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Parallel post-space preparation in different tooth types *ex vivo*: deviation from the canal centre and remaining dentine thickness

M. C. D. N. J. M. Huysmans[1], M. H. J. Klein[2], G. F. Kok[3] & J. M. Whitworth[4]

[1]Academic Center Oral Health Groningen, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands; [2]Private Dental Practice, Hattem, the Netherlands; [3]Private Dental Practice, Veenendaal, the Netherlands; and [4]School of Dental Sciences, Newcastle University, UK

Abstract

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Aim To determine the deviation of parallel-sided twist-drills during post-channel preparation and relate this to tooth type and position.

Methodology Human teeth with single root canals were selected: maxillary second premolars (group i); maxillary lateral incisors (group ii); mandibular canines (group iii); mandibular first premolars (group iv; all groups $n = 16$). The teeth were reduced to 17 mm length by sectioning the crown, and the root canals prepared and filled. Microradiographs were made in two directions. The teeth were individually embedded in a gypsum jaw and placed in a phantom head. Two operators performed parallel post-space preparation (12 mm length, 1.25 mm diameter) to the following protocol: gutta-percha removal with Gates Glidden drills numbers 2 and 3 and post-space enlargement with parallel drills numbers 3, 4 and 5, consecutively. Subsequently, microradiographs were re-exposed. The original and post-operative microradiographs were digitized and superimposed, and deviation of the post-space from the filled canal and remaining dentine thickness measured.

Results Overall, the mean deviation was 0.07 mm to the mesial (95% CI: 0.01–0.12), and 0.27 mm to the buccal (95% CI: 0.18–0.35). Group ii had significantly more buccal deviation than other groups ($P = 0.004$–0.008). A remaining dentine thickness of <0.5 mm occurred 16 times in 14 teeth, and of <1 mm occurred 97 times in 52 teeth.

Conclusions Deviation during parallel post-preparation was common, predominantly in mesial and buccal directions, especially in maxillary incisors. This deviation increased the risk of perforation considerably.

Keywords: dental dowels, post and core technique, perforation, post-channel preparation.

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Introduction

The survival of root-filled teeth may be compromised by the manner in which they are restored. Failure to protect against coronal microleakage and damaging occlusal loads are recognized risk factors (Hommez *et al.* 2002, Chu *et al.* 2005) whilst post-placement adds the dangers of compromised apical seal, weakening, fracture and perforation of the root. In a retrospective radiographic study of 277 post-restored teeth, root perforation by the post was observed in seven teeth (2.5%), and eccentric post-placement in 54 teeth (19.5%) (Ottl & Lauer 1998). A retrospective clinical study recorded 55 root perforations in 11 years in a university patient population (Kvinnsland *et al.* 1989). Post-preparation was the cause of perforation in 53% of cases, and of 12 cases requiring immediate extrac-

Correspondence: Marie-Charlotte Huysmans, Department of Cariology and Operative Dentistry, Academic Center Oral Health Groningen, University Medical Center Groningen, University of Groningen, Ant. Deusinglaan 1, 9713 AV Groningen, the Netherlands (Tel.: +31 50 363 3203; fax: +31 50 363 2696; e-mail: m.c.d.n.j.m.huysmans@med.umcg.nl).

tion, nine were due to post-preparation. Risks may be reduced by preserving as much sound tooth tissue as possible (Pereira *et al.* 2006) and avoiding the use of posts where they are not essential for restoration retention (Peroz *et al.* 2005, Willershausen *et al.* 2005).

However, current restorative regimes do not allow dentists to abandon posts, and their use is often essential, particularly for the reconstruction of anterior teeth. Equally, material science does not always allow dentists to use narrow posts, as enlargement and shaping of a post-space is often needed for adaptation and retention, and to create a post with adequate bulk to withstand the rigours of long-term function.

