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Effect of post length and diameter on remaining dentine thickness in maxillary central and lateral incisors

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Abstract

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Aim To investigate the effect of root canal and post-space preparation on the remaining dentine thickness in the apical region of maxillary central and lateral incisors.

Methodology Fifty extracted maxillary incisors (25 centrals and 25 laterals) were mounted and then sectioned at two levels: 5 and 7 mm from the apex. Computerized images were obtained and a digital image analysis system was used to measure dentine thickness for each section at eight sites: labial, mesial, distal, palatal, mesio-labial, disto-labial, mesio-palatal and disto-palatal. Measurements were repeated at baseline and after both root canal and post-space preparation. Central and lateral incisors were divided into five groups each ($n = 5$) according to the drill used for post-space preparation: Groups 1 through 4 were prepared using Parapost drills sizes 4.5, 5, 5.5 and 6 respectively. For group 5, size 4 Gates Glidden was used.

Results For both teeth, and at the two levels there was a significant difference ($P < 0.001$) between the baseline dentine thickness and that remaining after post-space preparation at all sites. There was a statistically significant difference ($P = 0.007$) between the remaining dentine thickness at 5 and 7 mm at all sites. The average amount of dentine removed ranged from 0.20 to 0.52 mm. In all groups, and for both teeth, some specimens had <1 mm of remaining dentine thickness.

Conclusions Posts should be used carefully when restoring root filled maxillary incisors.

Keywords: central and lateral incisors, posts, remaining dentine thickness.

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Introdution

A pulpless tooth has commonly lost substantial amounts of tooth structure as a result of caries, previous restorations, trauma, fracture and the access preparation for root canal treatment (Morgano *et al.* 2004). Because of that, the use of a post to provide retention for the core and the final restoration has become a common restorative procedure for root filled teeth (Cheung 2005). Preparation of a post space can lead to stripping of the canal and root perforation (Abou-Rass *et al.* 1982). Knowledge of root anatomy, as well as being familiar with the post system is crucial (Gutmann 1992). Failures involving the post and the final restoration can result in fracture of the post, loss of retention of the post, and/or most commonly fracture of the remaining tooth structure (Goodacre *et al.* 2003). Preparations for posts may weaken the tooth. The potential for root filled teeth to fracture increases proportionally with the amount of tooth structure removed (Guzy & Nicholls 1979, Trope *et al.* 1986, Sirimai *et al.* 1999, Marchi *et al.* 2008). Other factors that can affect the strength of root filled teeth include the characteristics of the post, such as the material composition, modulus of elasticity, diameter, and length (Cormier *et al.* 2001, Bell *et al.* 2005, Garoushi

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et al. 2007, 2009, Adanir & Belli 2008, Giovani *et al.* 2009, McLaren *et al.* 2009, Chuang *et al.* 2010, Hatta *et al.* 2011, Le Bell-Rönnlöf *et al.* 2011).

Ideally, the length of the post should be two-thirds of the root length, or at least the same length as the clinical crown (Holmes *et al.* 1996, Fuss *et al.* 2001, Büttel *et al.* 2009). Recently, this has been disputed since it has been found that increasing the length of the post does not increase fracture resistance and is usually accomplished with additional canal enlargement, which could decrease the strength of the root (Pilo *et al.* 2008, Giovani *et al.* 2009, Chuang *et al.* 2010). It is also important during post-space preparation to maintain an apical seal of gutta-percha. For this purpose, it is recommended to leave 4–5 mm of gutta-percha after post space preparation (Mattison *et al.* 1984, Raiden & Gendleman 1994, Fox & Gutteridge 1997). Similarly, it is recommended to keep the post-space preparation to no more than one-third of the root width, or leaving at least 1 mm of dentine around the post (Huysmans *et al.* 2007). It has been reported that the optimum post diameter required to minimize the likelihood of both post failures and root fractures is approximately one-quarter of the root diameter, measured at the root face (Mou *et al.* 2009). Narrow diameter posts failed under loading without root fracture, while large diameter posts tolerated loading forces but resulted in root fracture.

The purpose of this laboratory study was to evaluate remaining dentine thickness (RDT) and the canal area of maxillary central and lateral incisors after post-space preparation and to relate this to the distance from the apex and to the diameter of the twist-drill used for preparation. The null hypothesis tested was that, for root filled maxillary central and lateral incisors, the RDT will be more than 1 mm after post-space preparation irrespective of the length or diameter of the post drill.

