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Diagnosis and therapy of branched Root Canal Systems

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Key words *access cavity, branched root canal systems, dental operating microscope, intracanal endodontic diagnostics, tooth anatomy*

There is a narrow margin between success and failure of root canal treatment due to the complex anatomy of the root canal system. Visualisation of the complexity of the root canal system is offered by the impressive anatomical images taken by Walter Hess, an anatomist from Zurich, at the end of the last century. The endodontium includes, in total, the main communicating root canals, numberless small lateral canals and several ramifications. In the dental practice, the location, shaping and sealing of root canals which are closely related and have ramifications, represent a special challenge for the clincian and is very often an almost insolvable task. This highlights how the knowledge of anatomy decides the technical parameters of the root canal treatment and, at the same time, it decides upon the probability of success. Therefore, the following overview presents explanations concerning the incidence and classifications of ramifications and lateral canals in the literature and their clinical significance, as well as the resulting consequences and the treatment strategies illustrated by several clinical cases.

Introduction

The goal of any root canal treatment is the cleaning, disinfection and tight, three-dimensional obturation of the root canal system. The term root canal system refers to a complex endodontic cavity, which becomes more and more narrow and morphologically differentiated, as a result of the lifelong dentin formation of the pulp tissue[1]. An optimal cleaning of the system is possible, only if all root canals can be found, accessed and sealed. A very important - maybe the most important - premise for successful root canal treatment is the precise and detailed knowledge of the anatomical relations. The complexity of the anatomy of the root canal system is always a clinical challenge and it sometimes hides difficulties, which can endanger the goal of the therapy[2].

The regular visual observation of two-dimensional radiographs can affect the awareness and the perception, so that a strong simplified image of the effective root canal system is produced.

The famous study of the root canal anatomy by Hess[3] (1917) shows how illusive this representation is. Using 2800 human teeth, the study showed, with the help of plasticised rubber, the multiple ramifications of the root canal system. Since then, more often, the anatomical variations of human root canal systems have been assessed using different methods, recently using scanning electron microscopes, digital radiological procedures and micro-computed tomography (micro-CT). Despite the present technological developments, it is still very hard, sometimes impossible, to mechanically clean and shape the (main) canals of the endodontic system using traditional root canal instruments in order to allow, firstly, an optimal chemical cleaning and disinfection and, secondly, a bacterial free sealing of the shaped root canals and/or their ramifications.

Anatomy

Roots

Carabelli (1844) described for the first time the number and pathways of roots and root canals[4]. The number, size and form of the roots in each tooth are functionally determined by its crown, but are also subjected to the genetic polymorphism and show ethnic characteristics. There are teeth with one or multiple roots, the latter presenting generally two or three roots. The roots can be straight or with various types of curvatures in different planes.

With the help of cone beam computed tomography (CBCT), nowadays, it is possible to display the roots of a tooth three-dimensionally and with accurate dimensions[5-7]. But this technique is not available for all dental practitioners. Traditionally the two-dimensional radiographs are performed in order to display human teeth and their roots, offering indications concerning the real anatomical configuration of the roots. But the two-dimensional radiograph of a tooth does not allow the evaluation of curvatures in certain planes. Due to the fact that the plane of certain curvatures of a root cannot be properly determined on radiographs (even when using different projections) [8, 9], before initiating a root canal treatment, it is also important to take into consideration the statistical values concerning the root anatomy of the respective type of tooth.

For most cases it is possible to radiographically determine at least the number of roots and their anatomical contour. One of the rare situations where this cannot be done, is the superposition of the roots, i.e. in case of a radix entomolaris, especially if no other eccentric radiographs are available (Fig 1). The prevalence of such anatomical aberrations of the lower molars is reported to be at around 3% for Caucasians. For the Asian population the frequency of the radix entomolaris is much higher, up to 40%[10]. If, during the clinical examination of the tooth crown of a mandibular molar, a supplementary cusp (tuberculum paramolare) is found in combination with a cervical prominence or invagination, this can indicate the presence of the radix entomolaris. But this helpful indication is missing in cases of teeth which are already crowned.

The presence of two palatal roots in a maxillary molar (Figs 2 and 3) is both a seldom situation and one that is hard to diagnose on radiographs, all due to the superposition effects.

The anatomy of root canals

The shape of root canals is primarily determined by genetics, but it is also influenced, under the circumstances of a vital pulp, by external and internal stimuli. In comparison with the anatomy of other organs, the age of the patient has a high influence upon the anatomical relations within the tooth: the older a vital tooth is and the more it is subjected to mechanical, chemical, thermal and microbial stimuli, the more secondary and tertiary dentin that will be produced. The results are represented not only by a narrowing or partial obliteration of the root canal, but also by compartmentalisation into diverse root canal structures[11,12].

An example of this phenomenon is the lower incisor, which has a typical root with proximal, discrete grooves along the root length axis. Due to the progressive formation of secondary dentin, the pulp cavum narrows in cross section and the root canal obliterates from coronal to apical as one ages[13]. Together with the narrowing of the coronal pulp cavity, isthmuses can occur at the passing, from the coronal to the middle third, as well as in the apical third of the root[14]. During the lifelong production of secondary dentin, the system can split into two or multiple partially separated root canals [15].

The literature provides numerous classifications of different canal configurations, with pieces of information concerning the average value of the number of canals, and the length and shapes of canals for each tooth type, but due to the multiple variations, many teeth have an individual 'unique' anatomy, which diverts from the average values. It is very important to have knowledge of the 'normal anatomy' and the possible variations, because 'we see only what we know'[16]. The smaller the structures and details are, the more diversified the variations are.

Pineda and Kuttler (1972) examined 4783 extracted teeth with 7275 root canals, using two-dimensional radiographs in order to establish the number of canals, the distribution in the individual roots, the ramifications, the localisations of apical foramina and the frequency of apical deltas[17]. Vertucci and his team performed, between 1974 and 1986, statistical

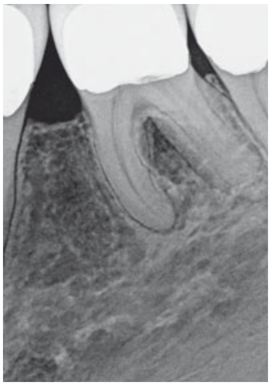


Fig 1 Radiograph of a mandibular molar with radix entomoralis. The dimension of the complexity of the root canal system is indicated by the postoperative eccentric radiograph in Fig 9.

Fig 2 Maxillary molar with two palatal roots. The detailed anatomy is not clearly recognisable on the diagnostic radiograph.

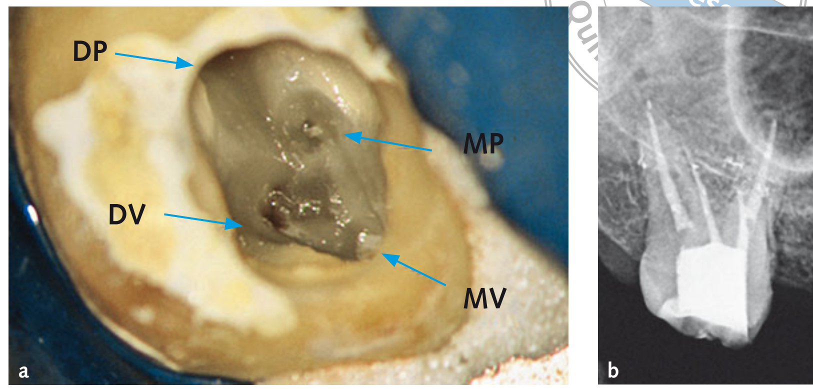


Fig 3 Clinical aspect of the pulp chamber floor during the intracanal diagnosis (a) and the control radiograph following root canal filling of the molar presented in Fig 2.

examinations on numerous transparent teeth, processed using demineralisation techniques, in order to establish the pathways of the main and lateral canals and the ramifications in the area of the apical foramen. Their classification is still the basis for many publications[18]. Other classifications have been made starting from Vertucci's classification. The most important root canal configurations described in the literature are summarised by Valencia de Pablo et al[19].