Post-systems and corresponding twist-drills are commercially available in a range of materials and shapes (Ricketts *et al.* 2005). Promotional advertising may draw attention to the benefits of design features, but few claims have been validated by sound clinical evidence (Ricketts *et al.* 2005) and the scientific basis on which our clinical decision-making is based is often weak.

Conventional guidelines for post-space preparation have suggested leaving a minimum of 3 mm of gutta-percha apically to safeguard the seal (Kvist *et al.* 1989) and widening to no more than one-third root width, or leaving at least 1 mm of dentine on each side of the post.

Laboratory-based studies with Peezo reamers (Raiden *et al.* 1999, 2001), Gates Glidden drills (Pilo *et al.* 1998) and ParaPost twist-drills have indicated that post-channel enlargement may thin root walls to an unacceptable degree, especially when anatomical features such as proximal concavities are present. These issues may be compounded by deviation from the canal long axis (Gegauff *et al.* 1988).

Although parallel-sided posts have enjoyed popularity and acceptable success in practice (Torbjorner *et al.* 1995), the potential risks of over-thinning due to over-enlargement, anatomical complexity and deviation must be recognized (Pilo & Tamse 2000). However, little is known about the risks of deviation from canal long axis in different teeth and at different anatomical locations.

The aim of this study was to determine the linear deviation of parallel-sided twist-drills during post-space preparation and relate this to tooth type and position.

Materials and methods

Sixty-four extracted human teeth were selected from a pool of teeth collected by general practitioners for education or research purposes. Approval from a medical ethical committee for such research is not required in the Netherlands. During collection, teeth had been stored in water. All had completely formed, single roots with minimal curvature, and were free from caries or restorations below the cemento-enamel junction. None had previously been root filled. Where doubts regarding the number of canals or previous root canal treatments existed, nonstandardized dental radiographs were made in a mesio-distal direction.

The final sample consisted of four groups.

1. Group i: Maxillary second premolars ($n = 16$).
2. Group ii: Maxillary lateral incisors ($n = 16$).
3. Group iii: Mandibular canines ($n = 16$).
4. Group iv: Mandibular first premolars ($n = 16$).

Each was allocated a random identification number before storage in tap water.

Experimental procedures

All teeth were reduced to a standard length of 17 mm by sectioning the crown with a diamond saw under constant water cooling. Teeth were hand-held for root canal treatment according to a standardized protocol: where access had not been achieved by the reduction in length, it was secured with round steel burs in a slow handpiece. Following canal negotiation with small files (K-Flexofiles, Dentsply Maillefer, Ballaigues, Switzerland), working length was determined at 16 mm (1 mm short of the anatomical root length). After canal flaring, enlargement was to size 30 in all canals, with step-back to file size 45. Preparation was accompanied by irrigation with sodium hypochlorite solution (2.5%, manufactured *in house*). The canals were filled by cold lateral condensation of gutta-percha (Dentsply Maillefer) with sealer (AH26, Dentsply Maillefer). After complete setting of the sealer, teeth were stored for 1–4 weeks in water at room temperature before post-preparation.

All post-preparation procedures were performed in a simulated clinical set-up, using a phantom head with gypsum jaws and moulded soft tissues (Fig. 1). The jaws were specially prepared for this study, with spaces prepared within the jaws at the anatomical location and in anatomically correct angulations. The teeth were inserted into the jaw using hot wax (Beauty Pink, Ubert, Lohfelden, Germany), so that the teeth could be removed after preparation and new teeth inserted. The spaces were only slightly larger than the single-rooted teeth, leaving only sufficient space for variations in tooth dimensions. Tooth inclination and position were thereby standardized for each tooth type.

