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Micro-computed tomography of tooth tissue volume changes following endodontic procedures and post space preparation

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Abstract

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Aim To compare the volume of hard tooth tissue lost after caries removal, access cavity preparation, root canal preparation, fibre post space and cast post preparation in carious premolar teeth. The null hypothesis tested was that there is no difference between the volumes of hard tooth tissue lost expressed as a percentage of the preoperative hard tooth tissue volume, after each operative procedure.

Methodology Twelve extracted human premolars with mesial or distal carious cavities penetrating into the pulp chamber were selected. Teeth were scanned using a microCT scanner. After each operative procedure the loss of hard tooth tissue volume was measured. The data were statistically analysed using one-way analysis of variance and Fisher's PLSD test with statistical significance set at $\alpha = 0.01$.

Results The percentage of preoperative hard tooth tissue volume lost after caries removal was 8.3 ± 5.83, after access cavity preparation the loss of volume reached 12.7 ± 6.7% (increase of 4.4%). After root canal preparation, fibre post space and cast post preparation the hard tissue volume lost reached, 13.7 ± 6.7 (increase of 1%), 15.1 ± 6.3 (increase of 1.4%) and 19.2 ± 7.4 (increase of 4.1%) respectively. Each procedure performed after caries removal significantly increased ($P < 0.01$) the amount of hard tissue volume lost with the exception of the root canal preparation.

Conclusions Access cavity and post space preparation are the procedures during root canal treatment which result in the largest loss of hard tooth tissue structure. Cast post space preparation causes a larger loss of tooth structure than fibre post space preparation. This should be taken into account when planning root canal treatment and restoration of root filled teeth that are to be restored with cuspal coverage restorations.

Keywords: cast posts, dentine, fibre posts.

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Introduction

Root filled teeth are more susceptible to fracture when compared with teeth with vital pulps. There are several reasons for the high incidence in fractures observed in root filled teeth. First, the physical properties of the dentine may be altered by the interaction of medicaments and irrigants (Grigoratos *et al.* 2001). A loss of proprioception occurs when the pulp tissue is removed. It has been shown that teeth with non vital pulps have a higher load perception and take up to twice the amount of loading compared with a vital pulp to register discomfort (Randow & Glantz 1986). Finally, loss of tooth structure, in particular loss of the marginal ridge(s) results in increased cusp flexure *ex vivo* (Reeh *et al.* 1989).

To assess how the loss of tooth tissue caused by restorative procedures and root canal treatment may

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weaken the tooth it is important to measure the amount of hard tooth tissue (dentine) removed at each stage of root canal treatment and subsequent restoration. This has not been assessed previously.

High resolution micro-computed tomography (micro CT) has been extensively used to evaluate three dimensional shapes and volumes of canals following root canal instrumentation (Peters *et al.* 2000, 2003).

In clinical studies comparing the survival of root filled treated teeth restored with different techniques, attempts have been made to standardize the loss of tooth structure before the start of the restorative treatment (Bolla *et al.* 2007). In one recent randomized clinical trial the loss of tooth structure was classified on the basis of the number of dental walls left (Ferrari *et al.* 2007), other studies have limited their investigation to Class 2 cavities (Mannocci *et al.* 2002). The use of posts in premolar teeth with three coronal walls is supported by the favourable results of a recent randomized clinical trial (Ferrari *et al.* 2007).

The aim of this micro CT study was to compare the loss of hard tooth tissue volume caused by various operative stages (caries removal, access cavity, root canal preparation with nickel titanium instruments, fibre post and cast post space preparation) involved in root canal treatment and subsequent restoration of the tooth in extracted premolar teeth with mesial or distal carious cavities penetrating into the pulp space.

The null hypothesis tested was that there is no difference between the loss of volume of hard tooth tissue expressed as a percentage of the preoperative hard tooth tissue volume, after each operative procedure.

Materials and methods

Twelve extracted human mature premolar teeth were used. The relationship of the lesion and the pulp chamber was assessed using periapical radiographs taken in bucco-lingual and mesio-distal projections. All teeth had mesial or distal lesions penetrating into the chamber. Teeth with both mesial and distal lesions and/or with previous restorations were excluded from study.