Weine suggested a classification in 1969[20], which is used even today, due to its simplicity. He distinguished the following four configurations (Fig 4):

- Type I: one root and one foramen;
- Type II: two canals, which join before the apex and one foramen;
- Type III: two canals with two separate foramina;
- Type IV: one canal, which separates before the apex into two canals.

This classification is also used in the present article.

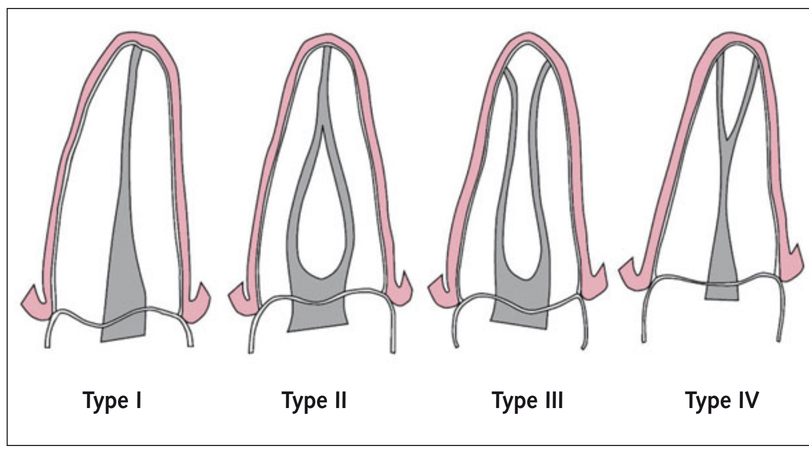


Fig 4 The four different types of root canal configurations as suggested by Weine.

Lateral canals

The entire pulp space is not a cavity with smooth walls; it is a complex, structured system of canals. The junctions between the endodontium, which are located coronally from the apical delta and the periodontium of the tooth are known as lateral canals. These are formed during the root development and can include conjunctive tissues, nerves and blood vessels. The presence of lateral canals can rarely be presumed on radiographs if there is a lateral lesion at one side of the root or lateral canals can be seen from time to time radiographically, if the canal was sealed by pressing in radiopaque root canal filling material (Figs 5a and 5b). The impact of lateral canals on the success of the root canal treatment has been controversely discussed for a long time[21, 22].

Lateral canals are more frequent in the apical third of the root than in the middle or coronal third[18,23]. In the most apical part of the root canal, the ramifications and accessory canals are the building form of the so-called apical delta (apical ramification) with accessory foramina. According to DeDeus, accessory canals are located in the coronal third (1.60%), in the

Fig 5a Periapical and lateral lesion of a maxillary incisor.

Fig 5b Following root canal filling using a thermoplastic compaction technique, multiple lateral canals were evident.

Fig 6 Three mesial root canal orifices in the mandibular molar shown in Fig 1.

middle third (8.78%), and in the apical third of the root (17.00%)[23].

The furcational canals of multi-rooted teeth, located on the pulp chamber floor and passing towards the furcation area, represent a particularity of the pulpo-desmodontal lateral canals[24].

Radiological findings

Most of the time, the internal structure of a tooth is evaluated only by means of two-dimensional radiographs, which enable only an insufficient representation: this is because morphological peculiarities such as the degree and radius of the curvature of the canal make the root canal treatment more difficult. Unfortunately, neither the degree nor the radius of curvature can be correctly assessed using conventional intraoral radiographs. Hints for the presence of ramifications, bifurcations or lateral canals are also very seldom seen on radiographs. Nevertheless, radiographs are still crucial for a correct diagnosis and for the planning of the treatment strategy. However, if the existence of an atypical canal configuration is suspected on the primary diagnostic radiograph, it is recommended that other diagnostic methods are carried out, which provide more detailed information.

The CBCT gains more and more importance for diagnosis[25] and selection of a treatment strategy. Before initiating CBCT imaging, it is recommended to perform a considerable basic diagnosis[6]. The field of view must be limited to the area of interest and a very high resolution must be targeted, meaning a voxel dimension of 120 µm or less[26]. The small volume, high resolution cone beam computed tomography is also indicated in case of suspecting or in case of the existence of a complex root canal system anatomy, as well as in cases of root fractures or perforations, separated instruments or root resorptions[5,6].

Clinical identification and preparation of branched root canal systems

Magnification

The root canal system, as part of the endodontium, is the smallest structure of the oral cavity, which is submitted to conscious and targeted mechanical or chemical treatment[1]. If for this work, a dental microscope is used, which gives a view in terms of micrometres, in order to examine the pulp chamber, the localisation of the root canals is much more successful[27].

After an adequate imaging diagnosis is performed, it is clinically recommended nowadays to use the dental microscope to perform the root canal

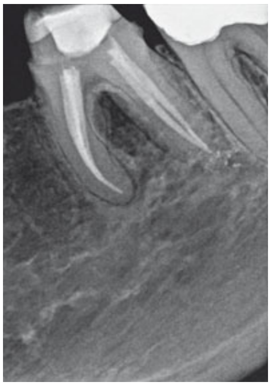


Fig 7a Control radiograph of the root canal filling in the orthoradial projection.

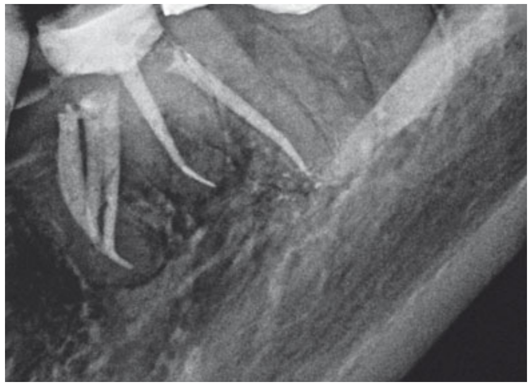


Fig 7b Control radiograph of the root canal filling in the angulated projection; the complexity of the root canal system can be identified much more easily.

Fig 8 Instruments for exposing root canal orifices: on the left side several ultrasonic tips, on the right side several round stainless steel burs with a long shaft, this includes those with a delicate, conical pointed shank ('goose neck burs') as well as a straight, thin shank (pulp burs, according to Müller), which allow adequate visibility during the work, which was under microscopic control.

treatment, because it enables an optimal intracoronal, as well as an intracanal diagnosis[28, 29].

Due to the use of the dental microscope, which combines magnification and coaxial light in the interior of the tooth, more pathological results can be identified inside the tooth and the root canals, in comparison with the traditional root canal treatment[30]. The identification of root canal orifices and deep canal bifurcations[31-33] is possible under microscopic vision, as well as removal of instrument fragments[34-36], closure of perforations[37,38], removal of intracanal obliterations[39] or treatment of complex anatomical anomalies[40,41].

Nowadays, it is decidedly known that the number of identified and adequately-shaped root canals depend essentially on the used means of magnification[27].