Materials and methods

Teeth selection, preparation and sectioning

Fifty maxillary incisors (25 centrals and 25 laterals) freshly extracted with fully formed roots and free of caries and restorations were used. Ethical approval of the Human Rights Committee and Research Committee at Kuwait University was obtained. Radiographs of the teeth were taken from the labial aspect with E-speed films (Eastman Kodak, Rochester, NY, USA) to ensure that the canal spaces were patent, the roots were fully developed, and relatively straight (maximum 10-degree curve) (Schneider 1971). The teeth were cleaned and stored in saline. The lengths of the teeth were measured using an endodontic ruler and only teeth of similar length were selected. Root thickness was measured at the cemento-enamel junction on the radiographs and only teeth of similar mesiodistal root dimensions were included.

Access cavities were prepared using high-speed carbide burs and water spray. Size 10 K-files were placed into each canal until the tip of the file was visible at the apical foramen to establish the working length 0.5 mm short of the point at which the file protruded through the foramen. The incisal edges were flattened using diamond discs in order to achieve the same working length for all teeth (23 mm). The access cavities were sealed with cotton pellet and zinc-oxide based Intermediate Restorative Material (IRM; Dentsply Caulk, Milford, DE, USA). The apices of the teeth were sealed with a small ball of utility wax. Then, using a putty mould the teeth were mounted to the level of cemento-enamel junction in clear acrylic resin. The roots were oriented parallel to the long axis of the mould. After hardening, the resin blocks were trimmed to a smaller size and two parallel grooves were prepared on the labial side of each block (Using size 6 round burs in a slow-speed handpiece). X-shaped grooves were also prepared on the palatal side of each block to help orientation later in the study (Fig. 1a,b). For each resin block the original putty mould was used to make an acrylic mounting resin cube to hold the sections of teeth together. The mounting cubes were prepared in two halves with interlocking sides so they could be reassembled in a reproducible way (Fig. 1c,d). For each embedded tooth, two cuts were made perpendicular to the long axis of the tooth with a 0.3-mm diamond saw (Isomet low speed saw; Buehler, Lake Bluff, IL, USA) at 5 and 7 mm from the apex. Computerized images were obtained for each section with a digital camera (Leica DC200; Leica Microsystems Wetzlar, GmbH, Wetzlar, Germany) linked to a stereomicroscope (Leica MZ6) using a fixed distance and the same magnification (10X). The microscope was linked to a computer with a digital image analysis system, (IM 500; Leica), which allowed measurement of the thickness of the dentine with an accuracy of 0.001 mm and calculation of the cross-sectional area. For each section, the dentine thickness (DT) was measured at eight sites: mesial, distal, labial, palatal, mesio-labial, mesio-palatal, disto-labial and disto-palatal. These areas were marked with a permanent

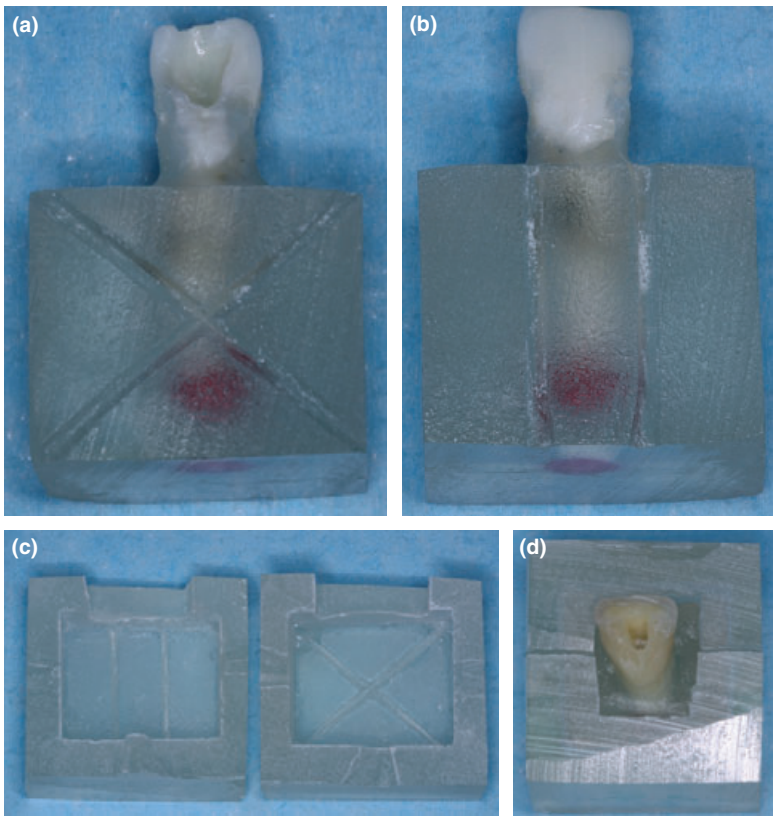

Figure 1 (a) Photograph of a mounted tooth showing the X-shaped grooves on the palatal side of the resin block. (b) Photograph of a mounted tooth showing the parallel grooves on the labial side of the resin block. (c) Photograph of the acrylic mounting resin cubes that was used to hold the tooth sections together. (d) Photograph of a tooth inside the mounting cube.

marker for reproduction of the measurements (Figs 2 and 3). The cross-sectional area of the canal was also measured (Fig. 4). After this initial imaging the tooth slices were repositioned into their respective cubes.