The teeth were scanned using a GE Locus SP microCT scanner (GE Pre-clinical Imaging, London, ON, Canada). A custom sample holder was built to position the specimens in the sample holder of the microCT scanner. A 0.01 mm aluminium and 0.01 mm copper filter were used to reduce beam-hardening artefacts and scattering. The geometrical magnification was chosen according to the principle of cone beam geometry. The reconstruction algorithm was a half scan Feldkamp Parker algorithm less weighting function. The settings for the Micro CT scanner were 80 kvp and 80 μA. The distance between each observed section was 21 μm.

The specimens were characterized further by making three-dimensional isosurfaces, generated, segmented and measured using Microview software (GE). Once the scan was completed the operator assessed the volume of hard tissue remaining. The setting for surface quality used was 0.85 and the setting for decimation factor was 26. To assess the hard tissue volume, each tooth was selected as the region of interest (ROI).

The automatic threshold tool was used with a histogram plot to identify the mid point between the tooth tissue and air. This value was then recorded and kept consistent for each tooth at the beginning and then used in subsequent scans to make the isosurfaces.

Caries removal

All operative procedures (caries removal, access cavity preparation, root canal preparation, fibre post and cast post space preparation) were carried out by the same operator (OI), the operator was unaware of the objectives of the study.

Once the preoperative volume of the tooth and root canals were recorded, caries was removed from each tooth. The occlusal section and box of the cavity were prepared using a diamond bur (REF 878–2800 Henry Schein, Gillingham, UK), in a high speed handpiece with water cooling and the caries was excavated with a slow speed hand piece and steel rose head bur (size 7 REF 100–3223 Henry Schein Gillingham, UK). Caries removal was verified using an explorer (04108 Dentsply; Ash Instruments, Dentsply, Gloucester, UK). If the remaining dentine did not cause the probe to stick caries removal was assumed to be completed. The teeth were then scanned again and the new volume of hard tissue volume was recorded. The scanning procedure was repeated after access cavity, root canal, fibre post and cast post space preparation.

Access cavity preparation

An oval access cavity was made in each tooth in the occlusal aspect. Access was completed when the roof of the pulp chamber was completely removed and a DG16

endodontic probe (DG-16 Endodontic Explorer, Ash UK) could be placed in the pulp chamber and the canals were visible to the naked eye.

Preparation of root canal

The root canals of the teeth were prepared initially using size 2, 3, and 4 Gates Glidden drills at 600 rpm. The working length was then measured using a size 10 K-file. The file was passed through the apical foramen and then wound backwards when it was no longer visible the length was recorded from a noted landmark. The teeth were then prepared up to a size 20 file with hand instruments to the working length and irrigated with sodium hypochlorite after each file. Recapitulation was performed with a size 10 K-file between instruments.

ProTaper® rotary instruments (Maillefer Dentsply, Baillagues, Switzerland) were then used to prepare the root canals. The Shaper 1 and Shaper 2 ProTaper files were used to the working length and the Finisher 1 and Finisher 2 files were used 1 mm short of the working length. During the root canal preparation a brushing technique was used on the outward stroke to permit three-dimensional coronal flaring of the canal. As before, between each file recapitulation with a size 10 file was performed and a 1% sodium hypochlorite solution was used to irrigate the canals.

Fibre post preparation

Post spaces were prepared using the Fibre White® post kit (Coltène/Whaledent, NJ, USA). For this the blue post drill (1.14 mm in diameter) was used. The post space preparation was carried out leaving at least 4 mm of the prepared apical root canal undisturbed. If the tooth had two canals the widest canal was selected for post preparation.

Cast post preparation

The preparations for the fibre posts were than modified into preparations for Parapost® (Coltène/Whaledent) cast post- cores of 1.14 mm in diameter by removing any undercuts that would prevent the cementation of the cast postcores. The Fibre White and Parapost are produced with identical diameters, for this reason no adjustment was made to the post space canal preparations.