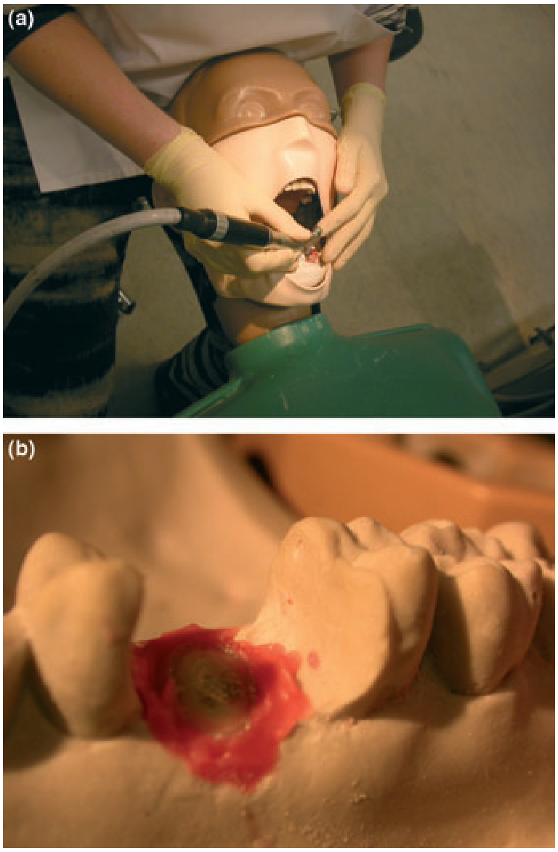

Figure 1 (a) View of one of the operators performing a post-preparation in a lower canine tooth, in the phantom head set-up. (b) Detail view of an upper premolar tooth inserted in the gypsum jaw.

Two operators (both right-handed final year dental students) with clinical experience of the post-system used, performed all of the post-preparations. Prior to the study, they received additional training on eight teeth (which were not included in the study) with an endodontic specialist. One tooth from each group (i–iv) was randomly selected from the sample and inserted in the jaws. Post-preparation was performed in a random order. Subsequently, the teeth were removed and four new ones inserted until all teeth were prepared. Post-preparation was performed with Gates Glidden drills (Dentsply Maillefer), sizes 2 and 3 consecutively, and ParaPost system (Coltene/Whaledent, Langenau, Germany) twist-drills, sizes 3, 4 and 5 (brown, yellow and red) consecutively in a standard slow-speed handpiece. Gates Glidden drills were fitted with rubber stops and extended 12 mm into the canal with gentle up–down motions, thermoplasticizing and removing gutta-percha. The canals were irrigated with water between instruments. The sequence of twist-drills followed, always working in a wet canal and gently feeding into the canal until 12 mm was reached. No heavy axial force was applied to the twist-drills. The twist-drills were cleaned after each use and a new set was employed for each group of eight preparations. All canals were enlarged to a standardized size 5 (1.25 mm diameter, red) twist-drill.

Microradiography and analysis

All teeth were microradiographed in a standardized manner at different stages.

1. After root canal treatment.
2. After post-preparation.

The teeth were placed in individual moulds, in an aluminium jig that could be reproducibly positioned in the imaging device (Fig. 2). Each tooth was radiographed in bucco-lingual and mesio-distal directions, in order to evaluate deviation in both directions. Radiographs were exposed using a X-ray generator (Philips PW 1730, Eindhoven, the Netherlands) with a copper anode with a focal spot of 1 × 1 mm, operated at 40 kV, 25 mA, exposure time 20 s. Focus-film distance was 34 cm and object-film distance was 2–3 mm. The high-resolution film (Fuji b/w positive film type 71337, Rotterdam, the Netherlands) was developed using standard procedures and the images were digitally captured using a camera (Teli CS 8310, Tokyo, Japan) mounted onto a microscope.

