Journal of Dentistry Indonesia

Volume 25
Number 2 *August*

Article 1

8-28-2018

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Journal of Dentistry Indonesia 2018, Vol. 25, No.2, 73-79
doi: 10.14693/jdi.v25i2.1206

ORIGINAL ARTICLE

In Vitro Evaluation of Apical Transportation during Calcium Hydroxide Paste Removal using Rotary Systems

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ABSTRACT

Objectives: To comparatively evaluate the incidence of apical transportation during calcium hydroxide paste removal using two rotary systems on 40° curved simulated root canal blocks. **Methods**: Two groups (n = 15; Group 1, iRace; Group 2, ProTaper) of simulated root canals (40° curvature) were instrumented until working length was achieved. Stereomicroscopic post-instrumentation images were captured, and the final file was inserted into canal to the working length. Calcium hydroxide paste with iodoform was placed until working length was achieved and removed after 7 days using the master apical file with copious irrigation. Stereomicroscopic images were taken after calcium hydroxide paste removal, with the final file inserted until working length was achieved to assess the incidence of apical transportation. Stereomicroscopic images were obtained and superimposed using Adobe Photoshop 8. **Results**: Mean angle change after rotary instrumentation and calcium hydroxide paste removal was observed in both groups and was greater in Group 2 than in Group 1. Superimposed images showed greater root canal deviation in Group 2 than in Group 1. **Conclusion**: Both file systems showed apical transportation upon calcium hydroxide paste removal from simulated-curved root canals. A greater angle deviation and apical transportation was recorded with ProTaper.

Key words: calcium hydroxide, iodoform, root canal

How to cite this article: Aditya Shetty, Lakshmi Nidhi Rao, Divya Tahiliani, Mithra N. Hedge. In vitro evaluation of apical transportation during calcium hydroxide paste removal using rotary systems. J Dent Indones. 2018;25(2):73-9

INTRODUCTION

Apical transportation is defined as the removal of the canal wall structure on the outside curve due to the tendency of files to restore them to their original liner shape during canal preparation. Mishaps are unfortunate incidences that may occur during an endodontic treatment. Thus, it is essential for clinicians to cultivate the "golden rules" for NiTi rotary preparation(1).

Biomechanical preparation is the most arduous and time-consuming phase, which involves meticulous cleaning and shaping of the canal. An ideal preparation calls for a continuous-tapered funnel shape while preserving the original anatomy with the largest diameter at the orifice, narrowing down to the smallest diameter at the apex, to ultimately provide an acceptable canal shape for filling in three dimensions(2,3).

A breach in the three-dimensional hermetic seal in obturation may cause residual microorganisms in the canal to proliferate, which is a major etiological factor of endodontic failures(4,5). One school of thought believes that a successful endodontic treatment requires the use of an intracanal medicament and has advocated the use of calcium hydroxide [Ca(OH)2](6,7).

A homogenous filling with the proper condensation of the material into the canal is required to expose its functional properties(8). Placing and removing calcium hydroxide is technically a simple procedure in straight and large-diameter canals. However, it is quite challenging to do so in curved and narrow canals. Thus, extra precaution is needed to ensure the complete removal of the paste before obturation, considering that the residual paste in the canal may deter the endodontic sealer penetration into the dentinal tubules[9], interfere with the sealing quality of the obturating material, and affect the canal patency during obturation[10]. Thus, complete calcium hydroxide removal from curved canals requires filing and copious irrigation with the risk of deviating from the original path that causes apical transportation. Therefore, the purpose of this study was to evaluate the incidence of apical transportation, if any, while removing calcium hydroxide with iodoform paste (Metapex, Meta Biomed, Korea) from biomechanically prepared canals using two different rotary systems: ProTaper (Dentsply Maillefer, Switzerland) and iRace (FKG Dentaire, Swiss) by measuring the angle change by Schneider's method and by superimposing stereomicroscopic images.

