Evaluation of Chemomechanical Caries Removal Using the Vickers Hardness Test: "An In Vitro Study"

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Abstract

Objectives: Invasive caries removal should be kept to a minimum. Chemomechanical caries removal is one of several alternative methods to conventional caries excavation that have been used and involves the selective removal of soft carious dentin and preservation of the sound dentin. The purpose of this study is to determine whether complete caries removal is possible using this technique. The Vickers hardness of the dentin at the cavity floor following the in vitro removal of caries by the Carisolv™ chemomechanical caries removal system; and the effect of Carisolv™ gel and sodium hypochlorite 0.25% on the microhardness of sound dentin will be evaluated.

Methods and Materials: The carious dentin of eighteen extracted human permanent molars was removed using Carisolv™ for one minute with instruments and excavation until the gel was clear. Caries removal was verified according to the color and hardness of the lesion. The Vickers Hardness Number (VHN) of the cavity floor was determined and the adjacent sound dentin for each tooth was used as a control reference. In addition, ten extracted caries-free teeth were sectioned from the occlusal third to expose the dentin. Adhesive tape was placed on the sectioned surface to separate the tested area from the control. Carisolv™ gel and sodium hypochlorite solution 0.25% were then applied on the sound dentin of the prepared teeth for three minutes (5 teeth for each material). After the removal of the adhesive tape, the VHN was measured for both tested and control areas.

Results: The VHN of the cavity floor of the carious teeth was almost similar to that of the adjacent sound dentin, while the VHN of the sound dentin treated with sodium hypochlorite 0.25% was much lower than the VHN of the sound dentin treated with Carisolv™ gel.

Discussion: The microhardness in this study indicated that Carisolv™ solution does not produce any adverse side effects on dentinal microhardness. Sodium hypochlorite randomly dissolved both demineralized and denatured dentin. The difference between the action of Carisolv™ containing sodium hypochlorite and the pure sodium hypochlorite solution could be explained by the amino acids added to Carisolv™. The amino acids might react with the sodium hypochlorite, thus reducing the organic tissue solving properties of the sodium hypochlorite in Carisolv™ gel.

Conclusions: Carisolv™ gel does not cause a significant change in the microhardness of sound dentin and the treated carious dentin. In addition, the aminoacids present in the Carisolv™ gel play a role in the control of the sodium hypochlorite and minimize its aggressive effect on sound dentin.

Clinical Significance: Optimum carious dentin removal by Carisolv™ is no longer difficult when the appropriate clinical procedure is followed. Therefore, cavity preparation with Carisolv™, provides a clean dentin surface without affecting the adjacent sound dentin and may also be favorable in clinical dentistry.

Key words: chemomechanical, caries removal, Carisolv™, Vickers hardness test.

Introduction

There has been considerable interest in developing alternative methods for cavity preparation and caries removal due to the disadvantages of using traditional rotating instruments, which can result in heat, pressure, dentin desiccation, vibration and pain, (Bulut et al., 2004). In addition, for patients with dental anxiety, caries removal by means of conventional instruments is often associated with discomfort (Banerjee et al., 2000 b). Furthermore, tissue should be preserved wherever possible; invasive treatment should be kept to a minimum and natural tissue should be replaced with artificial substitutes only when absolutely unavoidable (Haak et al., 2000).

Our traditional insistence that a cavity floor must be unstained and hard after cavity preparation may be

