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Dentinal tubules at the root ends of apicected teeth: a scanning electron microscopic study

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Summary. Two groups of teeth, one of which contained teeth of known age, were examined by scanning electron microscopy to ascertain the presence of a potential pathway for leakage at the root ends of apicected teeth. At a point approximately 3 mm from the apex, a level chosen as being typical for apicectomy, and half-way between the root canal and the dentine–cementum junction, there were found to be, on average, 27,000 tubules per mm^2. Older teeth also displayed large numbers of tubules. Close to the dentine–cementum junction, an area which may communicate with the root canal even in the presence of a retrograde root filling, an average of 13,000 tubules per mm^2 were found.

Introduction

Although conventional root filling enjoys a high rate of success, failures may occur, and in such cases retreatment via the canal is generally preferred to a surgical approach. Retreatment through the canal is not always possible, especially in teeth which have been crowned with retention posts in their canals. In these cases there is little alternative to a surgical approach. Unfortunately, root fillings are usually inadequate in some way and it is imperative not only to remove the pathological tissue from the apical region but also to clean the canal, or the accessible parts of it, and seal it off from the apical tissue if the recurrence of apical disease is to be prevented. After resecting the root, cleansing of the canal and preparation for refilling may be attempted using endodontic files grasped in a haemostat, but this is not always possible and reliance must then be placed upon the ability of a retrograde root filling to prevent leakage from the canal.

Different techniques and materials for retrograde sealing have been evaluated. Moodnik *et al.* (1975), Tanzilli *et al.* (1980) and Kaplan *et al.* (1982) concluded that cold, burnished gutta-percha provided the best seal, although Vertucci & Beatty (1986) concluded that the seal provided by amalgam was superior. Their findings did not confirm those of Tronstad *et al.* (1983) who claimed that the application of cavity varnish prior to the placement of amalgam enhanced the seal.

The problems of access often result in the root being resected at an oblique angle to facilitate visibility and the placement of the retrograde seal. This angled cut across the root introduces the possibility of creating another pathway for leakage to occur between the canal and the apical tissues, namely through the exposed dentinal tubules (Barnes 1984). Arens *et al.* (1981) recommended that a minimum amount of root end should be removed and stated that removal of more than 1 mm could induce failure, although they did not cite evidence as to why this might be so. They also advocated sectioning thin and lingually inclined roots at angles as steep as 60–70°. Vertucci & Beatty (1986), however, illustrated a situation whereby steeply angled root resections were observed to be more likely to allow leakage between the cut face and the root canal. Although dentine has been studied extensively (Tronstad 1973, Garberoglio & Brännström 1976), most studies have concentrated on coronal dentine. Nalbandian *et al.* (1960) concluded, on the basis of their light and X-ray microscopic study that although opaque coronal and root dentine were similar, the transparent apical dentine seen in older teeth was relatively sclerotic, the tubules being narrow and virtually obliterated by a highly radiopaque substance. Whittaker & Kneale (1979) using scanning electron microscopy found no precise relationship between age and tubule diameter. This finding was surprising

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in view of the accepted belief in a relationship between translucent root dentine and age. They suggested that at least some tubules are not obliterated even in the translucent dentine near the apex. Carrigan *et al.* (1984), however, demonstrated that tubule numbers decreased both with age and the proximity to the apex. Nevertheless, the extent of such tubule exposure at the level at which roots are resected is not known exactly, and in view of the potential for leakage between the canal and the apical tissues, and the possibility of the exposed dentinal tubules harbouring pathogenic micro-organisms, further investigation is warranted.

The aim of this study was to establish the existence and orientation of dentinal tubules at the level at which resection is normally performed and to investigate the presence of a potential pathway through the dentine between the root canal and the external surface of the tooth.

Materials and methods

Two groups of teeth were used. The first group comprised 10 anterior teeth of unknown age. The apices were removed at distances of between 2 mm and 4 mm from the apex and at angles ranging from 45 to 60°. Their roots were then sectioned longitudinally through the root canal using a diamond disc with a waterspray. The cut surfaces were then smoothed on a Knuth Rotor[1] using fine grit abrasive discs. The second group consisted of 12 teeth from patients whose ages were known: four teeth from the 35–42 age group, seven teeth from the 60–66 age group, and one tooth from an 81-year-old patient. After the crown and coronal half of the root was removed, the remaining root was reduced with coarse discs on the Knuth Rotor to expose the length of the root canal. The exposed surface was smoothed using a fine grit disc. As the purpose of this study was to establish only the existence, number and orientation of the dentinal tubules in the apical region, a regime of surface preparation was used which would allow the clear visualization of tubules without the distraction of the smear layer or other debris. All cut surfaces were cleaned by applying 37 per cent phosphoric acid for 15 seconds and washing with an air–water spray for a further 30 seconds before immersing in 5.25 per cent sodium hypochlorite solution for 24 hours. After further washing, specimens were air-dried before mounting and gold sputter coating prior to examination in the scanning electron microscope[2].