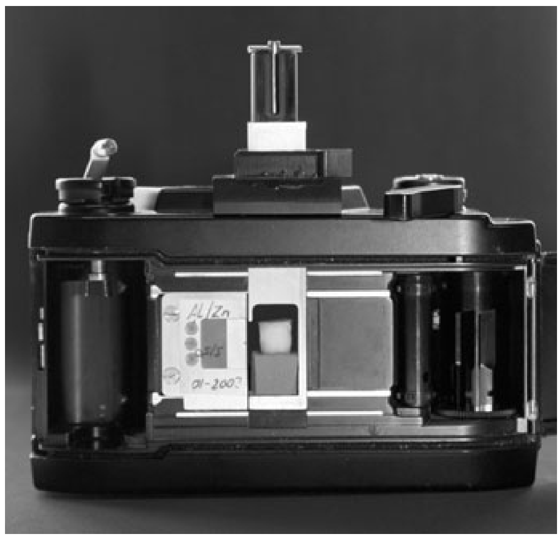

Figure 2 View of the opened camera used in the microradiography procedure, showing the tooth in the aluminium jig in the centre of the camera.

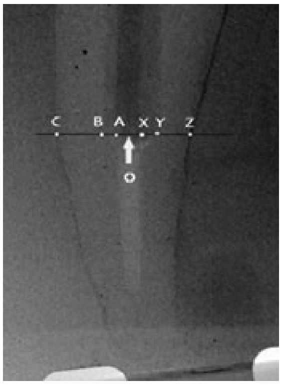

Figure 3 Apical part of superimposed microradiographs of a canine tooth in the mesiodistal plane, showing the measuring points used. O = origin [centre of canal obturation, position A + 0.5(X − A) set at 0], mesial and buccal directions were given positive values, distal and lingual directions negative values, C to Z = root thickness. B to Y = post-preparation thickness. [(A + X)/2]–[(B + Y)/2] = deviation.

Radiographs before and after post-preparation were superimposed digitally, using Adobe Photoshop (Adobe, San Jose, CA, USA). On these superimposed images, six measuring points were identified (Fig. 3) at the level of the apical end of the post-preparation. These points were used to calculate deviation of the post-preparation (distance between centre of gutta-percha and centre of post-preparation), remaining dentine thickness and total root thickness in both bucco-lingual and mesio-distal dimensions.

Statistical analysis

The data were statistically analysed using SPSS 11.0 (SPSS Inc., Chicago, IL, USA), by two-way ANOVA ($P < 0.05$), after establishing normal distribution by the Kolmogorov–Smirnov test. Independent variables were tooth type and side of the mouth (left/right). Dependent variables were: (i) deviation (in bucco-lingual and mesio-distal directions) and (ii) remaining dentine thickness in four directions.

Post hoc testing was carried out with *t*-tests (Bonferroni procedure). It was first determined if the operator had a significant influence on deviation and remaining dentine thickness. As it was observed that root thickness was significantly different between the operators (the teeth were randomly assigned to the operators and not stratified for initial root thickness), root thickness was used as a covariable in the analysis for remaining dentine thickness.

Results

During root canal treatment three teeth were found to have two root canals and were removed from the study (two maxillary second premolars and one mandibular premolar), no further exclusions were necessary. Thus, 61 teeth were analysed: group i ($n = 14$); group ii ($n = 16$); group iii ($n = 16$) and group iv ($n = 15$).

Results for root thickness at the apical limit of the post-channel (5 mm from root apex) are shown in Table 1. Root thickness in the mesio-distal dimension was 1.5 mm less than in the bucco-lingual dimension. Mesio-distal thickness was <3.25 mm in 45 teeth, which would necessarily leave <1 mm dentine thickness in mesial and/or distal direction in these teeth after post-preparation of a 1.25 mm post-channel. It was <2.25 in two teeth.

The measurements of deviation are shown in Table 2, and illustrated in Fig. 4. Overall mean deviation in the mesio-distal dimension was 0.07 mm to the mesial (95% CI: 0.01–0.12), and overall mean deviation in the bucco-lingual dimension was 0.27 mm to the buccal (95% CI: 0.18–0.35).