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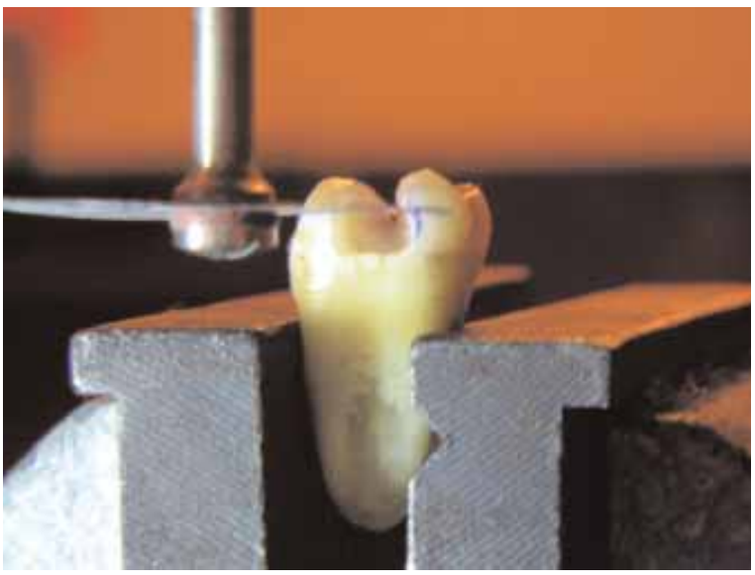

Figure 1: Tooth fixed on holder to facilitate sectioning.

unnecessarily destructive of tooth material and lead to carious exposures of the pulp. The following questions immediately arise: How 'clean' must a cavity be before restoration? What is the fate of slightly soft dentin if left behind, and is it a source of secondary caries (Kidd, 2004)? Kidd et al., (1993) took samples of carious dentin during cavity preparation and cultured the samples in order to count the number of bacteria. The number of bacteria recovered diminished significantly as the caries became dryer and harder and the cavity became deeper. There was no significant difference between the numbers of organisms cultured from medium dentin as opposed to hard dentin. The color of the sample was not associated with the number of bacteria recovered. This suggests that after the removal of wet soft dentin, further removal of medium, hard, stained dentin may not contribute to the further reduction of infected material.

The technique used in the removal of carious dentin has been developed since GV Black who, in 1893, initially proposed the principle of extension for prevention in the operative treatment of carious lesions. He also proposed that the removal of sound tooth structure and anatomical form at sites that might otherwise encourage plaque stagnation (e.g. occlusal fissure, approximal contact point), would help to minimize caries onset and progression. These principles of cavity preparation were based on the clinical presentation of caries and were constrained by the knowledge of the disease process and the restorative materials available at that time. However, in more recent years, with the advent of adhesive restorative material and the subsequent development in minimal cavity designs (Elderton 1984, Banerjee et al., 1998), the widely acceptable principle is now considered too destructive a method for caries removal (Banerjee et al., 2000b). Latest theories regarding the rationale of carious dentin removal are also beginning to question the amount of tissue that needs to be excavated in order to successfully treat a caries lesion, when removing demineralised dentin. It is not always apparent at what point excavation should be stopped as there is an obvious lack of objective clinical markers (Banerjee et al., 2000a). However, hardness of dentin might be a useful marker in this respect, with hardness of carious dentin being significantly lower than the non-carious dentin (Fusayama et al., 1966: Ogawa et al., 1983; Hosoya et al., 2000).

The removal of infected dentin while still preserving the dentin capable of remineralization has been a goal of conservative dentistry. Minimally invasive dentistry is reliant on this technique to minimize loss of tooth structure (Massler 1967). Reliable methods of limiting caries removal to infected dentin will advance minimally invasive dentistry (Banerjee et al., 2000c)

The best way to ensure the maximum lifespan of the natural tooth is to respect sound tissues and protect them from damage. Several alternatives have been introduced for conventional cavity preparation with rotary instruments and hand excavation. These methods include air-abrasion, air-polishing, ultrasonic instrumentation, sono-abrasion, different kinds of laser techniques and chemomechanical preparation of carious dentin. In common with all these techniques is their attempt to gain higher selectivity of removing only carious tissue and to avoid the painful and excessive preparation of sound dentin (Splieth et al., 2001; Fluckiger et al., 2005).