The percentages of the preoperative hard tooth tissue volume lost after each procedure were calculated and statistically compared using one-way analysis of variance and Fisher's PLSD test with statistical significance set at $\alpha = 0.01$.

Results

The values of hard tooth tissue lost in each tooth after each procedure are reported in Table 1. The mean

Table 1 Tooth hard tissue volumes in mm^3 and percentages of tooth hard tissue lost after caries removal, access cavity preparation, root canal preparation, fibre post space preparation, and cast post space preparation

	Tooth 1	Tooth 2	Tooth 3	Tooth 4	Tooth 5	Tooth 6	Tooth 7	Tooth 8	Tooth 9	Tooth 10	Tooth 11	Tooth 12
Initial												
Volume	462.227	417.72	310.667	447.408	469.022	465.954	450.965	264.278	411.56	502.265	378.143	512.933
% volume lost	0	0	0	0	0	0	0	0	0	0	0	0
After caries removal												
Volume	428.151	388.957	278.737	428.632	436.094	444.945	372.911	210.327	395.394	479.587	333.203	507.538
% volume lost	7.3	7	10.3	4.2	7.2	4.5	17.3	20.4	3.9	4.5	11.9	1.2
After access cavity												
Volume	393.115	346.75	272.105	416.72	413.415	434.462	352.32	199.931	371.932	470.873	313.601	499.089
% volume lost	15.1	17.1	12.2	6.9	12	6.6	21.7	24.6	9.7	6.3	17.1	2.5
After root-canal preparation												
Volume	389.969	340.961	265.301	409.991	398.337	433.615	351.024	197.07	371.646	469.189	308.237	494.14
% volume lost	15.8	18.4	14.5	8.5	15.1	6.9	22	25.3	9.7	6.5	18.5	3.5
After fibre post preparation												
Volume	389.2	339.98	264.78	408.65	395.24	425.95	344.256	194.52	361.78	457.67	307.81	482.81
% volume lost	15.6	18.7	15.9	8.7	15.7	9.6	23.5	26.5	13.1	9	18.5	5.9
After cast post preparation												
Volume	381.335	321.922	262.088	386.012	367.562	411.028	295.97	188.718	325.413	429.6	295.291	471.026
% volume lost	17.5	22.3	15.4	13.6	21.7	11.6	34.4	28.7	20.9	14.5	21.9	8

values of the percentage of preoperative hard tooth tissue volume lost after each procedure are reported in Table 2.

The percentages of the preoperative hard tooth volume lost after caries removal, access cavity preparation, root canal preparation, fibre post space and cast post preparation were 8.3 ± 5.83, 12.7 ± 6.7, 13.7 ± 6.7, 15.1 ± 6.3 and 19.2 ± 7.4 respectively. With the exception of the root canal preparation all procedures performed significantly increased ($P < 0.01$) the amount of hard tissue volume lost. Fig. 1 shows the tooth crown view and Fig. 2 the mesio-distal view of a tooth after each operative procedure.

Discussion

The micro CT technique used in this study produced slice thicknesses of 21 μm. This allowed a precise three-dimensional reconstruction of the teeth; however, the precision of the mass measurement is limited by the resolution of the machine (Peters *et al.* 2000). The measurement of absolute values of hard tooth tissue volumes was not the objective of the present study. Instead the objective was to assess the change of hard tooth tissue volume after each operative procedure. It is therefore reasonable to assume that the imprecision of volume measurement would be similar in scans conducted after the completion of each step of the endodontic treatment/postspace preparation.

