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Research Article

EFFECT OF ANTIOXIDANT AND RESIN INFILTRATION ON THE BOND STRENGTH OF COMPOSITE RESIN TO BLEACHED ENAMEL- *AN INVITRO STUDY*

SenthilKumar A, George Thomas, Sunil Jose, Adarsh VJ, Kishore Kumar and Kathiravan

Mahe Institute of Dental Sciences and Hospital, Chalakkara, Palloor, Mahe, Puducherry

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Background: Tooth discoloration is one of the most common esthetic complaints encountered by dentists worldwide. Bleaching combined with direct composite restorations is used for esthetic correction of moderate to severe intrinsic discolorations. Bleaching can lead to decreased bond strength of composite resin to bleached enamel. Antioxidants have been suggested for reversal of compromised bond strength in various researches. Therefore in this study, we have used antioxidant sodium ascorbate before resin infiltrant application to bleached enamel to test for reversal of bond strength of composite resin.
Aim: The aim of the study is to investigate the bond strength of composite resin to enamel bleached with 35% carbamide peroxide when the surface is pre-treated with 10% sodium ascorbate antioxidant and resin infiltration technique.
Methodology: Sixty extracted incisors were bleached with Opalescence (35% carbamide peroxide gel). Then the bleached samples were treated accordingly:
Group A(immediate bonding of composite).
Group B (10 % sodium ascorbate application followed by bonding of composite)
Group C (resin infiltration and bonding of composite)
Group D (10 % sodium ascorbate application followed by resin infiltration and bonding of composite)
Then the samples were subjected to shear bond strength testing in universal testing machine.
Values were recorded, tabulated, statistically analysed and results drawn.
Results: Group D(bleached enamel treated by 10 % sodium ascorbate followed by resin infiltration and bonding of composite) > Group C (bleached enamel treated by resin infiltration and bonding of composite) > Group B (bleached enamel treated by 10 % sodium ascorbate followed by bonding of composite) > Group A(bleached enamel with immediate bonding of composite).
Conclusion: Based on the results of this study, it was concluded that surface pretreatment with 10% sodium ascorbate antioxidant followed by resin infiltration can significantly improve the bond strength of composite to bleached enamel. Therefore, this study recommends and confirms the use of antioxidant as pretreatment on bleached enamel before the immediate placement of composite resin.

INTRODUCTION

Teeth play a vital role in the overall esthetics of human body. Any damage or discolouration of teeth breaks the sense of beauty or esthetics of an individual. Discoloured or disfigured teeth are major cause of concern to patients because it can affect the self-esteem and confidence of an individual.

Treatment options for discolouration include simple procedures like bleaching to more invasive procedures like composite restorations, microabrasion, veneers and full coverage crowns. These approaches can be combined to obtain better esthetic outcomes[1]. Bleaching being a minimally invasive approach can be combined with direct composite restorations for esthetic correction of moderate to severe intrinsic discolorations. Some commonly used methods for vital tooth-whitening include in-office or power bleaching and dentist-supervised home bleaching etc.. A wide variety of whitening products are currently available which contain mainly hydrogen peroxide and carbamide peroxide as active agents.

Bleaching can lead to decreased bond strength of composite to bleached enamel which is due to the presence of residual oxygen free radicals in enamel that interferes with the polymerization of resin-based materials[2]. Due to this decreased bond strength of resin-based materials, a waiting period of minimum 2-4 weeks is advised for achieving optimal bond strength[3] .This waiting period may be of great concern to the patient and the dentist. So the use of antioxidants have been advocated after enamel bleaching for immediate bonding of resin.

Antioxidants neutralize the free radicals on the bleached surface by donating their electrons and stabilizing the altered redox potential. In 2005 & 2006, Bulut *et al*. tested both the approaches of delayed bonding and immediate antioxidant treatment on bleached surface and found that both the approaches were effective in reversal of bond strength of resin to bleached enamel[4]. Bleaching followed by resin infiltration when used as combination therapy provides better results than bleaching alone according to various researches[5]. Even while using this combination approach, a delay or waiting period is

***Corresponding author:** **SenthilKumar A**
Mahe Institute of Dental Sciences and Hospital, Chalakkara, Palloor, Mahe, Puducherry

recommended[6].In some cases like early cavitated lesions resin infiltration followed by immediate placement of direct composite restorations may be indicated. So in this study we have used antioxidant sodium ascorbate before resin infiltrant application to bleached enamel to test for reversal of bond strength of composite resin.