Chemomechanical elimination of carious dentin has so far been the most promising method as an alternative treatment procedure, particularly in paediatric dentistry, as well as for anxious or medically compromised patients (Ansari et al., 2003). This new method of treatment involves the selective

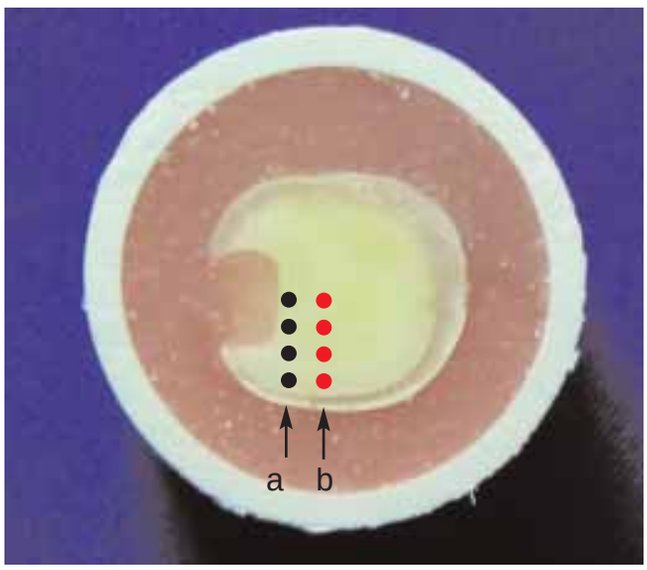

Figure 2: The picture shows points of microhardness measurements on the sample.
a) Carisolv™ treated dentin, area located 25µm next to the cavity floor.
b) Control points, area located 1000µm next to the cavity floor.

removal of soft carious dentin without the painful removal of sound dentin (Masouras et al., 2001). It can also be applied to patients where the administration of local analgesics is contraindicated, as local analgesia is not necessary for 82-92% of the patients with this technique (Haffner et al., 1999). Miller et al., (2003) found that negative experiences regarding smell, taste and noise were limited with the chemomechanical caries removal technique.

Chemomechanical caries removal is a method for minimally-invasive, gentle dentin caries removal, based on biological principles. The system uses a gel and special instruments that preserve healthy tissue with patient comfort significantly enhanced. The gel is applied to the carious dentin, softening the diseased portion of the tooth, while the healthy tissue is preserved. The softened, carious dentin is then removed with special instruments and the treatment is quiet and effective (Beeley et al., 2000). The dentinal surfaces formed after chemomechanical caries removal are very irregular with many overhangs and undercuts with visible patent and occluded dentinal tubules. The remaining dentin is sound, properly mineralized and well suited for restoration and bonding to modern restorative materials (Ansari et al., 2003).

The indications for the use of chemomechanical caries removal are exposed buccal lesions; cervical or root caries; very deep carious lesions (potential pulp exposure may be reduced) as well as the treatment of the uncooperative pediatric patient or the older, frightened patient. Contraindications include sessions when a short treatment time is necessary, as well as shallow pit and fissure caries where rotary preparation will suffice to remove caries with little discomfort (Ziskind et al., 2005).

In comparison with drilling, the chemomechanical method is often more time-consuming (Lager et al., 2003). To optimise the efficiency and effectiveness of Carisolv™ gel with respect to chemical caries dissolution and minimal effect on healthy dentin, a new, modified gel has been developed. The original Carisolv™ red gel contains three differently charged amino acids which are mixed with sodium hypochlorite prior to treatment. The new gel has no colour agent and contains half the concentration of amino acids and a higher concentration of sodium hypochlorite 0.475%, almost twice the 0.250% in the original Carisolv™ gel (Fure and Lingström, 2004).

The procedure avoids the painful removal of sound dentin but is ineffective in the removal of the hard eburnated part of the lesion. Removal of eburnated caries, however, may not be necessary (Kidd et al., 1993).

