Caries removal with Carisolv system: Criteria evaluation and microleakage test

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In the present study, cavities prepared by Carisolv were verified as being caries-free by two methods; by conventional visual and tactile criteria, and by DIAGNOdent. The results indicate that in the dental clinic, the efficiency of complete carious dentin removal with Carisolv is no longer difficult when a proper clinical guide is used. Furthermore, treatment of dentin surfaces with Carisolv is capable of decreasing marginal microleakage after composite resin restorations.
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INTRODUCTION

The most serious problem encountered during caries removal is fear and pain. Pressure and heat during mechanical preparation and the annoying noise from the handpiece are to blame,. Furthermore mechanical bur drilling often causes over preparation of sound healthy dentin, leading sometimes to pulp inflammation and even exposure.

To reduce these problems, chemo-mechanical carious dentin removal system was first reported by Habib *et al*.[1] as the GK-101 system using the pharmacodynamic action of sodium hypochlorite. Later, Schutzbank *et al.* developed a Caridex system, which was actually a modification of GK-101 system.[2] Recently, Ericson *et al.* developed the Carisolv system which contains sodium hypochlorite and three kinds of amino acids (glutamic acid, leucine, and lysine).[3,4] Carisolv is believed to be one of most effective chemo-mechanical caries removing system for carious dentin as an alternative to mechanical drilling. This system has become popular because of its minimally invasive character; removing carious dentin gently and safely. It effectively removes only carious dentin without affecting sound dental hard tissues. Less pressure on tooth structure during carious dentin removal produces less heat or sound; Carisolv system causes less pain when we compare it to conventional mechanical drilling system and local anesthesia is therefore not required in most of the cases.[5-9]

However, longer preparation time and the possibility of leaving carious dentin are the major disadvantages with this system; Splieth *et al.* reported that more than 50 μm of carious dentin were left following Carisolv treatment when compared to the conventional mechanical tooth preparation.[10] Other studies also showed residual bacteria following Carisolv treatment.[11,12] The firm feeling of sound dentin is not always differentiated,[13] and color and sound do not give a true indication of sound dentin.[12] Ricketts *et al.* also suggested that visual diagnosis should be unrelated to the level of dentin infection.[14] However, Hossain *et al.* reported that Carisolv is capable of removing complete carious dentin if proper clinical guide is applied.[15]

In the present study, after caries removal with Carisolv, prepared cavities were verified as being caries-free by two methods; 1) conventional visual and tactile criteria, and 2) DIAGNOdent, and the efficiency of these two methods was compared. Prepared cavities were then subjected to the evaluation for remaining caries with a caries detector, and microleakage test was performed to observe the adaptation of composite resin into the cavities.

MATERIALS AND METHOD

Sample preparation

Forty extracted human permanent teeth with dentinal caries were used. Prior to treatment, each carious lesion

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was analyzed according to the color, hardness of the lesion, and then by dental radiography. Carious lesions with a brown-to-black color and medium consistency (Resistance to probing but readily penetrated when tested with a sharp probe) were selected for this study. The extent of carious lesions was further assessed by mean of KaVo DIAGNOdent 2095 (KaVo Dental GmbH, Jena, Germany) that provided a pulsed 655-nm laser beam directed into the tooth. When the incident light encountered a change in tooth substance, it stimulates fluorescent light of a different wavelength. This was translated, through the handpiece, into a number from 0 to 99. For the selection of carious dentin in this study, the following criteria suggested by Lussi *et al*. were used: 0-13, no caries; 14+, caries were deeper into the enamel or into the dentin. Carious lesions that scored higher than 14 with this laser ray were used.[16] The authors employed a tapered fiber-optic tip (Tip A) for measurements. Before obtaining the measurements, the DIAGNOdent was calibrated against a ceramic standard following the manufacturer's instructions.

