

Assessment of the Chemomechanical Caries Removing Efficacy - Microtomographic Study -

한수경 · 김정욱 · 이상훈 · 김종철 · 한세현 · 장기택

서울대학교 치과대학 소아치과학교실

국문초록

건전 치질을 최대한 보존하고자 하는 노력의 일환으로 화학·기계적 우식 제거법이 개발되었다. 치아의 손상 없이 3차원 자료를 얻을 수 있는 미세 전산화 단층촬영과 V works program을 사용하여 이 방법의 우식 제거 효능을 평가하였다. 1군은 건전 상아질, 우식 상아질, 화학·기계적 방법을 사용하여 형성된 와동벽의 밀도값을 구하여 분석하였다. 2군은 건전 상아질, 고속 회전 절삭 기구를 사용하여 형성된 와동벽, 여기에 추가로 화학·기계적 우식 제거 용액을 적용한 후의 와동벽의 밀도를 구하여 분석하였다. 결과는 다음과 같다.

1. Carisolv™로 우식을 제거한 후의 와동벽 상아질의 밀도값은 정상 상아질 밀도값의 81.8 %이었다($p < 0.001$).
2. Bur를 사용하여 우식을 제거한 경우에는 와동벽과 정상 상아질 밀도값에 통계적으로 유의한 차이가 없었다($p = 0.234$).

주요어 : 화학·기계적 우식제거, 우식제거 효능, 미세 전산화 단층 촬영, 밀도값

I. Introduction

The first commercial attempt at chemomechanical caries removal was by Caridex® (National Patent Medical Products Inc, USA), which was initially introduced on the US market in 1985. Caridex® was not widely adopted, possibly due to its expense, additional clinical time and the bulky Caridex® delivery system. Since 1998, Carisolv™ (MediTeam Dental AB, Sweden) has been available to dentists as a chemomechanical approach to caries removal. Carisolv™ offers a number of advantages over conventional rotary instruments. First, it allows the selective removal of carious dentin thereby leaving a maximum amount of supporting tooth structure. Secondly, patients feel more comfortable and procedure is quite painless¹⁻³.

Earlier studies showed high rates of clinically com-

plete caries removal with Carisolv™ treatment from 94% to 100%, which was judged by using a dental explorer¹⁻³. In a more reproducible approach, Moran et al.⁴ evaluated the caries removal using an electric caries monitor (ECM), which resulted in similar values for Carisolv™ treatment and conventional caries removal with a round bur. In an *in vitro* study, Banerjee et al.⁵ reported similar autofluorescence readings for Carisolv™ treatment when compared with caries removal using conventional hand instruments. Splieth et al.⁶ evaluated the remaining caries with methyl red dye, and reported that caries removal using Carisolv™ leaves up to a mean of 50µm more carious dentin than the round burs.

The purpose of this study was to assess the efficacy of removing dentin caries with Carisolv™, evaluated by microcomputed tomography, together with commercial software for 3 dimensional image analysis.

※이 연구는 서울대학교 발전기금 및 간접연구경비에서 지원되는 연구비에 의하여 수행되었음.

II. Materials and methods

Specimen selection, preparation and scanning

20 human molars without fillings, which had distinct dentin caries were selected for this study. The teeth were stored in a physiologic saline solution at room temperature for a maximum of 2 weeks. The teeth were randomly divided into 2 groups (n=10).

〈GROUP 1; Caries was removed with Carisolv™〉

Before removing the caries, an initial 3D image was taken using a desktop X-ray micro CT scanner (SkyScan 1072, SkyScan b.v.b.a., Belgium) (Fig. 1. A). The carious dentin was then removed with the Carisolv™. The mixed gel according to the manufacturer's instructions was applied to the carious lesions with the recommended hand instruments. After 30 seconds, the softened carious dentin was removed with the same instruments. After cleaning the lesion with an air-water spray, the hardness of the dentin was examined with a dental explorer (EXS 8, Hu Friedy, Germany). This was repeated until the gel was no longer cloudy. According to the manufacturer's instructions, caries removal is considered to be completed if Carisolv™ gel is no longer cloudy. In every tooth, it was necessary to remove the enamel overhangs with a 1/2 round bur in a high-speed handpiece to allow for sufficient access. After finishing the caries removing procedure, a final 3D image was taken using SkyScan (Fig. 1. B).