The purpose of this in vitro study is to find out if the complete removal of carious dentin is possible with the Carisolv™ system alone, and to compare the effect of the "Carisolv™ gel" and 0.25% sodium hypochlorite solution (which is the same concentration used in Carisolv™ gel after mixing its components) on the microhardness of sound dentin. This study was also made to evaluate the effect of aminoacids present in the Carisolv™ gel in the control of sodium hypochlorite during caries removal using Carisolv™ gel.

Materials and Methods

Preparation of the Carious Samples

Eighteen permanent molars with carious dentin on the proximal surface and ten caries-free premolars extracted for orthodontic purposes, with patient age ranging between 20 to 45 years old, were used in the study. The teeth were stored in 0.1% thymol solution (BDH Chemicals Ltd. England) at room temperature to avoid dehydration and further microbial growth, and were used within 2 weeks after extraction. Each carious lesion of the eighteen teeth was analyzed according to the color and

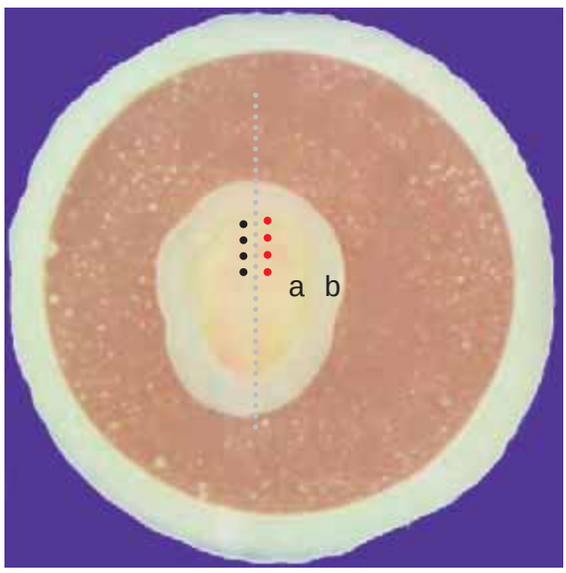

Figure 3: Picture shows carious free sample.
a) Points of measurements of the VHN at non treated control area.
b) Points of measurements of the VHN for Carisolv™ treated area.

hardness of the lesion. Carious lesions with a brown to black color and medium consistency (resistant to probing but readily penetrated when tested with a sharp explorer) were selected for this study.

All lesions had no enamel coverage and the dentin was easily accessible through the cavity openings. In addition, each tooth was evaluated by radiograph to ascertain whether the carious lesion extended to approximately half the distance through the dentin surface. If caries extended more than half the distance of dentin during treatment of the sample with Carisolv™ gel, the sample was neglected.

The Carisolv™ (MediTeam, GoteborgAB, Sweden) system was applied according to the manufacturer's instructions using Carisolv™ hand instruments.

For each tooth a fresh portion of Carisolv™ at room temperature was prepared. Prior to mechanical treatment, the solution was applied for one minute to the carious tissue. The caries was then gently excavated using specially designed instruments. The procedure continued for as long as carious tissue could be removed. The cavity was then rinsed thoroughly with water and gently dried. Caries removal was verified according to the color and hardness of the lesion by checking the hardness of the dentin with a dental explorer until a leather-hard texture was reached, or a sharp, scratching sound was heard as suggested by previous studies (Cederlund et al., 1999; Splieth et al., 2001).

All cavities were cross-sectioned perpendicularly to the tooth axis at the occlusal third of the crown using a diamond wheel cutter, with water cooling to avoid injury to the dentin. The tooth was placed in a jig to avoid movement of the sample during cutting (Figure 1). Cavity sections were flattened and smoothed with sandpaper of 400, 500 and 600 grit in a universal polishing machine. The sections were then embedded in chemically-cured acrylic resin so that the occlusal surface was exposed to external surface. The blocks were soaked in a container filled with distilled water with a few crystals of thymol, immediately at the dough stage of polymerization of the resin. At the doughy stage the rise in temperature as a result of autocuring is very low (Ferracane, 1995; Craig and Power, 2002) and will not affect the tooth tissue. After polymerization of the resin, each block was smoothed with sandpaper of 400, 500 and 600 grit. The blocks were kept in distilled water containing thymol 0.1% at room temperature until hardness measurement was completed within 24 hours.

