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Original Article

The effects of different irrigation agents on root canal dentine micro-hardness and surface roughness

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Abstract

Aim: Successful endodontic treatments rely on sufficient mechanical preparation and irrigation of the root canal followed by an adequate three-dimensional filling. This study investigated the changes in root dentine micro-hardness and surface roughness upon treatment with different irrigating agents.
Methodology: A total of 60 human maxillary incisors and canine teeth were used in this study. The crowns of all teeth were decoronated and roots were divided longitudinally. The samples were separated into three groups prior to irrigation. A 5% NaOCl irrigation agent was applied to the first group, a QMix agent was used for the second group, and a 2% CHX agent was used for the third group. All irrigations were performed for 15 minutes. Following irrigation, microstructural and surface-roughness measurements were taken again from all samples.
Results: Micro-hardness was not significantly different between QMix or 5% NaOCl ($p>0.05$). A significant difference was observed between the QMix- and 2% CHX-treated groups, and between the 5% NaOCl- and QMix-treated groups ($p<0.05$). A significant difference in surface roughness was observed between the QMix and 2% CHX, and between the 5% NaOCl and QMix ($p<0.05$). No difference in surface roughness was observed between 5% NaOCl or 2% CHX. The 5% NaOCl and QMix agents reduced the dentine micro-hardness equal to or more than that of the 2% CHX agent. The QMix agent also increased the dentine surface roughness significantly more than the other agents. The 5% NaOCl and 2% CHX agents increased surface roughness equally.
Conclusions: It was seen that all of the irrigation agents used in our study affected dentin microhardness and surface roughness at different rates.

Keywords: Micro-hardness, surface roughness, QMix, NaOCl, CHX

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Introduction

The aim of a root canal treatment is to disinfect the root canal sufficiently to prevent further infection (1). Thus, successful root canal treatments rely on adequate canal preparations, effective irrigation, and complete three-dimensional (3D) canal filling.

Irrigation is one of the most important procedures of root canal treatment since it is at this stage that pulp tissues, residues, smear layers, microorganisms, and toxic products are removed from the root canal (2). Therefore, the correct irrigation agents should be used and applied properly (3). Because the complicated anatomy of the root canal prevents mechanical cleaning from fully removing the above items, irrigation is required (2).

Sodium hypochlorite (NaOCl), chlorhexidine (CHX), and ethylenediaminetetraacetic acid (EDTA) are common irrigation agents, with NaOCl being the primary endodontic agent. However, NaOCl has no effect on inorganic structures (1). NaOCl removes the organic portion of the smear layer and exhibits broad-spectrum antimicrobial activities against viruses, bacteriophage, spores, and fungi (4).

CHX also has broad-spectrum antimicrobial activities that are bacteriostatic at low concentrations and bactericidal at high concentrations (5). Reports suggest that 2% CHX prevents damage to root canal dentine during disinfection (6), and it bonds to hard tissues to exhibit extended antimicrobial activity (7). Weak CHX solutions (0.1-0.2% concentrations) are often used as mouthwashes; however, more potent solutions (0.2-2%) are required for root canal irrigations (6).

QMix (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) is a new root canal irrigant formulated for root canal disinfection and the removal of the smear layer (8). QMix is a combination of the antibacterial agent bisbiguanide, the chelator poliaminocarboxylic acid, deionized water, and sulphactan (9). According to the manufacturer, QMix contains EDTA, CHX, and a surface-active agent (8). The detergents in QMix reduce surface tension and increase the surface wettability (10). Previous reports have suggested that Qmix be used as a post-washing solution; however, it may also disinfect root canals since this agent has been shown to open dentine tubules (7). QMix is used with chlorhexidine and NaOCl to prevent the formation of precipitates (11).

Tooth tissues or dental materials are often evaluated by their surface hardness, which is affected by multiple chemical and physical factors. Hardness (rigidity) refers to the "resistance of a material against deformation", including expanding, reshaping, and resistance to pulling and pressing. Surface hardness is also used to evaluate a material's resistance to abrasion (12). Multiple methods are available to assess surface roughness, including scanning electron microscopy (SEM) and surface profile analyses. Recently, 3D topographic images have also been obtained using atomic weight microscopy to evaluate surface roughness (13). Additionally, a diamond scanner bit on a profilometer machine also explores surface roughness (14) under multiple parameters, including the Ra, Rpm, Rz and Rz:Rpm ratio (15).