Aim

The aim of the study was to investigate the bond strength of composite resin to enamel bleached with 35% carbamide peroxide when the surface is pre-treated with 10% sodium ascorbate antioxidant and resin infiltration technique.

MATERIALS AND METHOD

The study was conceived in the Department of Conservative Dentistry & Endodontics, Mahe Institute of Dental Sciences & Hospital. 60 extracted human incisor teeth were collected from various sources. After removal of debris, calculus and soft tissue from tooth surface, the teeth were stored in saline till further use.

Inclusion criteria

Teeth extracted due to periodontal or orthodontic reasons were included in the study

Exclusion criteria

Teeth with cracks, extensive caries, huge restoration, fluorosis, intrinsic stains and severely discoloured teeth were excluded from the study.

METHODOLOGY

Ten grams of sodium ascorbate in the form of powder was dissolved in 100 ml of distilled water to obtain 10% sodium ascorbate.

Specimen preparation

The roots were embedded in self-cure acrylic resin blocks till cementoenamel junction leaving only the coronal portion exposed. Labial surfaces were flattened with 600-grit silicon carbide paper. All the samples were bleached with Opalescence (35% carbamide peroxide gel, Ultradent, Inc) for 30 min, according to manufacturer's instructions. The bleaching gel was completely rinsed off with water. Then, the specimens were randomly divided into four groups of 15 teeth each.

Group A- Bleached specimens were bonded with self-etch adhesive (3M ESPE Single Bond Universal Adhesive) followed by composite build up

Group B- Bleached specimens were treated with 10% sodium ascorbate for 10 mins and bonded with self-etch adhesive (3M ESPE Single Bond Universal Adhesive) followed by composite build up

Group C- Bleached specimens were treated with DMG ICON resin infiltrant and bonded with self-etch adhesive (3M ESPE Single Bond Universal Adhesive) followed by composite build up

Group D- Bleached specimens were treated with 10% sodium ascorbate for 10 mins and DMG ICON resin infiltrant and bonded with self-etch adhesive(3M ESPE Single Bond Universal Adhesive) followed by composite build up.

Composite build up

Plastic straws of 3mm internal diameter and 5mm height were used as mould for composite build up. Composite build up was done in 2mm increments and each increment was light cured for 20 seconds.

Testing procedure

Each specimen was loaded in universal testing machine for shear bond strength testing. The long axis of the specimen was perpendicular to the direction of the applied forces during shear bond strength testing. The knife edge was loaded at the interface between the composite and enamel surface. The shear bond strength was measured in shear mode at a crosshead speed of 0.5 mm/min until fracture occurred. The load required to dislodge each composite block was recorded in MPa and the values were tabulated for each group.

Statistical Analysis

The Statistical software IBM SPSS statistics 20.0 (IBM Corporation, Armonk, NY, USA) was used for the analyses of the data. Descriptive and inferential statistical analyses were carried out in the present study. Results on continuous measurements were presented as on Mean (SD). One way ANOVA was used to find the significance of study parameters between the groups and post hoc comparison was done using Bonferronni post hoc test. Level of significance was fixed at $p \leq 0.05$ and any value less than or equal to 0.05 was considered to be statistically significant.

RESULTS

Group A(control group) (bleached enamel with immediate bonding of composite)
Group B (bleached enamel treated by 10 % sodium ascorbate followed by bonding of composite)
Group C(bleached enamel treated by resin infiltration and bonding of composite)
Group D(bleached enamel treated by 10 % sodium ascorbate followed by resin infiltration and bonding of composite)

In this study, Group D had the highest shear bond strength value (18.008$\pm$ 6.810)of the groups tested and Group A had the least shear bond strength (3.373$\pm$1.125)of all the groups tested. (Table 1).

