Braz Dent J (2006) 17(1): 63-67 ISSN 0103-6440

Effectiveness and Efficiency of Chemomechanical Carious Dentin Removal

Cláudia Silami de MAGALHÃES[1]
Allyson Nogueira MOREIRA[1]
Wagner Reis da Costa CAMPOS[2]
Fernanda Magalhães ROSSI[1]
Guilherme Augusto Alcaraz CASTILHO[1]
Raquel Conceição FERREIRA[3]

[1]*Departament of Restorative Dentistry, Faculty of Dentistry, Federal University of Minas Gerais (UFMG), Belo Horizonte, MG, Brazil*
[2]*Center of Nuclear Technology Development (CDTN), Belo Horizonte, MG, Brazil*
[3]*Department of Dentistry, State University of Montes Claros, Montes Claros, MG, Brazil*

The aims of this *in vitro* study were both to determine the time necessary for removal of carious dentin (efficiency) and the Knoop Hardness Number (KHN) of the remaining dentin (effectiveness), using a chemomechanical method (Carisolv) or hand excavation. Thirty human molars were bisected through occlusal carious lesions into two equal halves. Each half was randomly excavated by hand in circular movements with a spoon excavator or using Carisolv gel according to the manufacturer's instructions. The duration of carious dentin removal was recorded. Tooth sections were resin-embedded, ground flat and polished. Dentin KHN was determined at distances of 100, 200, 300, 400 and 500 µm from the cavity floor. Data were analyzed by Wilcoxon's test (α=0.01), ANOVA and Student's t test (α= 0.05). The median of the time necessary for chemomechanical excavation was significantly greater than for hand excavation. KHN means (± SD) at 100, 200, 300, 400, 500 µm for chemomechanical method were, respectively: 15.6 (±4.96), 18.0 (±6.22), 21.3 (±9.30), 24.3 (±9.25), 28.5 (±11.80); and for hand excavation were: 21.2 (±10.26), 23.4 (±9.49), 28.2 (±11.62), 31.0 (±12.17), 34.3 (±11.95). It may be concluded that hand excavation presented higher efficiency and effectiveness than chemomechanical excavation.

Key Words: dental caries, dentin, Knoop hardness, Carisolv.

INTRODUCTION

It is generally agreed by clinicians that the objective in treating carious lesions is to remove the infected layer, while leaving the affected dentin. The outer carious dentin is irreversibly denatured, infected, non-remineralizable and must be removed. The inner carious dentin is reversibly denatured, not infected, remineralizable and must be preserved (1). The differentiation between these layers is clinically relevant in order to avoid the painful and unnecessary removal of sound tooth structure (2).

Caries excavation has traditionally been performed according to mechanical principles using drills and sharp-edged hand instruments. These methods, although often effective, have some major disadvantages. First, it is often difficult to establish exactly how much dentin should be removed because there is an apparent lack of objective clinical markers. Secondly, mechanical preparation often induces pain and discomfort, therefore local anesthesia is needed (3).

To prevent these drawbacks, alternative dentin caries removal methods have been proposed, including chemomechanical techniques (4-7), air abrasion with aluminum oxide or glass particles (8), sono-abrasion (9), ultrasonic instrumentation (10) and lasers (11).

Correspondence: Profa. Cláudia Silami de Magalhães, Av. Presidente Antônio Carlos, 6627 Campus Pampulha. Departamento de Odontologia Restauradora, 31270-901 Belo Horizonte, MG, Brasil. Tel: +55-31-3499-2440. Fax: +55-31-3499-2430. e-mail: silamics@yahoo.com

Chemomechanical caries removal is an attractive alternative to conventional mechanical caries removal procedures. In the 1970s, the possibility of removing carious tissue chemically using N-monochloroglycine was reported (12) and the Caridex system was introduced (National Patent Medical Products, New Brunswick, NJ, USA). More recently, a chemomechanical caries removal system called Carisolv (Medi Team, Savedalen, Sweden) was introduced to the European dental market. Carisolv consists of a red gel, containing glutamic acid, leucin, lysine, sodium chloride, erythrosine, carboxymethylcellulose, water and sodium hydroxide, and a transparent fluid containing 0.5% sodium hypochlorite (2,9).