METHODS

Resin blocks

Simulated root canals (n = 20) in hard transparent resin acrylic blocks with a 40° canal curvature (Dentsply Mallifer), prepared according to the Schneider's method, were used. All canals had 19-mm working length, with a straight coronal part measuring 13 mm and a curved apical part measuring 6 mm in length. To allow the free movement of irrigating solutions, there was no apical stop and the foramen opened directly outside the block.

Preparation of the blocks

Two groups with 15 blocks each were established. Each resin block was embedded in an opaque mold that masked the specimen during preparation. This condition mimicked the natural environment for preparation, where only tactile sense was felt. All preparations were performed by a single operator, and the operator knew the direction in which the canal curved. All blocks were sequentially prepared with pre-curved ISO hand K-files #15, #20, #25 (Dentsply Mallifer) for apical patency. The preparation was conducted as per the manufacturer's instructions. The instrumentation was gently operated in an in-and-out pecking motion until the working length was reached and immediately withdrawn upon reaching the working length.

Group 1 (iRace- FKG Dentaire)

The iRace rotary system was used with R1- 15/.06, R2-25/.04, and R3-30/.04 (apical size 30) in a sequential manner until reaching the working length. Recapitulation was performed using ISO hand K-file #15 (Dentsply Mallifer)

Group 2 (ProTaper- Dentsply Maillefer)

The preparation was as follows: S1, S2 used 1-mm short of working length followed by F1 (20/.07), F2 (25/.08), and F3(30/.09) (apical size 30) until reaching the working length. Recapitulation was performed using ISO hand K-file #15 (Dentsply Mallifer). The canals were flushed with EDTA GlydePrep (Dentsply Mallifer), saline, and 2.5% sodium hypochlorite using disposable plastic syringe with a 27-gauge needle, penetrating as deep as possible without binding to the block. The canals were dried with paper points. The file flutes were cleaned with ethyl alcohol swab in between instrumentation to remove the resin debris.

Calcium hydroxide placement

Calcium hydroxide with iodoform paste (Metapex) was inserted into the measured canal using the applicator tip available with the kit.

Calcium hydroxide removal

Calcium hydroxide with iodoform paste was removed completely from the canals using ISO hand K-files #15-25 and master apical file (R3 for Group 1 and F3 for Group 2) with intermittent saline and 2.5% sodium hypochlorite irrigation. The canals were considered to be clean and free of paste when no residual paste was left behind and clear fluid was flushed out from the canals. The canals were then dried with paper points.

Assessment of root canal preparation

The acrylic blocks were removed from the opaque medium and analyzed under stereomicroscope (Lawrence & Mayo) at 8 × 10X magnification after rotary instrumentation and after calcium hydroxide paste removal. Photographs were then taken and printed.

Canal measurement

The canal curvatures were determined by three independent examiners, and an average of the three measurements was considered for further analysis. The canal was measured using the Schneider's method, which involves creating a point in the middle of the file at the level of the canal orifice. A straight line was drawn parallel to the file image from the point "a" to a point where the instrument deviated from the line (point "b"). A third point "c" was made at the apical foramen, and the line was drawn from this point to point "b". The angle formed by the intersection of the lines was measured as the canal curvature[11]. A protractor and 0.5-mm lead pencil were used for measurements. The preparation was considered unacceptable (transportation) in case of observations of canal straightening and any deviation in the apical foramen among the specimens under the stereomicroscope.

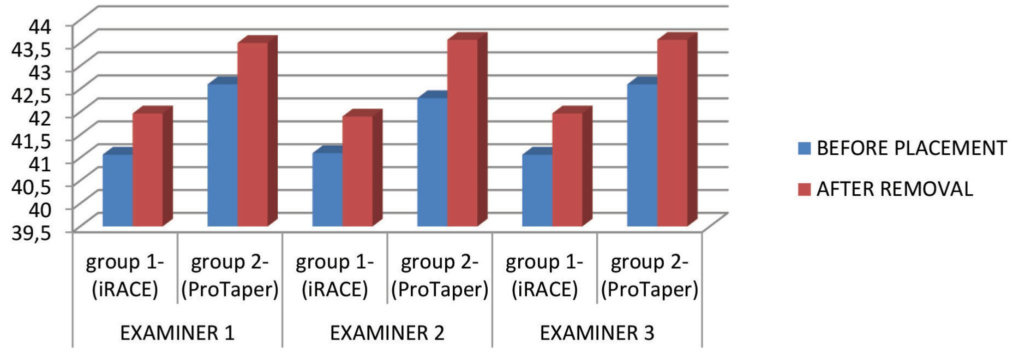
Canal shape

The canal shape was observed by superimposing the stereomicroscopic images using Adobe Photoshop 8 software. The images before and after calcium hydroxide paste removal were superimposed to examine any delineation in the path of the root canal.