Measurements of the Hardness of the Cavity Floor

Microhardness was measured with a Vickers hardness tester (Wolpert, Germany). Testing was performed with diamond pyramid indenters, which have a square-based diamond indenter with a 136º angle. Measurements were taken using a microscope of 200x magnification since identification was too small to be seen and measured with the naked eye. The test was determined using a load of 1 Newton (100 gm) applied to the specimens for 15 seconds as recommended in the pilot study (a pilot study was conducted to select the most appropriate preparation of the samples, The hardness test was first determined by using load of 0.5 Newton (50 gm) applied for 15 second at four points along the cavity. The indentation was too small and its boundaries neither clear nor sharp under the microscope. The load was thus increased to 1 Newton (100 gm) which gave a clear indentation). This load and time were constant for all samples throughout the study.

The Vickers Hardness Number (VHN) was measured at four points in each treated cavity where the minimum distance between two consecutive indentations was more than 40µm.

Table I. ANOVA Results for the VHN (kg/mm²) of Sound Dentin Treated with Carisolv™, NaOCl and Non Treated Control Groups.

Source	DF	SS	MS	F Value	P value
Factor	2	118.702	59.351	103.17	0.000
Error	17	9.780	0.575		
Total	19	128.482			

DF = Degree of Freedom, SS = Sum of Squares, MS = Mean square,
F value = F calculated, P value = Probability value.

The indentation was never close to any edge of the specimen or to any other indentation. The criteria for indentation acceptance were sharpness of diagonal edges, uniformity of diagonal shape (geometry) and absence of irregularities in the testing area.

To determine the degree of residual softened dentin, the hardness change of the adjacent sound dentin (reference control) on the same specimens was evaluated. Since obtaining a Vickers hardness measurement of the cavity surface was impossible, recordings were obtained next to the cavity floor. The hardness of the subsurface at a point 25 µm next to the cavity floor was used as that of the cavity floor and regarded as the Carisolv™ treated dentin (Harnirattisai et al., 1992). Adjacent sound dentin (areas at least 1000 µm next to the cavity floor) of the same samples was used as a control reference (Figure 2). The mean of the measurements was used as the VHN of the dentin A statistically significant difference between the VHN of the Carisolv™ cavity floor and adjacent sound dentin was determined by T-test. A value of $p \leq 0.05$ was considered significant.

Preparation of the caries free samples

Ten sound permanent premolars extracted for orthodontic purposes were used for this study. Samples were sectioned from the occlusal third of the crown using a water-cooled diamond wheel cutter and placed in moulds, in the same way as the carious samples, and then smoothed and polished. The blocks were placed in a container filled with distilled water, containing 0.1% thymol crystals at room temperature until measured.

Microhardness measurement of caries-free teeth

After preparation, the sample was fixed in an acrylic device and a shallow groove was made (bucco-lingually) at the midline of with a small diamond bur in a high-speed handpiece fixed on a surveyor. This was done to obtain a parallel line separating the test and control surfaces into two equal halves, creating a groove that could be seen in the microscope of the Vickers hardness machine. This groove was considered the boundary between the test and control surface of dentin. Adhesive tape was then placed on the cut dentinal surface parallel to the groove previously made to divide the control area from the tested area into two equal halves. The five randomly selected teeth were then treated with Carisolv™ gel, which was applied to the cross-sectioned dentin for three minutes and then rinsed with water. The other five teeth were treated with 0.25% sodium hypochlorite solution (NaOCl 0.25%) which was applied to the cut dentinal surface for 3 minutes and rinsed off with water. The tape was removed for both Carisolv™ and NaOCl treated samples and thus the same sample was used as a control.