The chemical action of Carisolv is similar to that of Caridex in softening the carious dentin but leaving the healthy dentin unaffected. Furthermore, this system is supplied for instruments designed to scrape in two or in several directions, which reduce the friction during caries excavation (13). Although this method has been shown to be more time-consuming than traditional excavation, it may have a higher degree of acceptance among pediatric patients and patients who feel anxiety and fear, as it offers gentle excavation close the pulp and excavation of root caries (3,7).

Thus, the working hypothesis is that, although the time required for chemomechanical caries removal is longer than hand excavation, it is a more selective method and leaves a softer dentin at the floor of cavities.

The aim of this study was to evaluate the efficiency (time taken) and the effectiveness (Knoop microhardness of remanescent dentin) of chemomechanical carious dentin removal using Carisolv, as compared to conventional hand excavation.

MATERIAL AND METHODS

Experimental Design. The independent variables investigated in this experiment were the methods of carious dentin removal on two levels (hand excavation and chemomechanical excavation) and the distance from the cavity floor on five levels (100, 200, 300, 400 and 500 micrometers). The response or dependent variables were the time required to remove dentin measured in seconds (efficiency) and the Knoop microhardness of the remaining dentin measured by a microhardness tester (effectiveness). The experimental units were 30 recently extracted human molars with occlusal carious lesions, bisected through the middle of the lesion and arranged in a split-tooth design.

Sample Selection. Local ethical committee approval was obtained for this study (COEP/UFMG Process number 074/02). Results of a pilot study were used to estimate a reasonably sized sample, comparing the means of two groups (14). Thirty human molars with occlusal caries lesions were collected at the Surgery Clinic of the Faculty of Dentistry of the Federal University of Minas Gerais and stored for no more than 30 days in 0.05 M phosphate buffered saline (pH=7.2). In an attempt to standardize the lesion depths, the inclusion criteria were molars with occlusal caries lesions extending towards the middle third of dentin.

Dentin Carious Removal. The crowns were separated from the roots and mesiodistally sectioned through the occlusal carious lesions into two equal halves, using diamond disks (KG Sorensen Ind. e Com. Barueri, SP, Brasil) mounted in a handpiece. One half of each tooth was randomly excavated by hand and the other half was excavated using Carisolv gel. A previously calibrated operator performed all procedures.

For hand excavation, a #23 hatchet (Duflex, SS White, Rio de Janeiro, RJ, Brasil) was used to gain access to the dentin through the enamel. Dentin excavation was accomplished in circular scratching movements from the dentinoenamel junction to the cavity floor, using #5 or #18 spoon excavators (Duflex, SS White, Rio de Janeiro, RJ, Brasil) according to the lesion size. Excavation was completed when dentin at the cavity floor was resistant to probing, following the clinical criteria of hard texture.

Carisolv system was used for chemomechanical removal, according to the manufacturer's instructions, using Carisolv hand instruments. Unsupported enamel was removed using the #5 instrument to gain access to the cavity that was then covered with Carisolv gel. After waiting for at least 30 s for the gel to act, the softened dentin was excavated with #2, #3, and #4 instruments. When the gel became cloudy it was removed with moistened cotton together with the dissolved carious dentin. Fresh gel was then applied and the cavity floor was repeatedly scraped until the gel became clear. Caries excavation of the was judged complete by tactile criterion, when the cavity floor felt hard on probing.

Efficiency. The time used for carious dentin excavation using hand and chemomechanical methods was recorded, in seconds, to determine the efficiency.

Effectiveness. After excavation, tooth halves were embedded in 5061 N polyester resin (Cray Valley Ltda, Taboão da Serra, SP, Brazil), planed in a water-cooled mechanical grinder, using 400-, 600- and 1200-grit Al_2O_3 abrasive paper (Carborundum Abrasivos, Recife, PE, Brazil) and polished with cloths using 0.6 to 4.5 µm Al_2O_3 solution (Farmacêutica Carlos Erba, Divisão Química, São Paulo, SP, Brazil).

The Knoop Hardness Number (KHN) was obtained in a microhardness tester (Durimet; Ernst Leitz GMBH D-6330 Wetzlar, Hannover, Germany) with a 25-g static-load applied for 15 s. Five indentations were made at the distances of 100 µm, 200 µm, 300 µm, 400 µm and 500 µm respectively, from the deepest point of the cavity floor to the pulp chamber roof. The KHN values are derived using the equation $KHN = 14229.K/L^2$, where K is the applied load in grams, and L is the indentation length, in micrometers.