Experimental procedure

Singlemix Carisolv gel system (Medi Team, Göteborg A B, Sweden) was applied according to the manufacturer's instructions using the special Carisolv hand instruments. This Carisolv gel used for this study supplied into two separate mixtures of the component; prior to use, each component was mixed. Carisolv gel was applied on the surface of the carious lesions for 30 seconds with instruments and excavation was performed until the gel was clear.

Following caries removal by Carisolv using the hand instrument, prepared cavities of twenty teeth were verified as being caries-free with conventional visual and tactile criteria (Group A) as suggested by Splieth *et al*.,[10] and Cederlund *et al*.[17]; at first the color, and then the hardness of the dentin was checked with a dental explorer until a lather-hard-texture was reached or a sharp scratching sound was heard as suggested by the previous studies.

The remaining twenty teeth, following caries removal by Carisolv using the hand instrument, were verified according to conventional visual and tactile criteria, and then as carious dentin removal progressed and the treated cavity floor became deeper and closer to the underlying intact dentin layer, the treated cavity was further assessed by means of DIAGNOdent (Group B). The procedure was repeated until DIAGNOdent showed a value less than 12.

Evaluation methods

Ten teeth from each group were then subjected to the evaluation for remaining caries using caries detector according to previous studies.[18,19] These teeth were embedded in polyester resin and sectioned with a diamond saw disc (Isomet, Buehler, IL) into specimens of 400-µm thickness. After the application of a caries detector, the microscopic images of the samples were used to evaluate remaining caries.

The remaining ten teeth from each group were subjected to microleakage test. After removal of carious dentin with Carisolv system, these cavities were acid-etched with a 30% phosphoric acid gel (Clearfil etching agent, Kurary Co., Kurashiki, Japan) for 30 seconds, washed with water spray for another 30 seconds, and dried with air for 20 seconds. Cavities were then filled with a light-curing composite resin (Clearfi lPhoto Bond, Kurary Co., Kurashiki, Japan) according to the manufacturer's instructions; The primer was applied for 30 seconds, dried with an air spray, and then the bonding agent was applied and light-activated for 20 seconds; finally, the cavities were filled with composite resin and light-cured for 40 seconds. All specimens were then polished with white points (Shofu White Points, Shofu Inc., Kyoto, Japan). The whole tooth surfaces except for the areas of filled cavities and 1 mm outside the margins of the cavities were double-coated

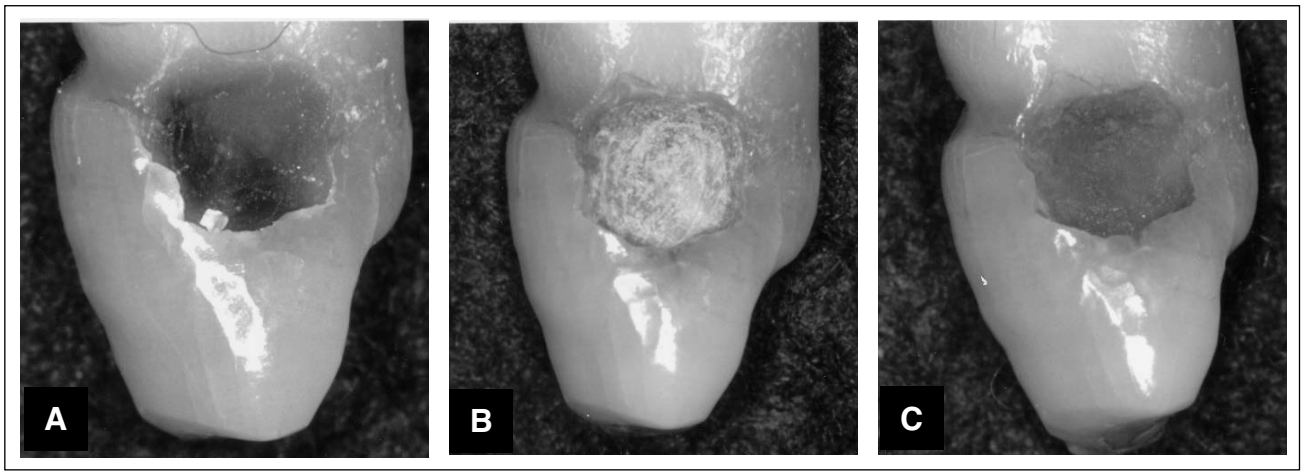

Figure 1. Example of caries removal in a primary tooth with Carisolv in Group A (a) preoperative view of dentinal caries, (b). postoperative view, (c) following application of caries detector,