Although the relative softening of dentine caused by chemical irrigants provides clinical benefits, including rapid preparation and opening of obstructed canals, such changes do not affect the adhesion or 3D filling of the channel-filler materials used to treat dentine (16). However, the changes caused by the irrigation solution reduce the resistance of dentine to stress, affects the removal of bacteria, and influences the ability of the filling materials to bind to the canal wall (17, 18).

Materials and Methods

A total of 60 non-carious maxillary incisors and canines were used in this study. All teeth were extracted for various periodontal reasons from patients aged 35-50. When extracting teeth, similarly-sized roots and teeth that had not previously undergone restorative or endodontic treatments were selected. Tooth radiographs were used to preferentially identify and select teeth with calcifications along the root canal, or those containing approximately the same width of pulp. Tooth crowns were separated from their roots at the enamel-cement boundary using a high-speed drill and stored in distilled water at room temperature (25 °C).

Roots that were separated from their crowns were longitudinally divided with a diamond saw (Horico, Berlin, Germany) using distilled-water cooling. Samples were embedded horizontally in polymerized acrylic blocks, ensuring that the root dentine remained open (Fig. 1). A total of 10 roots were embedded in each block. The dentine surfaces were sanded using sandpaper (silicon carbide abrasive paper; 500, 800, 1000, and 1200 grit) and distilled water, and polished using a 0.1-micron alumina suspension (Ultra-sol; Eminess Tec Inc, Monroe, NC, U.S.) and a felt disc.

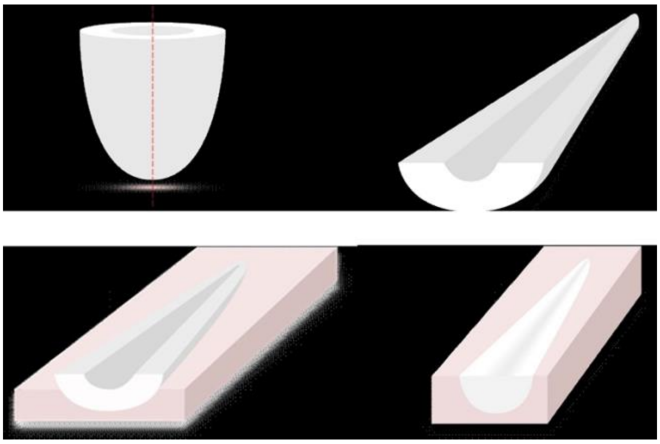

Figure 1. Three-dimensional image of the samples prepared prior to the study.

Samples were divided into A and B groups containing six acrylic blocks each. Each group was then further subdivided into A1, A2, A3, and B1, B2, B3 subgroups (Fig. 2 and Table 1).

Figure 2. Prepared samples

Group A was used to test the surface roughness of the dentine. Initial surface roughness measurements (Mitutoyo SJ 310 Kanagawa, Japan) were obtained according to the following: five measurements from each tooth were obtained over a length of 0.25 mm for each measurement. The probe speed was 0.5 mm/sec, and a total of 1.25 mm was measured. The arithmetic mean of all five values was then taken as the initial surface roughness value (mean Ra). 5% NaOCl was applied for 15 min to the A1 subgroup samples, the QMix 2-in-1 solution was applied for 15 min to the A2 subgroup samples, and 2% CHX was applied for 15 min to the A3 subgroup samples. Following the 15-min treatment, the samples were washed with distilled water and dried. Five additional measurements were then obtained for each sample, and the arithmetic mean was taken as the post-process surface roughness value.