The points where the Vickers test indenter was applied were at the mid distance of the dentin, moving parallel and near to the boundary groove between the test and the control area (Figure 3). Measurements were taken at 50micrometer intervals and the Vickers hardness test was applied for both the Carisolv™ and NaOCl treated samples in addition to the non-treated areas. The data were tabulated and statistically analyzed.

Data Analysis

For the carious samples data were analyzed using the T-test, with a value of $p \leq 0.05$ considered significant. For the caries free samples, the T-test was used for the VHN of both Carisolv™ and NaOCl treated dentin followed by the analysis of variance (ANOVA) to indicate if there is any statistical difference between Carisolv™, NaOCl treated sound dentin and control ($p \leq 0.05$). Duncan multiple range tests were then used to compare the significantly different groups.

Results

The results of this study can be analyzed by separately addressing the two types of samples used in the study, namely, carious samples and caries-free samples.

Carious Samples

The results revealed that the Vickers Hardness Number of the cavity floor prepared by Carisolv™ ranged from 60 to 63.5 kg/mm² (mean ±SD: 61.85 ±1.23) which did not differ

Table II. Duncan Multiple Range Test for the VHN (Kg/mm²) of the Carisolv™, NaOCl Treated and Non Treated Control Sound Dentin.

Source*	Mean**	N***	Duncan Group****
Control	62.56	10	A
Carisolv™	61.77	5	A
NaOCl	56.72	5	B*

Source of significance.
**: Mean of VHN (Kg/mm²).
***: Number of samples.
****: Means with the same letters are not significant.

statistically significantly from the VHN of the adjacent sound dentin that ranged from 61 to 64.6 kg/mm² (mean ±SD: 62.58 ±1.03). The results indicated no change in the microhardness of the dentin in the cavity floor after treatment with Carisolv™ gel compared with the adjacent control (p= 0.064).

The microhardness of the dentin in the treated cavity floor with Carisolv™ gel showed no statistical difference in the mean values compared with the adjacent sound untreated dentin.

Caries-Free Samples

The mean values of VHN for the Carisolv™ treated dentin was (61.77 ±0.599) and for the adjacent untreated dentin (control) was (62.57 ±0.576). The microhardness of dentin for the samples in which sound dentin was treated with Carisolv™ gel showed no significant difference compared with the adjacent untreated dentin.

The mean value of the VHN for the NaOCl 0.25% treated dentin was (56.72 ±1.07) and for the adjacent untreated dentin (control) (62.55 ±0.779). The microhardness for the samples in which sound dentin are treated with 0.25% sodium hypochlorite showed a significant difference compared with the adjacent untreated dentin.

A one way analysis of variance (ANOVA) was performed to make a comparison between the Carisolv™ and sodium hypochlorite treated sound dentin with their control, which showed significant difference ($p \leq 0.05$). The results of (ANOVA) are shown in Table (1). The Duncan multiple range test for the VHN revealed that the Carisolv™ treated sound dentin and control had no significant difference and that both of them are significantly different from NaOCl treated sound dentin (Table 2).

Discussion

Chemomechanical caries removal involves the chemical softening of carious dentin followed by the cleaning of the softened material with instruments similar to excavators. The typical chemicals used for such procedures are chloramines, prepared by mixing sodium hypochlorite with amino acids. The adverse effects of sodium hypochlorite on sound dentin and soft tissue are minimized using chloramines, but the effect on carious dentin is retained (Hosoya et al., 2005).

Variations in dentin hardness within a tooth may be due to several factors, the first of which is the calcification level of dentin (transparent dentin was found to be harder than the adjacent dentin). The second is the difference in dentinal tubule density at different locations (increased tubule density near the pulp was shown to correspond with reduced hardness). The third reason is the reduced hardness of the inter-tubular dentin when approaching the pulp. The fourth is the distance from the dentin-enamel junction (DEJ) (dentin hardness increased with distance from the DEJ) (Kinney et al., 1996). The locations for the indentation in this study were thus carefully selected. The dentin was inspected to avoid any irregular areas, and the equal distances from the DEJ to the pulp were kept constant for all indentations.