In the presented case with the radix entomoralis, the atypical configuration of the root canal system was distinguished only during examination with an operating microscope, where three mesial root canal orifices (Fig 6) and two distal orifices, with completely divergent canals were located (Figs 7a and 7b).

Clinical proceeding

The shape of the access cavity needs to respect the outline of the tooth crown, the inclination of the crown towards the root axis and the specific localisation of the pulp and the root canals in the tooth. After the preparation of a proper access cavity, comprising the removal of the secondary dentin covering the root canal orifices, these can be identified. For this purpose, round tungsten carbide burs with a long shaft and sizes between 005 and 014, i.e. Drux burs (Drux, Gummersbach, Germany) or Munce burs (Munce Discovery Burs, CJM Engineering, California, USA), but also ultrasonic tips with diamond coating, i.e. Spartan (Obtura Spartan, Missouri, USA) or made of hard-tempered stainless steel, i.e. Start-X (Dentsply Maillefer, Ballaigues, Switzerland) or with zirconium nitride coating, i.e. Access Refinement BUC Tips (Obtura Spartan) can be used (Fig 8).

When searching for the root canal orifices, the pulp chamber floor provides numerous orientation aids. After completion of the access cavity and often when the patient's mouth is properly open, the evaluation of the pulp chamber walls and floor, and the diagnostic indications offered by the 'endodontic map' cannot be properly assessed without optical magnification and supplementary light. For intracoronal diagnosis optimisation, a coaxial light source and magnification, ranging from four up to eight times scope, using magnifying glasses or a dental microscope are needed[42]. As a rule, the orifices of the main root canals can be located under an adequate magnification and by respecting the anatomical clues offered by the pulp chamber floor[43] and

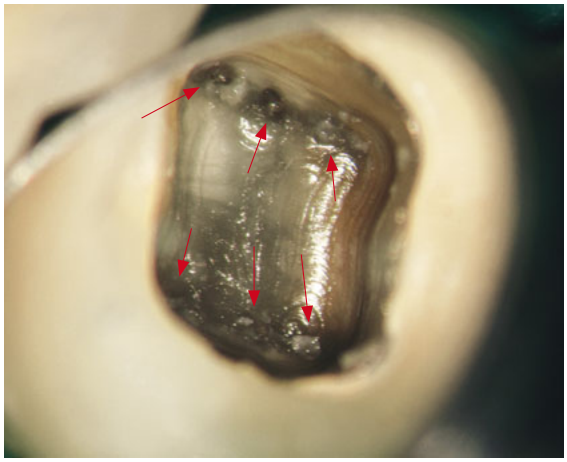


Fig 9 The 'endodontic map' of this molar reveals six canal orifices (arrows) when proper magnification is used.

the general rules of their positioning (Fig 9). In case of uncertainty, staining substances such as methylene blue (Canal blue, VDW, Munich, Germany), fuchsine or erythrosine (Caries Detector, Kuraray, Frankfurt, Germany) can be used in the area of the pulp chamber floor.

According to the imaging (intraoral radiograph and CBCT) and clinical findings (intracoronal diagnosis), four different clinical situations can be distinguished:

- Root canal visually identified – accessible canal;
- Root canal visually identified – inaccessible canal;
- Presumed root canal – accessible;
- Presumed root canal – inaccessible;
- Root canal with very close relationships / deep canal bifurcations / branched canals.

In situations where the canal orifices are located very close to each other or when deep bifurcations exist and the main root canal splits apically into two or more canals, it is very complex and clinically hard to manage. These canals or bifurcations can be identified and accessed, most of the time, by probing with adequate instruments (scouting) (e.g. Micro-Opener, Dentsply, C-Pilot-files, VDW).

Root canal visually identified – accessible canal (Fig 10)

Given that this situation is identified as the easiest, it enables the use of random strategies and techniques for the complete access and preparation of the root canal(s).

Root canal visually identified – inaccessible canal (Fig 11)

After the complete removal of the secondary and tertiary dentin, it may be possible to recognise a canal orifice but not be able to penetrate the canal with the smallest instruments of ISO sizes 06 to 10 (Fig 12). In such a case, partial obliteration of the canal is to be expected, which is a challenge, both from the point of view of further diagnosis and the therapeutic management[44].

For identification and access of such canals an optimal light and high magnification are needed. For a better view it is helpful to work under dry conditions at first (Fig 12b) and rinse the cavity for the removal of dentin chips only when these hinder the visibility of the relevant anatomical structures. Acting carefully, proceeding slowly and a satisfactory experience is a sine qua non condition to avoid unnecessary removal of hard substance and to prevent severe weakening of the tooth or iatrogenic perforations (Figs 12a to 12c).

Therefore, it is recommended, working under a dental microscope in order to ensure a continuous visual control. Information concerning the original position of the root canal can be given by the colour of the surrounding tertiary dentin or the storage of small debris. It is possible here, under visual control, to remove dentin, in a 'deepening' motion, with the help of round carbide burs with a long shaft ISO size 05 (Fig 17) or ultrasonic tips.

If sodium hypochlorite (NaOCl) is used as a cleansing agent, in order to remove the dentin chips, a quantity of the solution can be left in the 'small cavity' for a short time. If during the removal of the tertiary dentin, whilst approaching the pulp tissue of the original root canal, the pulp tissue comes into contact with the NaOCl solution, small bubbles will be formed, which can be recognised under the microscope (bubble or champagne test) (Fig 13a).

Another possible aid is the staining of the pulp chamber floor with methylene blue or caries-detector dye. After about 1 min the stain must be removed by cleansing. Due to the fact that, basically, only organic tissue is stained, narrow canal orifices containing soft tissue can be identified and accessed (Fig 13b).

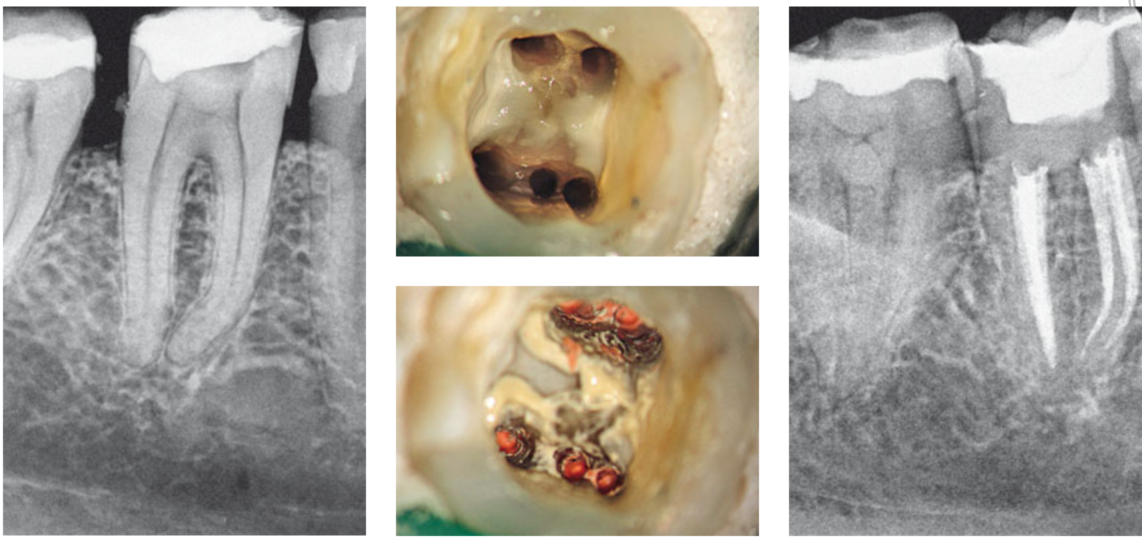


Fig 10 The diagnostic radiograph shows accessible root canals in both roots, but does not provide information regarding the number of canals. After the preparation of an adequate access cavity, the root canal orifices were found and the canals were shaped and sealed.