The average thickness of the post-preparation as measured radiographically was 1.1 mm. As the final twist-drills were 1.25 mm in diameter, it was concluded that due to the limitations of the radiographic method, the edge of the post-preparation was detected at least 0.075 mm too far centrally. Therefore, remaining dentine thickness was overestimated by at least that thickness. In order to control for this error, Fig. 5 illustrates remaining dentine thickness measurements with a correction of 0.075 mm deducted from each measurement.

The analysis of operator influence on deviation and remaining dentine thickness revealed no significant

Table 1 Root thickness at 5 mm from the apex as measured on the microradiographs, by group and quadrant

Group	Quadrant	Mesio-distal	SD	Bucco-lingual	SD
i	Both	3.18	0.54	4.58	0.59
	1	2.96	0.42	4.28	0.23
	2	3.39	0.58	4.89	0.69
ii	Both	2.78	0.42	4.46	0.47
	1	2.69	0.42	4.36	0.55
	2	2.88	0.42	4.56	0.37
iii	Both	3.04	0.44	4.34	0.75
	3	3.33	0.45	4.70	0.88
	4	2.82	0.31	4.07	0.52
iv	Both	3.09	0.32	4.53	0.42
	3	3.08	0.33	4.58	0.35
	4	3.12	0.34	4.47	0.51

Table 2 Results for the deviation measurements, by tooth type and quadrant (all results are given in mm)

Group	Quadrant	Mesial	Distal	SD	Buccal	Lingual	SD
i	Both	0.06		0.19	0.13		0.23
	1	0.07		0.23	0.13		0.24
	2	0.04		0.16	0.13		0.25
ii	Both		0.01	0.25	0.51		0.29
	1		0.01	0.24	0.60		0.32
	2		0.01	0.27	0.43		0.23
iii	Both	0.13		0.14	0.23		0.32
	3	0.08		0.11	0.24		0.38
	4	0.17		0.16	0.23		0.30
iv	Both	0.11		0.26	0.17		0.30
	3	0.04		0.26	0.34		0.23
	4	0.18		0.25		0.03	0.24

effect, therefore the data for the two operators was pooled. There was no apparent learning curve for either operator (correlation of deviation with preparation order <0.07 for both operators in both directions). Two-way ANOVA demonstrated a significant influence of tooth type only on bucco-lingual deviation and on remaining dentine thickness on distal and buccal surfaces. *Post hoc* testing showed that group ii showed more buccal deviation than group i (difference 0.38 mm, $P = 0.004$), group iii (difference 0.28 mm, $P = 0.007$) and group iv (difference 0.34 mm, $P = 0.008$). Group ii also had less remaining dentine distally than groups iii and iv (both difference 0.27 mm, $P = 0.01$), and less remaining dentine thickness buccally than groups i and iv (difference 0.44/0.36, $P = 0.004/0.01$, respectively). Two-way ANOVA revealed a significant influence of the side of the mouth only on remaining dentine thickness on mesial and lingual surfaces. *Post hoc* testing showed more remaining dentine in teeth on the left side (mesial: difference 0.21 mm, $P = 0.008$; lingual: difference 0.25 mm, $P = 0.04$).

Although no significant interaction between tooth type and side of the mouth effects occurred, a few nonsignificant trends were observed. In group iv, a deviation to the buccal of 0.34 mm on the left side and to the lingual of 0.03 mm on the right side was observed. Also, the mandibular teeth resulted in more deviation towards the mesial, especially in the right side of the jaw (Table 2).

Table 3 gives an overview of the number of locations and teeth where the remaining dentine thickness was extremely thin. A remaining dentine thickness of <0.5 mm occurred 16 times in 14 teeth. A remaining dentine thickness of <1 mm occurred 97 times in 52 teeth. Deviation from the centre of the canal at the apical limit of post-space preparation contributed to the occurrence of limited remaining dentine thickness, i.e. increasing the number of teeth with <0.5 mm remaining dentine in at least one direction from 2 (expected number) to 14 (actual number, 23%).