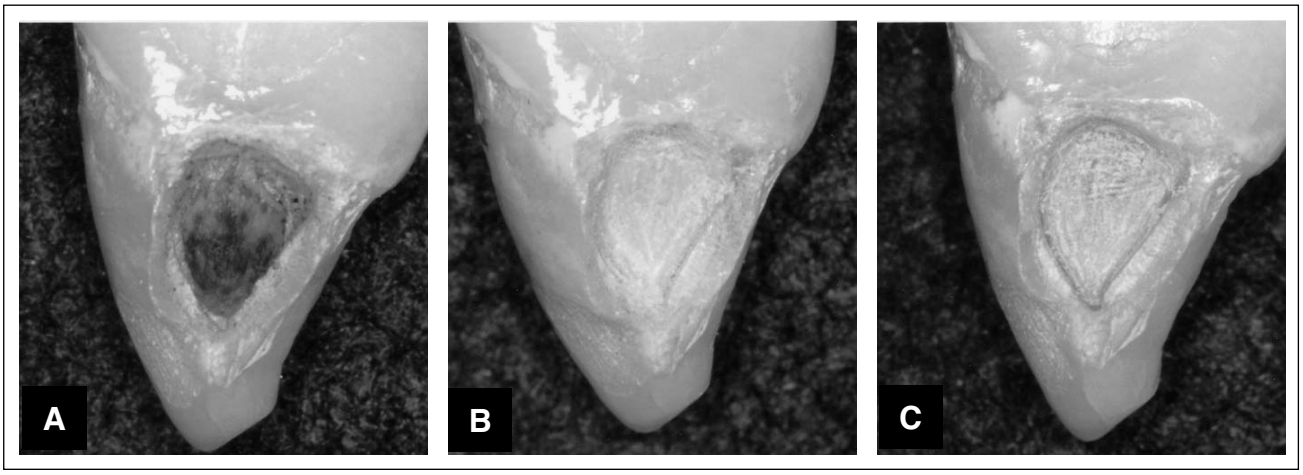

Figure 2. Caries removal with Carisolv in Group B (a) preoperative view of dentin caries, (b) postoperative view, (c) following application of caries detector,

Table 1. Scoring grade of microleakage test

Grade number	Content
0	No penetration
1	Penetrate only in the surround enamel
2	Penetrate into dentin
3	Penetrate into cavity floor

Table 2. Evaluation of remaining carious dentin

Group	1	2	3	4	5	6	7	8	9	10
A	Y	Y	Y	Y	Y	Y	Y	N	N	N
B	Y	Y	N	N	N	N	N	N	N	N

Y: Remaining carious dentin
N: Completely removal carious dentin

Table 3. Results of microleakage test

Group	1	2	3	4	5	6	7	8	9	10
A	0	0	0	2	2	1	3	3	3	3
B	0	0	0	0	0	0	1	1	2	3

* The numbers are following grade of Table 1

with a nail varnish. They were then thermocycled for 800 cycles between 5ºC (±2) and 55ºC (±2) with a one-minute dwelling time at each temperature, then immersed for four hours in a Rodamine buffered dye solution. The samples were transversely sectioned with a diamond saw disc (Isomet, Buehler, IL). The degree of microleakage using dye penetration was scored based on a 4 grade scale (Table 1) under a microscope by a technician who was not informed of the true nature and purpose of these experiments. If microleakage score numbers were different in the same tooth, the worse score was used in the evaluation. Statistical analysis was performed using the Mann-Whitney's U test and a value of $p < 0.01$ was considered significant.