Table 1 Descriptive statistics for shear bond strength

Descriptives								
Groups	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
A	15	3.3739	1.125	0.2907	2.7504	3.9975	1.83	4.88
B	15	9.9973	3.231	0.8342	8.2080	11.7867	6.10	18.90
C	15	17.358	5.128	1.3241	14.5180	20.1980	10.97	27.44
D	15	18.008	6.810	1.7585	14.2363	21.7797	10.36	28.66

Table 2 Comparison of mean values for shear bond strength of the four groups

ANOVA					
Comparison Groups	Sum of Squares	df	Mean Square	F	p value
Between Groups	2146.321	3	715.440	33.909	.000 Significant
Within Groups	1181.522	56	21.099		
Total	3327.842	59			

There was a statistically significant difference in shear bond strength between the groups except between Group C and Group D.(Table 2)

Table 3 Multiple comparison between the four groups

Multiple Comparisons- Bonferroni Posthoc test						
Groups	Comparison groups	Mean Difference (I-J)	Std. Error	Sig. p value	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	-6.62340*	1.67724	.000	-9.9833	-3.2635
	C	-13.98407*	1.67724	.000	-17.3440	-10.6241
	D	-14.63407*	1.67724	.000	-17.9940	-11.2741
B	A	6.62340*	1.67724	.000	3.2635	9.9833
	C	-7.36067*	1.67724	.000	-10.7206	-4.0007
	D	-8.01067*	1.67724	.000	-11.3706	-4.6507
C	A	13.98407*	1.67724	.000	10.6241	17.3440
	B	7.36067*	1.67724	.000	4.0007	10.7206
	D	-.65000	1.67724	.700	-4.0099	2.7099
D	A	14.63407*	1.67724	.000	11.2741	17.9940
	B	8.01067*	1.67724	.000	4.6507	11.3706
	C	.65000	1.67724	.700	-2.7099	4.0099

*. The mean difference is significant at the 0.05 level.

From multiple comparison using Bonferroni post hoc test (Table 3),

There was a statistically significant difference between Group B and Group A

Group C had a statistically significant difference when compared to Group B & Group A

Group D had a statistically significant difference when compared to Group B & Group A

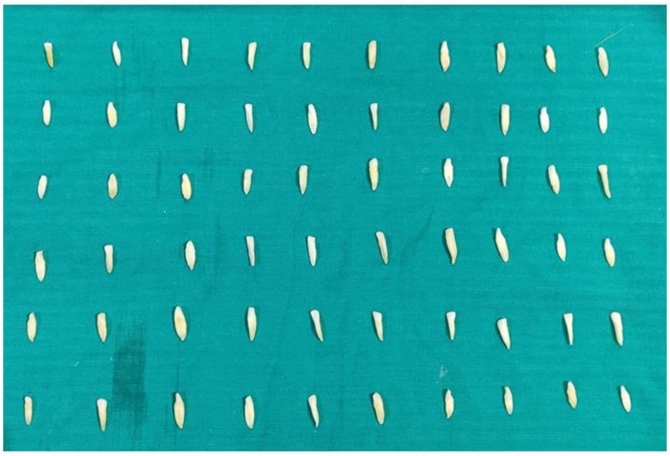

Fig 1 Freshly extracted human incisor teeth samples

Fig 2 Materials used

Results of mean shear bond strength were

Group D (bleached enamel treated by 10 % sodium ascorbate followed by resin infiltration and bonding of composite) > Group C (bleached enamel treated by resin infiltration and bonding of composite) > Group B (bleached enamel treated by 10 % sodium ascorbate followed by bonding of composite) > Group A (control group) (bleached enamel with immediate bonding of composite)

