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Effect of separated instruments on periapical pH using calcium hydroxide as an intracanal medicament in curved root canals

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ABSTRACT

Objective

To evaluate the effect of intracanal separated instruments with different lengths on periapical pH levels using calcium hydroxide (CH) as an intracanal medicament in curved root canals.

Materials and methods

120 teeth (root canal curvature >25°) were divided into six groups following the root canal preparation. In Group 1, 2mm and in Group 2, 4mm NiTi instruments were separated in the apical portion of the root canals and CH paste was applied. In Groups 3 and 4, no separated instrument but CH was applied. In Groups 5 and 6, neither a separated instrument nor CH was applied. The samples were placed inside a glass tube with distilled water. pH of this distilled water was measured at different time points.

Results: At all time points, pH values between the experimental groups were similar except at 1-day (Group 1 < Group 2, $P<0.05$). At the 2-day and 30-day time points, Group 3 showed higher pH values than Group 1 ($P<0.05$). At 7-day and 14-day points, pH values were similar.

Conclusion

The presence of a separated instrument with different lengths in curved root canals did not have a significant effect on the pH increase caused by CH used as an intracanal medicament.

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INTRODUCTION

Separation of endodontic files can occur,[1] particularly in the narrow and/or curved root canals[2] and in the apical third of the root canal.[3] When using rotary nickel-titanium (NiTi) instruments, which have been reported to be more resistant to deformation and separation and flexible than stainless-steel files (4), the incidence of instrument separation ranges from 0.4%–5%.[5] Regardless of the experience of the clinicians and the number of usage of the files, instruments can be separated without any visual warning signs.[6]

Removal of a separated instrument, particularly in the apical third of the root canal, can be challenging and has a lower success rate compared to traditional root canal treatment without file separation.[2] In curved root canals, the success rate in instrument retrieval is high for the separated instruments before the canal curvature, medium for those located in the curvature, and low for those located beyond the curvature.[4,7,8] Additionally, various complications, such as temperature increase on the external surface of the root, ledge formation, root canal transportation, decrease in root strength and perforations may occur during the removal process.[9] If a separated instrument cannot be removed, bypassing the separated instrument, shaping and obturating the coronal portion of the root canals, or performing retrograde endodontic surgery are the possible options.[1]

The separated instrument may prevent chemomechanical disinfection or obturation of the root canal and compromise the achievement of treatment goals, thereby affecting the prognosis of orthograde treatment,[1] especially if the apical part and/or the root canal area harboring the instrument fragment is not cleaned sufficiently.[10] In addition, the preoperative diagnosis of the pulp, especially the presence of periapical pathology, may adversely affect the treatment results.[1,10,11]

Calcium hydroxide (CH) is a widely used intracanal medicament. The effect of the CH depends on the alkaline pH caused by its rapid decomposition into hydroxyl (OH^-) and calcium ions (Ca^{+2}).[12] With a pH of around 12.5, CH can neutralise many microorganisms commonly found in infected root canals after short-term direct contact.[13] The alkalising effect of CH occurs by diffusion of OH^- ions through the apical foramen, ramifications, accessory canals and dentinal tubules.[12] Various factors such as the buffering effect of dentin,[14] the thickness of root canal dentin[15] and limited solubility may affect the pH level caused by CH and prevent CH from producing its expected biological effects.

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The relationship between separated instruments and the periapical pH value caused by the application of CH as an intracanal dressing in straight root canals was previously evaluated by AUTHOR *et al*.[16] This study aimed to evaluate the effect of the presence of separated instruments with different lengths on periapical pH levels using CH as an intracanal medicament in curved root canals. The null hypothesis was that the presence of a separated instrument does not affect the apical pH level when CH is used in curved root canals.

MATERIALS AND METHODS

This study was approved by the Ethics Committee of AUTHOR University, Medical Sciences (Decision no: 2017/130). Based on the target statistical power of 95%, when the type 1 error was determined as 0.05 ($\alpha = 0.05$) and the type 2 error was determined as 0.20 ($\beta = 0.20$), the number of teeth required for each group was determined as 20.