For further investigation to evaluate the gap between the dental material and dental hard tissues of each sample, cut surfaces were polished with wet silicon carbide paper, and then dehydrated in a graded series of aqueous ethanol (70%, 80%, 90%, 100% ethanol) for 24 hours in each solution, dried with liquid CO_2 using a critical point dryer devices (JCPD-3, JEOL, Tokyo, Japan), coated with a platinum layer and observed under scanning electron microscopy (SEM) (JSM-T220, JEOL, Tokyo, Japan) at 15 or 20 kV.

RESULTS

Figure 1 shows caries removal with Carisolv system in Group A; (a) preoperative view of dentinal caries, (b) postoperative view, (c) following application of caries detector. Figure 2 shows caries removal with Carisolv system in Group B; (a) preoperative view of dentin caries, (b) postoperative view, (c) following application of caries detector. Table 2 shows the degree of remaining caries as evaluated by the caries detector solution. It was revealed that 7 cavities of Group A (70 %), and 2 cavities of Group B (20%) showed remaining carious dentin following Carisolv treatment. Significant differences were noted between these two groups ($p < 0.01$).

Table 3 shows the results of microleakage scores found in this study. Three teeth of Group A (30%) and 5 teeth of Group B (50%) revealed no microleakage (score 0). In stereoscopic observation, these cavities showed good adaptation of the resin cement with dental hard tissues (Figure 3-a). SEM observation of the cross-cut sections also showed no gaps between the composite resin and dental hard tissues (Figure 3-b). However, the remaining cavities revealed some degree of microleakage. Complete microleakage (score 3) was observed in 4 (40%) specimens of Group A and one (10%) in Group B, and partial microleakage (scores 1 & 2) was detected in 3 (30%) samples of Group A, and 4 (40%) in Group B (Figure 4-a). It seemed that microleakage was due to a gap formation between the resin cement and dental hard tissues as seen in stereo-

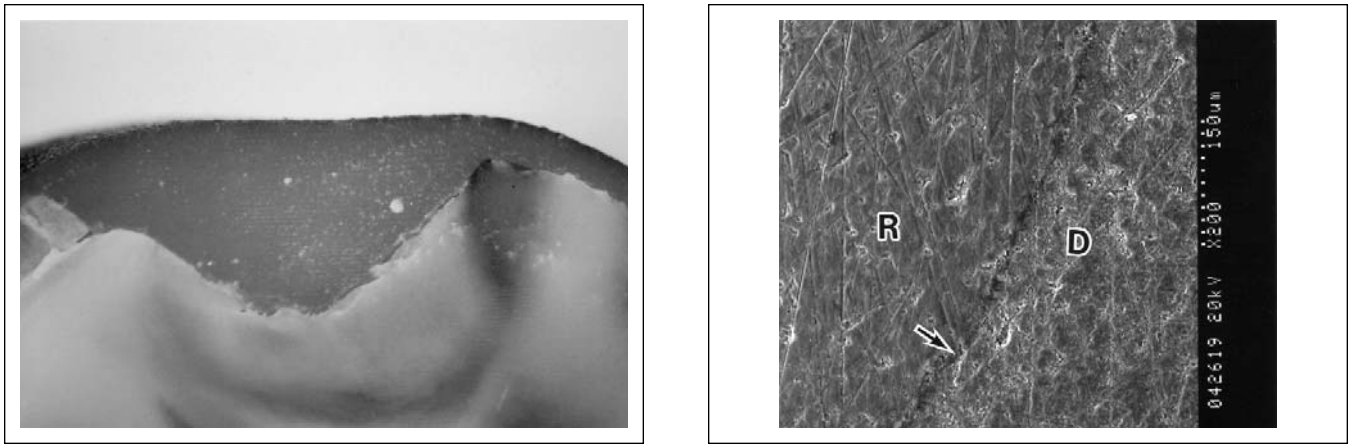

Figure 3. The evaluation for the adaptation of composite resin into the cavity in grade 0. stereoscopic observation, (b) SEM observation D: Dentin. R: Resin. Arrow indicates the interface between dentin and resin.