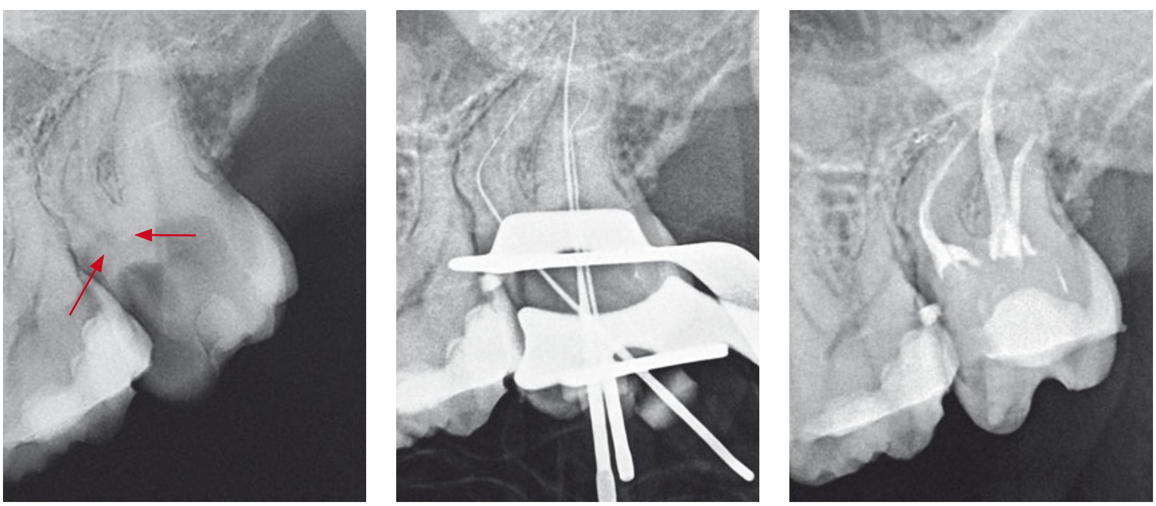


Fig 11 The root canals of the maxillary molar were radiographically recognisable but direct access to both mesiobuccal canals was not possible, because of the formed tertiary dentine.

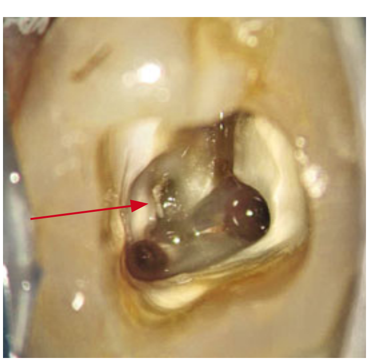


Fig 12a Calcification of the root canal orifices (here MB2) due to deposition of tertiary dentine.

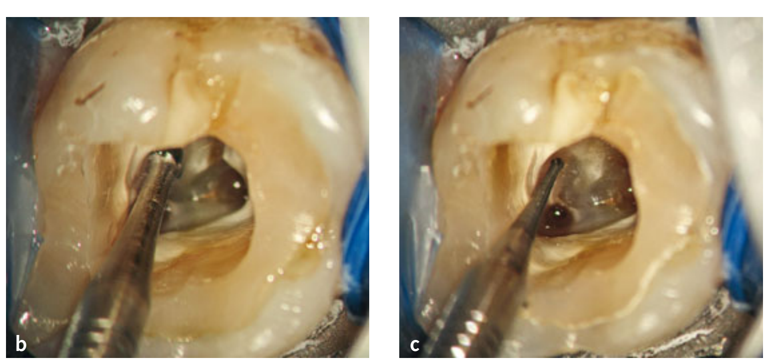


Fig 12b and c Accessing of a partially obliterated canal. Removal of tertiary (secondary) dentin under dry conditions using Drux burs with a long shaft allow continuous visual inspection under the microscope.

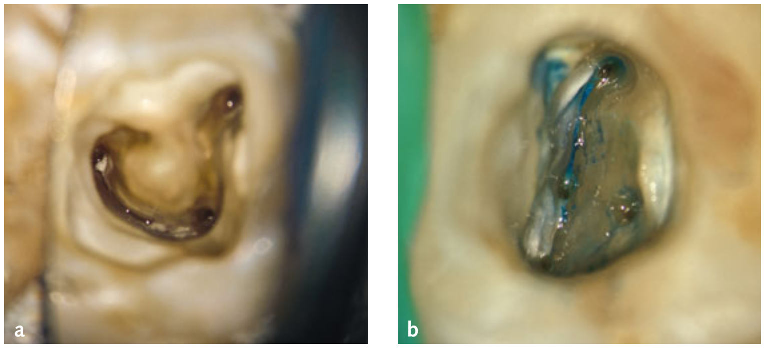


Fig 13a and b Identification of very narrow root canal orifices under microscope control: a) champagne test; b) staining of the pulp chamber floor using methylene blue.

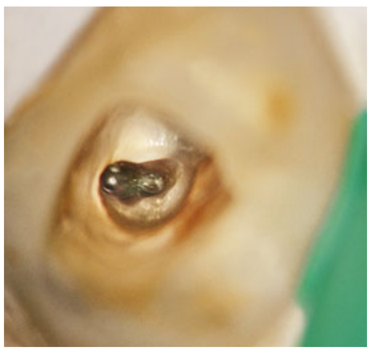


Fig 14a Visual identification of a deep bifurcation in the buccal root canal of a maxillary premolar, about 4 mm below the entrance in the main canal.

Fig 14b Control radiograph following root canal filling.

Once the canal orifice is identified, the root canal can then be negotiated by applying different techniques. In the classical variant, small K-files (ISO sizes 06 to 10) are used under slight rotation. In an alternative attempt, more rigid hand files (C-Pilot-File, VDW) with ISO sizes 06 to 10, mounted in an angled handpiece, which generates an oscillating working motion with identical angles clockwise and counterclockwise, i.e. M4 - angle piece (SybronEndo, Orange, USA) or Ti-Max Ti45 (NSK Europe, Eschborn, Germany) are used. It is very important to use only new instruments, in order to avoid file separation. The instrument should be allowed to glide through the canal, without forcing it apically. Therefore, it is essential to use EDTA glide gels and frequent irrigation.

Following negotiation of the root canal it is advisable to search for a deep bifurcation or a branched canal. If a bifurcation is found and if both canals are accessible up to their apical limit, the next steps should be followed, as described in the section '*Root canal visually identified – accessible canal*' (Figs 14a and 14b).

Presumed root canal – accessible

There are situations where there is large formation of tertiary dentin in the area of the canal orifices. On the diagnostic radiograph it can be seen that the first few millimetres in the area of the canal orifice are completely calcified. Unplanned, 'blind' attempts to locate the root canal lead to perforations and inaccessibility of the canal. If the concentricity rule is respected and the anatomy of the tooth and the root are taken into consideration, perforations into the periodontium or the furcation area during the search for the obliterated canal entries can be avoided[43]. Based on the orientation offered by the diagnostic radiograph, the removal of tertiary dentin can be directed, in the best cases, only in the mesiodistal direction (axis), but never buccolingually. It is safer to 'navigate' using a CBCT examination, allowing for the visually controlled removal of the tertiary dentin until the canal orifice is located (Fig 15).