Fig 3 Bleaching agent 35% carbamide peroxide

Fig 4 8[TH] Generation Bonding Agent

Fig 5 Nanohybrid Composite Resin

Fig 6 DMG Icon Resin Infiltrant

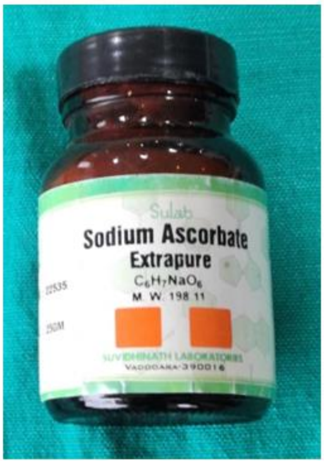

Fig 7 Sodium Ascorbate Powder

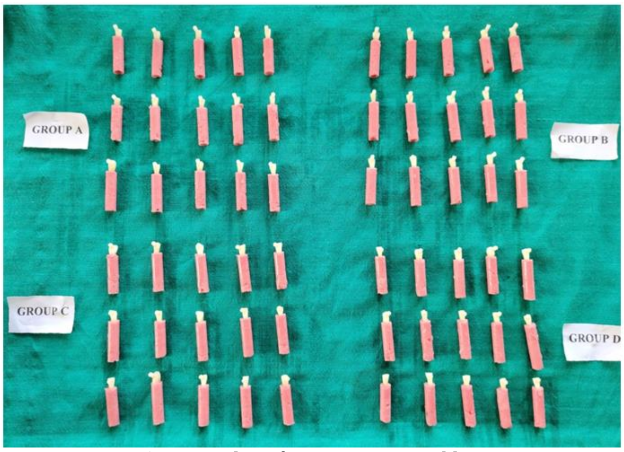

Fig 8 Samples After Composite Build Up

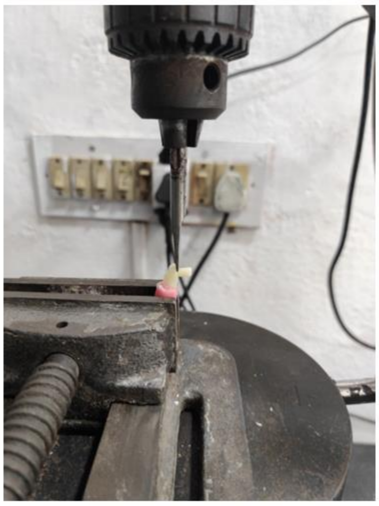

Fig 9 Sample Placed In Universal Testing Machine For Shear Bond Strength Testing

DISCUSSION

Tooth discoloration is one of the most common esthetic complaints encountered by dentists worldwide. Extrinsic causes of discoloration are tea, coffee and other foods, cigarettes, plaque ⁄poor oral hygiene, polyvalent metal salts and cationic antiseptics (e.g. chlorhexidine).

Intrinsic causes of discoloration are metabolic causes (e.g. congenital erythropoietic porphyria), inherited causes (e.g. amelo ⁄ dentinogenesis), iatrogenic causes, tetracycline, fluorosis, traumatic causes, enamel hypoplasia, pulpal haemorrhage products, root resorption and ageing.

Various treatment modalities for management of teeth discoloration are bleaching ,composite restorations, microabrasion, veneers and full coverage crowns out of which bleaching is a minimally invasive approach. Vital bleaching began as early as in 1868 with oxalic acid being used as the bleaching agent. The first report of hydrogen peroxide as bleaching agent was published in 1884 by Harlan which he called hydrogen dioxide. Haywood and Heymann in 1989 was the first to publish the innovative technique of nightguard vital bleaching in a custom made tray worn at night using 10% carbamide peroxide which marked the striking evolution of teeth whitening. Carbamide peroxide or urea hydrogen peroxide gets broken down in the presence of water to release free radicals that penetrate through the enamel pores and into the dentine to produce the bleaching effect.

The urea of carbamide peroxide gets further decomposed to carbon dioxide and ammonia thus resulting in elevation of the pH that facilitates the bleaching procedure further[7].

The breakdown of hydrogen peroxide into free radicals is as follows:

A. $H_2O_2 \longrightarrow 2HO^{\cdot}$

B. $HO^{\cdot} + H_2O_2 \longrightarrow H_2O + HO^{\cdot}_2$

C. $HO^{\cdot}_2 \Leftrightarrow H^+ + O^{\cdot}_2$

D. $2H_2O_2 \Leftrightarrow 2H_2O + 2\{O\} \Leftrightarrow 2H_2O + O_2$

E. $H_2O_2 \Leftrightarrow H^+ + HOO^-$

Hydrogen peroxide dissociates to produce free radicals like hydroxyl ($2HO^{\cdot}$) and perhydroxyl radicals ($HO^{\cdot}_2$) and superoxide anions ($O^{\cdot}_2$), reactive oxygen molecules(*{O}*), hydrogen peroxide anions(HOO^-).Thus, the long-chained, dark-colored chromophore molecules are attacked by the highly unstable free oxygen of these free radicals to be broken down into smaller, less colored and more diffusible (dissolvable) molecules, which results in whitening of the teeth[7].