Collys et al. (1992) suggested a load of 50g and more for studies of hardness in teeth because they found out that lower loads influence indentation size. They indicated two aspects for this load influence: 1) the sample surface is altered during the polishing process, producing a coating larger than the largest depth reached for the indenter; and 2) with lower loads, the difficulty to read the indentation marks increased. However, in this analysis, the use of a load of 100g gave a clear indentation to be observed under microscope.

In this study, the hardness change of human dentin following carious dentin removal by Carisolv™ was assessed by in vitro Vickers hardness measurement of the cavity floor. The Carisolv™ gel was used according to the manufacturer's instructions on carious dentin for one minute, followed by excavation with special instruments until the cavity was clean. In addition, the hardness of sound dentin when exposed to Carisolv™ gel and 0.25% sodium hypochlorite was studied to determine if Carisolv™ gel affects the hardness of sound dentin and whether the amino acids present in Carisolv™ gel had any role in minimizing the effect of sodium hypochlorite on sound dentin. The concentration is related to the amount of active chlorine, which is 0.25% after mixing the sodium hypochlorite with the aminoacid liquid (Fure and Lingström,

2004). A time of three minutes was chosen for this study from a clinical aspect for the use of Carisolv™ gel, as the material should be in contact with the adjacent sound dentin for at least three minutes during clinical work before the cavity is completely clean (Tonami et al., 2003).

Since this material is newly developed there are limited studies concerning the hardness of the treated cavity floor. However, previous studies have indicated that the complete removal of carious dentin is difficult with Carisolv™ treatment and that the possibility of remaining caries following the Carisolv™ treatment is a major concern. Caries removal with Carisolv™ leaves up to a mean of 50 µm more carious dentin than removal using round burs (Splieth et al., 2001). Clinical guidelines are therefore necessary to identify residual carious dentin. Splieth et al. (2001) and Cederland et al. (1999) verified caries removal according to the color and hardness of the lesion with a sharp explorer. The hardness of dentin was checked with a dental explorer until a leather-like hard texture was reached or a sharp scratching sound was heard.

The degree of softened dentin removal was determined by VHN measurement of the cavity floor and the adjacent sound dentin as suggested by Aoki et al. (1998). The results of the Vickers hardness measurements of the Carisolv™ cavity floor confirmed that the possibility of the remaining residual softened dentin was minimal in this study as no statistical significant difference was noted in the microhardness of the Carisolv™ cavity floor dentin and the adjacent sound dentin (reference control). The results further indicate that the efficiency of complete carious dentin removal by the Carisolv™ chemomechanical system is no longer difficult when a proper clinical guide is used. Carisolv™ gel appears to have no effect on sound dentin compared with sodium hypochlorite solution which has a softening effect on sound dentin when used in the same concentration present in the mixed Carisolv™ gel. This means that aminoacids do have a control effect on the sodium hypochlorite by limiting its effect to denatured and demineralized dentin without affecting the sound dentin.

Sodium hypochlorite has two main properties depending on the pH of the solution. The first is a sterilizing effect at around pH 7 and the second is a solvent effect on organic material at a higher pH. Chloramines are generally produced by a combination of sodium hypochlorite and amino nitrogen, which makes the effect of sodium hypochlorite less aggressive and prolonged. While chloramines are commonly used as a disinfectant, the solvent effect is expected in the application of chemomechanical caries removal.

