Root Canal Morphology in Incisor Teeth in the 6-15 Year Old Child

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EVERY tooth has an internal cavity, which extends nearly the whole length of its bony part . . . In general it may be said, that the whole of the cavity is nearly of the shape of the tooth itself, larger in the body of the tooth and thence gradually smaller to the extremity of the fang; simple where the tooth has but one root; and in the same manner compounded when the tooth has two or more fangs".

Since John Hunter wrote these words in 1788 many studies of root canal anatomy have been carried out but none of these has related specifically to developing teeth. The purpose of this paper is twofold. Firstly, the findings of an examination of the root canals of developing incisor teeth are described. Then, having discussed the objectives of root canal therapy in general, the techniques commonly used in endodontics are considered with particular reference to the younger patient.

EXAMINATION OF ROOT CANALS OF DEVELOPING INCISOR TEETH

The literature contains very little information concerning root canal shape during its development. The fullest description is still that given by Black in 1897. "*In the formative stage, i.e. during the growth of the root of the tooth, the root canal is large and funnel-shaped with the open end of the funnel towards the apex of the root. As growth proceeds, and the root approaches completion, this diminishes rapidly till the root is fully formed, when it is contracted to a small foramen*". An examination of the root canal in the developing dentition was therefore carried out with two objectives in mind :—

1 To describe the stages of development of the root canal and to relate them to the age of the patient.

2 To obtain measurements of the size of the root canal at each stage of development which could be related to a standard size for a canal prepared with the largest available hand reamers. The stage of development at which the matching reamer and filling point technique might be used effectively could then be estimated.

The anatomy of developing root canals can be examined either on extracted teeth or by carrying out a radiographic survey of the teeth during a child's development. The latter method not only requires a study extending over several years but is also limited in its usefulness since it shows only the mesio-distal dimensions of the root canal. It was, therefore decided to use extracted teeth.

Root development is a continuous process and any stages described in it are both arbitrary and transitory. However, it is possible to distinguish two main phases of root growth, firstly the achievement of full root length and secondly the so-called closure of the apex. Fanning (1961), in a radiographic survey of the developing dentition carried out on Boston school children, described the development of root length in seven stages and of apical closure in two. In the present investigation only extracted teeth were used and since eruption of incisor teeth does not take place until at least half of the root length has been reached Fanning's first three stages were not applicable. The remaining six stages were used to assess the stage of development of each tooth. These were as follows and they will be referred to by the symbols shown :—

$R\frac{1}{2}$ = half root length
$R\frac{2}{3}$ = two-thirds root length
$R\frac{3}{4}$ = three-quarters root length
Rc = root length complete
$A\frac{1}{2}$ = apex half closed
Ac = apical closure complete

MATERIALS AND METHOD

203 incisor teeth from children between 6 – 15 years of age were collected from the

extraction department of the Birmingham Dental Hospital and from school dental clinics throughout the Midlands. Of these 27 were rejected because there was evidence of apical resorption or root fracture and the remaining 176 teeth were used in this examination. The following details were obtained with each tooth.

1 The identity of the tooth.
2 The patient's name and sex.
3 The age of the patient at the time of extraction.
4 The reason for the extraction.
5 The time that had elapsed since the occurrence of trauma, if any.

The teeth were examined in two ways :—

a **Radiographic examination**

Radiographs were taken of each tooth in two positions in order to show both the mesiodistal and labiolingual dimensions of the root canal. A fine grain film was used throughout and the radiographs were examined under a magnifying lens over a Walton X-ray viewer. From an examination of the films showing the mesiodistal dimension (i.e. a similar picture to that obtained on intra-oral radiographs) the stages of development were assessed and the teeth were grouped accordingly.

b **Ground sections**

Teeth representative of each stage of development were then selected. They were embedded in clear acrylic resin, mounted in a tooth cutting machine (Bovis, 1968) and cut with a diamond impregnated circular saw. Ten transverse sections were taken at 1 mm. intervals starting at the apex and progressing towards the crown. Each section was numbered with small dots of nail varnish on the clear acrylic resin so that the number of dots represented the distance in mms. by which the section was separated from the apex. These sections were examined under a projection head microscope and measurements were taken of the maximum labiolingual and mesiodistal dimensions of the root canal.