Table 1. One-sample t-test showing the mean angle value of the root canal

GROUP		Mean	Std. Deviation	P value	Mean Difference
Group 1 (iRACE)	BEFORE PLACEMENT Examiner 1	41.067	0.3716	<0.001	1.0667
	BEFORE PLACEMENT Examiner 2	41.1	0.2803	<0.001	1.1
	BEFORE PLACEMENT Examiner 3	41.067	0.3716	<0.001	1.0667
	AFTER REMOVAL Examiner 1	41.967	0.4419	<0.001	1.9667
	AFTER REMOVAL Examiner 2	41.9	0.4706	<0.001	1.9
	AFTER REMOVAL Examiner 3	41.967	0.4419	<0.001	1.9667
Group 2 (ProTaper)	BEFORE PLACEMENT Examiner 1	42.6	0.5412	<0.001	2.6
	BEFORE PLACEMENT Examiner 2	42.3	0.4551	<0.001	2.3
	BEFORE PLACEMENT Examiner 3	42.6	0.5412	<0.001	2.6
	AFTER REMOVAL Examiner 1	43.5	0.5669	<0.001	3.5
	AFTER REMOVAL Examiner 2	43.567	0.5627	<0.001	3.5667
	AFTER REMOVAL Examiner 3	43.567	0.5627	<0.001	3.5667

Std. Deviation: Standard Deviation



Y-axis: simulated root canal angle measurement.

Figure 1. Simulated root canal angle measurement before and after calcium hydroxide placement by three examiners

Data analysis

The data was recorded on Excel sheet (Microsoft Office 2010) and subjected to statistical analysis.

RESULTS

Data analysis was performed using SPSS 19 software. One-sample t-test was performed to compare the angle change to the standard value of 40°. Statistically significant difference was noted ($p < 0.001$) between the two groups and between the intra-group specimens by all examiners.

The mean angles measured after instrumentation (before calcium hydroxide placement) in Group 1 (iRAce, FKG Dentaire) by three examinations were 41.06, 41.1, and 41.06, while those for Group 2 (ProTaper, Dentsply Maillefer) were 42.6, 42.3, and 42.6, respectively. The mean angles after calcium hydroxide removal for Group 1 were 41.96, 41.9, and 41.96, while those for Group 2 were 43.5, 43.56, and 43.56, respectively. The mean difference in the angle in comparison with the standard value of 40° was greater in Group 2 (3.5°) than in Group 1 (1.9°) (**Table 1; Figure 1**).

Paired t-test was conducted to compare the angle difference among the examinations of each group. Statistically significant difference ($p < 0.001$) was obtained in the angle formed (**Table 2**).

F-test was conducted to examine the inter-observer variability. The comparison of the angle measured before and after placement of calcium hydroxide in the three examinations in groups 1 and 2 was >0.9, which indicates excellent agreement (**Tables 3, 4**).