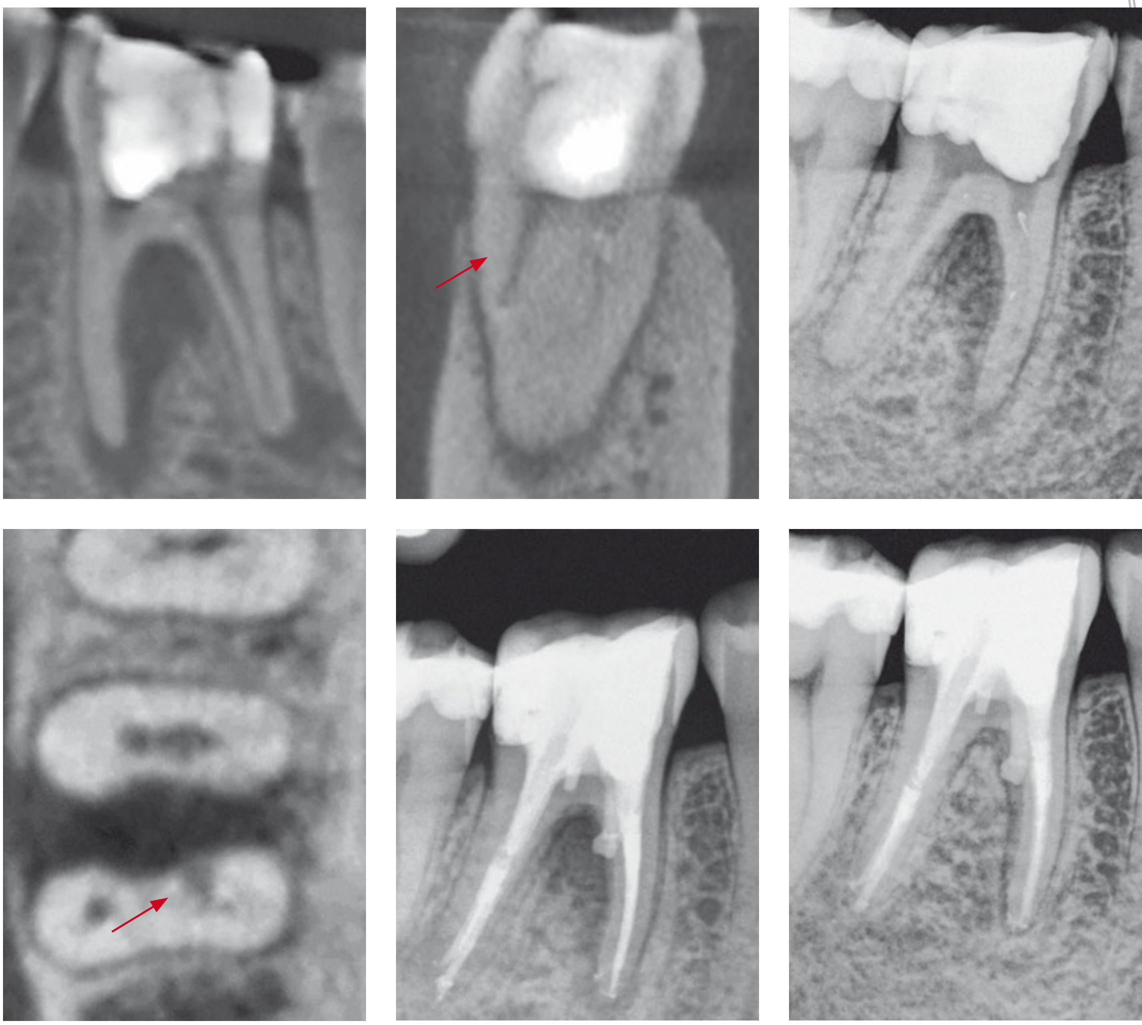


Fig 15 Tooth 46: The intraoral radiograph reveals an interradicular radiolucency in the area of the mesial root (top right). The entire extension of the interradicular lesion and the presence of the periapical lesions can be seen only on the sagittal plane images of the cone beam computed tomography imaging (top left). The transverse plane images (top middle) show that during the attempt to access and shape the mesiolingual canal, the original course was not respected (arrow). The axial plane images (bottom left) reveal the perforation in the interradicular region, as well as the original course of the canal (arrow). Following shaping and cleaning of the original canal with the help of CBCT, the sealing of the perforation and root canal filling (bottom and middle), which is an obvious reduction of the radiolucency, is apparent on the subsequent 2D control radiograph. This image is courtesy of Dr Michael Arnold, Dresden.

Presumed root canal – inaccessible (Fig 16a)

An unfavourable clinical situation is when the root canal is not visible or at best, slightly visible on the radiograph and appears completely calcified during a microscopic evaluation. In such cases it is recommended to perform a CBCT with a small field of view and a very high resolution[26].

Based on the CBCT evaluation and the microscopic intracoronal diagnosis and by taking into account the endodontic map, especially the different colours of the physiological primary and secondary dentin, it is possible to remove, under visual control, hard substance from the calcified root canal system with the help of ultrasound tips or small round carbide burs (Drux or Munce), until the signs of a canal orifice manifests, which can then be accessed and shaped with the smaller instruments (Fig 16b).

Root canal with very close relationships / deep canal bifurcations / branched canals (Fig 17)

It is very hard to diagnose and treat teeth showing a root canal configuration class 4, according to Weine, meaning a root canal bifurcation located in

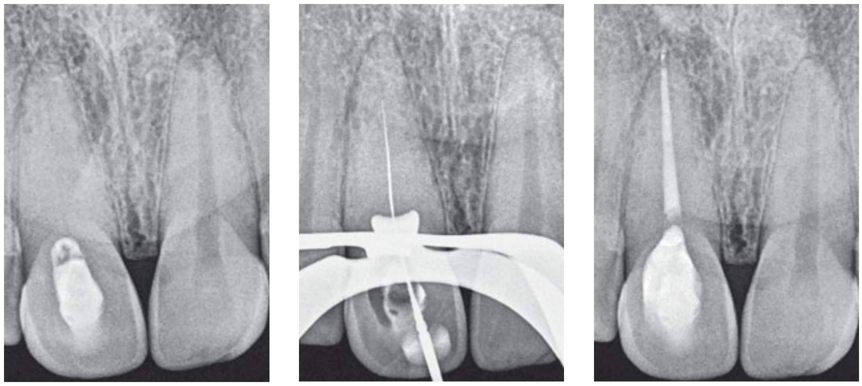


Fig 16a On the diagnostic radiograph the root canal of tooth 11 appears almost completely calcified in comparison to the root canal of tooth 21, but its pathway can be presumed. Following localisation of the root canal, negotiation of the apical third of the canal was possible under microscopic visual control.

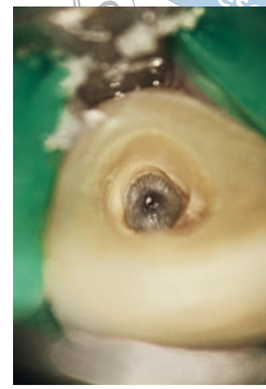


Fig 16b The microscopic inspection of the access cavity allows the 'tracing' of the course of the calcified canal by visually-controlled dentine removal.