Statistical Analysis. The medians of the time needed to remove carious dentin by hand and chemomechanical excavation were calculated, considering 30 time recordings for each method. Wilcoxon test (α = 0.01) was used to compare the medians and determine the efficiency of each method. Statistical analysis considered the means of 30 indentations (KHN) for each method of caries removal, at each distance from the cavity floor. Analysis of Variance (ANOVA) (α = 0.05) was used to compare the experimental conditions. The interaction among the factors was analyzed (excavation methods and distances from the cavity floor). Student's t test (α = 0.05) was used to compare the levels of factors under study and to determine the efficacy of the caries removal methods.

RESULTS

The Wilcoxon test (α= 0.01; Z = 4.43) demonstrated that the median of the consumed time for chemomechanical excavation (319 s) was significantly greater than for hand excavation (173 s) (Table 1).

The results of ANOVA for each factor (caries removal method and distance from cavity floor) analyzed separately was significant (p=0.000), while the interaction between them was not significant (p=0.981). These results allowed an independent comparison of the levels of the factors, despite their interaction.

The Student's t test (α = 0.05) demonstrated that, at all distances, the dentin remaining after hand excavation presented Knoop microhardness significantly higher than chemomechanical excavation (Table 2).

Table 1. Medians, maximum and minimum values of time necessary, in seconds, to remove carious dentin using hand excavation or chemomechanical excavation.

Excavation Method	Time (s)
Hand	173 (102 - 383)a
Chemomechanical	319 (134 - 762)b

*Statistical differences are expressed by different letters (α = 0.01; Z = 4.43).

DISCUSSION

This *in vitro* study evaluated the efficiency and the effectiveness of chemomechanical carious dentin excavation using the Carisolv system in comparison to conventional hand excavation. Because natural lesions were used, it was not possible to standardize all variables of the sample, e.g., age, shape and activity status of the lesions. Therefore, a split-tooth methodology was used to minimize these variables as the source of carious dentin, allowing in this way for comparisons to be made between different, paired excavation methods (15).

Hand excavation was more efficient than Carisolv assisted-hand excavation of carious dentin, as indicated by their corresponding consumed time. Other authors have also shown that chemomechanical excavation using Carisolv gel was the slowest technique (3,7,15). An *in vitro*, split-tooth study showed that Carisolv-assisted excavation times were around twice as long as

Table 2. Knoop microhardness (KHN) means (± SD) of dentin remaining after hand excavation and chemomechanical excavation, according to the distance from the cavity floor (µm).

Distance from the cavity floor (µm)	Excavation method	
	Hand	Chemomechanical
100	21.2 ± 10.26a	15.6 ± 4.96b
200	23.4 ± 9.49a	18.0 ± 6.22b
300	28.2 ± 11.62a	21.3 ± 9.30b
400	31.0 ± 12.17a	24.3 ± 9.25b
500	34.3 ± 11.95a	28.5 ± 11.80b

* Statistically significant differences are expressed by different letters compared in line (α = 0.05; $lsd_{student}$ = 1.34).

conventional hand excavation (15). Another *in vitro* study found that excavation with Carisolv took 14.2 (±4.0) min on average. This longer time was justified as the manufacturer does not specify the minimum application time, but rather states that the cavities should be treated until the gel becomes clear to be considered caries free (3). Although Carisolv assisted-hand excavation could be less painful for the patients, a multicentre prospective study stated that the only cause of investigator's dissatisfaction with Carisolv was the prolonged treatment time, which increased with the stage of progression of the carious lesion (7).

Hardness has been associated with the relative infectiveness of carious dentin, helping the dentist distinguishing between either heavily infected (soft) and minimally infected (hard) dentin (16). In this study, the use of a microhardness tester with a Knoop diamond indentor allowed measuring the hardness of the remaining dentin, as an indicator of treatment effectiveness.

Dentin hardness has been studied by a number of researchers and the Knoop method is the most popular (17). KHN for healthy dentin quoted in the literature range from 50 to 70 KHN (16,17). However, the microhardness of dentin remaining after mechanical carious removal differs from that of the intact dentin. The dentinal floors of cavities after caries removal using hand instruments presented a lower microhardness, suggesting that it is less mineralized than the underlying sound dentin. Nevertheless, dentin with lower microhardness would not necessarily need to be removed for biological reasons. The intact collagen in the demineralized inner dentin layer of a carious lesion can be remineralized and hardened (1).