Discussion

Previous studies into the safety aspects of post-preparation have concentrated on remaining dentine thickness. In the present study, assessment of deviation from

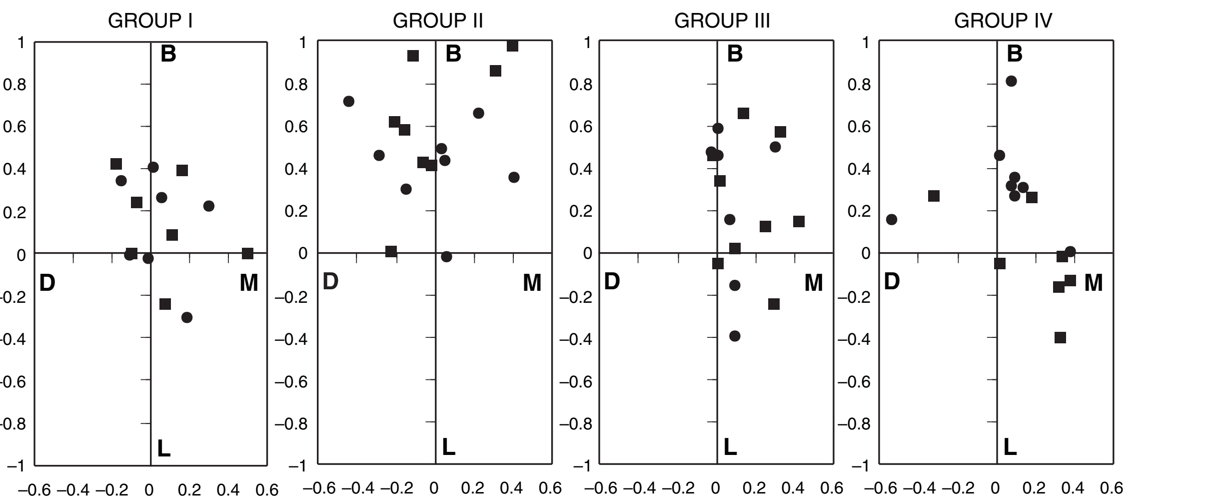

Figure 4 Deviation of post-preparation from center of obturated canal, for the four tooth types. Squares denote right side (quadrant 1/4), circles denote left side (quadrant 2/3).