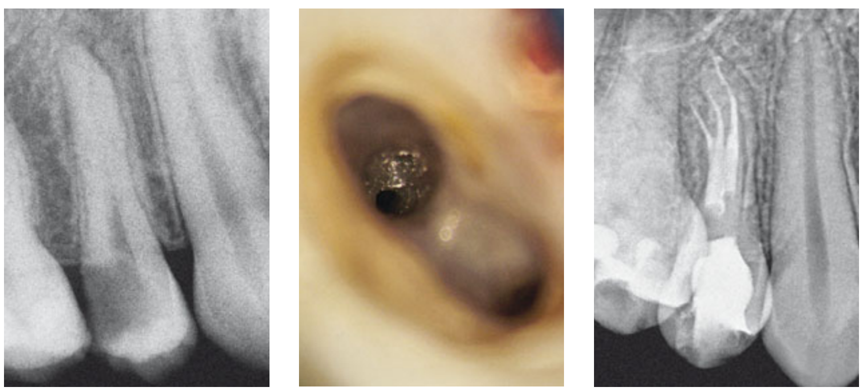


Fig 17 The diagnostic radiograph of the maxillary premolar reveals a large centred root canal that abruptly 'disappears' in the middle third of the root. During the intracanal inspection, a ramification of the main canal was obvious in the depth of the buccal root. The final radiograph reveals the complex anatomy of the root canal system.

the middle, up to the apical third of the root. A treatment performed with classical methods has a very limited outcome in such cases. Such a configuration is seen very often in lower premolars, but can also be found in lower incisors, canines or other types of teeth as well.

In many cases, only the main canal is located and scouted or even shaped and filled. Most frequently, in such cases, the result is a failure and the causes are subsequently hard to identify (Fig 18).

The diagnostic radiograph provides an initial hint for this atypical configuration, when the course of the main root canal is abruptly interrupted (Fig 19). A further valuable hint provides the working length radiograph, especially in eccentric projections. If the instrument is not located centrally in the root, it should be assumed that a further root canal exists (Fig 20). Moreover, in some cases a periapical lesion without any relationship to the radiological root apex might indicate a further independent or a branched canal (Fig 21). The most decisive diagnosis of a branched canal or bifurcation is offered by the intracoronal and intracanal microscopic observation (Fig 22). Therefore, the use of a microscope is almost indispensable in such cases.

Clinically, during the scouting of an apparent patent root canal, ledge-like obstructions can be seen, hindering the creation of a glide path towards the apex. This can be considered the 'middle area' of a ramification (Fig 23). However, if a ramification or a branched canal arises, attempts should be made to expose this area. Therefore, the more coronal part of the canal should be enlarged and properly irrigated with sodium hypochlorite solution. Sodium hypochlorite with a concentration of more than 1% has the potential to dissolve organic tissues[45] and form small bubbles. This effect can be very useful for the localisation of a presumed bifurcation. If using the dental microscope, small bubbles can be recognised in a certain place while using NaOCl solution, it can be presumed that there is an entrance into a bifurcation or a lateral canal. Attempts to force

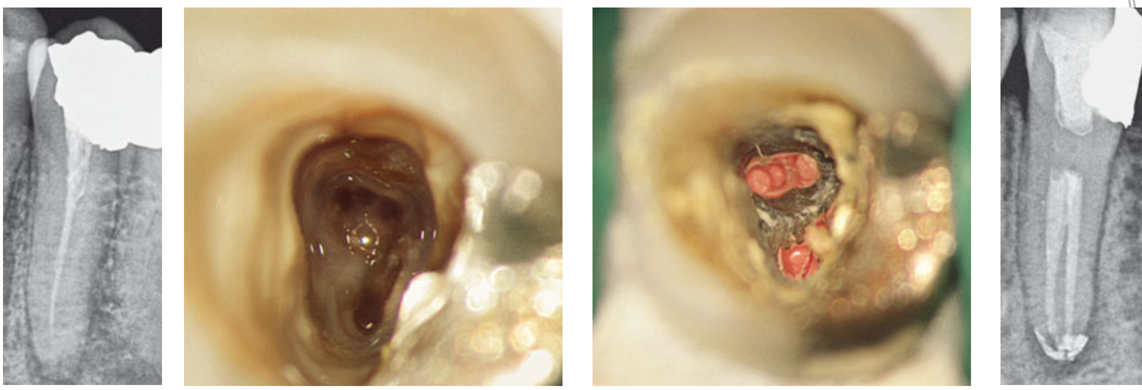


Fig 18 Root canal-filled mandibular premolar associated with an apical periodontitis. During retreatment, the microscopic inspection reveals a ramification of the canal system in the middle third of the root.

Fig 19 Indication of an atypical canal configuration: a large canal shows an apparent disruption ('disappearing') in the middle third of the root.

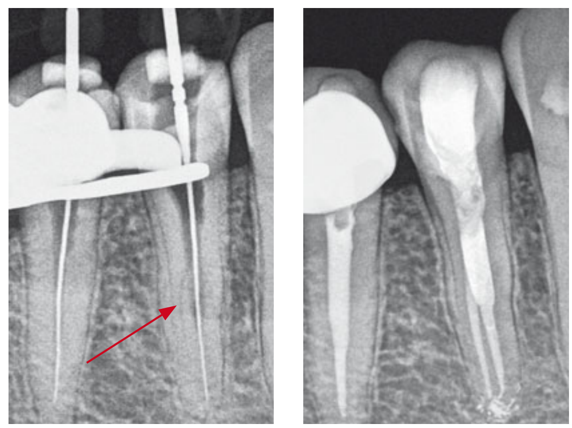
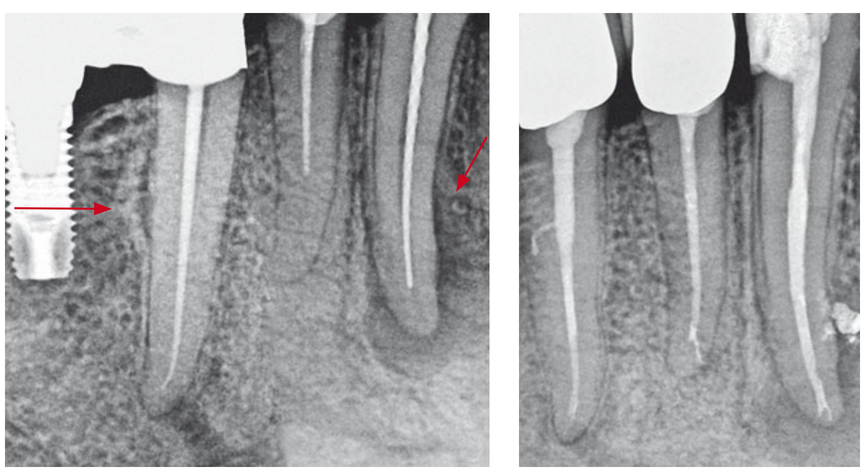


Fig 20 The eccentric working length radiograph reveals a branched canal (arrow).

Fig 21 Periradicular radiolucency as an indication for a branched canal or a large lateral canal (arrows).



an unbent root canal instrument into this entrance should be avoided.

If a bifurcation is detected and exposed, further preparation has to be performed with special instruments and methods. A first option is to try to access the lateral canal with pre-bent stainless steel hand instruments, preferably using an angulated file holder, or a micro-opener or micro-debrider, allowing for direct visual control. Due to the pre-bent instruments, it might be possible to negotiate the branched canal and thereafter shape and clean this canal (Fig 24).