After examination in the scanning electron microscope, each specimen from the second group was removed from the stub and an apicectomy performed 3 mm from the apex, this was considered a level used frequently in clinical practice. After cleaning, the tooth was remounted at right angles to that of the first examination. The cut root face was examined at three locations, i.e. close to the root canal,

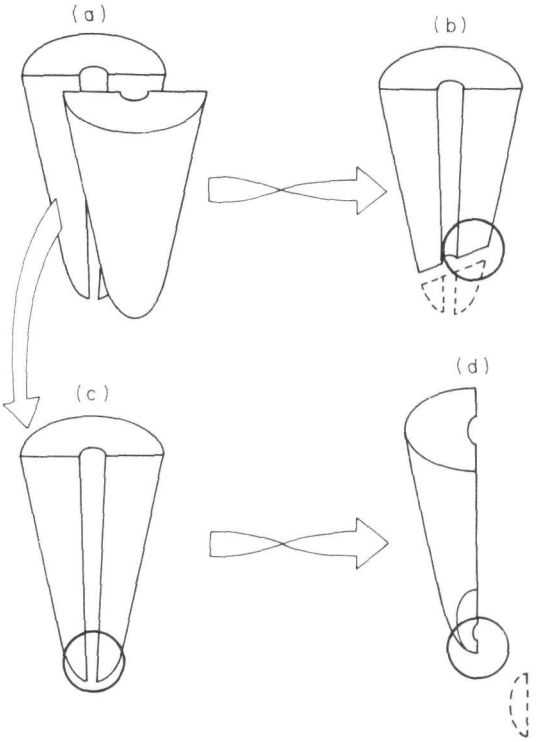

Fig. 1. The sequence of specimen sectioning: (a) the root was sectioned longitudinally in a buccolingual direction; (b) one-half was apicected and mounted for examination; (c) the other half was examined in the same configuration and (d) then this half remounted after apicectomy, the angled root face being examined. The areas examined are circled.

[1]Struers Scientific Instruments, Copenhagen, Denmark.

[2]Stereoscan 360, Cambridge Instruments Ltd, Cambridge, UK.

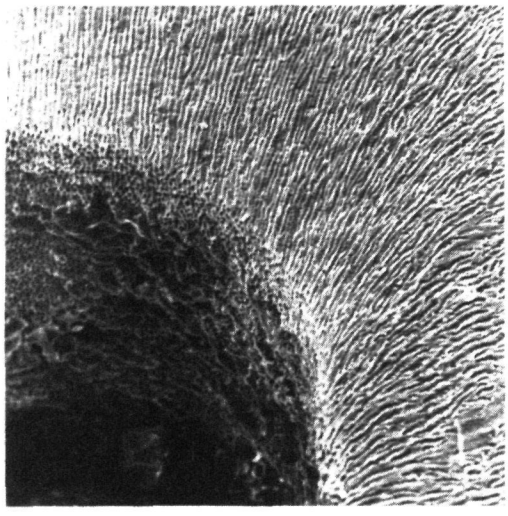

Fig. 2. Dentinal tubules are seen running radially from the root canal across the cut root face (original magnification × 100).

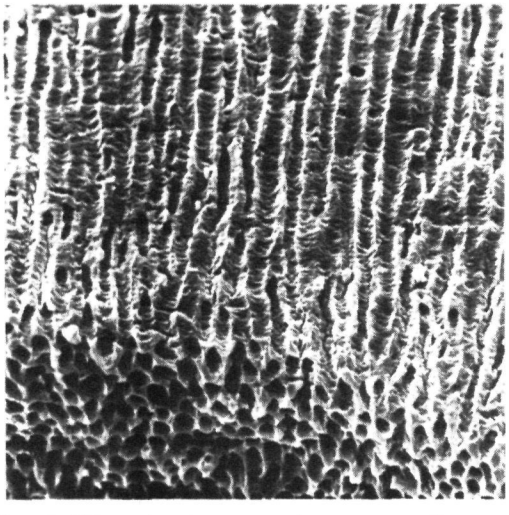

Fig. 3. The edge between the cut root face and the root canal at a greater magnification (original magnification × 600).

