional investigations of bond strength stability and clinical trials are needed to confirm the promising enamel etching effectiveness of TCA reported in the current study. Until then, it remains clinically advisable to use the conventional etching application technique.

CONCLUSIONS

Within the limitations of this study, it can be concluded that:

1. The application of TCA to ground enamel surfaces results in the etching of enamel, producing favorable bond strengths.
2. The accidental contact of TCA with enamel prior to conventional etching with phosphoric acid in tooth-colored cervical restorations may have a positive effect on the immediate bond strength of resin composite to enamel.
3. Typical etched surfaces were observed on surfaces etched with TCA alone. Additional changes of enamel surfaces were observed on surfaces etched with 35% TCA and phosphoric acid. An erosive enamel surface (over-etched surface) was observed with 50% TCA and phosphoric acid.

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