A further sample of the teeth were sectioned longitudinally to allow an examination of the full length of the root canal and to provide more detailed information concerning the surface of the root canal walls and the apical foramen.

RESULTS

69 maxillary central incisors, 72 maxillary lateral incisors and 35 mandibular incisors were used for this investigation. The mandibular central and lateral incisors were examined as one group since the total number collected was small and previous studies (Green 1955, Sommer. Ostrander and Crowley 1966) had shown that the morphology of their root canals was very similar.
The teeth were equally distributed between the sexes.

Table I shows the reasons for extraction of the teeth examined. The group headed "Caries" includes some teeth extracted because of their unsightly appearance, e.g. hypoplastic teeth, and also as a result of general neglect of the mouth requiring a clearance.

The age at which each stage of development was reached is shown in Table II. There was a range of up to 5 years in the age at which each stage might be reached but the figures shown represent the average age for teeth in each group.

The ages for stages A½ and Ac for maxillary centrals and laterals are very similar

TABLE 1 — REASONS FOR EXTRACTION OF TEETH

Reason for Extraction	Maxillary Centrals		Maxillary Laterals		Mandibular Incisors		Total	
Trauma	34	(49.3%)	6	(8.3%)	7	(20.0%)	47	(26.7%)
Orthodontics	3	(4.3%)	37	(51.4%)	20	(57.1%)	60	(34.1%)
Caries	30	(43.5%)	22	(30.6%)	3	(8.6%)	55	(31.2%)
Not known	2	(2.9%)	7	(9.7%)	5	(14.3%)	14	(8.0%)
TOTAL	69	(100.0%)	72	(100.0%)	35	(100.0%)	176	(100.0%)

and it seems probable that this is the result of examining a sample of teeth from patients up to but not beyond 15 years old. The average ages for stage Ac might well have been higher if the age-limit had been raised. The figure for stage Ac mandibular incisors is probably more accurate since this is two years later than the average age for mandibular incisors.

TABLE II -- AVERAGE AGE AT EACH STAGE IN YEARS AND MONTHS

Stage	Maxillary Centrals	Maxillary Laterals	Mandibular Incisors
$R\frac{1}{2}$	7.9*	10.9**	—
$R\frac{2}{3}$	8.8	8.9*	9.2**
$R\frac{3}{4}$	8.11	10.9	8.7
Rc	11.3	11.8	10.0
$A\frac{1}{2}$	13.8	13.6	11.7
Ac	13.9	13.7	13.8

*One tooth only collected

**two teeth only collected

Description of root canal during development

Figures 1, 2 and 3 show radiographs of one tooth at each stage of development arranged to show a progression of root canal growth for their respective types of teeth.

1. *MAXILLARY CENTRAL INCISORS* — (see Fig. 1.)

Mesiodistally the pulp chamber is large and fan-shaped with two horns extending towards the incisal angles. It converges as it approaches the neck of the tooth so that there is a constriction at or just below the amelo-cemental junction. The pulp widens again as it enters the root canal and at stage $R\frac{1}{2}$ it diverges steadily, being widest at the apex. As root length increases the apical part of the canal narrows so that by stage $R\frac{3}{4}$ the apex is shaped like a small funnel. The widest point is now in the gingival third. The canal continues to narrow and at stage $A\frac{1}{2}$ a small constriction is found in most teeth about $\frac{1}{2}$ mm before the pulp emerges through a v-shaped foramen at the apex. By stage Ac the pulp horns have begun to shorten and the root canal has become very narrow over its apical third.

Labiolingually the pulp chamber begins as a single fine horn incisally which at stage $R\frac{1}{2}$ diverges steadily right up to the apex of the root. By stage $R\frac{3}{4}$ the walls of the canal are roughly parallel and the position of the widest point may vary throughout most of its length. There is little evidence of the funnel shaped apex seen mesiodistally at this stage. By stage $A\frac{1}{2}$ in most teeth the canal is tapering steadily over its apical two thirds but, in a few teeth, the canal remains wide until close to the apical constriction. The widest point now lies in the gingival third of the root. By stage Ac the shortening of the pulp horn can be seen and the canal has become narrow but only just before reaching the apex.