Problems with this technique appear if the original diameter of the branched canal is very narrow (0.10 or 0.15 mm, corresponding with ISO sizes 10

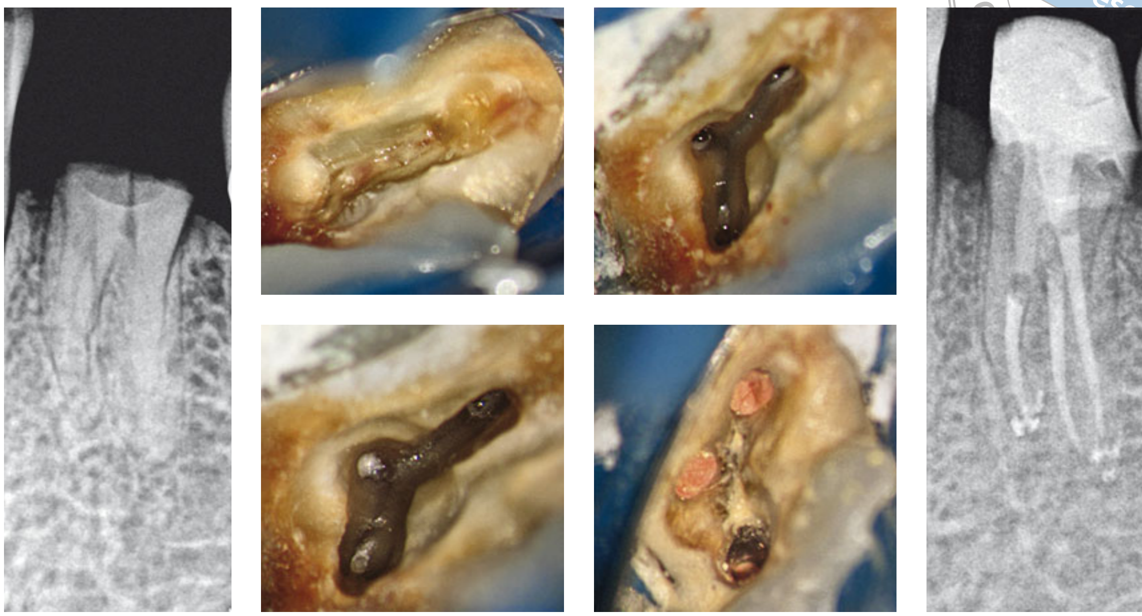


Fig 22 Localisation and preparation of completely calcified root canals.

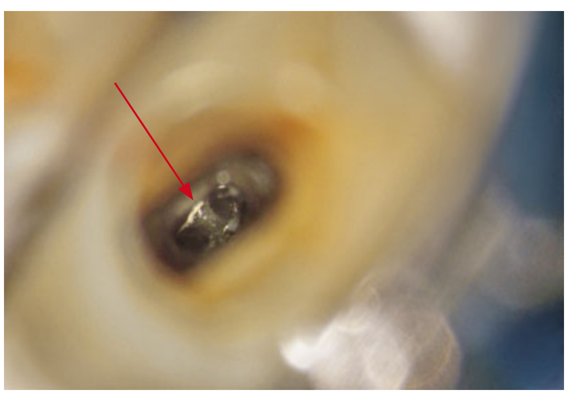


Fig 23 Indication for an atypical canal configuration during a microscopic inspection: step-like obstacle in the middle third of the canal, which hinders access towards the apical area.

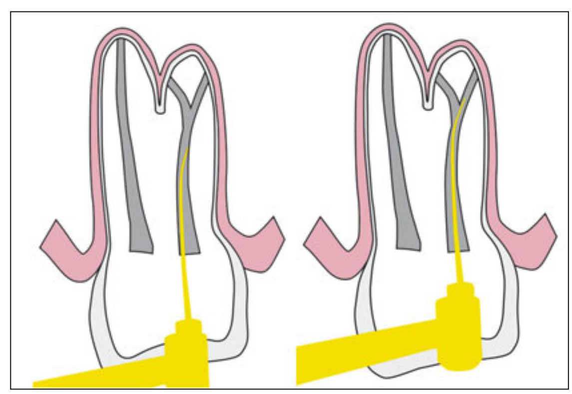


Fig 24 Schematic representation of 'slipping' into ramifications of the micro-opener or bended instruments held in the file support: the microscopic visual control is possible due to the bent instruments.

to 15) and also calcified. In such cases the taper of the hand instruments is not sufficient (2% for all ISO-sized hand instruments) because of the low buckling resistance of these instruments. In such cases, the access and shaping of the narrow-branched canal might be possible using special handpieces like M4 (SybronEndo) or Ti-Max Ti45 (NSK Europe) and pre-bent nickel-titanium instruments having tapers of 4% up to 6% (i.e. ProFile 15.04 and/or 15.06; Dentsply Maillefer). The pre-bending of the nickel-titanium instruments, which normally return to their original shape due to their superelasticity, can be done using an Endo-Bender (SybronEndo, California, USA).

Even with pre-bent instruments it is sometimes impossible to mechanically clean and prepare branched canals due to their multiple curvatures. In such cases the only possibility for intense chemical preparation remains (Fig 25a). The canal should be irrigated several times with copious amounts of NaOCl and the efficiency of the irrigant should be increased by ultrasonic activation[46,47]. This allows penetration of the irrigant into the apical part of the branched canal that is not accessible for mechanical preparation and promotes chemical dissolution of pulp tissue. To achieve adequate chemical debridement of the canal, sufficient irrigation times are mandatory. Thermoplastic root canal obturation

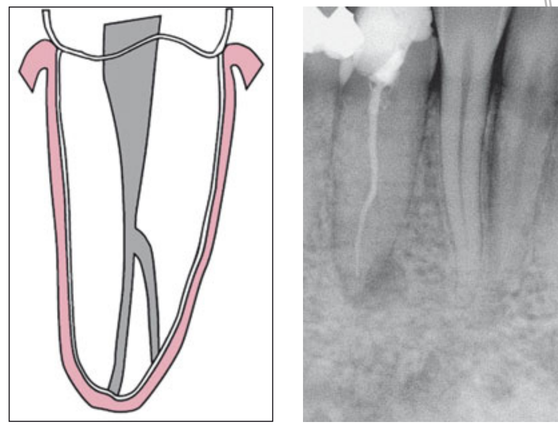


Fig 25a Severely deflected branched canal in a mandibular premolar: mechanical preparation of the branched canal with pre-bent instruments was not possible (courtesy of Dr Thomas Beyl – Lahnstein).

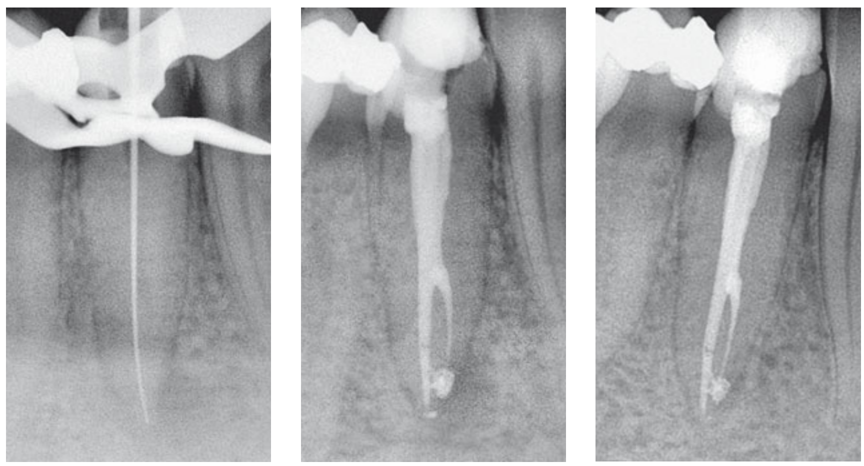


Fig 25b Following copious irrigation and passive ultrasonic activation of the irrigant (sodium hypochlorite), the branched canal was obturated using a thermoplastic obturation technique (courtesy of Dr Thomas Beyl – Lahnstein).

techniques are best suited to fill the chemically debrided bifurcations or branched canal (Fig 25b).