Group B samples were used to evaluate surface micro-hardness using the Vickers hardness test. Prior to the irrigation process, the average micro-hardness in each block was defined as the average of three measurements from the apical triplet, middle triplet, and cervical triplet of the roots using a Vickers hardness-testing device (Shimadzu HMV-2, Japan) with a 300 gr force for 20 seconds. 5% NaOCl was applied for 15 min to the A1 subgroup samples, the QMix 2-in-1 solution was applied for 15 min to the A2 subgroup samples, and 2% CHX was applied for 15 min to the A3 subgroup samples. Following the 15-min treatment, the samples were washed with distilled water and dried. Three surface micro-hardness measurements were again obtained from each sample and the averages were recorded. The pre- and post-irrigation surface micro-hardness values were evaluated using the Annova-Tukey test.

Table 1. Classification of teeth used in this study.

Group	Group A (Surface Roughness)	Number of Teeth	Group B (Micro-hardness)	Number of Teeth
5% NaOCl	A1	20	B1	20
QMIX	A2	20	B2	20
2% CHX	A3	20	B3	20

Statistical Analysis

Data were analyzed using SPSS software (Statistical Package for Social Sciences, version 21.0) SPSS Inc., Chicago, ll., USA). In the statistical analysis of the groups ANOVA analysis of variance and Tukey test was applied and a significant difference in all groups in statistically was observed ($p < 0.05$). The results are given with 95% confidence intervals.

Results

Statistical significances and standard deviations for the assessments of root dentine micro-hardness and surface roughness are provided in Tables 2 and 3.

Micro-hardness was not significantly different between samples treated with QMix or 5% NaOCl ($p > 0.05$). Treatment with these agents caused similar reductions in micro-hardness. A significant difference was observed, however, between the QMix- and 2% CHX-treated groups, and between the 5% NaOCl- and QMix-treated groups ($p < 0.05$). Treatment with 2% CHX reduced the micro-hardness to a lesser extent than the other irrigation agents.

A significant difference in surface roughness was observed between the QMix and 2% CHX treatments, and between the 5% NaOCl and QMix treatments ($p < 0.05$). The QMix treatment increased the surface roughness more substantially than did treatments with the other agents. Based on binary comparisons, no difference in surface roughness was observed between treatments with 5% NaOCl or 2% CHX.

Table 2. Assessments of root micro-hardness.

Group	N	Vickers Micro-Hardness Values (Mean ± SD)
Pre-Irrigation		
QMix 2-in-1	20	55.50 ± 10.25
5% NaOCl	20	51.56 ± 10.88
2% CHX	20	55.26 ± 5.35
Post-Irrigation		
QMix 2-in-1	20	38.16 ± 4.44
5% NaOCl	20	39.07 ± 11.13
2% CHX	20	53.54 ± 5.47

Table 3. Assessments of root dentine surface roughness.

Group	N	Roughness Values (Mean ± SD)
Pre-Irrigation		
QMix 2-in-1	20	0.24 ± 0.09
5% NaOCl	20	0.20 ± 0.05
2% CHX	20	0.18 ± 0.05
Post-Irrigation		
OMix 2-in-1	20	0.47 ± 0.11
5% NaOCl	20	0.22 ± 0.05
2% CHX	20	0.19 ± 0.05

Discussion

The irrigation procedure, which is one of the most important steps in root canal treatment, affects the root dentine micro-hardness and surface roughness parameters. All of the irrigation agents used in this study reduced dentine micro-hardness and increased surface roughness. While the QMix irrigation agent and 5% NaOCl reduced dentine micro-hardness equally, 2% CHX caused less of a decrease than the other agents. The QMix agent also caused a significant increase in surface roughness, whereas 5% NaOCl and 2% CHX caused equal increases, albeit less than that observed with QMix.

The Knoop pit micro-hardness (19) and the Vickers micro-hardness tests (20) have been used previously with the Vickers micro-hardness test, and have been shown to be appropriate for assessing dental tissues treated with chemicals (20, 21). Although some studies have used the Knoop hardness test to evaluate surface changes of hard dental tissues, the Vickers micro-hardness test was considered more suitable for the current study (19).