Each tooth was numbered from 1 to 10. Under V works™ 4.0 (CyberMed, Korea) program using the reconstructed 3D image, 10 image slices of the tooth cavity were selected. Each slice of the initial and final image presented the same portion of the tooth. For example, the 1st slice of the tooth No.1 in the initial image represents the same portion in the 1st slice of the tooth No.1 in the final image.

Using density-measuring program in V works, following three variables were measured : (a) the density of the radiolucent dentin in the initial image (caries dentin), (b) the density of the radiopaque dentin in the initial image (sound dentin), and (c) the density of the cavity wall (remaining dentin after

Carisolv™ use) in the final image. Each variable was the mean of 5 values measured on the 5 sites in a single slice (Fig. 2. A, B). The characteristics of the measured sites were as follows.

the area of the dot: 30000-50000 μm^2

range of the diameter of the dot: 200 μm -250 μm

(a): the middle of the radiolucent dentin area.

(b): the middle of the radio-opaque dentin area excluding the sclerotic dentin. Generally it was 1/4 of the DEJ to the pulp, and close to the pulp side.

(c): the cavity wall as surface as possible.

Number of indeed measured sites: 1500

Number of the variables for statistical analysis:
1500/5=300

Number of the cases=number of the slices=
300/3=100

Therefore, in the statistical analysis (PC/SPSS 11.0), there were 100 cases and 3 variables. The mean values and standard deviations for each variable were compared and differences were tested for statistical significance with a paired t-test. A p value < 0.05 was considered significant.

〈GROUP 2; Caries was removed with high speed bur〉

Caries dentin was completely removed using #330 high speed bur. Routine clinical evaluation was done with dental explorer. An initial image was taken, and Carisolv™ gel was then applied for 10 minutes without any instrumentation. A final image was then taken.

In the initial image, (a) the density of the cavity wall (remaining dentin after bur use), and (b) the density of the sound dentin were measured. In the final image, (c) the density of the cavity wall (remaining dentin after Carisolv™ use) was measured (Fig. 3. A, B). All other steps were similar to those done in group 1.

The operator used 80k/100 μA x-ray microfocus tube, average cross-section pixel size was 12.4 μm , and average cross-section to cross-section distance was 26.3 μm .

III. Results

<GROUP 1>

After Carisolv™ treatment, the remaining dentin was judged to be caries-free by the clinical criteria. The density values of the sound dentin (preopaque), the carious dentin (prelucent), the cavity surface dentin after Carisolv™ treatment (postopaque) and p-values are shown in Table 1.

Simple linear regression analysis was used to de-

termine the correlations between the variables. The regression equations resulting from this analysis are described below (r = Pearson's correlation coefficient) (Fig. 4.).

<GROUP 2>

The density values of the sound dentin (presound), the remaining dentin after bur use (prewall), the remaining dentin after Carisolv™ use (postwall) and p-values are shown in Table 2.

Table 1. The density values and p-values (GROUP 1)

	preopaque	prelucent	postopaque	p-values
Density values (mean)	65.8±12.4	27.2±9.7	53.8±9.7	preopaque-prelucent* preopaque-postopaque* prelucent-postopaque*

The statistical significance was evaluated by paired t-test (*: p < 0.001)