scopic and SEM observation in the these cavities. (Figure 4-b)

DISCUSSION

A Previous study indicated that the determination to completely remove carious dentin is difficult with the Carisolv treatment and 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 round burs.[10] Some clinical guidelines are, therefore necessary to identify residual carious dentin. Splieth *et al*.[10] and Cederlund *et al*.[17] verified caries removal according to the color and hardness of the lesion with a sharp explorer; the hardness of the dentin were checked until a rather-hard-texture was reached or a sharp scratching sound was heard as suggested by previous studies. As these methods are operator dependent, Hossain *et al.* recommended a combination of hardness testing by explorer and DIAGNOdent.[20] The usefulness of DIAGNOdent device for the assessment of carious dentin removal has previously been reported by Lussi *et al*.[16] In the present study, gross caries removal was verified according to the color and hardness of the lesion with a sharp explorer as suggested by Splieth *et al*.[10] and Cederlund *et al*.[17] Subsequently, the treated cavity was carefully assessed by means of DIAGNOdent.

It was revealed that when caries removal was verified according to the color and hardness of the lesion with a sharp explorer only (Group A), 7/10 cavities (70%) showed a remaining of dentin caries following Carisolv treatment. The results found in the present study confirm the result reported by Splieth *et al*.[10]; Carisolv leaves up to a mean of 50 μm more carious dentin than round burs. However, only 2 cavities (20%) in Group B showed remaining carious dentin following Carisolv treatment and they were statistically significant ($p < 0.01$). This indicates that the efficiency of complete carious dentin removal by the Carisolv chemo-mechanical system is no longer difficult when a proper clinical guide (e.g. DIAGNOdent assessment and caries detector solution) is used.

Some previous studies have demonstrated that the Carisolv cavity surface possessed some distinguishing features compared to the surfaces of conventional mechanical bur.[20-22] These structures have previously

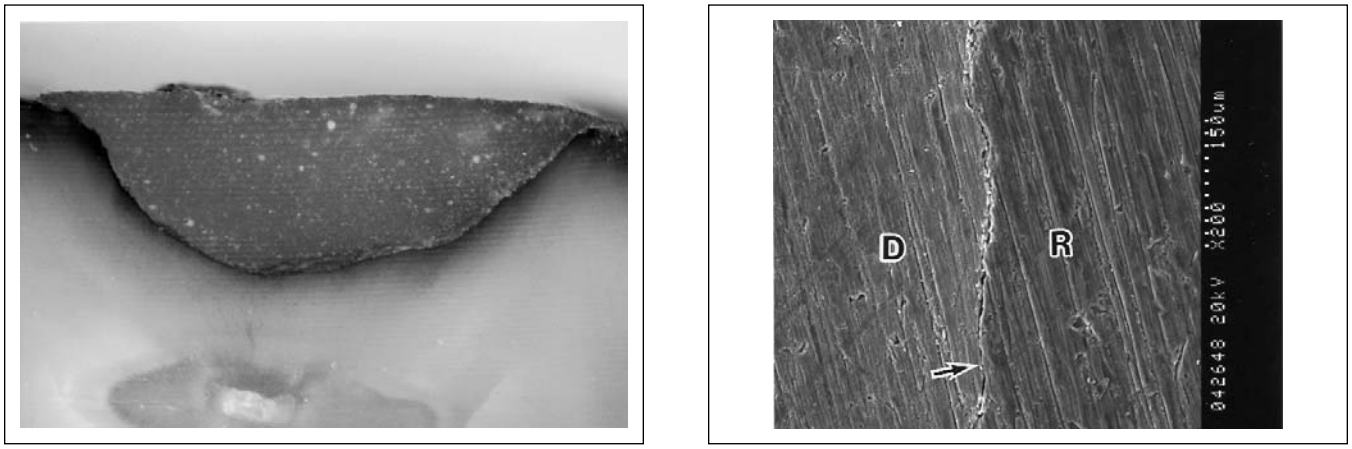

Figure 4. The evaluation for the adaptation of composite resin into the cavity in grade 3. (a) stereoscopic observation, (b) SEM observation. D: Dentin. R: Resin. Arrow indicates the interface between dentin and resin.