A total of 120 freshly extracted human mandibular and maxillary incisor teeth were used. Radiographs were taken from the buccal and proximal directions to confirm the root canal anatomy (Vertucci - Class I) (17), mature apex, no resorption, no root canal calcification, no previous root canal treatment and root canal curvature of >25°.[18] The teeth with a width of 2-2.5mm in bucco-lingual and mesio-distal directions at 2mm far from the root tip were used.

The teeth were kept in a 5% sodium hypochlorite (NaOCl) solution (Werax, SDD, İzmir, Turkey) for 1h, then the periodontal soft tissue residues and calculi were removed and washed under distilled water. All teeth were shortened to 14mm with a low speed 0.3mm thick diamond separator (930 D, Meisinger, Neuss, Germany) by flattening the incisal edge. A coronal access cavity was opened using a diamond bur (Diatech; Coltene Whaledent, Altststten, Switzerland) and a high-speed handpiece.

A size of 10-K file (VDW, Munich, Germany) was inserted into the root canal until the tip of the file was visible at the major apical foramen and the working length (WL) was determined as 1mm subtracting from this measurement under an operating microscope (Opmi Pico; Carl Zeiss, Oberkochen, Germany). If the 10-K file did not squeeze in the apical third part of root canal, the sample was renewed. Teeth were coated with two layers of nail polish, except for the apical tip of 3mm.

The samples were randomly divided into six groups ($n = 20$).

Group 1: Teeth were prepared with the Revo-S NiTi (Micro-Mega, Besancon, France) system using SC1 (#25, 0.06; Micro-Mega) in the coronal portion of the root canal and SC2 (#25, 0.04; Micro-Mega) to the WL, with rotating motion according to the manufacturer's recommendations. Apical patency was controlled with a 10-K file.

Next, unused Revo-S SC2 files were weakened 2mm from the tip using a low-speed diamond separator and washed in an ultrasonic bath to avoid debris. The instruments were mounted into a handpiece and placed into the root canals to the WL, and then the handpiece was activated. The instruments were separated at the weakened point by the rotating movement. The level and length of the separated instrument in the root canals were confirmed with radiographs. If the separated instrument was below or above the WL, the sample was replaced. The coronal part of the root canal above the separated instrument was manually prepared to #50 up to #70 using the step-back technique.

During the instrumentation, 5% NaOCl was used for irrigation. The final irrigation was performed with 5ml of 17% EDTA (Cerkamed Company, Stalowa Wola, Poland), 5ml of 5% NaOCl and 10ml of distilled water, respectively. Then, the root canals were dried with paper points (DiaPro, Diadent Group Int, Chungcheongbuk-do, Korea).

A CH paste mixed with propylene glycol (Merck, Darmstandt, Germany) with a ratio of 1g powder to 0.4ml liquid was placed into the root canals using a #25 Lentulo spiral filler (Paste carriers, Dimsan Dental, Ankara, Turkey) located 6mm deep to the coronal tip. The intracanal dressing was confirmed with radiographs. The access cavities were sealed with composite resin (EsFlow, Spident, Kore) and the crowns were sealed with two layers of nail polish.

The teeth were placed in glass test tubes containing 3.5ml of deionised distilled water. The tubes were stored in an incubator at 37°C with 100% humidity. After 1h and 1, 2, 7, 14, and 30 days, the pH of the solution in the tubes

Table I. Means and standard deviations of pH values for groups at different time points.