$$\text{Postopaque} = 0.671 \text{ Preopaque} + 9.594 (r=0.737, p < 0.05)$$

$$\text{Postopaque} = 0.561 \text{ Prelucent} + 38.463 (r=0.480, p < 0.05)$$

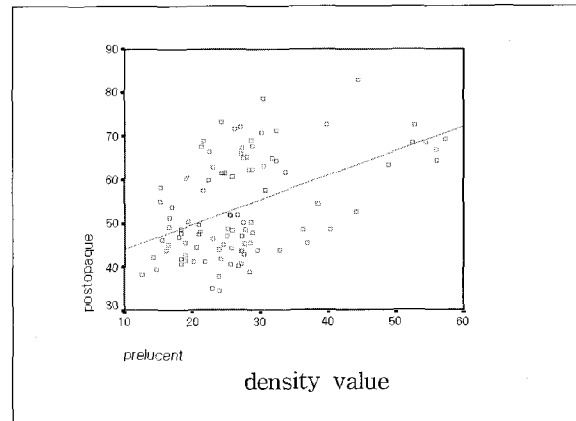
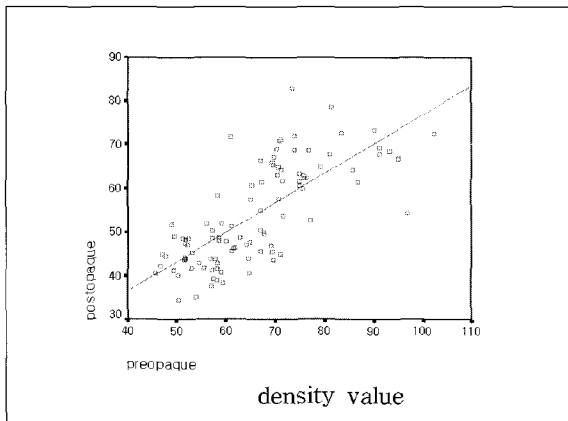


Fig. 4. Linear Regression Analysis.

Table 2. The density values and p-values (GROUP 2)

	presound	prewall (bur)	postwall (Carisolv™)	p-values
Density values (mean)	70.8±14.2	69.8±14.4	66.2±14.6	presound-postwall* prewall-postwall*

The statistical significance was evaluated by paired t-test (*: p < 0.001)

$$\text{postwall} = 0.851 \text{ preound} + 5.905 \quad (r=0.824, p < 0.05)$$

$$\text{postwall} = 0.867 \text{ prewall} + 5.677 \quad (r=0.854, P < 0.05)$$

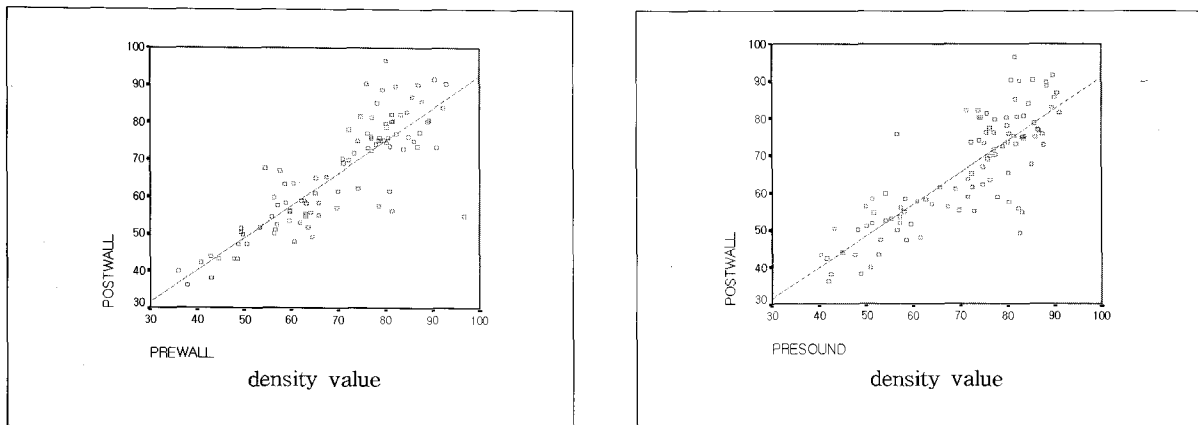


Fig. 5. Linear Regression Analysis.

IV. Discussion

Determining whether the remaining dentin after Carisolv treatment was caries-free was of major interest to us. Table 1. shows that the dentin remaining after Carisolv™ use has an 81.8% density of sound dentin. According to Table 2., the amount of sound dentin remaining after bur use has no statistically significant difference with sound dentin ($p=0.234$). In addition, applying Carisolv™ after bur use slightly reduced the density value(5.2%). These results suggest that Carisolv™ leaves behind much more radiolucent dentin than bur does, and can slightly reduce the density of the cavity wall.