been described as flaky or with an irregular surface.[23-25] The results of microleakage test of the present study have confirmed that treatment of dentin surfaces with Carisolv (especially in Group B) is capable of decreasing marginal microleakage after composite resin restorations. The highly irregular surfaces or high roughness values without a smear layer in Carisolv cavities could provide a suitable surface for good adhesion or strong bonding with restorative materials as reported in previous studies using the Carisolv system. When cross sections of Carisolv cavities were examined by SEM, good adhesion and sealing between the restorative material and dental hard tissues was noted. However, many cavities in Group A showed some degree of microleakage. Complete microleakage (score 3) was observed in 4 (40%) specimens of Group A and one (10%) in Group B, and partial microleakage (score 1 & 2) was detected in 3 (30%) samples of Group A, and 4 (40%) in Group B (Figure 4-a). It seemed that microleakage was due to a gap formation between the resin cement and dental hard tissues as seen in stereoscopic and SEM observation in the these cavities (Figure 4-b). Debris that develops due to crushing and burnishing of the special Carisolv excavator on the dentinal surface as seen in a previous study may also interfere with adhesion. Therefore, it is still too early to say that Carisolv treatment could omit the need for acid etching or highly acidic self-etching primer for bonding. Further research is necessary to confirm this study.

According to the new criteria as DIAGNOdent assessment and caries detector solution, more quantities of carious dentin should be scrapped away compared with assessment by color and hardness of the lesion; this sometimes leads to pulp inflammation or exposure. Therefore, the most important factor for the success of pulp therapy is to remove carious dentin completely without damaging the pulp. Therefore, further consideration is necessary for the treatment of deep caries with Carisolv. The two-steps indirect pulp capping technique may be a method of choice. This technique consists of the following steps before permanent restorative filling; first, leave a thin layer of carious dentin and place calcium hydroxide on the surface of carious dentin, and then place a temporary filling material. After six to 8 weeks, if reparative dentin is seen on a dental radiograph, then remove all carious dentin completely, and fill it with a permanent restoration. Dimaggio *et al.* found more than ninety percentages success rate with this technique using calcium hydroxide paste.[26] Calcium hydroxide is known to induce reparative dentin formation. Furthermore, due to its high pH, it can sterilize of residual bacteria. Based on the present study together with that of the previous studies, we therefore suggest that it is better to follow two-steps indirect pulp capping technique with calcium hydroxide following treatment of deep caries by Carisolv system. Further research is necessary to confirm this hypothesis.