Table 2. Paired t-test showing the mean angle value of the root canal

Group			Mean	Std Deviation	Mean	Std Deviation	P value
Group 1 (iRace)	Pair 1	Before paste placement Examiner 1	41.067	0.3716	−0.9	0.207	<0.001
		After paste removal Examiner 1	41.967	0.4419			
	Pair 2	Before paste placement Examiner 2	41.1	0.2803	−0.8	0.3684	<0.001
		After paste removal Examiner 2	41.9	0.4706			
	Pair 3	Before paste placement Examiner 3	41.067	0.3716	−0.9	0.207	<0.001
		After paste removal Examiner 3	41.967	0.4419			
Group 2 (ProTaper)	Pair 1	Before paste placement Examiner 1	42.6	0.5412	−0.9	0.2803	<0.001
		After paste removal Examiner 1	43.5	0.5669			
	Pair 2	Before paste placement Examiner 2	42.3	0.4551	−1.2667	0.4577	<0.001
		After paste removal Examiner 2	43.567	0.5627			
	Pair 3	Before paste placement Examiner 3	42.6	0.5412	−0.9667	0.2289	<0.001
		After paste removal Examiner 3	43.567	0.5627			

Std. Deviation: Standard Deviation

Table 3. Inter-observer comparison of the variables before placement of calcium hydroxide paste using F-test (Intraclass Correlation Coefficient)

GROUP		Intraclass Correlation[b]	95% Confidence Interval		F-Test with True Value 0			
			Lower Bound	Upper Bound	Value	df1	df2	Sig
Group 1 (iRACE)	Average Measures	.901[c]	.764	.964	10.081	14	28	.000
Group 2 (ProTaper)	Average Measures	.936[c]	.847	.977	15.526	14	28	.000

Two-way mixed effects model, where people effects are random and measures effects are fixed.
b. Type C intraclass correlation coefficients using a consistency definition—the between-measure variance was excluded from the denominator variance.
c. This estimate was computed, with the assumption that the interaction effect was absent, because it was not estimable otherwise.

Table 4. Inter-observer comparison of the variables after removal of calcium hydroxide paste using F-test

GROUP		Intraclass Correlation	95% Confidence Interval		F-Test with True Value 0			
			Lower Bound	Upper Bound	Value	df1	df2	Sig
Group 1 (iRACE)	Average Measures	.983[c]	.959	.994	57.308	14	28	.000
Group 2 (ProTaper)	Average Measures	.989[c]	.974	.996	90.538	14	28	.000

Two-way mixed effects model, where people effects are random and the measured effects are fixed.
b. Type C intraclass correlation coefficients using a consistency definition—the between-measure variance was excluded from the denominator variance.
c. This estimate was computed with the assumption that the interaction effect was absent, because it was not estimable otherwise

Figure 2. Adobe Photoshop superimposition image of the simulated root canals before (red) and after (green) calcium hydroxide paste removal.

Thus, the results showed an angle increase after NiTi rotary biomechanical preparation and after calcium hydroxide removal from the canals in both the groups.

Adobe Photoshop images of the simulated root canals before and after calcium hydroxide removal were superimposed (**Figure 2**), and greater deviation from the original axis, loss of centrality was observed in Group 2 specimens than in Group 1 specimens. Greater apical transportation was noted in Group 2 than in Group 1 after calcium hydroxide removal. All canals remained patent following the instrumentation; however, a few specimens in Group 2 had calcium hydroxide paste residues in the apical portion.

DISCUSSION

Endodontic success can be achieved with the clinician's ability and skill to maintain the canal shape while effectively debriding it at every step of the biomechanical preparation. Calcium hydroxide is widely used as an inter-appointment therapeutic dressing[12]. In this study, calcium hydroxide with iodoform paste (Metapex) was used according to manufacturer's instructions to achieve a deep, dense homogenous three-dimensional filling. Until date, two experimental simulations have been proposed and used in evaluating the root canal apical transportation: extracted human teeth and simulated root canals in resin blocks. Although the use of natural teeth mimics the clinical scenario, it possess large morphological variations[13], thus making it challenging for the operator to standardize the study methodology.

Hence, our study used high hardness resin (Knoop = 40) acrylic blocks, which according to Weine is almost close to dentine, 40 kg/mm^2 in natural teeth[14]. Standardizing the study conditions by maintaining the same working dimensions such as the length, diameter, and angle of curvature, which allowed direct pre-instrument and post-instrument canal angle measurements[15]. Therefore, it has been validated that such blocks can be used as reliable experimental models for the study of endodontic preparation techniques[16,17]. However, there are certain disadvantages of using the simulated block. For instance, the chemical reaction of calcium hydroxide paste (Metapex) differs from its reaction in the real root canal environment and the heat generation, while using rotary instruments may soften the resin material or lead to the binding of the cutting blades and separation of the instrument[18,19]. In 1989, Ahmad found no difference in the incidence of apical transportation between human extracted teeth and resin blocks[20].