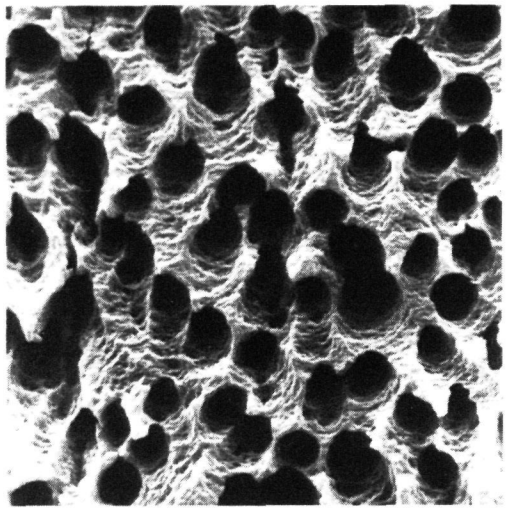

Fig. 4. Large, closely packed tubule orifices opening onto the cut root face near the root canal (original magnification × 1000).

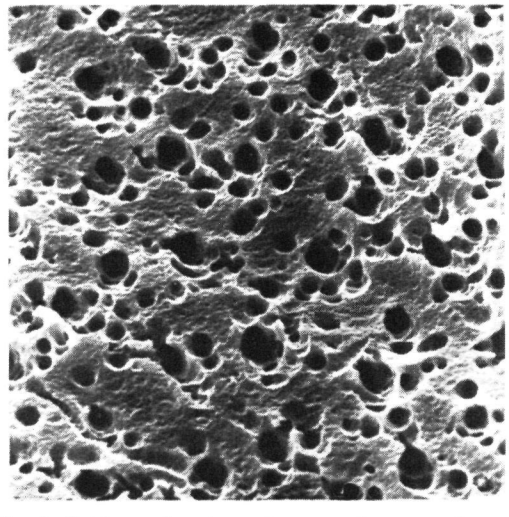

Fig. 5. Orifices of various sizes opening onto the cut root face near the dentine-cementum junction (original magnification × 1000).

about half-way between the canal and the dentine–cementum junction and just inside the dentine–cementum junction.

The scanning electron microscopy was carried out at accelerating voltages of 20 kV and magnifications ranging from × 50 to × 5000. An electronic grid was superimposed over images photographed at a standard magnification of × 500 to calculate the number of tubules per mm^2. All photomicrographs obtained were tilt compensated. The areas examined are indicated in Fig. 1, which also depicts the sequence of specimen preparation. The number of tubules in specific areas was obtained by counting all the large and medium sized orifices in five squares considered representative of the area as a whole. A second examiner also counted five squares, the numbers from both examiners being averaged. The number of tubule orifices per square millimetre was calculated from the mean per grid square, the area of which was 918 μm^2.