In this study, the mean of dentin microhardness at 100 µm from cavity floor after hand excavation was 21.2 KHN (±10.26), which is in agreement to Fusayama and Kurosaki (1), who described the hardness of the remaining dentin after removal of soft dentin with spoon excavator was 22.8 KHN (± 9.64). However, when Carisolv was used, the KHN values were significantly lower, at the distance intervals evaluated (100, 200, 300, 400, 500 µm). The possible explanation for this result is that a more demineralized dentin may be left on the cavity floor after Carisolv gel-assisted excavation, so this treatment could be considered more selective because it preserved remineralizable tissue.

Banerjee, Kidd and Watson (15) found that hand excavation and Carisolv gel-assisted excavation removed similar quantities of tissue and appeared to be more selective than burs for carious dentin removal. An *in vitro* study has shown that the Carisolv system left up to 50 µm more carious dentin on average, as compared to the use of a round bur (18). These findings are consistent with those of a biochemical study that found that the collagen content of dentin remaining after treatment with Carisolv gel has an increased portion of denatured collagen in comparison to sound dentin (19).

The lower KHN of dentin left after Carisolv assisted-hand excavation could be associated with a possible effect of the gel on its inorganic content. However, no significant differences were found between the quantities of calcium and phosphorus or Ca/P ratio of Carisolv-treated cavities with that of the adjacent sound dentin. Furthermore, no differences were observed in KHN of Carisolv cavity floor (60.30 ± 4.16) and the reference control (62.50 ± 5.05) (20). The findings of the present study do not agree with these results, but any comparison is quite difficult due to the great variation between methods used to select groups of teeth, tooth surfaces, the extent of carious lesions and the way of defining a caries-free surface. In the afore-mentioned study (20), the authors selected only carious lesions with a brown-to-black color and medium consistency on the proximal surface. Gross caries removal was verified according to the color and hardness of the lesion with a sharper explorer. Subsequently, the treated cavity was assessed by means of a pulsed 655-nm laser beam. Although the usefulness of this device for the assessment of carious dentin removal has previously been reported, further research on its ability to detect dental caries should be performed (20).

The effectiveness measured as Knoop microhardness of remaining dentin indicates hand excavation as the more effective method because of the harder dentin produced. However, due to biological variation, there is no absolute KHN, which could be used as criterion to distinguish carious dentin requiring removal. It should be clear that although the manufacturer's instructions indicate stopping Carisolv excavation when the gel appears clear, the method of determining when to end excavation (by using a dental probe) was the same for both treatments.

It is still unknown if the clinical marker used (hardness/texture) is reliable and will discriminate between the outer, necrotic, highly infected zone that needs to be excavated and the inner, reversibly damaged, less infected zone that could be maintained. Hardness as assessed by tactile means with hand instruments is very inconsistent, showing a wide variation between different investigators and also for a same individual on different occasions (1). Although other caries parameters, such as dyes, electric monitor (ECM), autofluorescence and laser beams have previously been studied, at present there are no clear, objective clinical markers available to delineate which dentin portion should be removed (16). It is, therefore, important to determine a clinically reliable guide to control the quality and quantity of tissue removed by individual operators (9).

RESUMO

O objetivo deste estudo *in vitro* foi determinar o tempo gasto para a remoção de dentina cariada (eficiência) e a microdureza Knoop (KHN) da dentina remanescente (eficiência), usando o método químico-mecânico (Carisolv) ou escavação manual. Trinta molares humanos foram seccionados através da lesão de cárie oclusal, produzindo duas metades iguais. Cada metade foi escavada, aleatoriamente, utilizando um escavador manual ou o kit Carisolv gel, seguindo as instruções do fabricante. O tempo gasto para a remoção da dentina cariada foi registrado. As hemisecções foram incluídas em resina, planificadas e polidas. KHN da dentina remanescente foi determinada nas distâncias de 100, 200, 300, 400 e 500 µm, a partir do assoalho cavitário. Os dados foram analisados pelos testes de Wilcoxon (α=0,01), ANOVA e t de Student (α=0,05). O tempo gasto na escavação químico-mecânica foi significativamente maior que na escavação manual. As médias e os desvios-padrão de KHN a 100, 200, 300, 400, 500 µm foram, respectivamente, para o método químico-mecânico: 15,6 (±4,96), 18,0 (±6,22), 21,3 (±9,30), 24,3 (±9,25), 28,5 (±11,80); e para a escavação manual: 21,2 (±10,26); 23,4 (±9,49); 28,2 (±11,62); 31,0 (±12,17); 34,3 (±11,95). Concluiu-se que a escavação manual apresentou maior efetividade e eficiência que a escavação assistida pelo Carisolv.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to Mr. Tanius Rodrigues Mansur, Chief of the Structural Integrity Service – EC 2, Center of Nuclear Technology Development (CDTN/CNEN) for the facilities. The authors are also grateful to MediTeam Dental for providing Carisolv gel used in this study. Supported by CNPq (Process number 47.4011/2001-1).