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REFERENCES

1. Habib CM, Kronman J, Goldman, M. A chemical evaluation of collagen and hydroxyproline after treatment with GK-101 (N-chloroglycine). Pharmacol Ther Dent 2: 209–215,1975.
2. Schutzbank SG, Galaini J, Kronman JH, Goldman M, Clarke RE. A comparative in vitro study of effect of GK-101 and GK-101 E in caries removal. J Dent Res 57: 861–864, 1978.
3. Ericson D. In vitro efficacy of new gel for chemo-mechanical caries removal. J Dent Res 77: (abstr. 360) 1252, 1998.
4. Ericson D, Bornstein R, Götrick B, Raber H, Zimmerman M. Clinical multi-centre evaluation of a new method for chemomechanical caries removal. Caries Res 32: (abstr. 119) 308, 1998.
5. Ericson D, Zimmerman M, Raber H, Götrick B, Bornstein R, Thorell J. Clinical evaluation of efficacy and safety of a new method for chemomechanical removal of caries. A multi-centre study. Caries Res 33: 171–177, 1999.
6. Munshi AK, Hegde AM, Shetty PK. Clinical evaluation of Carisolv in the chemo-mechanical removal of carious dentine. J Clin Pediatr Dent 26: 49–54, 2001.
7. Nadanovsky P, Cohen Carneiro F, Souza de Mello F. Removal of caries using only hand instruments: a comparison of mechanical and chemo-mechanical methods. Caries Res 35: 384–389, 2001.
8. Rafique S, Fiske J, Banerjee A. Clinical trial of an air-abration/chemomechanical operative procedure for the restorative treatment of dental patients. Caries Res 37: 360–364, 2003.
9. Fure S, Linström P. Evaluation of the chemomechanical removal of dentine caries in vivo with a new modified Carisolv gel. Clin Oral Invest 8: 139–144, 2004.
10. Splieth C, Rosin M, Gellissen B. Determination of residual dentine caries after conventional mechanical and chemomechanical caries removal with Carisolv. Clin Oral Invest 5: 250–253, 2001.
11. Lager A, Thronqvist E, Ericson D. Cultivable bacteria in dentine after caries excavation using rose-bur or Carisolv. Caries Res 37: 206–211, 2003.
12. Yazici AR, Atilla P, Ozgunaltay G, Muftuoglu S. In vitro comparison of the efficacy of Carisolv and conventional rotary instrument in caries removal. J Oral Rehabil 30: 1177–1182, 2003.
13. Shovelton DS. Studies of dentin and pulp in deep caries. Int Dent J 20: 283–296, 1970.
14. Ricketts DN, Kidd EA, Beighton D. Operative and microbiological validation of visual, radiographic and electronic diagnosis of occlusal caries in non-cavitated teeth judged to be in need of operative care. Br Dent J 179; 214–220, 1995.
15. Hossain M, Nakamura Y, Tamaki Y, Yamada Y, Jayawardena JA, Matsumoto K. Dentinal composition and Knoop hardness measurements of cavity floor following carious dentin removal with Carisolv. Oper Dent 28: 346–351, 2003.
16. Lussi A, Hibst R, Paulus R. DIAGNOdent: an optical method for caries detection. J Dent Res 83:80–83, 2004.
17. Cederlund A, Lindskog S, Blomlöf J. Efficasy of Carisolv-assisted caries excavation. Int J Periodontics Restorative Dent 19: 464–469, 1999.
18. Kushunoki M, Oikawa M, Itoh K, Hisamitsu H. SEM observation of the dentin staining with caries detector. J Dent Res 81: (abstr. 593) A-98, 2002.

19. Oikawa M, Kusunoki K, Itoh K, Hisamitsu H. The experimental caries detector containing polypropylenglycol. J Dent Res 83: (abstr. 757) A-, 2004.
20. Hossain M, Yamada Y, Nakamura Y, Murakami Y, Tamaki K, Matsumoto K. A study on surface roughness and microleakage test in cavities preparated by Er:YAG laser irradiation and etched bur cavities. Lasers Med Sci 18: 25–31, 2003.
21. Erick JD, Wilko RA, Anderson CH, Sorensen SE. Scanning electron microscopy of cut tooth surfaces and identification of debris by use of the electron microprobe. J Dent Res 49: 1359–1368, 1970.
22. Smith DC. Buonocore memorial lecture: A milestone in dentistry. Oper Dent 7: 14–25, 1982.
23. Cederlund A, Lindskog S, Blomlöf J. Effect of a chemo-mechanical caries removal system (Carisolv) on dentin topography of non-carious dentin. Acta Odontol Scand 57: 185–189, 1999.
24. Wennerberg A, Sawase T, Kultje C. The influence of Carisolv on enamel and dentine surface topography. Eur J Oral Sci 107: 297–306, 1999.
25. Banerjee A, Kidd EA, Watson TF. In vitro evaluation of five alternative methods of carious dentin excavation. Caries Res 34: 144–150, 2000.
26. Dimaggio JJ, Hawes RR, Kiryati A. Histological evaluation of direct and indirect pulp capping. J Dent Res 42: (absrt 38), 1963.