In this study only premolars with three coronal walls left were used, this meant the inclusion of teeth with a similar amount of residual tooth structure. The largest loss of hard tooth structure was caused by caries removal (~8%). This confirms that, in a case of a tooth with three remaining coronal walls (in all likelihood the smallest possible loss of tooth tissue associated with a 'nonelective' root canal treatment), caries removal is the major cause of tooth tissue loss and potentially, the major cause of tooth weakening. The loss of tooth tissue because of caries removal varied from 1.2 to 20.4%, this suggested that teeth with three remaining coronal walls may present with very different amounts of loss of tooth structure and this may affect their long-term prognosis. The preparation of the access cavity caused the second largest loss of tooth structure (~4.4%), followed by cast post (4.1%) and fibre post (1.4%) space preparation. The only procedure that did not result in a significant increase of tooth tissue loss was the root canal preparation (1%). These results

Table 2 Mean percentages* and standard deviations of hard tissue volume loss after caries removal, access cavity preparation, root canal preparation fibre post and cast post space preparation

Initial	0%	% increase
After caries removal	8.3 ± 5.83a	8.3
After access cavity	12.7 ± 6.7b	4.4
After root canal preparation	13.7 ± 6.7b	1
After fibre post preparation	15.1 ± 6.3c	1.4
After cast post preparation	19.2 ± 7.4d	4.1

*Groups with the same letter showed no statistically significant difference ($P < 0.01$).

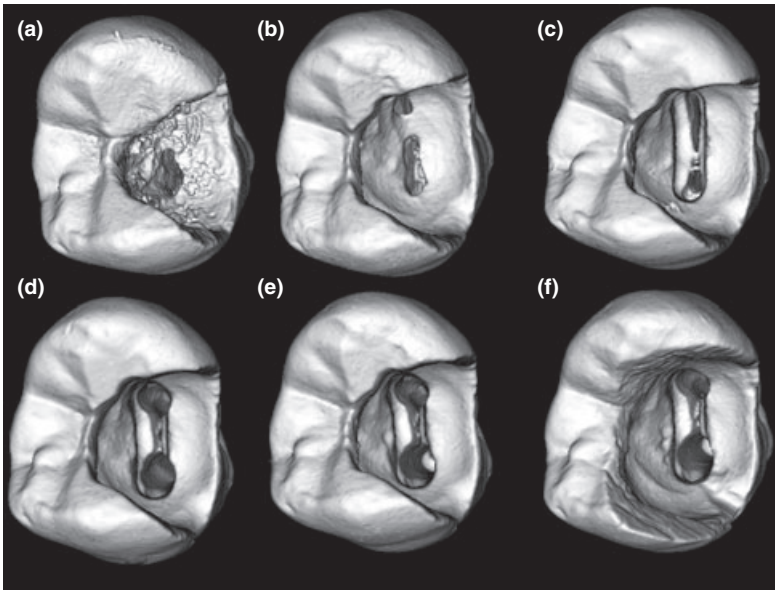

Figure 1 Tooth crown view of a tooth before caries removal (a), after caries removal (b), after access cavity preparation (c), after root canal preparation (d), after fibre post preparation (e), and after cast post preparation (f).