REFERENCES

1. Fusayama T, Kurosaki N. Structure and removal of carious dentin. Int Dent J 1972;22:401-411.
2. Beeley JA, Yip HK, Stevenson AG. Chemomechanical caries removal: a review of the techniques and latest developments. Br Dent J 2000;188:427-430.
3. Cederlund A, Lindskog S, Blomlöf J. Efficacy of Carisolv-assisted caries excavation. Int J Periodontics Rest Dent 1999;19:465-469.
4. Zinck JH, McInnes-Ledoux C, Capdeboscq C, Weinberg R. Chemomechanical caries removal - a clinical evaluation. J Oral Rehabil 1988;15:23-33.
5. Yip HK, Beeley JA, Stevenson AG. Mineral content of the dentine remaining after chemomechanical caries removal. Caries Res 1995;29:111-117.
6. Hannig M. Effect of Carisolv™ solution on sound demineralized and denatured dentin – an ultrastructural investigation. Clin Oral Invest 1999;3:155-159.
7. Chaussain-Miller C, Decup F, Domejean-Orliaguet S, Gillet D, Guigand M, Kaleka R, Laboux O, Lafont J, Medioni E, Serfaty R, Toumelin-Chemla F, Tubiana J, Lasfargues JJ. Clinical evaluation of the Carisolv™ chemomechanical caries removal technique according to the site/stage concept, a revised caries classification system. Clin Oral Invest 2003;7:32-37.
8. Horiguchi S, Yamada T, Inokoshi S, Tagami J. Selective caries removal with air abrasion. Oper Dent 1998;23:236-243.
9. Banerjee A, Watson TF, Kidd EAM. Dentin caries excavation: a review of current clinical techniques. Br Dent J 2000;188:476-482.
10. Nielsen AG, Richards JR, Wolcott RB. Ultrasonic dental cutting instrument I. J Am Dent Assoc 1955;50:392-399.
11. Bassi G, Chawla S, Patel M. The Nd:YAG laser in caries removal. Br Dent J 1994;177:248-250.
12. Goldman M, Kronman JH. A preliminary report on a chemomechanical means of removing caries. J Am Dent Assoc 1976;93:1149-1153.
13. Ericson D, Bornstein R. Development of a tissue-preserving agent for caries removal. In: Tissue Preservation in Caries Treatment. Albrektsson T (Editor). Surrey: Quintessence; 2001. p. 153-166.
14. Soares JF, Siqueira AL. Introdução à estatística médica. Belo Horizonte: Departamento de Estatística da UFMG, 1999.
15. Banarjee A, Kidd EA, Watson TF. *In vitro* evaluation of five alternative methods of carious dentine excavation. Caries Res 2000;34:144-150.
16. Banerjee A, Sherriff M, Kidd EAM, Watson TF. A confocal microscopic study relating the autofluorescence of carious dentine to its microhardness. Br Dent J 1999;187:206-210.
17. Meredith N, Sherriff M, Setchell DJ, Swanson SAV. Measurement of the microhardness and Young's modulus of human enamel and dentine using an indentation technique. Archs Oral Biol 1996;41:539-545.
18. Splieth C, Rosin M, Gellissen B. Determination of residual dentine caries after conventional mechanical and chemomechanical caries removal with Carisolv. Clin Oral Invest 2001;5:250-253.
19. Jepsen S, Acil Y, Zuch B, Albers HK. Biochemical analysis of the collagen structure of residual dentin following chemo-mechanical caries removal (Carisolv) apud Hannig M. Effect of Carisolv™ solution on sound demineralized and denatured dentin – an ultrastructural investigation. Clin Oral Invest 1999;3:155-159.
20. Hossain M, Nakamura Y, Tamaki Y, Yamada Y, Jayawardena JÁ, Matsumoto K. Dentinal composition and Knoop Hardness measurements of cavity floor following carious dentin removal with Carisolv. Oper Dent 2003;28:346-351.

Accepted May 30, 2005