In principle, the mechanism of action of Carisolv™ is basically the same as that of monochlorine-DL-2-amino butyric acid(NMAB), which is the active ingredient in Caridex®⁷⁾. When sodium hypochlorite is mixed with an amino acid at high pH, the chlorine reacts with the amino groups to form a relatively stable N-monochlorinated amino acid. This reaction renders the chlorine atom less reactive and therefore markedly less aggressive to healthy tissue. However, it still retains its electronic state and thereby its chemical mode of action. The softening effect on the carious dentin is the result of several reactions that act in concert to disrupt the collagen fiber structure (the conversion of hydroxyproline in partially disrupted carious collagen to pyrrol-2-carboxylic acid).

Chlorinated amino acids are probably able to disrupt the several types of electrostatic bond that hold the fibrous structure together. The peptide chains of collagen are comprised of hydrophilic (positively or negatively charged) and hydrophobic(non-charged) patches. Therefore each of the three chloroamino acids in Carisolv™ with different electrostatic charges attracts one of these patches electrostatically, effectively bringing reactive power to the full length of the target, the collagen fiber, while minimizing the unwanted side-reactions from hypochlorite. Although the softening effect on carious dentin is less well defined with chloramino acids than with hypochlorite, the sound and carious dentin can be separated easily.

The caries removal efficacy of the Carisolv™ has been assessed in many ways in earlier studies. As was the case for the Caridex® system, chemomechanical caries removal with Carisolv™ resulted in acceptable rates of clinically caries-free lesions as diagnosed using an explorer¹⁻³⁾. The clinically determined hardness of a dentin lesion is a sufficient prerequisite for the success of the following restoration, and Kidd et al.⁸⁾ found significantly less cariogenic bacteria in the hard dentin than in the soft one. However, the clinical hardness does not automatically correspond to the amount of carious dentin that needs to be removed for biological reasons. For example, the intact collagen in the demineralized inner dentin lay-

er of a carious lesion can be remineralised, i.e., hardened⁹. Therefore, it does not have to be removed from a biological point of view¹⁰. Especially when dentin-bonding agents are subsequently used, it is unclear according to which parameters and up to which point caries has to be removed. Studies measuring the bonding strength of dentinal adhesives and dentin-bonded composites have also reported similar results for lesions treated with chemomechanical removal or with round burs, which indicates sufficient caries removal^{11,12}.

The method described in this investigation is a new and objective way for assessing caries removal efficacy. An X-ray system usually produces two-dimensional shadow images of complete internal three-dimensional structures. However, the depth information is completely mixed in a single two-dimensional shadow projection. Only an X-ray tomograph system allows the imaging and measuring of complete three-dimensional object structures without sample preparation or chemical fixation. Typically the spatial resolution of conventional medical CT-scanner ranges from 1 to 2.5mm, which corresponds to a 1 to 10 cubic mm voxel (volume element) size. The system "SkyScan 1072" system allows to reach a spatial resolution of 10 μm , which corresponds to an almost 1 10^{-6} cubic mm voxel size¹³. The hardware device used in this study was a SkyScan 1072 which provided data sets that were used for qualitative and quantitative purposes. The system consists of a combination of an x-ray shadow microscopic system and a computer with tomographic reconstruction software. This system allows for a non-destructive three-dimensional reconstruction of an object's inner structure from a two-dimensional X-ray shadow projections. The equipment contains an x-ray microfocuss tube with a high-voltage power supply, a specimen stage with a precision manipulator, a two-dimensional x-ray CCD camera connected to the frame-grabber and a Dual Pentium computer with a color monitor.

V works program was used for analyzing 3D images. V works is a PC-based program used to reconstruct medical images from CT, MRI, and 3D Ultrasonography into various image formats. It can also create, save, and manage 3D medical models and other images as clinician demands. In this study, the major use was to create 3D images of the

tooth crowns, and measure density values of the image slices.