	Group 1 (2mm)	Group 2 (4mm)	Group 3 (Positive Control of Group 1)	Group 4 (Positive Control of Group 2)	Group 5 (Negative Control of Group 1)	Group 6 (Negative Control of Group 1)
1-hour	9,44 (9,21-9,9)^{A}	9,94 (9,5–10,2)^{A}	10,04 (9,6–0,3)^{A}	9,7 (9,51-10,03)^{A}	6,65 (6,59–6,75)^{B}	6,6 (6,5–6,7)^{B}
1-day	8,10±0,83^{A}	8,79±1,14^{B}	8,35±0,77^{AB}	7,94±0,68^{A}	7,2±0,12^{C}	7,11±0,10^{C}
2-day	6,96 (6,8–7,52)^{A}	7,01 (6,93–8,18)^{AB}	7,21 (7-7,67)^{B}	7,09 (7–7,4)^{AB}	7,06 (7,01–7,15)^{AB}	6,97 (6,89–7,04)^{AC}
7-day	7,9 (7,75–8,3)^{A}	7,88 (7,7–8,3)^{A}	8,27 (7,93–8,33)^{AB}	7,82 (7,55–8,02)^{AC}	7,78 (7,63–7,9)^{AC}	7,61 (7,5–7,7)^{D}
14-day	7,92 (7,7–8,39)^{A}	7,92 (7,73–8,11)^{A}	8,1 (7,84–8,56)^{A}	7,85 (7,73–8,35)^{A}	7,85 (7,5–8,5)^{A}	7,86 (7,64-8,45)^{A}
30-day	7,7 (7,56–8,31)^{A}	7,8 (7,6–8,54)^{ABC}	8,29 (7,73–8,63)^{B}	7,82 (7,7–7,95)^{AB}	7,67 (7,42–8,41)^{A}	7,57 (7,48–8,26)^{AC}

Different letters indicate statistical difference [$P<0.05$ for all time points; except 1 hour ($P<0.001$)].
Descriptive statistics values; Median (25-75) on the 1h, 1 and 7, 14 and 30-day time points; mean-standard deviation at 1-day time point.

www.sada.co.za / SADJ Vol. 78 No.4
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was measured using a pH meter (Hanna 83141; Hanna Instruments, Woonsocket, RI, USA) that was calibrated before each measurement with the known pH (4, 7 and 10) of the solutions. After every measurement, the teeth were placed in new tubes containing fresh deionised distilled water with a pH of 6.9.

Group 2: Same procedure as in Group 1, but the length of the separated instruments was set to 4mm.

Group 3 (Positive Control Group of Group 1): Same procedure as in Group 1 but without a separated instrument in the root canal.

Group 4 (Positive Control Group of Group 2): Same procedure as in Group 2 but without a separated instrument in the root canal.

Group 5 (Negative Control Group of Group 1): Same procedure as in Group 3 but without placement of CH paste.

Group 6 (Negative Control Group of Group 2): Same procedure as in Group 4 but without placement of CH paste.

Statistical analysis

Statistical analysis was performed using SPSS software (ver 20.0; SPSS Inc, Chicago, IL, USA). The normality of the distributions was confirmed by the Kolmogorov-Smirnov test. One-way ANOVA was used for the inter-group and between the groups' comparisons with the normal distribution, and the Kruskal-Wallis test for the groups with non-normal distribution. After the Kruskal-Wallis analysis of variance, Bonferroni correction was used for pairwise comparisons (P<0.05).

RESULTS

Table 1 shows the means and standard deviations of pH values for groups at different time points. At the 1h and 1-day time point, the experimental and the positive control groups showed significantly higher pH values than the negative control groups (P<0.05). At all time points, pH values between the experimental groups were similar (P>0.05) except at the 1-day time point [Group 1 (2mm) < Group 2 (4mm) P<0.05]. At the 1-day time point, Group 1 (2mm) and Group 4 (positive control of 4mm) showed significantly lower pH values than Group 2 (4mm; P<0.05). At the 2-day and 30-day time points, Group 3 (positive control of 2mm) showed significantly higher pH values than Group 1 (2mm; P<0.05).

DISCUSSION

The presence of a separated instrument in the canal during root canal treatment may have a negative effect on the outcomes of the treatment, depending on the location of the fracture, chemo-mechanical preparation stage and the periapical status.[1,10,11] However, there is no consensus yet on which treatment procedure should be performed in cases where the separated instrument cannot be removed. In this study, the alkalising effect of CH as an intracanal medication on periapical tissues was evaluated in the presence of separated instruments of two different lengths in the apical third of curved root canals. According to the results of this study, the alkalising effect of CH was not affected by the presence of separated instruments.