Obturation of branched root canals

Problems can occur not only during the chemical and mechanical preparation of branched canals, but also during their obturation. Usually, the access cavity is too narrow for the placement of more than one 0.04 tapered or even greater tapered gutta-percha points at the same time. Thus, the two gutta-percha points necessary for the filling of bifurcated canals cannot be placed at the same time. If just one gutta-percha point is introduced in one of the bifurcated canals and cut in the coronal or middle part of the root canal, the access needed for obturation of the second bifurcated or branched canal might be blocked.

This dilemma can be solved with a modification of the classic Schilder technique. As usual for all root canal obturation techniques, a master cone will be adapted for each prepared root canal. The tip of the master cone must have the same diameter and taper as the last instrument used for canal preparation and the gutta-percha point must be checked for tug-back.

The gutta-percha points selected for obturation of branched canals must be individually checked for their intracanal fit and thereafter the points must be extraorally shortened to the length of the bifurcation area.

In order to determine the root canal length between the bifurcation and the apex, the length of the canal from the apical endpoint of the preparation to the occlusal reference point (total working length) should be marked on the gutta-percha point. A larger root canal instrument then has to be introduced into the root canal until it meets the step-like obstruction of the bifurcation. This length represents the length of the root canal from the bifurcation to the coronal reference point. The difference between

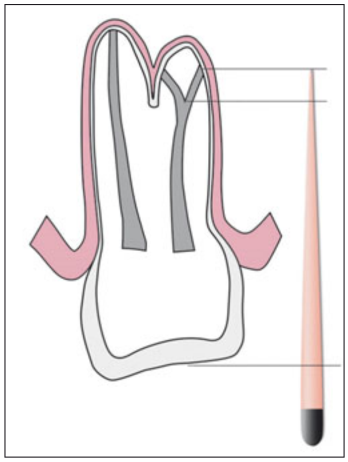


Fig 26 Length measurement of the branched canal segment: the difference between the total length of the canal and the distance from the coronal reference point to the bifurcation gives the respective length of the branched part of the root canal from the bifurcation to the apex.

Fig 27 Fixing of the adequately cut gutta-percha point at the tip of a plugger.

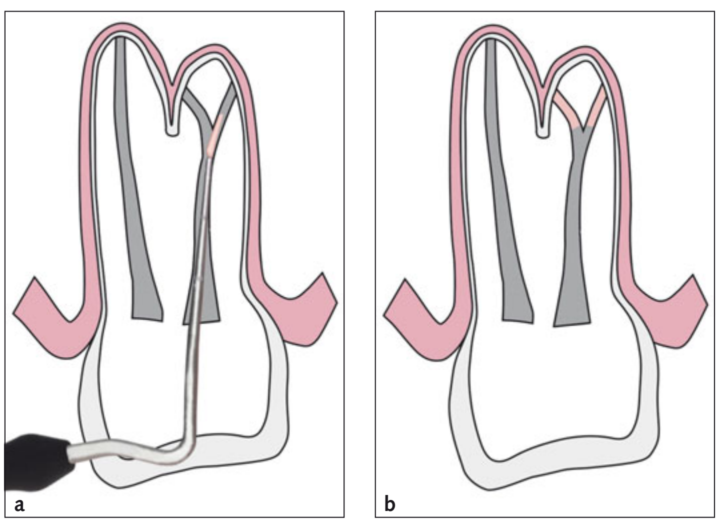


Fig 28 a) Schematic illustration of placing a gutta-percha point, fixed to a plugger, into the first branched canal. b) After obturation of the first branched canal the access to the second branched canal remains free.

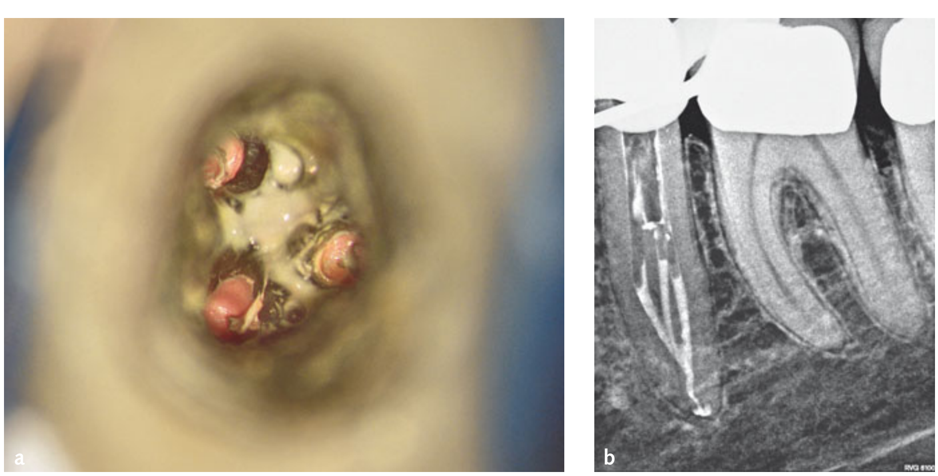


Fig 29 a) Three gutta-percha points placed in the apical ramifications of a mandibular premolar have been individually thermoplastically-condensed under visual control ('down-pack'); b) control radiograph of the 'down-pack' procedure.

these two lengths represents the length of the bifurcated root canal section from the bifurcation to the apex (Fig 26).

After properly cutting the gutta-percha points, some sealer is applied on the canal walls by means of paper-points, using circular, slightly pumping movements. In order to introduce the gutta-percha points into the bifurcated canals, a plugger must be used. The points can be fixed at the tip of the plugger after warming it up slightly (Fig 27). In this way, the gutta-percha points can be introduced individually (Fig 28a) and successively in each of the branched root canals. Due to the fact that the gutta-percha point is placed completely in the appropriate branched canal section, the access to the other branched part of the canal remains accessible (Fig 28b).

Thereafter, the gutta-percha points introduced in the branched canals are individually thermoplastically-condensed, preferably under visual control, using a heating plugger (i.e. System B [SybronEndo] or BeeFill Pack [VDW]) and compacted using an adequate cold nickel-titanium plugger. The pressure upon the softened gutta-percha must be exerted for at least 10 s in order to compensate for the thermal contraction during the cooling down of the heated gutta-percha (down-pack phase; Figs 29a and 29b).

Subsequently the main canal is filled using a gutta-percha injection technique (back-fill phase). Therefore, the gutta-percha injection cannula should be placed in direct contact with the down-packed gutta-percha for about 5 s in order to soften the gutta-percha, thereby ensuring a homogenous connection of the back-fill and the down-pack. An injection cannula, with diameters ranging between 0.45 and 0.80 mm should be selected and layers of 2 to 3 mm gutta-percha should be injected. Each layer must be compacted during the cooling down phase with the hand pluggers being used during the down-pack phase. The use of alpha gutta-percha is recommended because it is highly flowing when heated.

Conclusions

Important conditions for the detection of branched root canals are: excellent knowledge of the anatomy of the root canal system, adequate imaging (radiographs and CBCT) and the use of proper magnification and illumination. The preparation of branched root canals requires special instruments, a precise technique and clinical experience. Even branched canals can be adequately obturated using thermoplastic root canal filling techniques.

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