Root canal treatment

The cubes were hand-held for root canal treatment procedures according to a standardized protocol. Canal preparation was performed using the K3 Nickel-Titanium rotary system (SybronEndo, Orange, CA, USA) used in a slow speed reduction handpiece (300 rpm) powered by a torque limited electric motor. Orifice shapers size 25, 0.10 taper and size 25, 0.08 taper were used for straight line access. This was followed by a crown down preparation to working length, proceeding in 1 mm increments, starting from size 60, 0.06 taper K3 files to size 20, 0.06 taper instruments. The master apical file for all teeth was size 30. Instruments were coated with lubricant (File-Eze, Ultradent; South Jordan, UT, USA) before each insertion in the canal. The instruments were used according to the manufacturer's instructions using a gentle in and out motion. The instrument was withdrawn if resistance was felt and changed to the next instrument in size. Teeth were irrigated using sodium hypochlorite solution (2.5%, prepared in house by mixing Clorox® regular (the Clorox Company, Oakland, CA, USA) with sterile water in 1 : 1 ratio) using a 27 gauge needle after each use of file. Then canals were dried with size 30 paper points to the working length. The slices were disassembled from the acrylic block to repeat the same measurements as described previously.

Post-space preparation

After taking the second measurements, the slices were repositioned into their respective cubes and then presented to a prosthodontist for post-space preparation. Central and lateral incisors were divided into five groups each. The first four Groups were prepared using Parapost® Fiber Lux™ drills (used with Esthetic Post System, a parallel-side post) (Coltène/Whaledent, Cuyahoga Falls, OH, USA) sizes 4.5, 5, 5.5 and 6 respectively. The diameters of these drills (in mm) are: 1.14, 1.25, 1.40 and 1.50. For the fifth group size 4 Gates Glidden (G.G.) (diameter 1.1 mm) was used for post-space preparation.

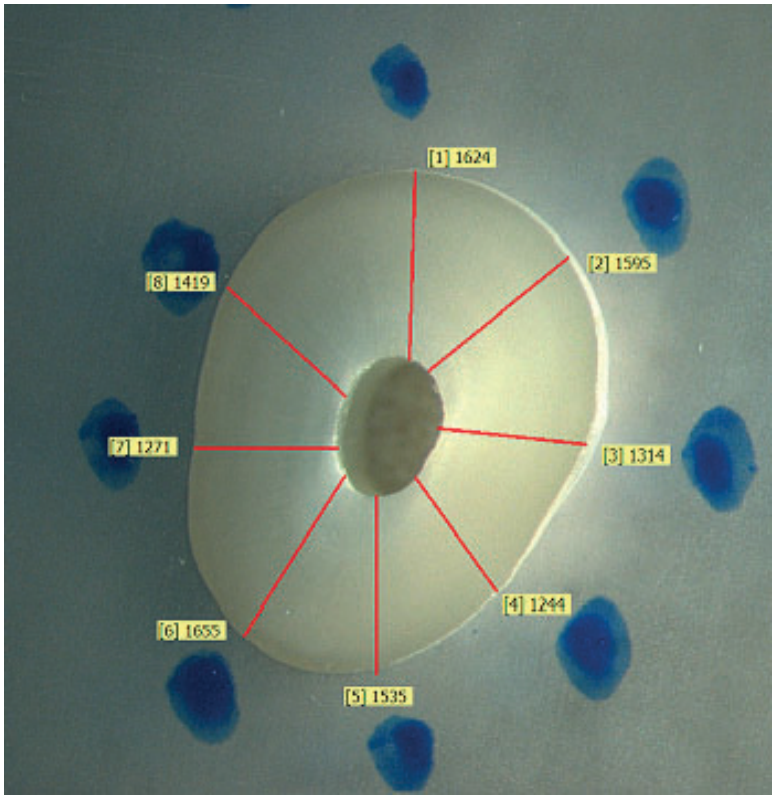

Figure 2 Photograph showing a lateral incisor root slice at 5 mm from the working length with remaining dentine thickness measurements before instrumentation.