Bleaching has its own adverse effects apart form its whitening effect on teeth. It may cause soft tissue burns [Barghi and Morgan *et al*.(1997)], changes in chemical composition of dental hard tissues [Rotstein *et al*.(1996), Basting *et al*.(2003), Cakir *et al*.(2011)], changes in enamel surface morphology [Josey *et al*.(1996)], adversely affect marginal seal and cause increased microleakage of composite restorations[Crim *et al*.(1992), Ulakapi *et al*.(2003)] and negatively affect the bond strength of composite resin [Dishman *et al*.(1994),Gokce B *et al*.(2008), Bansal M *et al*.(2019)].

Dishman *et al*. (1994) suggested that the compromised bond strength of composite resin to bleached enamel may be due to the oxygen present in the surface porosities of the enamel which is released by the decomposition of the residual peroxide bleaching agent. This oxygen might inhibit the polymerisation of the resin by diminishing the extent of resin tags in enamel. But Perdigao and colleagues (1998) obtained contradictory results showing no difference in quantities of oxygen in enamel between bleached and unbleached teeth. They suggested that bleaching may cause micromorphological alterations .i.e loss of minerals like calcium and phosphorus which results in decreased microhardness subsequently resulting in reduced bond strength[8].Titley *et al*.(1991) found that resin tags in bleached enamel were sparse, shorter, poorly defined and many areas of enamel were resin free which reduced the adhesive and cohesive potential and resulted in lower bond strength values[9].

In order to overcome the clinical problems related to compromised bond strength after bleaching several methods have been followed such as removal of superficial layer of enamel [Cvitko *et al*.(1991)], pre-treatment of bleached enamel with alcohol[Barghi and Godwin *et al*.(1994)] and use of adhesives containing organic solvents [Kalili *et al*.(1991), Sung *et al*.(1999)] and application of antioxidant agents [Lai SC *et al*.(2001),(2002), Bulut *et al*.(2006),Nair R *et al*.(2019)]. But the most common approach is to delay any bonding or restorative proocedures post bleaching, as the compromised bond strength to freshly bleached enamel is transient . A post bleaching delay of 2-4 weeks has been suggested before bonding or restorative procedures by various studies[3,4,10].

Resin infiltration is a novel concept that involves the infiltration of porous enamel lesions with a low viscosity resin and an intermediate approach between prevention and restoration of carious lesions up to the first third of dentin. Principle of resin infiltration is that the resin perfuses the porous enamel by capillary action which arrests lesion progression thus occluding the microporosities which acts as diffusion pathways for acids and dissolved materials. Therefore, resin infiltration creates a barrier inside the lesion and not on the surface[11].

Resin infiltration is initiated by application of Icon-Etch according to the manufacturer's recommendations and allowed for 2 minutes, followed by 30 seconds of rinsing with water, drying, and applying Icon Dry for 30 seconds for drying the body of lesion completely and Icon infiltrant application for 3 minutes and dispersed with air and light cured for 40 seconds followed by another application of Icon infiltrant for 1 minute and excess is removed and light cured for 40 seconds[12].

Bleaching followed by resin infiltration can be used as combination approach in case of white spot lesions. But bleaching can negatively affect the penetration of resin infiltrants so a waiting period of 2-4 weeks is recommended[6]. According to the results of this study, Group D [bleached enamel treated by 10 % sodium ascorbate followed by resin infiltration and bonding of composite] showed the highest bond strength (18.008$\pm$ 6.810) compared to all the other groups tested. Group A [bleached enamel with immediate bonding of composite] showed the lowest bond strength (3.373$\pm$1.125) compared to the other groups.

The reduced bond strength of the Group A when compared to other groups may be due to presence of residual oxygen in enamel from bleaching agent which would have hampered the polymerisation of resin (Dishman *et al*.1994) or due to the micromorphological alteration in enamel(loss of calcium and phosphorus) (Perdigao *et al*.1998).

