Microtensile bond strengths to caries-affected dentine treated with Carisolv

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SCIENTIFIC ARTICLE

Australian Dental Journal 2003;48:(2):110-114

Microtensile bond strengths to caries-affected dentine treated with Carisolv®

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Abstract

Background: Little information is available regarding the bonding performance of adhesive restorative materials to caries-affected dentine after the use of Carisolv®. The aim of this study was to compare the microtensile bond strengths of two resin-based adhesives, a conventional glass ionomer cement and resin modified glass ionomer cement to 'normal' dentine and caries-affected dentine after Carisolv treatment.

Methods: Specimens were prepared using molar teeth with small carious lesions. Caries was removed with the Carisolv® solution and the whole surface was bonded with either SE Bond, One Coat Bond, Fuji IX or Fuji II LC. After 24 hours, specimens were prepared for the microtensile bond strength test and stressed in tension at 1mm/min until rupture of the bond. Mean bond strengths and mode of failure were determined and analysed with the LSD test and chi square test respectively.

Results: The results showed no statistical difference for SE Bond, One Coat Bond or Fuji IX, but a difference was observed for the resin-modified GIC, Fuji II LC.

Conclusions: It was concluded that carious dentine treated with Carisolv did not affect the adhesion of the adhesive restorative materials tested in this study with the exception of Fuji II LC.

Key words: Bond strength, dentine bonding, Carisolv.

(Accepted for publication 24 October 2002.)

INTRODUCTION

The practice of operative dentistry is undergoing rapid change, including the philosophies of minimal intervention and the healing of lesions rather than surgical excision, and also the introduction of various ways in which carious tooth structure may be removed in association with improved adhesive restorative materials. One of the most recent means of removing carious tooth structure is a modification of the chemomechanical technique introduced as Caridex in the 1980s. Caridex, or GK 101, was a combination of sodium hypochlorite with N-mono-chloro-DL-2-aminobutyric acid.[1] This solution proved to be of little clinical benefit due to the large volume required and the prolonged time to remove carious tooth structure. The concept of chemomechanical removal of caries has been re-introduced by using a solution of sodium hypochlorite combined with three amino acids; L-glutamic acid, L-luecine, and L-lysine,[2] and is marketed as Carisolv (Mediteam, Sävedalen, Sweden).

The aim of chemomechanical caries removal is to remove the outer, permanently damaged layer of carious ('infected') dentine, but to leave the demineralized 'affected' dentine which can be healed.[3] The time taken for removal of carious tooth structure using Carisolv was shown to be only slightly longer than conventional rotary instruments, but the caries-affected dentine is left intact.[2,4] The action of Carisolv is essentially dissolution, assisted by mechanical removal of carious tooth structure with the non-cutting excavators or burs supplied with the solution. The nature of the underlying caries-affected dentine is not well understood, and how the adhesion of resin-based or glass ionomer-based adhesives will be affected is unknown.

The adhesion of resin-based adhesives to dentine is by the formation of a hybrid layer, as described by Nakabayashi.[5] Essentially, the hybrid layer is the consequence of permeation of a resin around collagen fibres that have been exposed during prior acid demineralization of the dentine surface. This same process occurs when bonding to a caries-affected dentine surface. Nakajima *et al*.[6,7] and Sakoolnamarka *et al*.[8] have shown that hybrid layers in caries-affected dentine tend to be much thicker, and depending on the bonding system used, bond strengths tend to be the same or less than those to normal dentine. With respect to glass ionomer cement, no data exist with regard to its ability to bond to caries-affected dentine. It is known that the bonding mechanism of glass ionomer materials

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Table 1. Manufacturers, composition and batch numbers of materials investigated

Material	Manufacturer	Constituents	Batch number
Clearfil SE Bond	Kuraray Co, Osaka, Japan	Self-etching primer: MDP, HEMA, hydrophilic dimethacrylate, dl-camphorquinone, N,N-diethanol-p-toluidine, water	00105A
		Adhesive Resin: MDP, Bis-GMA, HEMA, hydrophobic dimethacrylate, dl-camphorquinone, N,N-diethanol-p-toluidine, silanated colloidal silica	00032A
One Coat Bond	Coltene-Whaledent, Altstätten, Switzerland	HEMA, UDMA, hydroxypropylmethacrylate, glycerol dimethacrylate, polyalkenoate methacrylized, amorphous silicic acid	HB 938
Fuji II LC	GC International, Tokyo, Japan	Fluoroaluminium silicate glass, polyacrylic acid, HEMA	150687
Fuji IX	GC International	Fluoroaluminium silicate glass, polyacrylic acid, polybasic carboxylic acid	100787