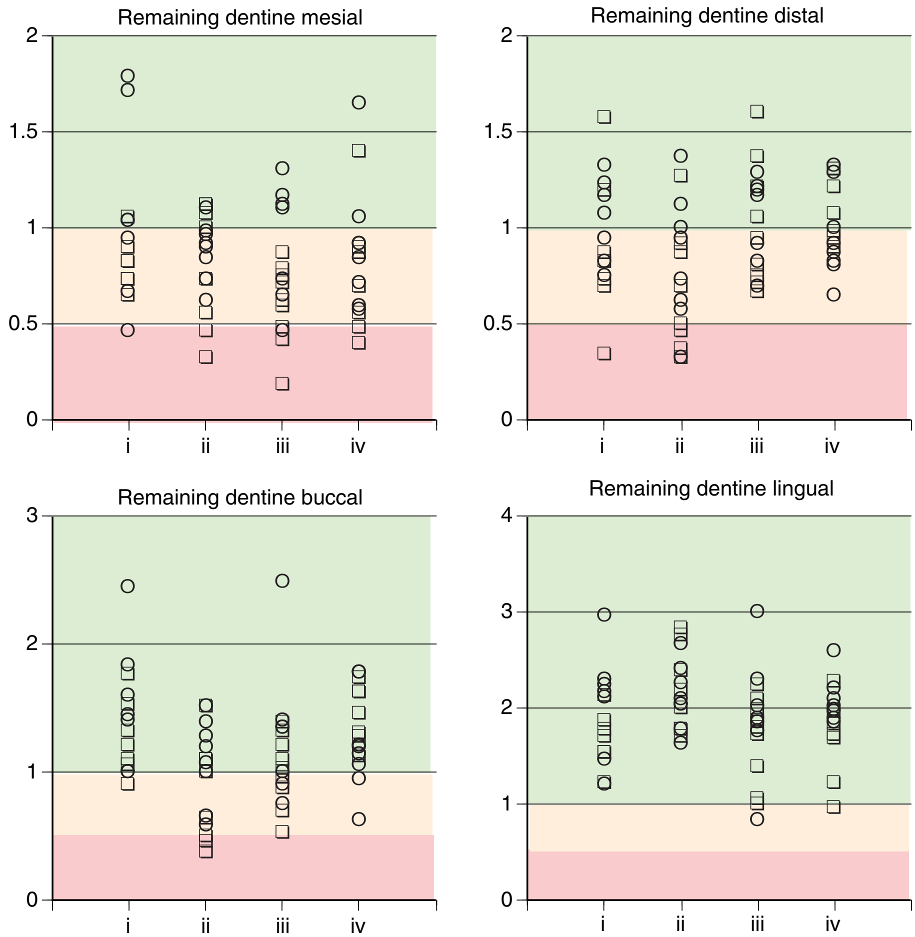

Figure 5 Remaining dentine thickness in the four directions, for the four tooth types. Squares denote right side (quadrant 1/4), circles denote left side (quadrant 2/3). Orange and red areas indicate ''danger zones''.

Table 3 Number of locations/teeth where the remaining dentine thickness was <0.5 mm or 1 mm

	Remaining dentine thickness <0.5 mm						Remaining dentine thickness <1 mm					
	Locations				Teeth		Locations				Teeth	
Group	M	D	B	L	Actual	Predicted	M	D	B	L	Actual	Predicted
i (14)	1	1	–	–	2	–	9	8	1	–	10	9
ii (16)	2	4	2	–	6	2	11	12	6	–	16	15
iii (16)	4	–	–	–	4	–	12	8	6	1	12	11
iv (15)	2	–	–	–	2	–	12	8	2	1	14	10
All (61)	9	5	2	–	14	2	44	36	15	2	52	45

The predicted number of teeth was calculated by subtracting the post-preparation thickness (1.25) from the measured root thickness in both directions (assuming post-preparation with no deviation). All predicted remaining dentine thicknesses below 0.5 or 1 mm were in the mesio-distal direction.

the centre of the filled canal was the primary aim. For this reason certain choices were made in the experimental set-up, which resulted in various limitations.

First, the evaluation method was radiography. Although it is suitable to evaluate deviation in two dimensions, it has been shown by Raiden *et al.* (2001) that it leads to an underestimation of remaining dentine thickness. However, the method of sectioning the roots for direct anatomical observation was not possible in the present study, as this would not have enabled us to measure deviation. Although a muffle-type set-up (Kuttler *et al.* 2001) would allow for pre-preparation and post-preparation comparisons, such a muffle is very difficult to include in a set-up attempting to simulate clinical preparation conditions. The radiographic method in this study used high-resolution film and a high contrast exposure setting, commonly used for quantitative microradiography (Thomas *et al.* 2006). However, there is still a threshold for detecting small differences in X-ray absorption, as can be seen from the error in post-space detection. Minimal post-space underestimation was calculated and used to correct remaining dentine thickness estimation. However, post-space underestimations may have been higher (Gegauff *et al.* 1988) and the error in detecting the root surface (Raiden *et al.* 2001) could not be corrected for. It is therefore very likely that the remaining dentine thickness values in this study are actually even smaller than reported. This problem might have been reduced, if not eliminated, by using microCT as an evaluation method. However, as the results for remaining dentine thickness can only be considered as a first impression, due to the small sample size and the fixed preparation length, the current method was considered adequate.