The findings of this study showed reduced bond strength of bleached enamel to immediate composite build up which concur with the results of the studies by Arumugam *et al*.(2014), Nair R *et al*(2019). Murchison DF *et al*.(1992) evaluated 10% carbamide peroxide for its effects on bond strength of resin to enamel and enamel surface hardness and found that short term 10% carbamide peroxide did not significantly affect the bonding ability and surface hardness of enamel which were contradictory to the results obtained in this study[13].

Group B had a higher bond strength(9.973$\pm$3.231) compared to the Group A and the difference between the groups was statistically significant .This increase in bond strength could be explained by the ability of sodium ascorbate to quench free radicals .The antioxidant property could be supported by the role of ascorbate in biological systems to neutralize and reverse the oxidizing effects of hypochlorites (chloramines).[Hawkins and Davies, *et al* 1999; Carr *et al*., 2000, Lai SC *et al*.2001].Lai *et al*.(2001) stated that it is possible that sodium ascorbate provides for the free radical polymerisation of adhesive resin without premature termination and contributes for the increased bond strength thus reversing the compromised bond strength of hydrogen peroxide treated dental substrate[14].The results of this study with 10% sodium ascorbate treatment concur with studies by Lai SC *et al*.(2002), Turkun *et al*.(2004), Eggula E *et al*.(2019), Kavitha M *et al*.(2016), who used 10% sodium ascorbate and obtained reversal of compromised bond strength in bleached enamel[3,15,16].

Group C had higher bond strength (17.358$\pm$5.128) compared to Group A and Group B and the difference was statistically significant. The increased bond strength of Group C could be explained by the findings of Soveral *et al*. which suggest that the bond strength of demineralised enamel in case of white spot lesions is increased by resin infiltration and Wei *et* *al*.(2020) which suggest that resin infiltration uses HCL etching which may create holes and result in deeper penetration of the low –viscosity resin which fills micropores and avoid disintegration of demineralised enamel[6]. Jia Liuhe *et al*.in 2012 found that pretreatment with caries infiltrant increased the bond strength of self-etch adhesives to sound and demineralised enamel. Jia Liuhe *et al*. also stated that bond strength may be affected by the penetration ability of the adhesive and TEGDMA and HEMA and ethanol solvent may increase the penetration ability[17].The results of increased bond strength of Group C could be attributed to these findings. The findings of increased bond strength with Group C concur with the findings of the study by Al-Mayali *et al*. and Chrispim *et al* who obtained increased bond strength with use of Icon resin infiltrant[18].

The results of this study are contradictory to the results obtained in the study by Jia L.*et al*.(2013) which suggested that resin infiltrant application did not impair shear bond strength but hydrochloric acid or the resin infiltrant with hydrochloric acid reduced the shear bond strength of the tested adhesives[19].

Group D had the highest mean bond strength(18.008$\pm$6.810)of all the groups tested which was statistically significant difference when compared to Group A and Group B. The findings of Lai SC *et al*. (2002),Turkun *et al*.(2003), Arumugam *et al*.(2019) who have used 10% sodium ascorbate for reversing the compromised bond strength of bleached enamel and achieved increased bond strength could be attributed to the increased bond strength of Group D in this study[3,15]. The increased bond strength of Group D could also be explained by the findings by Wei *et al*.(2020) and Perdigao *et al*.(2019) which suggested that HCL used in resin infiltration treatment was more efficient in partially removing the mineralized surface layer of white spot lesions and open wider surface porosities compared to the conventional phosphoric acid etching and contribute for the better penetration of low viscosity resin[6,8].

In the present study, failure mode analysis and SEM evaluation of enamel-composite resin interface were not performed. Other clinical parameters like oral environment, moisture etc. may have a significant role in the clinical outcome of composite restoration bonded to bleached enamel.

CONCLUSION

Within the limitations of this study, it can be concluded that surface pretreatment with 10% sodium ascorbate antioxidant followed by resin infiltration can significantly improve the bond strength of composite to bleached enamel.

Therefore this study recommends the use of antioxidant therapy and resin infiltration technique in cases where immediate adhesive restorations are indicated.

Further studies may be needed to corroborate other physical properties affecting the bonding to bleached enamel.

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