According to the results of this study, the highest pH values of the experimental and control groups were observed at 1h and 1-day time points (P > 0.05), similar to the results of AUTHOR *et al*[16] (and AUTHOR *et al*).[19] This may be due to direct contact of the medication through the apical foramen and the sudden release of the OH^-.[20] Also, the pH values decreased with time and the lowest values were detected at the 30-day time point. Similarly, AUTHOR *et al*[21] reported a decrease in the pH values toward 30 days. However, AUTHOR *et al* (16) and AUTHOR *et al*[22] reported an increase in pH over time. The buffering effect of dentin that can inactivate the alkalinising effect of CH[23] can explain the results of this study. The alkalising effect of CH is associated not only with time but also with the amount of CH paste in the root canal.[24] The dilution of CH paste over time may be another reason.

Based on the results, the effect of the presence of a separated instrument on pH levels was not significant at all time points compared to the control groups. Group 3 (Positive control of 2mm group) showed higher pH values than Group 1 (2mm) at all time points, but the difference was significant only at 1- and 30-day time points ($P < 0.05$). Similarly, at 2- and 4-day time points, Group 4 (Positive control of 4mm group) showed higher pH values than Group 2 (4mm; $P > 0.05$), while Group 2 (4mm) showed higher values at other time points ($P > 0.05$). These results are contrary to the results of AUTHOR *et al*[16] who reported that the presence of separated instruments had a significant effect compared with the control groups. The main method for CH to act is that the material diffuses through the apical foramen, which may be hindered by a separated instrument. The inconsistent results between studies can be explained by differences in method, such as the use of roots with different curvatures, differences in mechanical shaping, root dentin of different thicknesses resulting from the different shaping procedures, and the possibility that the separated instrument may produce a more inadequate physical plug-in curved root canals than in straight root canals. Also, a 2mm instrument may cause physical obstruction/compression of more than 4mm.

According to the results of this study, when the experimental groups with different lengths of separated instruments were compared, the effects on pH were similar at all time points except the 1-day time point [Group 1 (2mm) < Group 3 (4mm; $P < 0.05$)]. However, AUTHOR *et al*[16] reported significantly lower pH values in the presence of a 4mm separated instrument than 2mm. This difference may be due to the abovementioned reasons.

Several precautions were taken to standardise the samples. The diffusion of OH ions may be affected by the thickness of dentin and cementum, the volume of root canal at apical third, shape and structure of the apical foramen, the presence and number of lateral canals and ramifications;[22] the amount and size of dentinal tubules in the apical third,[23] and dentin buffering effect capacity. Moreover, the standardisation of the root canal curvature is important since the instrument that was separated was close to the maximum canal curvature position due to torsional fatigue.[25] Since the Schneider Method is based on the angle of curvature alone, it provides limited information compared to techniques that suggest using multifactorial measurement with three-dimensional (3D) imaging.[26] Also, the contact area between the separated instrument and the inner root canal dentin may affect the penetration of intracanal dressing. Another limitation of the study is that different NiTi files produced

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from metals that have gone through different production stages and treatments may affect the pH provided by CaOH and should be investigated in further studies.

CONCLUSION

Within the limitations of this study, the presence of a separated instrument in curved root canals did not have a significant effect on the pH increase caused by CH used as an intracanal medicament. Also, the effect of separated instruments of different lengths is similar. Additionally, in the presence of a separated instrument, to keep the alkalising effect of the CH paste high, it may be recommended to replace the medication every 24h. Further microbiological and clinical studies are needed to investigate the impact of a separated instrument in curved root canals using different types of medications.

Conflict of interest

None declared.

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CPD questionnaire on page 222

The Continuing Professional Development (CPD) section provides for twenty general questions and five ethics questions. The section provides members with a valuable source of CPD points whilst also achieving the objective of CPD, to assure continuing education.

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