Along with the teeth, the prosthodontist received the followings: a radiograph of the tooth, the working length of the tooth, a set of size 4 G.G. drills with rubber stops, an endodontic ruler and eight kits of ParaPost Fiber Lux. In all of the groups the canal space was prepared to the same length that is 4 mm short of the working length. Post-preparations were performed according to the manufacturers' instructions with a

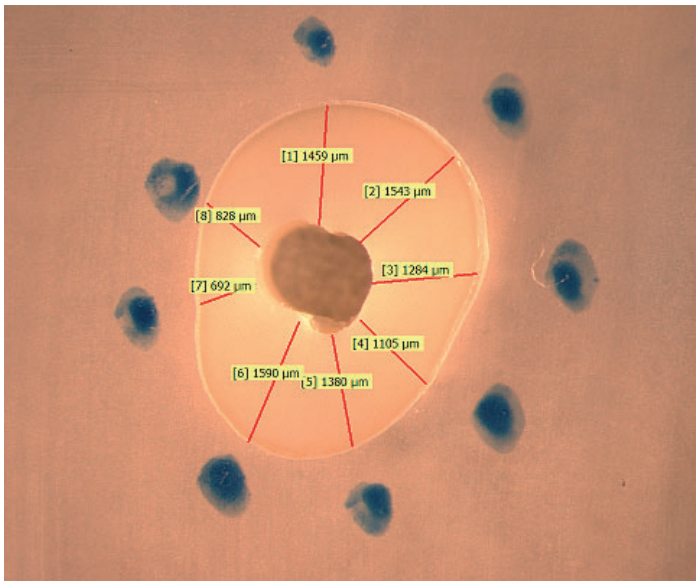

Figure 3 Photograph showing a lateral incisor root slice at 5 mm from the working length showing the measurements of the remaining dentine thickness after post-space preparation.

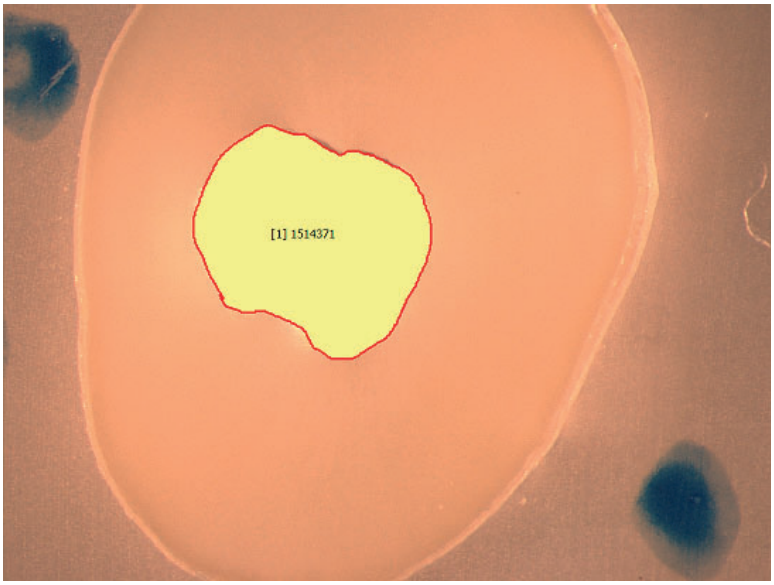

Figure 4 Photograph of a lateral incisor root slice at 5 mm from the working length showing the measurement of the canal area.

slow-speed handpiece and in a random order. The twist-drills and the G.G. drills were cleaned after each use and a new set was employed for each group of five preparations. Teeth were irrigated with 2.5% sodium hypochlorite solution using a 27 gauge needle to remove dentine debris. Post-space preparations were dried with paper points and the slices were dissembled from their blocks to repeat the same measurements taken before.

All measurements were taken by two examiners independently and at two different occasions and the average of the two readings was taken. Prior to the investigation, calibration of both examiners was undertaken by reading five pilot samples, which were not included in the study. A Kappa value of 0.9 was achieved.

Statistical analysis

The data were analyzed statistically with SPSS 17.0 (SPSS Inc., Chicago, IL, USA) using descriptive statistics and two-way ANOVA ($P < 0.05$). Furthermore, comparison by pairs between baseline measurements and those after post-space preparation was achieved using the paired *t*-test ($P < 0.05$). Independent variables were 'group' and 'level' inside the canal (5and 7 mm). Dependent variables were: (i) RDT in eight directions, (ii) area of the canal and (iii) number of teeth with <1 mm remaining dentine thickness. The average amount of dentine at removed each site was calculated as the difference between the average of the initial DT and the average of RDT after post-space preparation. The total amount of dentine removed was also calculated for each group as the total of the removed dentine at each of the eight sites for that group.