The results are also in agreement with Hanning (1999) who compared Carisolv™ with sodium hypochlorite and reported that Carisolv™ selectively dissolved an artificially demineralized and denatured dentin, but did not dissolve a demineralized dentin of no denaturation. Sodium hypochlorite unselectively dissolved both demineralized and denatured dentin. The

difference between the action of Carisolv™ containing sodium hypochlorite and the pure sodium hypochlorite solution could be explained by the amino acids added to Carisolv™. The amino acids might react with the sodium hypochlorite, thus reducing the organic tissue solving properties of the sodium hypochlorite in Carisolv™ gel.

Tonami et al., (2003) reported that Carisolv™ softened only the outer layer of carious dentin and the hardness of the inner layer of carious dentin and the sound dentin was not changed, and that Carisolv™ selectively dissolved the degenerated collagen in carious dentin. The results are in agreement with the results in this study.

Ericson et al., (1999) explained the behavior of amino acids in Carisolv™ gel from two aspects. One is the reduction of the aggressive effect of the sodium hypochlorite on sound tissue and the other is that the chlorinated three amino acids of different electric charge reacted to different moieties of carious dentin.

Hossain et al., (2003) evaluated the dentinal composition and Knoop Hardness measurements of the cavity floor following the removal of carious dentin by the Carisolv™ chemomechanical caries removal system in vitro and found that there were no significant differences between the quantities of calcium content (Ca weight %), phosphorus content (P weight %) and the Ca/P weight ratio of Carisolv™ cavities with that of the adjacent sound dentin ($P<0.01$). The Knoop Hardness number of the Carisolv™ cavity floor was almost similar to that of the adjacent sound dentin. The scanning electron microscope analysis revealed an extremely rough or irregular surface and there remained minimal debris like smear layer; most of the dentinal tubules were opened. The results indicate that Carisolv™ does not produce any adverse side effect on dentinal compositions of the treated cavities. The possibility of remaining residual softened dentin was also minimal in this study.

The results in this study were compared with the results of the previous study made by Hossain et al., (2003) that utilized Knoop microhardness based on the study by Ryge et al., (1961) who demonstrated that when working with loads between 50 and 100g, Knoop and Vickers microhardness is equivalent. The results were in agreement with each other.

In this study the Vickers hardness test was used instead of the Knoop hardness test as Maria and Jorge, (2003) suggested that the Vickers indenter should always be used in tooth hardness studies. Furthermore, according to Guetierrez-Salazar and Reyes-Gasga (2003), the Vickers indentor is more useful in tooth hardness studies than the Knoop's because a square shape has to be always conserved and that close to the outer surface and the DEJ, a small elongation of the diagonals of the indentations that produce errors in hardness measurements, is easily detected.

The results in this study disagree with Splieth et al., (2001) because it was found that complete caries removal is not difficult with Carisolv™ alone. The results in this study are in agreement with the results of several researchers who investigated the hardness of carious dentin after chemomechanical caries removal with Carisolv™ and concluded that when a proper technique is used, this treatment will result in complete caries removal without affecting the sound dentin (Hanning, 1999; Hossain et al., 2003; Tonami et al., 2003).

The results of the microhardness in this study indicated that Carisolv™ solution does not produce any adverse side effects on dentinal microhardness. Furthermore, complete carious dentin removal by Carisolv™ is facilitated by following proper clinical procedure. Therefore, cavity preparation with Carisolv™ provides a clean dentin surface without affecting the adjacent sound dentin, which may be favorable in clinical dentistry.

Conclusion

Carisolv™ gel does not cause a significant change in the microhardness of sound dentin and the treated carious dentin. In addition, the aminoacids present in Carisolv™ gel play a role in the control of the sodium hypochlorite and minimize its aggressive effect on sound dentin. This is because when NaOCl is used alone in a concentration of 0.25% (which is the same concentration used in the mixed Carisolv™ gel), it will cause a softening effect on the sound dentin. However, when mixed with amino acids such as those found in Carisolv™ gel, this effect is minimized. Furthermore, it was found that the complete removal of carious dentin is possible with the Carisolv™ system alone when a proper clinical procedure is used.

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