In the large majority of teeth at all stages of development the labiolingual dimension is wider than the mesiodistal so that in cross section the canal is somewhat oval. The widest point does not reach the gingival third in both dimensions until stage $A\frac{1}{2}$. In both dimensions the root canal lies close to the long axis of the tooth.

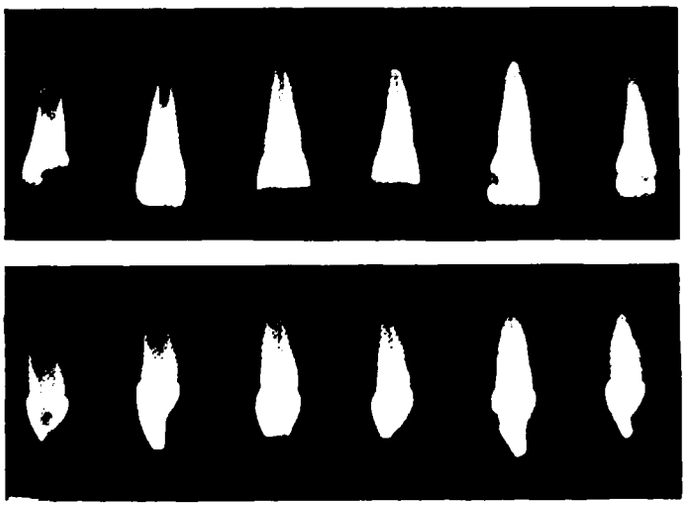

Fig. 1. STAGES OF DEVELOPMENT — MAXILLARY CENTRAL INCISORS

From left to right, $R\frac{1}{2}$, $R\frac{2}{3}$, $R\frac{3}{4}$, Rc, $A\frac{1}{2}$ and Ac

Above — mesiodistal dimension. Below — Labiolingual dimension

2. *MAXILLARY LATERAL INCISORS* (see Fig. 2.)

The shape of the root canal in the maxillary lateral is very similar to that in the central mesiodistally at all stages and labiolingually at $R\frac{1}{2}$ and $R\frac{2}{3}$. The most significant difference is that the overall width of the root canal is narrower mesiodistally than the central while labiolingually it is similar. The canal is, therefore, more markedly oval in cross-section.

Labiolingually as the root develops a considerable variation may be found in the shape of the canal. At stage $R\frac{3}{4}$ the widest point lies in the middle or apical thirds of the canal and it does not reach the gingival third in many teeth until stage Ac. Even then while some canals taper fairly steadily towards the apex, some are spindle-shaped and others pursue an irregular course sometimes widening in their apical third. The apical foramen may vary in shape from nearly round to a narrow slit-like opening.

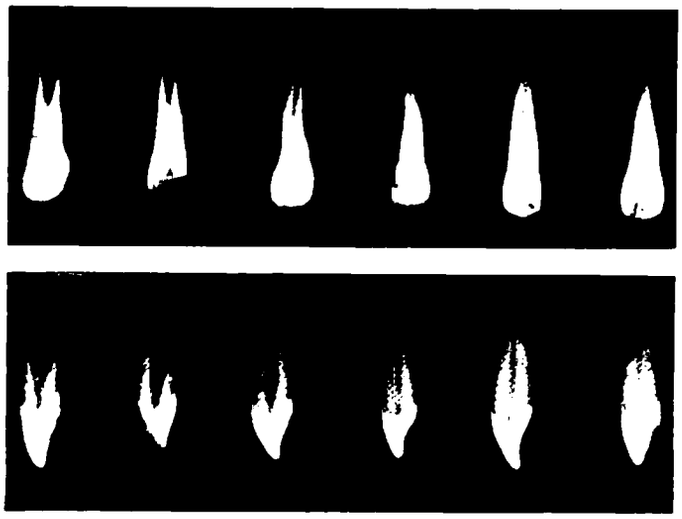

Fig. 2. STAGES OF DEVELOPMENT – MAXILLARY LATERAL INCISORS

From left to right, $R\frac{1}{2}$, $R\frac{2}{3}$, $R\frac{3}{4}$, Rc, $A\frac{1}{2}$ and Ac

Above — mesiodistal dimension, Below — labiolingual dimension

3. *MANDIBULAR INCISORS* (see Fig. 3)

Mesiodistally the root canal is very much smaller than in the maxillary incisors. The pulp chamber is again fan-shaped but the pulp horns are short. The constriction at the base of the pulp chamber is seen at stage $R\frac{2}{3}$ when the canal diverges slowly to the apex, but is scarcely evident by stage Rc when the canal tapers gradually to become an almost parallel channel close to the apex. By stage Ac the canal is extremely narrow and there is usually a slight constriction about $\frac{1}{2}$ mm from the apex.