Results

At 5 mm from the working length, the mean RDT (in mm) for central and lateral incisors are presented in Tables 1 and 2 respectively. For central incisors, the paired-t test revealed significant differences ($P < 0.001$) between the mean baseline DT and the RDT after post-space preparation at all eight sites. As shown in Table 1, the average amount of dentine removed ranged from 0.20 mm (lingually) to 0.52 mm (labial). The total amount of removed dentine was highest when drill size 6 was used (3.3). There was a significant difference between drills size 5.5 and 6 and the other groups (drills 4.5, 5 and G.G size 4) in the total amount of dentine removed ($P = 0.005$).

For lateral incisors, at all the eight sites, the paired-t test revealed a significant difference between the baseline DT and the RDT after post-space preparation ($P < 0.001$). As shown in Table 2 the average amount of removed dentine ranged from 0.22 mm (distal) to 0.42 mm (labial). The total amount of dentine removed was highest when drill size 6 was used (3.6). There was significant difference between drill size 6 and the other groups in the total amount of dentine removed ($P = 0.04$). There was no significant difference between drill size 4.5 and G.G. size 4 and also between drill size 5 and drill size 5.5 ($P = 0.15$).

Table 1 Mean of RDT (mm) at 5 mm from the working length of central incisors for the five groups at eight locations

	Parapost drill size				G.G.size		
Location	4.5	5	5.5	6	4	Average	Average of Dentine Removed ± SD
Labial							
B	1.7	1.8	1.7	1.6	1.7	1.70	0.52 ± 0.12
RC	1.6	1.6	1.5	1.5	1.5	1.54	
P	1.2	1.2	1.1	1.0	1.4	1.18	
Palatal							
B	1.8	1.9	1.8	1.7	2.0	1.84	0.20 ± 0.14
RC	1.6	1.9	1.8	1.6	2.0	1.78	
P	1.6	1.9	1.5	1.3	1.9	1.64	
Mesial							
B	1.5	1.5	1.5	1.6	1.6	1.54	0.24 ± 0.14
RC	1.4	1.4	1.4	1.5	1.6	1.46	
P	1.4	1.3	1.3	1.1	1.4	1.30	
Distal							
B	1.4	1.5	1.7	1.5	1.7	1.56	0.30 ± 0.08
RC	1.2	1.5	1.6	1.4	1.6	1.46	
Post	1.1	1.2	1.4	1.4	1.4	1.26	
Mesio-Labial							
B	1.6	1.7	1.7	1.7	1.7	1.68	0.28 ± 0.04
RC	1.5	1.5	1.6	1.6	1.6	1.56	
Post	1.3	1.4	1.4	1.4	1.5	1.40	
Disto-Labial							
B	1.6	1.7	1.8	1.6	1.7	1.68	0.40 ± 0.11
RC	1.4	1.6	1.7	1.5	1.5	1.54	
Post	1.2	1.2	1.4	1.4	1.4	1.28	
Mesio-Palatal							
B	1.7	1.8	1.6	1.6	1.8	1.70	0.22 ± 0.18
RC	1.6	1.8	1.5	1.5	1.8	1.64	
Post	1.6	1.8	1.3	1.1	1.6	1.48	
Disto-Palatal							
B	1.6	1.8	1.8	1.7	1.9	1.76	0.26 ± 0.11
RC	1.6	1.8	1.8	1.6	1.8	1.72	
Post	1.5	1.6	1.5	1.4	1.5	1.50	
Total of removed dentine	2.0	2.1	2.7	3.3	2.0		2.42

B, Baseline; RC, After root canal preparation; P, After post-space preparation; RDT, remaining dentine thickness.

Tables 3 and 4 show the mean RDT (in mm) for central and lateral incisors at 7 mm from the apex. For central incisors, the average thickness of dentine removed ranged from 0.20 mm (palatal) to 0.42 mm (labial). The total amount of dentine removed was highest when drill size 6 was used (3.6) and it was significantly different than the other groups. The paired-t test revealed significant differences ($P = 0.005$) between the baseline DT and the RDT after post-space preparation at all the sites except the palatal.

For lateral incisors, the average amount of dentine removed ranged from 0.26 mm (palatally) to 0.34 mm (mesial). The total amount of removed dentine was highest for drill size 6 (3.6) and lowest for drill size 4.5. Both of these groups were significantly different from each other and from the other groups ($P = 0.03$). The paired-t test revealed significant differences ($P = 0.005$) between the baseline DT and the mean RDT after post-space preparation at all the sites.

The mean RDT at section 7 was significantly higher ($P = 0.007$) than that at section 5 at all sites and for the two teeth.

