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Full Length Research Paper

Effect of sodium hypochlorite on the shear bond strength of fifth- and seventh-generation adhesives to coronal dentin

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The aim of this study was to investigate the effect of sodium hypochlorite (NaOCl) on the shear bond strength of fifth- and seventh- generation adhesive resins to coronal dentin. Thirty human third molars were selected and sectioned into two halves buccolingually. Sixty samples were randomly divided into four groups (n = 15). The crowns were separated from the roots. Subsequent to the removal of pulp tissue, the inner surfaces of tooth crowns were rubbed using 600-grit silicon carbide paper in order to obtain flat dentin surface. In group 1, Single Bond (the fifth generation adhesive resin) was used. In group 2, single bond adhesive resin was used subsequent to NaOCl solution application. In groups 3 and 4, the same procedures as described for groups 1 and 2, were repeated respectively, except for the fact that instead of the fifth generation adhesive resin, the seventh generation adhesive resin (Clearfil S3 Bond) was used. Subsequent to composite resin placement over dentin surfaces, the samples were subjected to shear bond strength test. Data were analyzed using ANOVA and Tukey test. The significance level was set at $p<0.05$. There were statistically significant differences between the groups ($p<0.05$). The use of NaOCl reduced the shear bond strength of fifth- and seventh-generation adhesive resins to dentin and there was no difference in the shearing bond strength of both adhesive resins.

Key words: Shear bond strength, sodium hypochlorite, fifth generation adhesive resins, seventh generation adhesive resins.

INTRODUCTION

Lack of a proper adhesion and seal between the final restoration and tooth structures in endodontically treated teeth may result in a poor prognosis of the root canal treatment because penetration of microorganisms through the tooth crown once again contaminates the root canal system. Therefore, the quality of the final restoration of the tooth is an important factor for the evaluation of prognosis after root canal treatment (Ozturk and Ozer, 2004). At present, there is an increasing tendency to restore non-vital teeth with composite resins due to the introduction of dentin-bonding systems. Restoration of endodontically treated teeth with adhesive systems has numerous advantages over conventional non-adhesive restorative materials. With the use of adhesive resins, the functional forces are transferred to tooth structures by the bonded surfaces, reinforcing the undermined remaining tooth structures (Ozturk and Ozer, 2004). Fifth-generation dentin-bonding resins are total-etch adhesives, in which the etching procedure is carried out separately and the primer and bonding agent have been incorporated into one bottle. Recently, seventh-generation adhesives (all-in-one) have been introduced, which belong to self-etch adhesives and do not require a separate etching and rinsing procedure, and saves time. In these systems, the etchant, primer and bonding agent have been incorporated in one bottle (Van Meerbeek et al., 2006).

On the other hand, chemical solutions, such as sodium hypochlorite (NaOCl), are used to irrigate the canals in endodontic treatment. The use of NaOCl results in debridement and lubrication of the canals, elimination of

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microorganisms, dissolution of tissue tags, the removal of collagen layer and dehydration of dentin (Ozturk and Ozer, 2004). Various studies have evaluated the effect of canal irrigation solutions, such as NaOCl, on endodontically treated teeth which have been restored using fifth-and sixth-generation dentin-bonding resins (Ozturk and Ozer, 2004; Nikaido et al., 1999; Morris et al., 2001; Ari et al., 2003; Hayashi et al., 2005). It has been reported that the use of 5% NaOCl has a negative influence on the bond strength of fifth- and sixth-generation adhesive resins to the lateral walls of the pulp chamber (Ozturk and Ozer, 2004; Hayashi et al., 2005; Fawzi et al., 2010). However, little information is available about the effect of NaOCl on the restoration of such teeth with seventh-generation adhesives. The aim of the present study was to evaluate the effect of NaOCl on the shear bond strength of a fifth- and seventh-generation adhesive to coronal dentin.

MATERIALS AND METHODS

Thirty heathy human third molars, which had been extracted at most, two months before the study, were used in this *in vitro* study. On the whole, 60 specimens were prepared because tooth crowns were divided into two halves in a buccolingual direction. The teeth were placed in 0.5% chloramines T solution after they were extracted and kept at 4°C. One week before the laboratory procedures, the teeth were cleaned of any calculus or soft tissue remnants and stored in distilled water. The specimens were randomly divided into four groups of 15.