HEMA=2-hydroxy ethylmethacrylate; Bis-GMA=bisphenyl glycidylmethacrylate; MDP=10-methacryloyloxydecyl dihyrdrogen phosphate.

is the formation of an ionic bond between the liquid component of the cement and the calcium of the hydroxyapatite of the tooth. In addition, micromechanical bonding to exposed collagen fibres on the dentine surface can occur after a weak demineralizing agent has been used to remove the smear layer. This occurs more with the resin-modified glass ionomers than the conventional glass ionomer cements.[9] The formation of a distinct layer between a GIC and dentine has been described previously by Tanumiharja *et al*.,[9] but its microstructure is not yet characterized.

The aim of this study was to compare the microtensile bond strengths of two resin-based adhesives, a conventional glass ionomer cement and a resin-modified glass ionomer cement to caries-affected dentine, after using Carisolv to remove the infected carious dentine, and comparing them to those obtained to 'normal' dentine. The null hypothesis proposed is that bond strengths to caries-affected dentine will be no different from those to normal dentine.

MATERIALS AND METHODS

Freshly extracted human molars were used with carious lesions not extending further than half-way between the occlusal dentino-enamel junction and pulp chamber. The teeth were stored after extraction at 4°C in saline containing a few crystals of thymol. The occlusal carious lesion was exposed by removing the enamel from the occlusal surface using a model trimmer with copious water spray. The carious lesion was excavated with the Carisolv solution and supplied hand instruments until the surface of the dentine felt hard when scraped with a blunt dental explorer. Following this, the surrounding non-carious dentine was removed using wet 600-grit silicon carbide paper until normal dentine was at the same level as the base of the excavated carious lesion. Where possible a flat surface was obtained across the whole of the tooth surface. Care was taken not to touch the Carisolv treated surface by frequently checking the dentine surface during polishing of the surrounding normal dentine. The exposed normal and caries-affected dentine were bonded with one of the adhesives listed in Table 1. Each of the adhesives was used according to the manufacturers' instructions, and in the case of the resin-based materials a block of resin composite was built up on the dentine surface. The teeth were placed in water at 37°C for 24h prior to sectioning and milling of the specimens for the microtensile test as described by Phrukkanon *et al*.[10] The teeth were marked so as to locate where the bonded caries-affected dentine was when the teeth were sectioned for production of the specimens for the microtensile bond test. Briefly, the teeth were sectioned vertically to produce approximately four sections per tooth. At least one section contained a caries-affected bonded specimen. The sections of bonded dentine were then milled using an ultra-fine grit round diamond in a small lathe to produce dumb-bell shaped specimens. The specimens were then placed in the testing jig and stressed in tension at a crosshead speed of 1mm/min until failure of the bond. The specimens were kept wet during the milling and test procedures. The maximum stress at failure was recorded and converted to MPa.

In addition, the failure pattern of each specimen was evaluated using a scanning electron microscope. The specimens were divided in to one of three broad groups: cohesive failure in the restorative material or dentine of the specimen (Group 1) (Fig 1); mixed failure which was a combination of adhesive failure between the adhesive and dentine, and cohesive failure in the

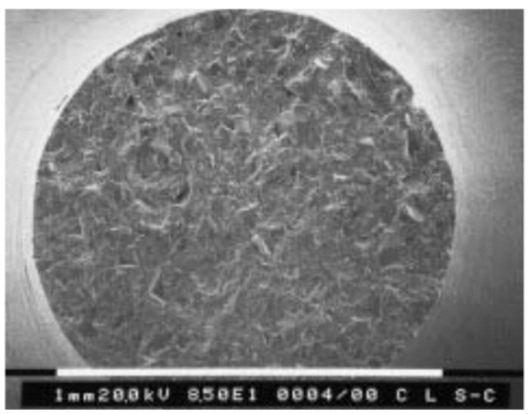

Fig 1. SEM micrograph showing cohesive failure of resin composite of a debonded specimen.