Micro-hardness can provide information about mineral loss or gain in teeth (22) since the hardness of dentine depends on its physical properties and structure. The number and diameter of dentine tubules play an important role in the efficacy of an irrigation agent (23, 24). The hardness of the tissues nearest the pulp is lowest and is similar to dentine (25). In fact, Pashley et al. reported that dentine micro-hardness became lower as it progressed from the surface to the deep zone (19). Additionally, the amount of hydroxyapatite and the intertubular agent's mineral content are important factors in evaluating the hardness of dentine (26).

The application times of irrigants also influence tooth strength and structure (27). Studies have shown that a 15-min treatment of NaOCl of varying concentrations or a 10-min application of 6% NaOCl were sufficient to reduce dentine micro-hardness (28, 29, 30). Similarly, another study showed that dentine micro-hardness varied between treatments of 2.5% and 6% NaOCl for 5-20 min, with reductions being most pronounced upon treatment with 6% NaOCl. The same study also showed that the 5-min application caused the same change in dentine micro-hardness as the extended treatments (30).

Studies of CHX revealed that a 5-min treatment of the distal root canal dentine of the lower third molars with a 2% CHX/CHX Plus surface modifier solution caused no changes in micro-hardness. Similar studies have also reported that irrigation agents supplemented with surface modifiers failed to alter dentine micro-hardness (31). Additionally, Ari et al. reported that lower incisors treated for 15 min with 0.2% CHX did not experience alterations to dentine hardness (28), and the adhesive binding strength of teeth treated with CHX solution was also higher than teeth treated with other solutions (32). However, no studies have assessed the combined impact of 2% CHX on root canal dentine micro-hardness and surface roughness (29).

Arande-Garcia et al. evaluated the reducing effects of 17% EDTA, BioPure MTAD, SmearClear, and QMix irrigation solutions and found no differences (33). However, the current study found a significant reduction in dentine micro-hardness upon treatment with EDTA, CHX, or detergents containing irrigation agents.

QMix has been shown to increase the binding strength of the root canal filling material (34), which could be explained by the fact that this solution contains EDTA and CHX. QMix also significantly reduced the amount of bacteria on teeth; however, it was not as effective as NaOCl. Treatments with QMix for as little as 1 min were sufficient to decrease bacterial counts, but extended incubations were required for bactericidal activity (35).

The solubility of organic matter in NaOCl solutions could explain the observed increase in surface roughness (36). Notably, Ari et al. reported a significant increase in surface roughness upon treatment with NaOCl (28) that was also supported by assessments using atomic force microscopy (37).

Treatment with NaOCl (0.5%, 1%, 2.25%) significantly decreased the amino-phosphate ratio in dentine in a dose-dependent manner. However, the treatment time did not affect the amino-phosphate ratio as treatments of 0.5% NaOCl for 1, 5, or 10 min caused the same changes. Thus, it is possible to avoid changes in surface roughness caused by the dentine deproteinisation while obtaining high antibacterial activities over extended applications (38).

The softening effects of chemical irrigants on the dentine wall provide a clinical benefit during the preparation of small root canals (39). Surface roughness can also provide clinical benefits by increasing the micromechanical bond strength of the adhesive materials; however, rough surfaces also lead to plaque formation by encouraging bacterial adhesion (40). Thus, root canal dentine permeability and roughness positively influence the adhesion of canal fillers on the dentine surface (41, 42). However, an over-expansion of dentine may cause gaps that result in the diffusion of the filler onto the dentine surface (43).

The abrasiveness of irrigation solutions may cause changes to the dentine surface that could affect bacterial penetration or increased apical leakage (33). Therefore, further studies are required to determine the relationship between the optimum surface roughness, root canal strength, and channel-filler binding.

Conclusions

According to the results of microhardness it is observed that 5% NaOCl and QMix combination of both irrigation agents reduce the level of micro hardness of the dentine equal and more than CHX 2% irrigation agent.

According to the surface roughness results QMix combination of both irrigation agent is caused a further increase in the dentine surface roughness than others. 5% NaOCl and 2% CHX agents has been the caused equal and less increase on the surface roughness.

Ethical Approval: Ethics committee approval was received for this study from Dicle University.

Peer-review: Externally peer-reviewed.

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