At first, the crowns were separated from the roots at about 1 mm apical to cemento-enamel junction (CEJ) using a diamond saw (Isomet, Buehler, Lake Bluff, USA) in a low-speed straight handpiece under constant water spray. Then the crowns were divided in half in a buccolingual direction. After removal of pulp remnants, the inner surfaces of the crowns were ground to produce a flat and smooth dentin surface; to this end, 600-grit silicon carbide abrasive paper was used under constant water spray. After 3 cutting procedures, the diamond saw was replaced by a new one and a new piece of silicon carbide paper was used for each tooth. Then the prepared dentin specimens were mounted in self-cured acrylic resin (Triplex, Ivoclar Vivadent AG, FL-9494 Schaan/Liechtenstein).

In group 1, the exposed dentin surface was etched with 35% phosphoric acid gel (Scotchbond Etchant, 3M ESPE, St. Paul, MN, USA) for 15 s; then the surface was rinsed with water spray for 15 s and dried with a gentle air current in a manner in which the dentin surface preserved its shiny appearance. Then, the fifth-generation Single Bond (3M ESPE, St. Paul, MN, USA) adhesive resin was applied according to manufacturer's instructions. Z100 composite resin (3M ESPE, St. Paul, MN, USA) and transparent plastic cylinders with an inner diameter of 2 mm and a height of 2 mm were used to produce composite cylinders. The transparent cylinders were filled with the A1 shade of composite resin and placed on the prepared dentin surface which had been fixed with a clamp. Then it was covered with a piece of clear matrix band and pressed with finger pressure; then extra composite resin was removed with an explorer. Light-curing was performed with an Astralis 7 light-curing unit (Ivoclar Vivadent AG, FL-9494 Schaan/Liechtenstein) at a light intensity of 400 mW/cm^2, while the tip of the light conductor was perpendicular to the surface; the exposure time added up to 40 s, 20 s from each direction. The specimens were kept in distilled water for 24 h at 37°C. Then a thermocycling procedure, consisting of 500 cycles, was carried out at 55 ± 2°C / 5 ± 2°C with a dwell time of 30 s and a transfer time of 10 s. Then the shearing bond strength was measured using a universal testing machine (Hounsfield Test Equipment, Model H5K-S, Tinius Olsen Ltd, Surrey, England); a chisel-shaped blade was placed at tooth-composite interface at a strain rate of 0.5 mm/min. Shear bond strengths were recorded in Newton and converted to mega Pascal (MPa).

The procedures in group 2 were similar to those in group 1; however, in this group before acid application, the exposed dentin surface was irrigated with 10 ml of 5.25% NaOCl (Merck, Germany) for 5 min and then rinsed with distilled water for 1 min (Ozturk and Ozer, 2004).

In groups 3 and 4, the procedures were the same as those in groups 1 and 2, except for the fact that in these groups seventh-generation dentin-bonding resin (Clearfil S3 Bond, Kuraray Medical Inc., Tokyo, Japan) was used according to manufacturer's instructions.

The specimens were evaluated under a stereomicroscope by two examiners (Nikon, Tokyo, Japan) at magnification of 20× after bond failure and failure modes were classified as follows (Ozturk and Ozer, 2004):

1. Adhesive failure: Sound dentin without any traces of composite restorative material on dentin surface.
2. Cohesive failure: Failure in the bulk of the dentin or the restorative material.
3. Mixed failure: A combination of adhesive and cohesive failures.

Statistical analysis

Data for shear bond strength were analyzed with one-way ANOVA and pairwise comparisons were made by Tukey test. Statistical significance was set at $p<0.05$.