The advantages of this method are as follows: First, this method is much more objective when compared with the explorer, because the data in figures can be visualized using the V works software. Tactile sensation and dentinal color cannot be an objective standard. Second, microcomputed tomography is nondestructive, as opposed to microbiologic study. Third, because the specimen preparation process is omitted, the operator can freely choose and change any portion of the tooth to be analyzed. Fourth, a before-and-after comparison can be made on the specific portion of the tooth. This ability allows a more accurate analysis of the tooth than a random selection of a slice or a tooth dissection, which gives only one comparison per tooth.

But whether the remaining dentin after CarisolvTM is carious or not is still unclear. There are some problems that need to be considered. First, there are no established standard of micro CT density values for caries determination because this methodology is entirely new. Second, because the surface after CarisolvTM treatment is more irregular than that after the bur,^{6,7,14-16} the density can be lower even though it is carious free. Despite these uncertainties, the results of this study confirm those of the study which used a methyl red dye⁶ as a caries detectors. In an ultrastructural investigation, CarisolvTM dissolved the denatured dentin to a lesser extent than did a 0.25% sodium hypochlorite solution¹⁷.

CarisolvTM treatment reduced the density of the cavity wall which had been prepared by high speed bur. In SEM studies on teeth that were treated with a hand excavation, a slow-speed bur, sono-abrasion and the CarisolvTM system, CarisolvTM gel was the only method examined that consistently removed the smear layer during excavation to leave exposed dentin tubules at the end of cavity preparation¹⁵. Hosoya et al. concluded that CarisolvTM treatment on sound dentin partially removed the smear layer particularly in the permanent teeth¹⁸. In a TEM study, CarisolvTM had no effect on fractured sound dentin¹⁷. Therefore, CarisolvTM dissolved¹⁵ or modified⁶ the smear layer that was left after bur preparation and the density value was reduced as a result. However Cederlund et al.¹⁹ studied about the effect of

Carisolv™ on the topography of the non-cariou dentin, and showed that Carisolv™ treatment failed to remove the smear layer. Arvidsson et al.²⁰⁾ reported that there were no statistically significant difference between the sound dentin and the cavity surface after either the bur or Carisolv™, when analyzed by FT-Raman spectroscopy. Wennerberg et al.¹⁴⁾ used atomic force microscopy and a contact profilometer to assess the influence of Carisolv™ on an enamel and dentin surface topography. When the surface was investigated over a small area using atomic force microscopy, the healthy enamel appeared to be unaffected by Carisolv™, while the healthy dentin became smoother. When the surfaces were monitored with a contact profilometer, no effect of Carisolv™ could be detected on the healthy enamel or dentin.

Further studies of the chemomechanical treatment to determine whether or not the mean differences in the micro CT density values are needed.

V. Conclusions

Assessing the efficacy of the chemomechanical caries removing agent using microcomputed tomography, the results were,

1. The density value of the remaining dentin after Carisolv™ treatment was 81.8% of the sound dentin ($p < 0.001$).
2. The density value of the remaining dentin after conventional rotary instrument showed no statistically significant difference from that of the sound dentin ($p = 0.234$).

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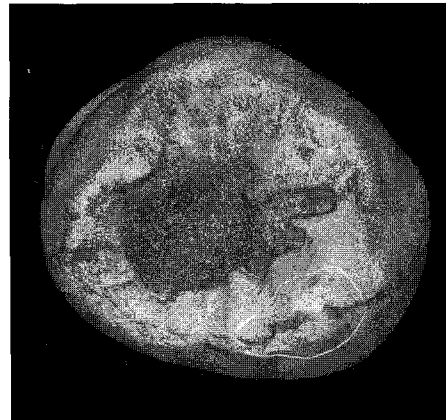
Reprint requests to:

Ki-Taeg Jang, D.D.S., M.S.D., Ph.D.
Department of Pediatric Dentistry, college of Dentistry, Seoul National University
28-1, Yeongun-Dong, Chongno-Gu, Seoul, 110-749, Korea
E-mail : jangkt@snu.ac.kr

Explanations of Figures



Fig. 1. A: Initial 3D image, occlusal view.