The Schneider's technique was the first root canal angle measuring method that is still acceptable, considering that it is a simple and reliable mode for measuring canal curvatures[11,21]. Pruett et al. indicated the downside of this technique, stating that the radius of the curvature is not measured by this method[22]. Long, narrow, and curved canals are at the highest risk of developing apical transportation during instrumentation[23], as instruments tend to straighten in the outer curvature; this deformity can cause serious issues during root canal therapy. Thus, an optimum enlargement is essential as wider preparation can cause canal straightening and undesirable weakening of the tooth structure, whereas minimal enlargement may leave tissue remnants and infected dentine behind[24]. According to Lambrianidis et al.[25,26], no single technique can completely remove calcium hydroxide from the root canal.

In this study, ProTaper instrumentation removed more resin on the outer side of the curvature in comparison to that in the inner side of the curvature. In a similar study by Calberson et al. in 2004, a deviation in the path of canal was noted on assessment using image superimposition, causing apical transportation[27]. Owing to its alkaline pH and the ability to rapidly dissociate into hydroxyl and calcium ions, calcium hydroxide has proven beneficial in various clinical scenarios. Its duration of action ranges from 7 days as an intracanal medicament to 6–24 months for apexification[28].

Calcium hydroxide paste needs to be removed completely from the root canals before sealing and obturating with permanent materials. According to Silva et al., as the clinician proceeds closer to the apical third, the difficulty level rises and the efficiency reduces in the removal of the intracanal dressing; predominantly due to anatomical complexities in this region[29]. *In vitro* studies by Lambrianidis et al.[25] described that calcium hydroxide paste, which was three-dimensionally packed apically, may jeopardize the outcomes of the treatment if residues are left behind on removal[25]. These remnants can obstruct sealer penetration into the dentinal tubules and may cause incomplete adhesion of resin sealers to the dentine, which in turn can remarkably increase the apical leakage of the root canal-treated teeth[30]. In addition, the residual paste may block the apical area of the root canal, markedly affecting the apical patency of the curved canals or may also interact with eugenol sealers, deteriorating their physical property by making them brittle and granular[31]. Hence, Buchanan's emphasis on maintaining apical patency throughout the endodontic treatment is therefore essential[32]. On facing an apical blockage in the canal, the file will go in a straight direction, thereby transporting the canal anatomy. Similarly, White et al.[33] indicated that the use of calcium hydroxide for 5 weeks decreases the root dentine strength, which could favor apical transportation in the long period of time. Thus, the complete removal of calcium hydroxide from the root canal before obturation becomes mandatory.

Our study revealed that three out of 15 specimens had incomplete calcium hydroxide removal from the apex of the canal with ProTaper instrumentation in comparison to 0 out of 15 specimens with iRace rotary instrument. This difference in the outcome may be attributed to the metallurgy of ProTaper and its tendency to straighten[13]. Ozer et al.[34] demonstrated a higher degree of canal straightening of 1.2° with ProTaper as compared to 0.7° with iRace rotary instruments. This study suggested that the ProTaper file system should be implemented in combination with files of decreasing taper size to prepare the apical third of the root canal in order to prevent apical transportation.

CONCLUSION

Within the limitation of this study, complete calcium hydroxide removal was achieved with the use of the iRace rotary system. A greater angle deviation and apical transportation was recorded with varying taper rotary system with ProTaper as compared to that with iRaCE. The loss of centrality was observed for all specimens. Thus, both the file systems showed apical transportation on removing the calcium hydroxide paste from simulated-curved root canals.

ACKNOWLEDGEMENT
None other than the contributors are involved.

CONFLICT OF INTEREST
The authors report no conflict of interests related to this manuscript.

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(Received March 4, 2018; Accepted August 10, 2018)