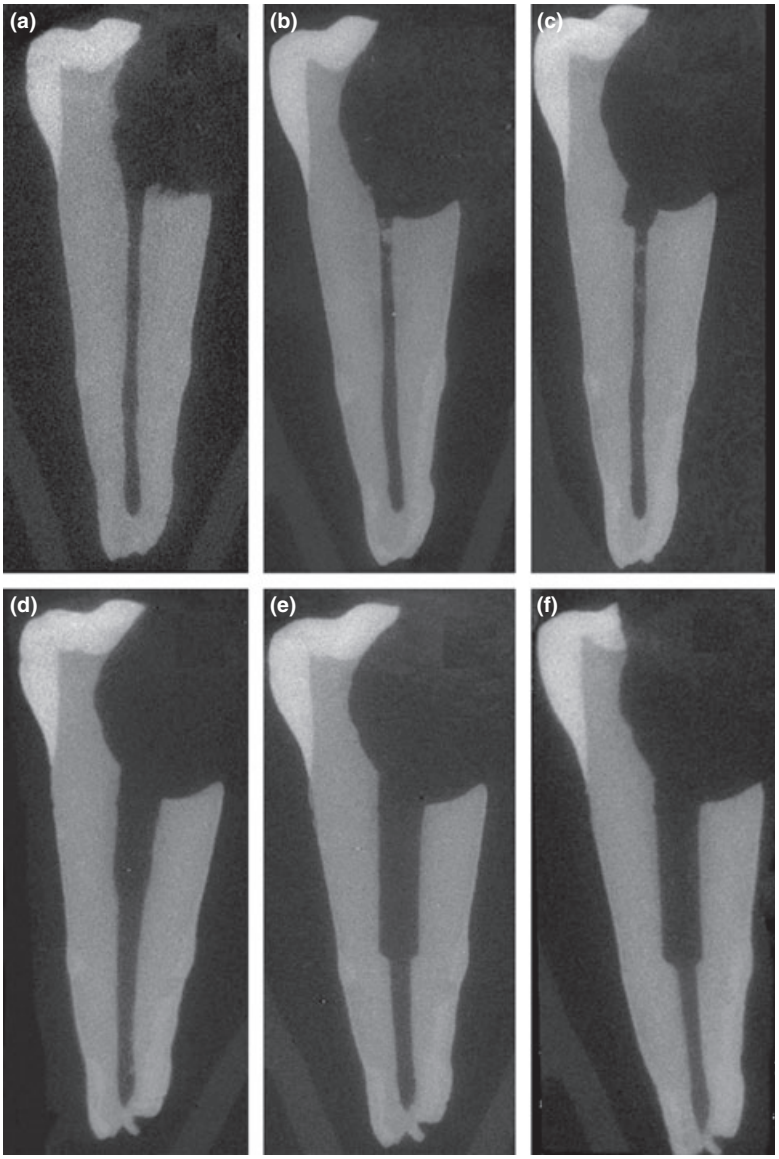

Figure 2 Mesio distal view of the same tooth shown in Figure 1 before caries removal (a), after caries removal (b), after access cavity preparation (c), after root canal preparation (d), after fibre post preparation (e), and after cast post preparation (f).

suggest that the loss of tooth structure caused by root canal instrumentation alone is small, especially taking into account the relatively aggressive root canal preparation technique used in this study which included the use of Gates Glidden drills in the coronal aspect and F2 ProTapers in the apical aspect of the root canal. The loss of tooth tissue in the coronal and root structure might well have a very different effect on the fracture resistance of the teeth, indeed finite element analysis studies have shown a high concentration of stress caused by occlusal forces in the mid-root area when posts are used (Lanza *et al.* 2005). The loss of root structure caused by root canal and post space preparation may result in a significant loss of fracture resistance. However, this is relatively insignificant when compared with the loss of coronal tooth structure after access cavity preparation.

Lang *et al.* (2006) assessed the rigidity of the teeth after access cavity preparation and post space preparation, they found a significant reduction of the root rigidity after both clinical procedures. The results of the present study strongly suggest that this loss of rigidity is associated with significant loss of hard tooth tissue structure. The loss of tooth structure caused by fibre and cast post space preparation observed in this study bears perhaps, the most relevant clinical implication.

A recent systematic review of the literature (Bolla *et al.* 2007) found only one randomized clinical trial comparing fibre and cast posts (Ferrari *et al.* 2000) providing evidence of a longer survival for fibre post restored teeth, but the evidence was regarded as weak. In 2 year (Ferrari *et al.* 2007) and 3 year (Cagidiaco *et al.* 2008) randomized clinical trials on root filled premolars restored with crowns, it was shown that the cementation of a fibre post increased the survival probability of teeth which initially presented with loss of tooth tissue similar to that investigated in the present study. There is no clinical study proving that the same is true for cast posts. This study demonstrates that modification of a preparation from a fibre post to a cast post of the same shape and size by removing the undercuts to facilitate the cementation of the cast post and core placement, more than doubles the loss of hard tooth tissue. This provides further support for the use of direct fibre post/composite restorations of root filled premolars with three remaining coronal walls which are to be subsequently restored with cuspal coverage restorations.

Conclusion

Access cavity and post space preparation are the procedures during root canal treatment that cause the largest loss of hard tissue structure. The loss of coronal tooth structure caused by the cast post space preparation is larger than that caused by the preparation of a fibre post of the same size. This needs to be taken into account in planning root canal treatments and restorations of root filled teeth that are to be restored with cuspal coverage restorations.

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