Labiolingually at stage $R\frac{2}{3}$ the pulp starts in the crown as a fine horn which diverges steadily to reach its widest point at the apex. By stage Rc the canal has begun to narrow especially near the apex, but it remains wide throughout much of its length even at stage Ac. The widest point may vary considerably in its position.

In cross section the root canal at first resembles a narrow slit but as growth progresses it starts to close centrally, and may appear like a flattened figure 8 or two beads joined by a small length of string. In many teeth from stage $A\frac{1}{2}$ onwards small radiopaque islands are visible on the radiographs showing the labiolingual dimension of the canal. However, in no tooth in the age group examined was there a complete division of the root canal into two separate parts.

Root canal measurements

The measurements confirmed that for maxillary centrals in the large majority of teeth the labiolingual dimension of the canal was wider than the mesiodistal dimension over its apical 7 mm. They showed that in maxillary laterals the labiolingual dimension of the canal was frequently 2 – 3 times as wide as mesiodistally. In mandibular incisors the mesiodistal dimension was only one half to one third of the width in maxillary centrals, whereas labiolingually it was as wide and often wider.

Effectiveness of reaming in the 6 – 15 year old child

A standard size for the canal that could be prepared with the largest available hand reamers was estimated by reaming the canals in 5 adult maxillary incisors up to a number 12 reamer*, sectioning the roots as described above and measuring the diameter of the prepared canals. It was interesting to find that even in these teeth on at least one section a small portion of the root canal wall remained untouched in the apical half of the root. However, it was possible to produce an average size from these measurements

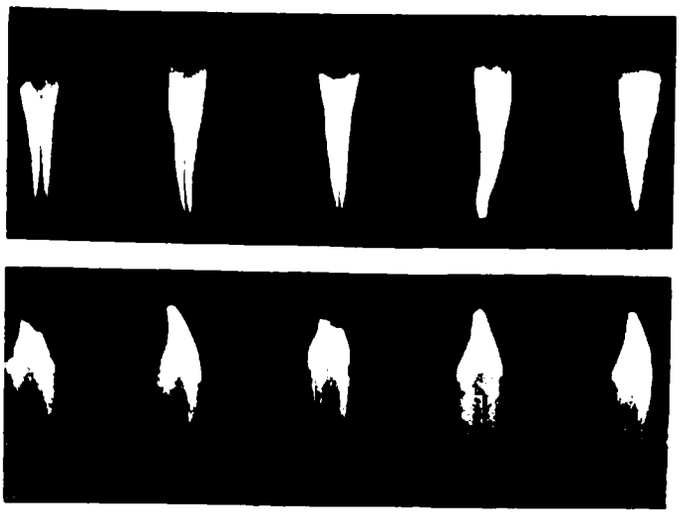

Fig. 3. STAGES OF DEVELOPMENT — MANDIBULAR INCISORS

From Left to right, R$\frac{3}{4}$, R$\frac{1}{4}$, Rc, A$\frac{1}{2}$ and Ac
Above — mesiodistal dimension, Below labiolingual dimension

and this was compared with the sizes of the root canal at the various stages of development.

It was found that for maxillary centrals a number 12 reamer could be expected to carry out effective mechanical preparation over the apical third of the root canal mesiodistally in most teeth at stages A$\frac{1}{2}$ and Ac but not at Rc. But in the labiolingual dimension at the same stages in some teeth it would be effective over the apical 3 mms of the canal but in others not at all. Therefore, it is unlikely that the root canal can be machined with a number 12 reamer to a conical shape throughout its apical third in any maxillary central incisor at 15 years or less. Some areas of root canal wall will remain completely untouched.

Recently numbers 13, 14 and 15 reamers in the same series have become available and it is possible that these could be used effectively in a few maxillary incisors at stage Ac.