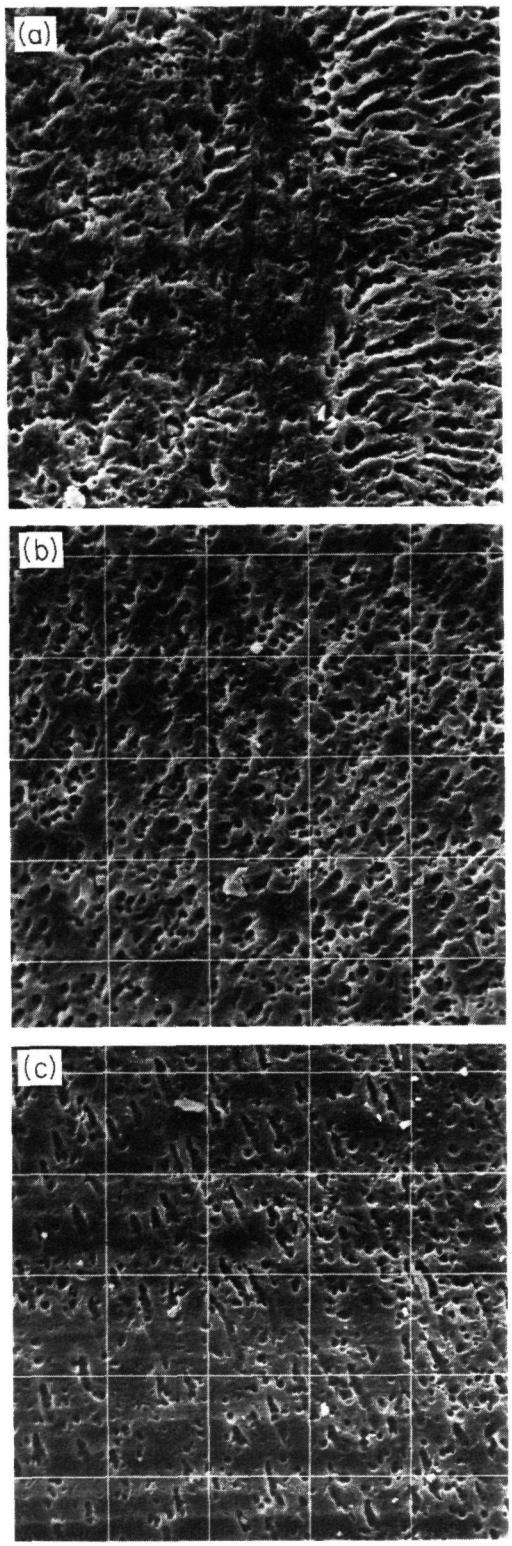

Fig. 6. Tooth from the 81-year-old patient: (a) close to the root canal irregular dentine lines the canal at the left and more regular dentine to the right; (b) mid-way between the canal and the dentine–cementum junction; and (c) close to the dentine–cementum junction (original magnification × 500). The side length of each grid square is 30.3 μm.

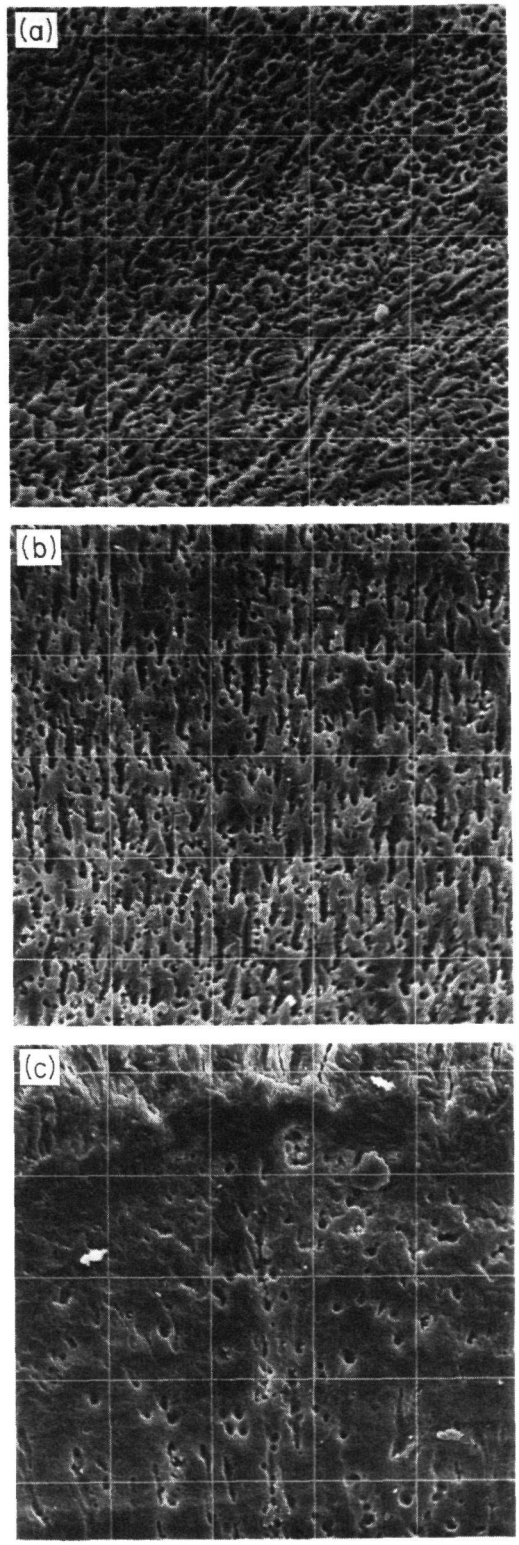

Fig. 7. Tooth from 44-year-old patient: (a) close to the canal wall the tubules are tightly packed; (b) mid-way between the canal wall and the dentine–cementum junction; and (c) at the dentine–cementum junction tubules are more widely separated and the cementum can be seen at the top (original magnification × 500). The side length of each grid square is 30.3 μm.

Results

Group 1: teeth of unknown age

Scanning electron microscopic observation of the apicected root faces revealed that in all 10 teeth dentinal tubules were exposed. Superficial tubules could be seen to communicate with the root canal at their proximal ends (Figs 2 and 3) and with the external surface at their peripheral ends, although the number, size and orientation of the tubules and their orifices varied widely (Figs 4 and 5). The variation in sectioning levels and angles in this group made any determination of tubule numbers difficult and was therefore not attempted.