Table 5 represents the average canal area at both 5 and 7 mm from the apices at baseline and after endodontic and post-space preparation for both central and lateral incisors. As shown the average canal area increased more than 4 times after post-space preparation at the two levels and for the two teeth. Drill size 6 resulted in the largest area after post-space preparation (statistically significant; $P < 0.001$) for both central and lateral incisors and at the two levels. There was no

Table 2 Mean RDT (mm) at 5 mm from the working length of lateral incisors for the five groups at eight locations

	Parapost drill size				G.G. size		
Location	4.5	5	5.5	6	4	Average	Average of dentine removed ± SD
Labial							
B	1.6	1.9	2.0	1.6	2.0	1.82	0.42 ± 0.14
RC	1.4	1.7	1.9	1.5	1.8	1.66	
P	1.2	1.5	1.5	1.0	1.8	1.40	
Palatal							
B	1.6	2.0	1.9	1.7	1.9	1.82	0.30 ± 0.14
RC	1.5	1.9	1.8	1.6	1.8	1.72	
P	1.5	1.8	1.5	1.2	1.6	1.52	
Mesial							
B	1.2	1.4	1.3	1.2	1.2	1.26	0.30 ± 0.06
RC	1.1	1.3	1.2	1.0	1.0	1.12	
P	1.0	1.1	1.0	0.8	0.9	0.96	
Distal							
B	1.1	1.2	1.2	1.3	1.5	1.26	0.22 ± 0.04
RC	1.0	1.1	1.1	1.2	1.3	1.14	
P	0.9	1.0	1.0	1.0	1.3	1.04	
Mesio-Labial							
B	1.4	1.7	1.8	1.5	1.7	1.62	0.30 ± 0.06
RC	1.3	1.6	1.7	1.3	1.5	1.48	
P	1.2	1.4	1.5	1.1	1.4	1.32	
Disto-Labial							
B	1.3	1.6	1.5	1.5	1.8	1.54	0.32 ± 0.04
RC	1.2	1.5	1.4	1.4	1.7	1.44	
P	1.0	1.3	1.2	1.1	1.5	1.22	
Mesio-Palatal							
B	1.4	1.6	1.7	1.4	1.4	1.50	0.28 ± 0.08
RC	1.3	1.4	1.6	1.2	1.3	1.36	
P	1.2	1.3	1.4	1.0	1.2	1.22	
Disto-Palatal							
B	1.5	1.8	1.7	1.9	2.0	1.78	0.30 ± 0.10
RC	1.3	1.5	1.6	1.6	1.8	1.54	
P	1.3	1.5	1.4	1.5	1.8	1.48	
Total of removed dentine	1.8	2.3	2.6	3.6	2.0		2.44

B, Baseline; RC, After root canal preparation; P, after post-space preparation; RDT, remaining dentine thickness.

significant difference between drill size 4.5 and G.G. size 4 for both teeth and at the two levels ($P = 0.25$).

Table 6 represents the number of teeth (both central and lateral) where the remaining dentine thickness was <1 mm at any of the eight sites at both 5 and 7 mm from the working length. In all of the groups, and for both teeth, there were areas of <1 mm of RDT at 5 mm level. The number of teeth with <1 mm RDT were greater at 5 mm than at 7 mm for both teeth. There were more lateral incisors with areas of <1 mm RDT than central incisors.

Discussion

The purpose of this study was to evaluate the remaining dentine thickness (RDT) and canal area of maxillary central and lateral incisors after post-space preparation at 5 and 7 mm from the apex. The null hypothesis was that RDT will be more than 1 mm after post-space preparation irrespective of the length or diameter of the post drill. According to the results, the null hypothesis has been rejected as there were teeth with <1 mm RDT after post-space preparation in all of the groups.

In this study two sections were made for each tooth at levels 5 and 7 mm from the apex. These two levels were selected since it is usually recommended to leave 5 mm of the gutta-percha in place. Making more sections coronally would have made repositioning of the sections after each reading extremely difficult. In this study custom-made acrylic blocks were used for repositioning of the sections. Repositioning of the

Table 3 Mean of RDT (mm) at 7 mm from the working length of central incisors for the five groups at eight locations