B: Final 3D image.

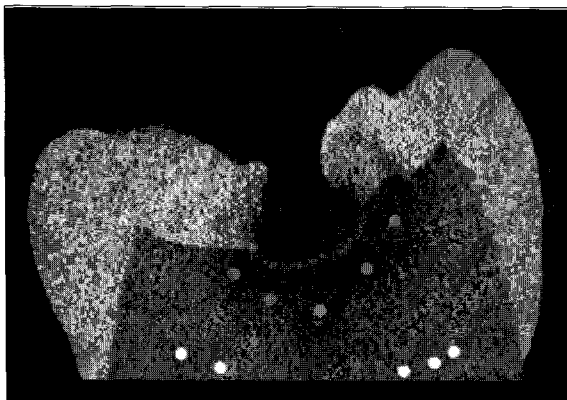


Fig. 2. A: measured sites of one initial image (black dots: radiolucent dentin, white dots: radiopaque dentin).



B: Indeed measured sites of one final image (black dots: remaining dentin after Carisolv™ use).

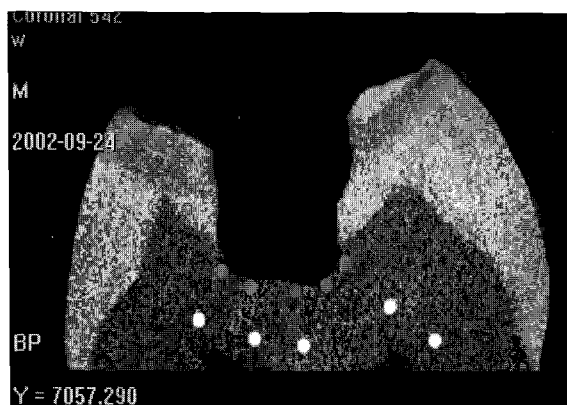
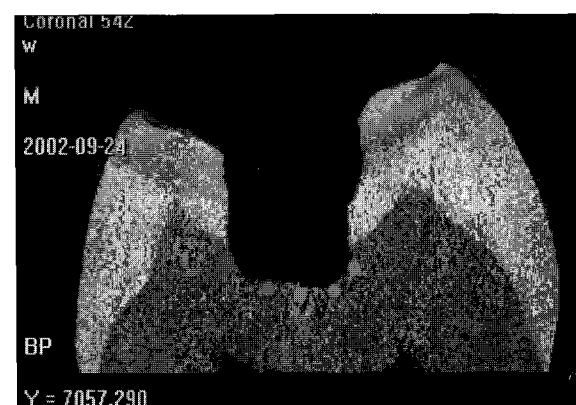


Fig. 3. A: After bur use (black dots: cavity wall, white dots: sound dentin).



B: After Carisolv™ use (black dots: cavity wall).

Abstract

ASSESSMENT OF THE CHEMOMECHANICAL CARIES REMOVING EFFICACY
- MICROTOMOGRAPHIC STUDY -

Soo-Kyoung Hahn, Jung-Wook Kim, Sang-Hoon Lee,
Chong-Chul Kim, Se-Hyun Hahn, Ki-Taeg Jang

Department of Pediatric Dentistry, College of Dentistry, Seoul National University

Chemomechanical approach to caries removal was introduced in order to preserve the maximum amount of sound tooth structure. The efficacy of chemomechanical caries removal was assessed using microcomputed tomography which offers 3 dimensional data without destroying the tooth, and the V works program. In group 1, the density values of the sound dentin, carious dentin, and remaining dentin after chemomechanical treatment were analyzed. In group 2, the density values of the sound dentin, cavity wall prepared using high speed bur, and the remaining dentin after additional Carisolv™ gel application on the same cavity were analyzed. The results were as follows:

1. The density value of the remaining dentin after the Carisolv™ treatment was 81.8% of the sound dentin($p < 0.001$).
2. The density value of the remaining dentin after the conventional rotary instrument showed no statistically significant difference from that of the sound dentin($p = 0.234$).

Key words : Chemomechanical caries removal, Caries removing efficacy, Microcomputed tomography, Density value