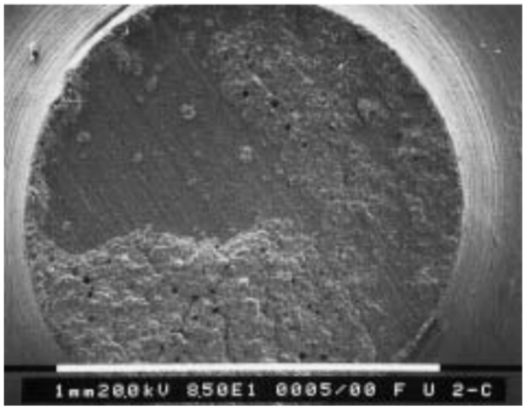

Fig 2. SEM micrograph showing mixed failure. The top left shows adhesive failure between the dentine and GIC. The lower portion of the photograph show cohesive failure of the GIC.

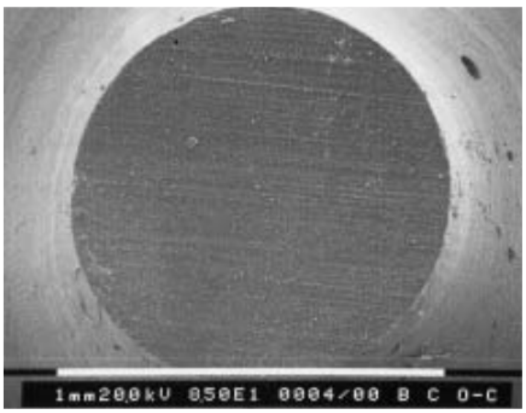

Fig 3. SEM micrograph showing adhesive failure between dentine and resin composite.

bonding resin and/or resin composite (Group 2) (Fig 2); and adhesive failure between the resin and bonded dentine surface (Group 3) (Fig 3).

Statistical analysis was performed using One-way Analysis of Variance and the Least Square Difference (LSD) test for intergroup comparisons at the 95 per cent level of confidence for the bond strength results, and chi square analysis for the fracture mode.

RESULTS

The results for the bond test are illustrated in Table 2. No specimens were lost during preparation for the bond test. A statistical difference was noted only for the Fuji II LC group, in which the bond strength to the caries-affected dentine (16.4MPa) was significantly lower than to normal dentine (22.8MPa) ($p<0.05$). The bond strengths of the resin-based adhesives were higher than the GIC materials, and the lowest bond strengths were recorded for the conventional GIC, Fuji IX.

With respect to failure mode, no statistical differences were observed between the normal and caries-affected dentine for each material (Table 3). However, on closer inspection there were slight variations. For SE Bond, there was an increase in the number of specimens exhibiting cohesive failure in the dentine for the caries-affected group, a similar pattern was noted for One Coat Bond and Fuji II LC. For Fuji IX, it was observed that cohesive failure in the cement decreased in the Carisolv, caries-affected dentine group.

Table 2. Mean microtensile bond strengths to normal and Carisolv-treated dentine

Adhesive	MPa(SD); n		
	Normal dentine	Carisolv-treated dentine	Significance
Clearfil SE Bond	31.6 (7.1); 8	28.7 (6.9); 6	No difference
One Coat Bond	29.4 (7.9); 4	27.4 (6.4); 11	No difference
Fuji II LC	22.8 (4.6); 6	16.4 (5.6); 7	P<0.05
Fuji IX	10.8 (4.0); 10	13.4 (3.9); 7	No difference

DISCUSSION

The current study used the microtensile bond test method so that one or two specimens could be tested for each carious lesion and the remaining 'normal' dentine surrounding the excavated carious tissue could be used as a comparison substrate. This allowed the tooth to become its own control and perhaps reduce some of the variability frequently observed in bond studies. However, studies such as this one are quite difficult to perform due to the difficulty of obtaining teeth with small carious lesions, in order to ensure that bonding is performed in dentine that is not close to the pulp. Because of this, it is somewhat difficult to obtain equal numbers of specimens for each test group.

The use of Carisolv has been shown to remove carious tooth structure but conserve sound dentine, whereas conventional rotary instrumentation can frequently lead to over preparation.[4] With respect to changes in the dentine, the work by Dammaschke *et al*.[11] demonstrated that Carisolv can cause damage to odontoblast processes but leaves the dentinal collagen

Table 3. Mode of failure of bonded specimens (percentage)

	Fracture mode	Normal dentine	Carisolv-treated
Clearfil SE Bond	1	29	80
	2	54	20
	3	14	0
One Coat Bond	1	37.5	60
	2	37.5	30
	3	25	10
Fuji II LC	1	20	50
	2	60	50
	3	20	0
Fuji IX	1	62.5	33
	2	25	33
	3	12.5	33

Fracture mode 1=cohesive failure in dentine; 2=mixed failure – a combination adhesive failure and cohesive failure of the resin; 3=adhesive failure between the resin and bonded dentine surface. No statistical difference was observed among each material group $p>0.05$.

intact. Therefore, this should not cause any problems when bonding to dentine, and it would be most likely that the odontoblast processes would have been affected by the caries process prior to application of the Carisolv solution.