	Parapost drill size				G.G size		
Location	4.5	5	5.5	6	4	Average	Average of dentine removed ± SD
Labial							
B	1.9	2.0	2.0	2.0	2.0	1.98	0.42 ± 0.08
RC	1.8	1.9	1.9	1.9	1.7	1.84	
P	1.6	1.6	1.6	1.5	1.5	1.56	
Palatal							
B	2.0	2.2	2.2	2.2	2.2	2.16	0.20 ± 0.11
RC	2.0	2.1	2.1	2.1	2.2	2.10	
P	1.9	2.0	2.0	1.8	2.1	1.96	
Mesial							
B	1.7	1.6	1.9	2.0	1.9	1.82	0.30 ± 0.11
RC	1.7	1.6	1.8	1.8	1.7	1.72	
P	1.5	1.4	1.6	1.5	1.6	1.52	
Distal							
B	1.6	1.8	1.8	1.8	1.8	1.76	0.36 ± 0.16
RC	1.4	1.7	1.8	1.7	1.8	1.68	
P	1.2	1.5	1.3	1.3	1.7	1.40	
Mesio-Labial							
B	2.0	1.9	2.1	2.2	2.0	2.06	0.34 ± 0.08
RC	1.9	1.8	2.0	2.1	1.8	1.92	
P	1.7	1.6	1.9	1.8	1.6	1.72	
Disto-Labial							
B	1.9	2.0	2.1	2.1	2.1	2.04	0.40 ± 0.09
RC	1.7	1.9	2.1	2.0	1.9	1.92	
P	1.6	1.5	1.8	1.6	1.7	1.64	
Mesio-Palatal							
B	1.9	2.1	1.9	2.1	2.1	2.02	0.24 ± 0.10
RC	1.8	2.0	1.8	2.0	2.0	1.92	
P	1.7	1.8	1.8	1.7	1.9	1.78	
Disto-Palatal							
B	1.9	1.9	2.1	2.1	2.0	2.0	0.26 ± 0.12
RC	1.8	1.9	2.1	2.0	1.9	1.94	
P	1.7	1.8	1.7	1.7	1.8	1.74	
Total of removed dentine	2.0	2.3	2.6	3.6	2.2		2.56

B, Baseline; RC, After root canal preparation; P, after post-space preparation; RDT, remaining dentine thickness.

sections was accurate and reproducible. The microscopic images were analyzed with a computer software which helped to evaluate the RDT and to calculate the canals area directly. This reduced the incidence of errors and allowed for direct comparison of the sections at different stages of the procedure.

For both central and lateral incisors, increasing the post-drill diameter resulted in a significant increase in the amount of dentine removed at both 5 mm and 7 mm from the apex. A laboratory study has reported that increasing the diameter of the post resulted in more root fractures (Mou *et al.* 2009). Also it has been reported that thicker root dentine walls increase significantly the fracture resistance of root filled teeth (Zogheib *et al.* 2008). In this study it is obvious that the RDT at the 5mm portion was less than the RDT at 7 mm. In addition, there were more teeth with <1 mm RDT at 5 mm than at 7 mm for both central and lateral incisors.

The effect of post length on the fracture resistance of root filled teeth varies between studies. Some have found that root filled teeth restored with glass-fibre posts shorter than their clinical crowns had reduced resistance to root fracture (Adanir & Belli 2008, Büttel *et al.* 2009, Giovani *et al.* 2009). Other studies had found that both long and short fibre posts provided similar root fracture resistance (Garoushi *et al.* 2007, Adanir & Belli 2008, Chuang *et al.* 2010, Hatta *et al.* 2011, Le Bell-Rönnlöf *et al.* 2011). These studies have revealed that using short glass fibre composite resin posts for anterior teeth with a 2 mm ferrule would

Table 4 Mean of RDT (mm) at 7 mm from the working length of lateral incisors for the five groups at eight locations

	Parapost drill size				G.G size		
Location	4.5	5	5.5	6	4	Average	Average of dentine removed
Labial							
B	2.0	2.1	2.2	2.0	2.3	2.10	0.32 ± 0.08
RC	1.9	1.9	2.1	1.9	2.2	2.0	
P	1.8	1.8	1.8	1.6	2.0	1.78	
Palatal							
B	2.0	2.2	2.0	2.1	2.4	2.14	0.26 ± 0.14
RC	1.9	2.1	1.9	2.0	2.3	2.04	
P	1.9	2.0	1.7	1.6	2.2	1.88	
Mesial							
B	1.4	1.6	1.5	1.5	1.6	1.52	0.34 ± 0.11
RC	1.3	1.5	1.3	1.4	1.3	1.36	
P	1.2	1.3	1.1	1.0	1.3	1.18	
Distal							
B	1.4	1.3	1.4	1.5	1.6	1.44	0.32 ± 0.04
RC	1.3	1.1	1.2	1.3	1.5	1.28	
P	1.1	1.0	1.1	1.1	1.3	1.12	
Mesio-Labial							
B	1.6	1.9	2.0	1.9	2.0	1.88	0.30 ± 0.10
RC	1.5	1.8	1.9	1.8	2.0	1.80	
P	1.4	1.6	1.6	1.5	1.8	1.58	
Disto-Labial							
B	1.6	1.7	1.8	1.7	2.0	1.76	0.34 ± 0.05
RC	1.5	1.5	1.7	1.5	1.9	1.62	
P	1.3	1.4	1.4	1.3	1.7	1.42	
Mesio-Palatal							
B	1.7	1.9	1.8	1.7	2.0	1.82	0.28 ± 0.14
RC	1.6	1.9	1.7	1.6	1.9	1.74	
P	1.6	1.7	1.5	1.2	1.7	1.54	
Disto-Palatal							
B	1.8	1.8	1.8	1.9	2.4	1.94	0.26 ± 0.14
RC	1.7	1.7	1.6	1.8	2.3	1.82	
P	1.7	1.6	1.5	1.4	2.2	1.68	
Total of removed dentine	1.5	2.5	3.0	3.4	2.4		2.42