RESULTS

Shear bond strength

The means and standard deviations of the shear bond strength of Single Bond and Clearfil S3 bond are presented in Table 1. Data analysis with one-way ANOVA demonstrated statistically significant differences between the groups ($p<0.05$). Therefore, a post hoc Tukey test was used for two-by-two comparison of the groups. Comparison of the means of shearing bond strength values revealed significant differences between groups 1 and 2 ($p = 0.002$). In other words, the use of NaOCl had significantly decreased the shearing bond strength of the fifth-generation adhesive resin. The same results were observed in the seventh-generation adhesive resin. Comparison of the means of shearing bond strength values in groups 3 and 4 revealed significant differences between these two groups ($p = 0.004$), which means NaOCl had decreased the shearing bond strength of the seventh-generation adhesive resin.

The results of the present study did not demonstrate any significant differences in the means of shearing bond strength values between the fifth- and seventh-generation adhesive resins before the use of NaOCl ($p = 0.178$). In addition, there were no significant differences in the means of shearing bond strength values between the

Table 1. Mean shear bond strength (MPa) and standard deviations for Single Bond and Clearfil S3 bond.

Type of pretreatment	Single Bond (fifth-generation adhesive)			Clearfil S3 bond (seventh-generation adhesive)		
	Mean ± SD	**Minimum**	**Maximum**	**Mean ± SD**	**Minimum**	**Maximum**
Without NaOCl	32.38 ± 5.78	23.80	41.70	25.91 ± 5.03	18.80	37.50
With NaOCl	28.12 ± 3.95	23.50	36.21	22.15 ± 3.96	14.90	29.40

Table 2. Mode of failure for adhesive resins.

Type of pretreatment	Single Bond (fifth-generation adhesive)			Clearfil S3 bond (seventh-generation adhesive)		
	Adhesive	**Cohesive**	**Mixed**	**Adhesive**	**Cohesive**	**Mixed**
Without NaOCl	9	2	4	9	4	2
With NaOCl	10	3	2	11	3	1

fifth- and seventh-generation adhesive resins after the use of NaOCl ($p = 0.245$).

Failure mode

Table 2 shows the results of the evaluation of failure modes of the specimens under a stereomicroscope. As it can be observed, in all the groups, the majority of the failures were of the adhesive type.

DISCUSSION

A durable bond between the tooth structure and composite resin is necessary for the clinical success of tooth-colored restorations because bond failure at restoration margins results in the microleakage of oral liquids and penetration of bacteria, leading to recurrent caries. Acid etching increases bond strength of composite resins to enamel. In this technique, after etching the enamel with phosphoric acid, the resin penetrates into the etched surfaces and produces micromechanical retention after curing (Torii et al., 2002). The formation of a hybrid layer is necessary for dentin bonding. In total etch systems, at first, the smear layer which has covered the prepared dentin surface is removed and the underlying dentin is decalcified. Dentin decalcification exposes the collagen network. In the next step, the adhesive resin should completely penetrate into the exposed collagen network (Torii et al., 2002).

Recent advances in adhesive systems have once again led to the concept of using the smear layer as a substrate for bonding. Development of self-etch adhesives has increased the odds of using the smear layer as a part of the hybrid layer. The bonding mechanism of self-etch adhesives is dependent on penetration into the smear layer, demineralization of the substrate under the smear layer, penetration of the resin into the demineralized dentin and finally, the formation of the hybrid layer. This process preserves the dentin mass and at the same time, dissolves the hydroxylapatite crystals around the collagen fibers, allowing the monomers of the adhesive to penetrate into the periphery of collagen fibers. Dentin demineralization and monomer penetration occur simultaneously and there is no need for separate rinsing and drying steps. Therefore, saving time and better clinical efficacy are advantages of self-etch adhesive systems (Erhardt et al., 2004).

Two characteristics of dentin-bonding systems, which are often evaluated, are bond strength and sealing ability. An ideal dentin adhesive should have a high bond strength and should completely prevent microleakage. It appears high bond strength will decrease microleakage; however, the relationship between bond strength and microleakage is not clear cut. Nevertheless, it has been demonstrated that bond strength is a better determinant in evaluating the potential of adhesive bonding when compared to sealing ability (Ozturk and Ozer, 2004).