In maxillary lateral incisors it was found that the mesiodistal dimension of the canal could be reamed effectively over its apical third with a number 12 reamer in most teeth from stage Rc onwards, but, labiolingually few if any could be prepared properly. Furthermore, if reaming was continued up to a number 12 there would be a considerable danger of perforating the side of the root in the mesiodistal plane close to the apex since the width of the root is very much less than that of a maxillary central.

For the same reason it would be wrong to attempt to prepare the root canal in mandibular incisors with a number 12 reamer which is frequently wider than the mesiodistal width of the root itself. Mechanical preparation in these teeth must involve the use of smaller reamers followed by files to cleanse the labiolingual dimension of the root canal.

To summarise therefore, it has been shown firstly that the labiolingual dimension of the root canal is wider than the mesiodistal dimension not only in maxillary laterals and mandibular incisors but also in most maxillary centrals in the 6 - 15 year old age group. This means that intraoral radiographs show only the narrower dimension of the root canal. Secondly the canals of few if any incisor teeth in this age group can be reamed satisfactorily to a conical shape in the apical third. Mandibular incisors present a particularly difficult problem due both to their elongated transverse shape and to the narrowing and partial division of the canal in its mesiodistal dimension.

OBJECTIVES OF ROOT CANAL THERAPY

The most common method for root filling single rooted teeth used in this country is the matching reamer and filling point technique (Curson 1966). The requirements for this may be expressed as follows :—

1 To enlarge the root canal to a known taper over its apical part.

2 To fill the canal with a point which fits this taper and can be sealed in place with a small amount of cement i.e. the root filling is primarily the point and only a minimum of sealer is required to produce a good apical seal.

The purpose of enlarging the canal is twofold, firstly to eliminate infection and secondly to produce a suitable shape to receive the root filling. This is usually achieved by enlarging the canal with reamers but how do we know in clinical practice that enlargement has been satisfactorily completed? It is impossible to specify a particular size of reamer to which a tooth should be reamed because of the change in root canal dimen-

sions with age and the considerable variation in size found within any type of tooth. Curson (1966) claimed that satisfactory mechanical preparation of the apical portion of the root canal had been completed when two successive reamers had removed clean dentine from the apical part of the canal. But this was tested in vitro and it was found that while in some teeth a circular cross section can be produced, in others large portions of the canal wall are left unreamed in the apical third of the canal. As so often happens when a purely mechanical procedure is carried out in a biological situation, it is probable that in most teeth the best that can be achieved is a compromise. The canal is tapered overall but contains a number of areas of the wall which have not been touched by the reamers.

Why should a root canal be sealed? Clinical experience shows that many teeth have remained in a satisfactory state for long periods of time although the root filling has failed to seal the canal. Most modern thinking on this subject is based on the "hollow tube theory" propounded by Rickert and Dixon in 1921, but recent reports, including those of Torneck (1966) and Browne and Friend (1968), suggest that this theory is not true. There appear to be two main reasons for sealing the root canal; firstly, to seal off any infection that remains, and secondly, to prevent the later re-introduction of infection into the apical portion of the root canal. This might occur, for example, during the preparation of the tooth to receive a post crown.

How much of the root canal should be sealed? Kuttler (1955) has shown that the apical foramen is commonly situated between 0.5 – 0.7 mm from the anatomical tip of the mature tooth. It was noted during the present measurement of the 5 adult maxillary incisor teeth prepared with a number twelve reamer that the canal reamed out did not coincide with the true root canal on the sections cut at 1 mm from the apex and not always at 2mm. There is often a sharp bend in the root canal just before it reaches the apical foramen and it would seem that as suggested by Nicholls (1967) there is little to be gained by attempting to fill the canal beyond 1.0 — 1.5 mm. from the apex. It is probable that any necrotic remnants left in that region can be dealt with by the body and several workers have shown that granulation tissue is capable of growing some way into the apical part of the root canal. There is the further advantage that a deliberate attempt to root fill 1.0 – 1.5 mm. short of the apex will reduce the chances of forcing the filling material into the periapical tissues.