B, Baseline; RC, After root canal preparation; P, after post-space preparation; RDT, remaining dentine thickness.

Table 5 Average canal area (mm^2) for central and lateral incisors and for all the groups at both 5 and 7 mm sections

	Tooth											
	Central						Lateral					
	5 mm			7 mm			5 mm			7 mm		
Drill size	B	RC	P	B	RC	P	B	RC	P	B	RC	P
4.5	0.35	0.79	0.86	0.45	0.83	0.86	0.31	0.80	0.86	0.43	0.83	0.90
5	0.37	0.81	1.44	0.49	0.86	1.46	0.27	0.89	1.42	0.42	0.85	1.72
5.5	0.35	0.81	1.83	0.51	0.87	1.88	0.27	0.89	1.89	0.39	0.88	1.93
6	0.37	0.79	2.66	0.49	0.87	2.71	0.28	0.80	2.86	0.34	0.89	2.72
G.G 4	0.34	0.78	1.15	0.48	0.80	1.18	0.24	0.83	1.26	0.34	0.89	1.23
Average	0.36	0.80	1.60	0.48	0.85	1.62	0.27	0.84	1.66	0.38	0.87	1.70

B, Baseline; RC, After root canal preparation; P, after post-space preparation.

resist normal occlusal forces (Garoushi *et al.* 2007, 2009). The result of the present study supports these previous studies, and suggests that long posts should be discouraged since increasing the length of post-space preparation might unnecessarily weaken the canal wall and increase the danger of perforation.

Table 6 Number of teeth where RDT was <1 mm at any site at 5 mm and 7 mm from the apex for both central and lateral incisors

	Tooth							
	Centrals				Laterals			
	5 mm		7 mm		5 mm		7 mm	
Drill size	RC	P	RC	P	RC	P	RC	P
4.5	1	2	0	1	1	3	1	1
5	0	3	0	1	2	3	0	2
5.5	0	4	0	1	2	5	2	4
6	1	5	0	3	2	5	0	5
G.G 4	0	1	0	0	2	3	0	1
Total	2	15	0	6	9	19	3	13

RC, After root canal preparation; P, after post-space preparation; RDT, remaining dentine thickness.

Previous studies have documented the deviation from the central axis of the canal as ranging between 0 and 1 mm during post-space preparation (Al-Sudani & Al-Shahrani 2006, Huysmans *et al.* 2007). In this study canal deviation was not calculated, however, the difference in the canal area initially and after post-space preparation occurred not only due to the diameter of the post-drill, but most often it was due to the deviation from the central canal direction. Most of the deviation in the canal has been found to be in labial direction (Huysmans *et al.* 2007). The results also revealed that most of the dentine removed (for both central and lateral incisors) was from the labial and mesio-and-disto-buccal sides of the canal. In the aforementioned study, Huysmans *et al.* (2007) found that 10 out of 16 lateral incisors had <1 mm RDT 5 mm from the working length after post-space preparation. In the present study similar results occurred, 19 out of the 25 lateral incisors had <1 mm RDT at 5 mm from the CWL after post-space preparation.

Overall, the results support the current trend in restorative dentistry of avoiding the use of posts whenever possible. If a post has to be used, long and large size posts should be avoided for central and lateral incisors. Root size and root canal morphology should be the leading factors in post selection.

Conclusions

Within the limitations of this study, the following conclusions can be withdrawn:

1. For both central and lateral incisors the amount of dentine removed during post-space preparation ranged from 0.20 to 0.52 mm. It was greatest on the labial side of the canal.
2. For both teeth, there was a larger increase in the area of the canal after post-space preparation than was anticipated from the size of the drill.
3. There were areas of remaining dentin thickness less than the recommended 1 mm at both 5 and 7 mm sections for both teeth.
4. Both central and lateral incisors have thicker dentine on the labial and palatal areas than on the mesial and distal areas of their roots.

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