On the other hand, NaOCl is a non-specific proteolytic material which can remove organic materials and magnesium and carbonate ions (Perdigão et al., 2000). NaOCl is widely used as an intracanal irrigation solution because of its antimicrobial and tissue dissolving properties. NaOCl destroys phospholipids and disrupts cellular metabolism. It has oxidative properties and deactivates bacterial enzymes and destroys lipids and fatty acids (Estrela et al., 2002).

The aim of the present study was to evaluate the effect of NaOCl on shearing bond strength of two fifth-generation (Single Bond) and seventh-generation (Clearfil S3 bond) adhesive systems.

The results of the present study showed that the use of 5.25% NaOCl significantly decreased shearing bond strength to dentin ($p<0.05$). Evaluation of failure modes confirmed this finding. The number of adhesive failures increased in both adhesive systems subsequent to NaOCl pretreatment. The decrease in bond strength subsequent to the use of NaOCl might be attributed to its oxidative properties. NaOCl breaks down into sodium chloride and oxygen; the oxygen released from this chemical breakdown prevents polymerization of the adhesive (Rueggeberg and Margeson, 1990). Application of 10% sodium ascorbate subsequent to the use of NaOCl significantly increases bond strength of single bond adhesive to dentin (Vongphan et al., 2005). Since ascorbic acid and its salts have anti-oxidative properties (Gutteridge, 1994), it is probable that sodium ascorbate decreases oxidative potential of NaOCl through reduction reaction. Sodium ascorbate allows the adhesives to polymerize and neutralizes the negative effects of NaOCl in preventing polymerization of adhesive systems (Lai et al., 2001).

Decrease in bond strength as a result of the use of NaOCl can also be attributed to damages to the organic matrix of dentin, especially to collagen fibers (Nikaido et al., 1999). Approximately 22 wt% of dentin is composed of organic materials, which predominantly consist of type I collagen; they have an important role in the mechanical properties of dentin. NaOCl reacts with amino acids of dentin proteins and breaks down peptide chains; therefore, it may change the mechanical properties of dentin by destroying the organic content of dentin (Marending et al., 2007). In addition, NaOCl can react with the amino acids of type I collagen fibers to produce chloramine. Chloramine is a potent oxidative agent, which can compete with the free radicals released from the adhesive as a result of light activation to prematurely terminate the polymerization reaction (Rueggeberg and Margeson, 1990).

The results of the present study are consistent with the results of previous studies (Ozturk and Ozer, 2004; Nikaido et al., 1999; Perdigão et al., 2000; Lai et al., 2001). They showed that NaOCl damages the organic component of dentin; therefore, organic monomers do not sufficiently penetrate into the demineralized dentin, resulting in a lack of proper bond strength. They pointed out that collagen fibers have an important role in the process of adhesion.

Contrary to the results of the present study, some studies have reported that NaOCl increases the bond strength of some adhesive systems (Vargas et al., 1997; Prati et al., 1999; Saboia et al., 2000; Osorio et al., 2010). They attributed bond strength increase to the elimination of collagen layer and concluded that the elimination of collagen layer is beneficial for a better adhesion in some systems. The discrepancies in the results of those studies and the present study might be attributed to differences in sample preparation methods. In the earlier-mentioned studies, the surfaces of the samples were initially etched with phosphoric acid and then NaOCl was applied. The use of phosphoric acid eliminated the smear layer and demineralized dentin; subsequently, collagen layer was eliminated by NaOCl. The process led to a better penetration of the adhesive into inter-tubular dentin. However, in the present study, NaOCl was used prior to the application of adhesive resins. Furthermore, the irrigation time of NaOCl can be considered as another reason for different results. In a study carried out by Cecchin, NaOCl application was repeated every 5 min for 1 h and this yielded higher microtensile bond strength of XENO III self-etching adhesive resin to dentin (Cecchin et al., 2010).

It is suggested that the composite-dentin interface, produced by different adhesive resins subsequent to NaOCl pretreatment, evaluated by scanning electron microscopy in future studies.

According to the results of the present study, there was no difference in the shearing bond strength of fifth- and seventh-generation adhesive resins and the use of NaOCl decreased the shearing bond strength of both adhesive resins.

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