How far should the seal extend towards the crown? Kuttler (1958) suggested that for an ideal root filling the dentinal canal should be completely obturated. However, Marshall and Massler (1961) used radioisotopes to show that an effective seal could be produced by filling the apical third of the canal. This is also recommended by Curson (1966) and is implicit in the sectional silver point technique (Allred, Grundy and Hatt 1961.) It seems, therefore, that a satisfactory root filling should aim to seal approximately 5 mm. of the canal ending 1.0 – 1.5 mm from the apex.

APPLICATION OF FINDINGS OF THIS STUDY TO ROOT CANAL THERAPY IN YOUNGER PATIENTS

Access

Classically access to the pulp chamber in an incisor tooth is gained through its lingual surface and it should not be forgotten that this approach is a compromise. The pulp chamber and root canal lie close to the long

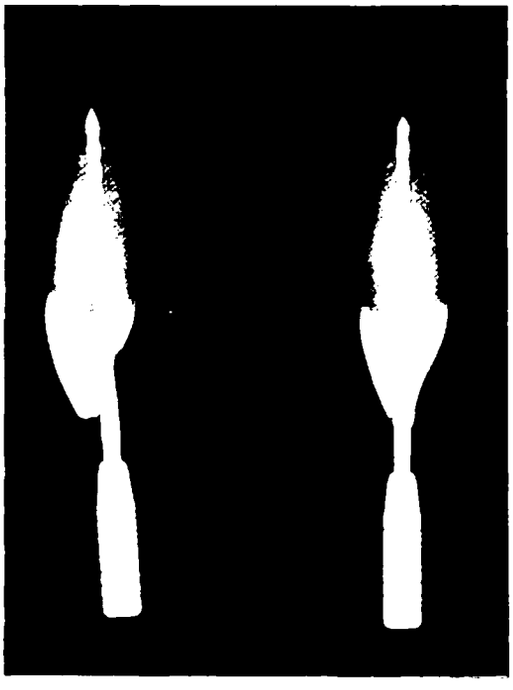

Fig. 4. EFFECT OF POSITION OF ACCESS
On left reamer inserted through lingual approach
On right through incisal approach

axis of the tooth and the pulp horns extend towards the incisal edge. Fig. 4 shows two teeth with reamers in the root canal. The pulp chamber in the tooth on the left has been entered through a lingual approach while that on the right straight through the incisal tip. It can be seen that when using a lingual approach the blade of the reamer tends to press against the buccal wall of the root canal close to the apex, and this tendency increases as the size of the reamer gets larger and its shank presses against the incisal margin of the access cavity so shifting its long axis lingually. The canal resulting from this approach is quite different in its position to that obtained by going straight through the incisal margin. In addition large areas of the lingual wall of the canal near the apex may be left untouched. A further possibility is that the buccal movement of the reamer close to the apex will result in perforation of the root and subsequent insertion of root filling material into the periodontal ligament in a situation which cannot be detected on an intra-oral radiograph. It is not convenient to use an incisal approach routinely because in so doing the integrity of the buccal surface of the tooth is destroyed, but it should be employed whenever possible. This is especially so when the crown is already fractured or discoloured and an artificial crown will later be needed. When it is not possible to employ the incisal approach the best compromise is obtained by removal of some of the dentine on the lingual wall of the root canal just inside the access cavity which should be placed well up towards the incisal margin. Care should be taken to include the full extent of the incisal pulp horns.

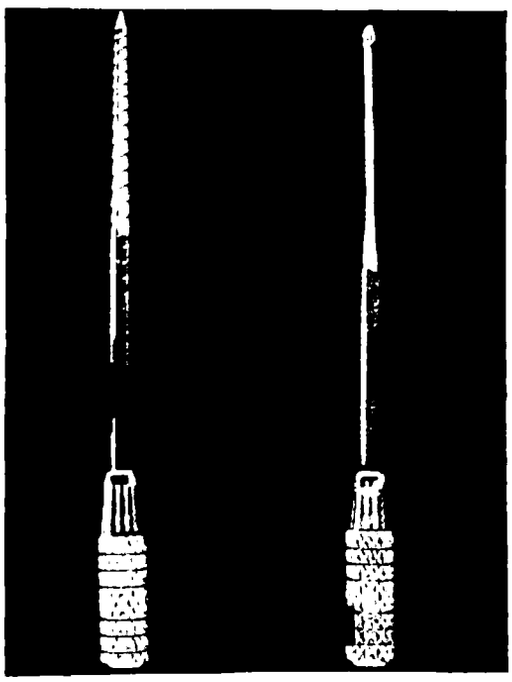

Fig. 5. On left No. 12 file —
On right No. 12 file modified to leave projection near tip and blunted end.