Secondly, it was decided to reduce all teeth from the coronal aspect to a length of 17 mm, and to standardize post-preparation at 1.25 mm diameter and 12 mm length for all teeth. This had the effect of eliminating possible factors in deviation such as remaining coronal dentine and total length of preparation. In a clinical situation both post-diameter and preparation depth would be guided by the mesio-distal root thickness as observed on radiographs. Therefore, the results for remaining dentine thickness should be viewed with caution. However, they do give an indication of how little space there was in the roots of the included teeth for post-preparation.

It was expected that deviation would be influenced by the position of the tooth in the jaw and the position the operator would have to assume to prepare the post-space. It was therefore necessary to simulate carefully the anatomical and clinical situation, as was done in this study. Within the limitations of a laboratory study, tooth position, angulation and clinical operating conditions were reproduced.

Deviation from the central canal direction occurred frequently and was variable, ranging between 0 and 1 mm. The deviations compare with a previous study using only mandibular canine teeth and preparing up to ParaPost number 5 to a depth of 10 mm (Gegauff *et al.* 1988). They found a combined mesio-distal and bucco-lingual deviation at a depth of 7.5 mm of 0.34 mm, whereas in the present study this was calculated as 0.42 mm in the complete sample and 0.39 in group iii only (at the complete preparation depth of 12 mm). This confirms that the use of final year student operators as opposed to experienced operators did not influence the negative results.

There was a statistically significant preference for deviation in the mesial and the buccal direction. The tooth type only significantly influenced bucco-lingual deviation, with the maxillary lateral incisors having more deviation than the other groups. This corresponds with a clinical report, where perforations were found mainly in mesial and buccal surfaces, and the maxillary lateral incisor having the highest frequency of perforations (Kvinnsland *et al.* 1989). There was a trend for teeth in the lower jaw to have more mesial deviation; however, this was not significant. The difficulties of right-handed operators working in the mandibular right quadrant have been recognized (Smith *et al.* 1993). The results from the present study, obtained by two right-handed operators, partially point in the same direction, considering mesial deviation and remaining dentine in mesial and distal directions, but the opposite trend for buccal deviation may indicate a more complicated aetiology.

The study of Gegauff *et al.* (1988) noted that the trend for deviation was smaller for Gates Glidden drills than the parallel twist-drills. Although adhesive procedures may allow for loosely fitting posts, the use of parallel drills is necessary for optimal fit in other cases. Even when taking maximum care in preparation, and using all drills in succession so that the preparation was only enlarged by 10% at each new drill, the deviation in the present study was substantial, with extreme values of up to 1 mm. Deviations have been attributed to restrictions by coronal access (Kvinnsland *et al.* 1989) but this factor was excluded by the experimental model. It is more likely that a misjudgement of root inclinations plays an important role, especially in maxillary incisors.

The results for remaining dentine thickness, notwithstanding the standardized preparation length compare well with previous reports. In a study using maxillary premolar teeth, where the preparation depth was chosen to equal crown height resulting in a mean distance from the apex of 7.7 mm, the average remaining dentine thicknesses for a 1.30 mm diameter post-preparation were: mesial 0.65 mm, distal 0.8 mm, buccal 1.72 mm and lingual 1.78 mm (Raiden *et al.* 1999). The corresponding values in this study were: mesial 0.96 mm, distal 0.98 mm, buccal 1.42 mm and lingual 1.89 mm. In both studies, even a post-diameter of only 0.7 mm (which could be considered too thin for resistance requirements) would leave <1 mm remaining dentine in some cases, in the present study in 12 of 61 teeth.

Overall, the results support the current trend to avoid post-preparation whenever possible. If a post has to be used, long parallel posts should be avoided and apically tapered posts should be considered. Root size and root canal morphology should be the leading factors in post-selection. Considering the limitations of conventional radiography, a safety margin should be used. Perhaps in the future three-dimensional information will be available, through for instance cone beam tomography, to support clinical decision-making.

Conclusion

Deviation during parallel post-preparation occurred frequently, and predominantly in mesial and buccal directions (especially in maxillary incisors). This increased the risk for perforation considerably, over and above the given risk due to limited root thickness.

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