Group 2: teeth of known age

At a distance of 3 mm from the apex, and approximately half-way between the root canal and the dentine–cementum junction, the number of tubules varied between 16,000 and 35,000 per mm^2, with a mean of 27,000 (SD 5930). Older teeth also had large numbers of tubules, indeed, at this level of the root the 81-year-old patient had 25,000 tubules per mm^2.

The re-examination of these specimens at right angles after performing a simulated apicectomy enabled tubules to be counted in three specific places on the cut root face. Close to the root canal the number of exposed tubules ranged from 19,000 to 48,000 per mm^2, with a mean of 28,000 (SD 8410). Half-way between the canal and the dentine–cementum junction the range was 18,000 to 30,000 per mm^2, with a mean of 24,000 (SD 2840). Just inside the dentine–cementum junction the number of exposed tubules ranged from 7000 to 17,000, with a mean of 13,000 per mm^2 (SD 2470) (Figs 6 and 7).

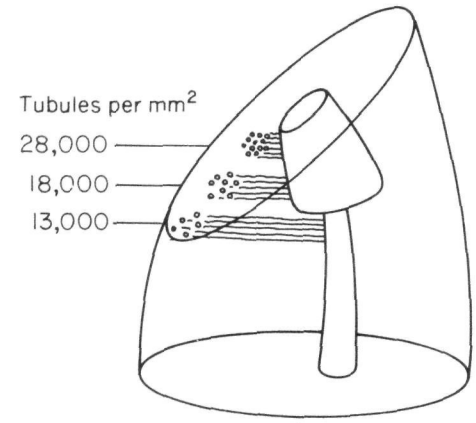

Fig. 8. Tubule density at three locations on an apicected root face: top, close to the root canal; middle, mid-way between the canal and the dentine–cementum junction; and bottom, close to the dentine–cementum junction. Potential for leakage exists if the angle of the cut face is steep and/or the retrograde filling extends for only a short distance into the canal.

Discussion

Leakage around retrograde fillings of various types has been extensively investigated, but less is known about the pattern of leakage that might occur through the dentine of the cut root face. Ichesco *et al.* (1986), using a spectrophotometric analysis of dye penetration, concluded that the resected root end of an endodontically treated tooth quantitatively exhibited more leakage than teeth without resection. Beatty (1986), using a similar method for the analysis of dye penetration, examined the leakage that occurred in roots which had been resected at different angles and contained different retrograde preparations filled with amalgam. He concluded that significantly more leakage occurred in those roots where the apical cavity preparation did not extend to the height of the bevel. This finding gave credence to the proposal by Vertucci & Beatty (1986) that exposed dentinal tubules may constitute a potential pathway for leakage. The numbers of tubules found in this study are not dissimilar to those given by Carrigan *et al.* (1984). Differences are most likely to be related to the difficulty in judging whether any particular hole is a main tubule or a branch of a tubule. This technical problem of identification is relatively unimportant as the study clearly demonstrates that a potential for leakage exists. Of further interest was the high number of tubules seen in older teeth, and it may well be that the root dentine of older teeth is more permeable than hitherto believed. In this study, however, permeability was not investigated, indeed the method of preparing the surfaces for examination precludes comment regarding tubule diameters which could well differ from those *in vivo* (Michelich *et al.* 1978).

Nevertheless, on the grounds of the number of tubules apparently communicating between the apicected root face and the root canal, it is suggested that not only should the angle of the bevelled root face be kept to a minimum, but also that the retrograde root filling should extend back into the canal at least to the level of the coronal end of the bevel (Fig. 8). Unfortunately, this is not always easy to achieve clinically, due to problems created by the need for surgical access and the configuration of the roots and their canals. For this reason it would be desirable to develop means of sealing the exposed dentinal tubules on the cut root face. Quite apart from the potential for leakage of toxic products between the root canal and the apical tissues via dentinal tubules, exposed tubules may harbour micro-organisms (Adriaens *et al.* 1988). If this is the case, it provides an additional reason for developing means of sealing the root face after apicectomy. Whether leakage actually does occur through these tubules remains to be shown, and it is to be expected that the presence or absence of a smear layer may have some influence.

Conclusions

This study demonstrates the existence of large numbers of exposed tubule orifices on the cut root faces of apicected teeth. Although the number diminishes closer to the dentine–cementum junction, there are still, on average, 13,000 per mm^2 in this region. The angle of the bevel on the root face should be kept to a minimum and retrograde root fillings should extend back into the canal, preferably beyond the level of the most coronal aspect of the bevel. Improved methods and materials need to be developed for sealing both canal orifices, and exposed dentine surfaces.

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