Mechanical Preparation

In mature teeth this is carried out largely with reamers, but in developing teeth the emphasis should be on filing. Reamers will remove a considerable amount of dentine mainly from the mesial and distal surfaces of the root canal, but they are invariably inadequate by themselves even in the later stages of development.

When the apex is still open the root canal should be prepared to approximately 2 mm short of the tip of the root. This will prevent damage to the periapical tissues and to the granulation tissue which is frequently found in the apical part of the root canal.

Haemorrhage can cause considerable difficulties in these teeth and it can be avoided or minimised if the sharp point at the end of the reamer or file is first blunted.

The file should be used so that the complete circumference of the root canal is cleansed. Modification of one of the larger files (as shown in Fig. 5) leaves a projection near the tip which can be used to remove debris from the less accessible parts of the canal.

Root Filling

At the earlier stages of root development before full root length is achieved root filling can be approached in two ways. After mechanical preparation has been completed the root canal can be medicated with a calcium hydroxide preparation and left for up to 2 years in an attempt to induce the formation of a calcific barrier across the root apex. Alternatively it can be filled with a plastic filling material, such as Diaket, so that root treatment is completed without further delay.

At the later stages of development if the matching reamer and filling point technique is used special attention must be paid to lateral condensation in order to seal the apical third root of the root canal. It is worth

emphasising that a root canal which may appear to be well filled on a standard intra-oral radiograph may be grossly underfilled labiolingually, particularly as it is this dimension that is usually the larger. For this reason the sectional silver point technique is contra-indicated in incisor teeth in patients under 16 years of age. Although a seal may be achieved in the apical 1 – 2 mm of the root, if an apicectomy is necessary later, the amputated silver point may be lost during the operation. An example of the inadequacy of this seal is shown in Fig. 6.

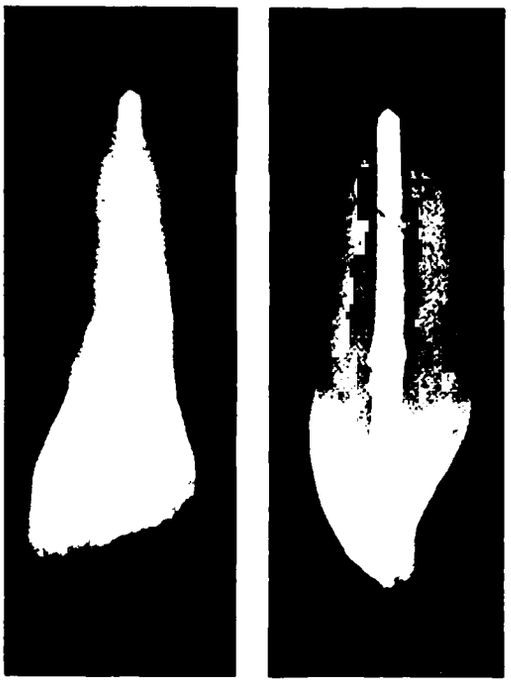

Fig. 6. $\underline{1}$ well sealed with sectional silver point in mesiodistal dimension
On left, seal is deficient lingually in labio-lingual dimension on right

Thus in developing teeth the root filling should consist largely of a plastic material capable of filling any irregularities left in the prepared root canal. At the later stages of development $A\underline{1}$ and Ac the root canal is widest in its gingival third and it is usually possible to effect a satisfactory seal in maxillary incisors with gutta-percha, using a master point plus smaller accessory ones and an ample amount of sealer. In the mandibular incisors the canal is narrow mesiodistally and a silver point may be indicated since being rigid it is less likely to buckle than gutta-percha. In this case an excess of cement should be inserted into the canal first to obtain a good seal.

It is not the purpose of this paper to discuss in detail the various methods recommended for root filling immature teeth but it is hoped that what has been said has emphasised the importance of a thorough knowledge of root canal anatomy as the basis for satisfactory root canal therapy in developing teeth.

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