To date there are only two studies that have evaluated the bond strength to dentine treated with Carisolv. Hosoya *et al*.[12] investigated the bond strengths of three dentine bonding systems to sound permanent and primary dentine. They found that the bond strengths to primary dentine were significantly lower, whereas the converse occurred for the permanent dentine. The other study by Haak *et al*.[13] compared the bonding of five resin-based adhesives to Carisolv or conventional rotary removal of carious dentine. They concluded that no adverse affect on bonding was observed. However, their study used teeth that had been stored in ethanol, therefore making their results questionable. This is because the ethanol will change the collagen, possibly making it stiffer and likely to alter the outcomes of the bond test. Previous work has been shown this to be the case (Nakabayashi N, personal communication, 1994).

The two groups with the fewest specimens (One Coat Bond and Fuji II LC) were in normal dentine. Previous work on the microtensile bond strength of these two materials has been published with the same test method and researcher.[14,15] The results from the previous work (One Coat Bond, 21.9±5.6MPa; Fuji II LC, 18.5±4.0MPa) validated the outcomes of the current study, being little different, hence the small number of specimens tested was regarded as acceptable for comparative purposes.

It would seem that the use of Carisolv to prepare the dentine surface prior to bonding is quite satisfactory and confirms the findings of the other bond studies.[12,13] Three of the test groups showed no significant difference in the bond strengths, although each group treated with the Carisolv had a slightly lower bond strength. Whether this was an affect of the Carisolv or bonding to caries-affected dentine is unknown. Previous work on bonding to caries-affected dentine showed that for some bonding systems the bond strength decreased significantly,[6,7] whereas this was not the case in this study. The only group in which the bond strength was significantly different was the Fuji II LC group. The reason for this result is unknown. It is possible that the caries-affected dentine is not so mineral rich and the use of Cavity Conditioner removes even further mineral, thus reducing the ability of the ionic bond to the calcium to occur. Hence, it is possible that most of the bond strength was due to the resin component of the resin-modified glass ionomer cement infiltrating around the exposed collagen fibres after conditioning.

With respect to failure mode, it was noted that Fuji II LC behaved in a manner similar to the resin-based materials. Although not statistically different, there was an increase in the level of cohesive failures in these groups when bonded to Carisolv-treated caries-affected dentine. This may relate to the differences in the nature of the bond such as thickness of the hybrid layer, perhaps increased moisture in the Carisolv-treated dentine that may lead to a slightly greater number of microscopic defects in the whole bonded layer. The recent study by Dammaschke *et al*.[11] showed that dentinal collagen was not affected by the Carisolv solution. Sakoolnamarka[16] has shown that the calcium to phosphorous ratio correlated with the microhardness of active carious lesions. Although the use of Carisolv was able to remove the affected dentine to an extent that the dentine hardness was little different from 'normal' dentine, there may have been some differences in the dentine that lead to the changes in failure mode. A further study by Sakoolnamarka *et al*.[17] showed that the interfibrillar spaces in conditioned dentine were greater in Carisolv-treated teeth compared with 'normal' dentine. This was believed to be the reason for observing thicker hybrid layers, especially in those cases where phosphoric acid was used as the demineralizing agent, e.g., One Coat Bond. In contrast, there was a decrease in the number of cohesive failures for Fuji IX; this again may relate to changes in the nature of the Carisolv-treated dentine and the remaining caries-affected dentine which may be slightly more elastic in nature due to the more open network remaining after the use of Cavity Conditioner.

From the clinical point of view, it would seem that the placement of either a glass ionomer cement or resin-based dentine adhesive on Carisolv-treated caries-affected dentine should not pose any problems. There are still issues with respect to the increased time needed to remove the carious dentine compared with conventional instrumentation and the odour of the solution that children seem to dislike.[18] However, one of these issues has been overcome with modifications to the Carisolv solution which has greatly enhanced the speed at which the infected dentine can be removed. Carisolv appears to be a good material for removing carious tissue conservatively. Clinical trials are necessary to determine if the efficacy of the bond observed in this study is maintained in the clinical setting.

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