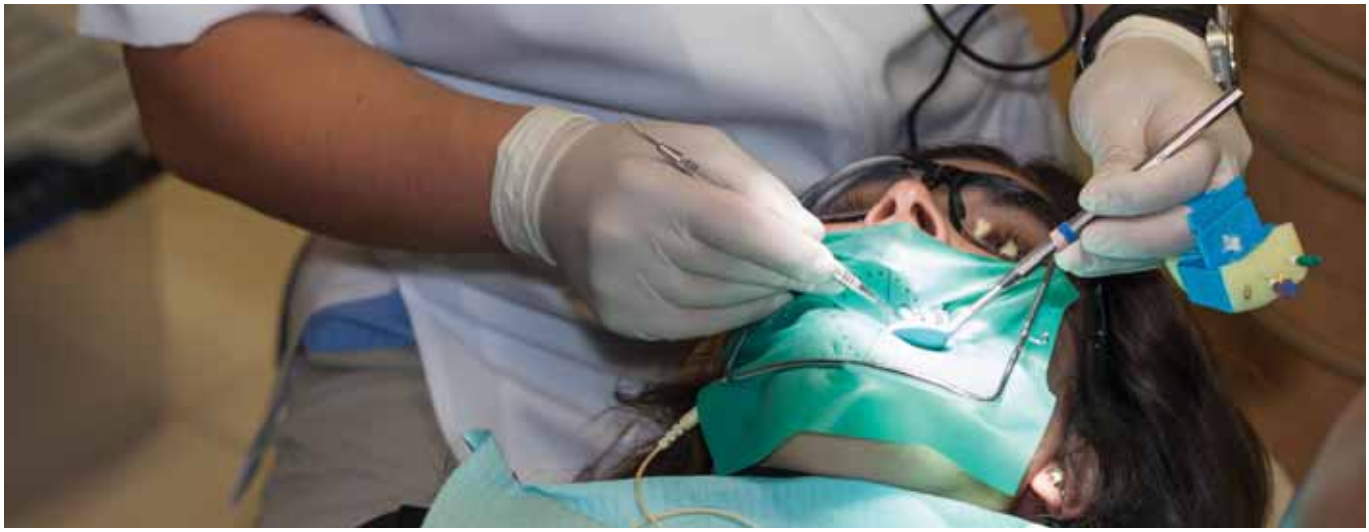
Five steps for success in endodontics

Assuming that the correct diagnosis and treatment plan are in place, the patient has given informed consent and good anaesthesia has been obtained, there are a number of areas that may impact on clinical success in endodontics.



This article discusses five areas that may contribute to an improvement in the overall success rate of root canal treatment.

1 Use of the rubber dam

"Starting the daily use of the rubber dam is the beginning of wisdom. When the rubber dam comes through the door, slipshod methods go out of the window. It marks the beginning of better dentistry."

These were remarks made by Dr JM Prime in 1937, who appreciated the value of working in an isolated environment to achieve optimum standards in dentistry.

The rubber dam has been around for over 150 years and is considered mandatory for endodontic treatment. Credit is usually given to Sanford Christie Barnum for its introduction in 1864 in the US. Opinion among dentists and patients on the use of rubber dam is divided. A small percentage of patients hate it and a small percentage love it. However, the majority do not have a problem with it and understand its usefulness, particularly during endodontic therapy. Likewise, a small percentage of dentists dislike it and avoid using it as it is perceived as being difficult to place and unnecessary.

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If it is not possible to isolate a tooth with the rubber dam then there is a question mark over whether endodontic treatment should be attempted at all. If a dentist finds that the use of the rubber dam is too difficult then the question needs to be asked if they have sufficient skill to be attempting root canal treatment.

The objectives in root canal treatment are to instrument, disinfect and fill the root canal to the apical foramen/constriction.[1] Essential in this is the elimination of bacteria in infected root canals and the prevention of infection in vital pulps. The use of the rubber dam assists in achieving these objectives.

The advantages of using the rubber dam are:[2]

1. Patient protection from aspiration or swallowing of endodontic instruments/materials.
2. Retraction of tissues.
3. Improved visibility.
4. Prevention of contamination of the root canal.

It also improves the flow of treatment and increases efficiency, as there are fewer interruptions.

In spite of the fact that the use of the rubber dam is considered the standard of care in endodontics, and in spite of its advantages, the percentage of general dentists in the US who routinely use it for endodontics is reported to be as low as 59%.[3]

The advantages of the rubber dam far outweigh the perceived disadvantages, which include the difficulty in placement of the rubber dam and clamps, irritation of the skin by the latex rubber of the dam, difficulty for some patients in swallowing and feeling of claustrophobia.

FIGURE 1: Hu-Friedy clamps.

FIGURE 2 (above and left): Use of Wedjets.

The skin irritation can be reduced by the use of a dental dam napkin. Patients who feel claustrophobic can be managed well once they realise that nothing will fall down their throat and they can breathe as normal. Latex sensitivity or allergy can be overcome by using a non-latex or silicone dam.

By far the biggest problem dentists have with the dam is the difficulty in placement. Selecting an appropriate clamp prior to placement goes a long way in facilitating this. Most dentists have their favourite clamps but it is important to minimise the inventory. In my experience the Hu-Friedy molar clamps 12A and 13A, premolar clamp 2AS and anterior clamp 9S (**Figure 1**) can be placed on over 90% of teeth.

Wedjets (Hygenic Corporation: Akron, Ohio) can also be used as a means of reducing the need for clamps, especially when treating anterior teeth (**Figure 2**). Alternatively, a piece of the rubber dam can be rolled up and used in a similar fashion.

Partially erupted teeth can be difficult to isolate, especially if there are no teeth distal to place a clamp. Acid etching buccally and lingually and bonding small segments of composite can provide ledges and undercuts for the clamp to grip, reducing slippage. Likewise, badly broken down teeth can provide a challenge and consideration should be given to placing a pre-endo build-up to temporarily restore these teeth prior to treatment (**Figure 3**). This will allow for caries removal and assessment of restorability prior to treatment. It also assists in disinfection by allowing for a reservoir of irrigant in the access cavity and aids retention of a temporary filling in the access cavity in multiple visit treatment.

> "The only tooth that may be treated without the rubber dam is the tooth that is so severely damaged that the only instruments to be used are the extracting forceps."
>
> Castellucci. *Endodontics*, Chapter 10, page 226.

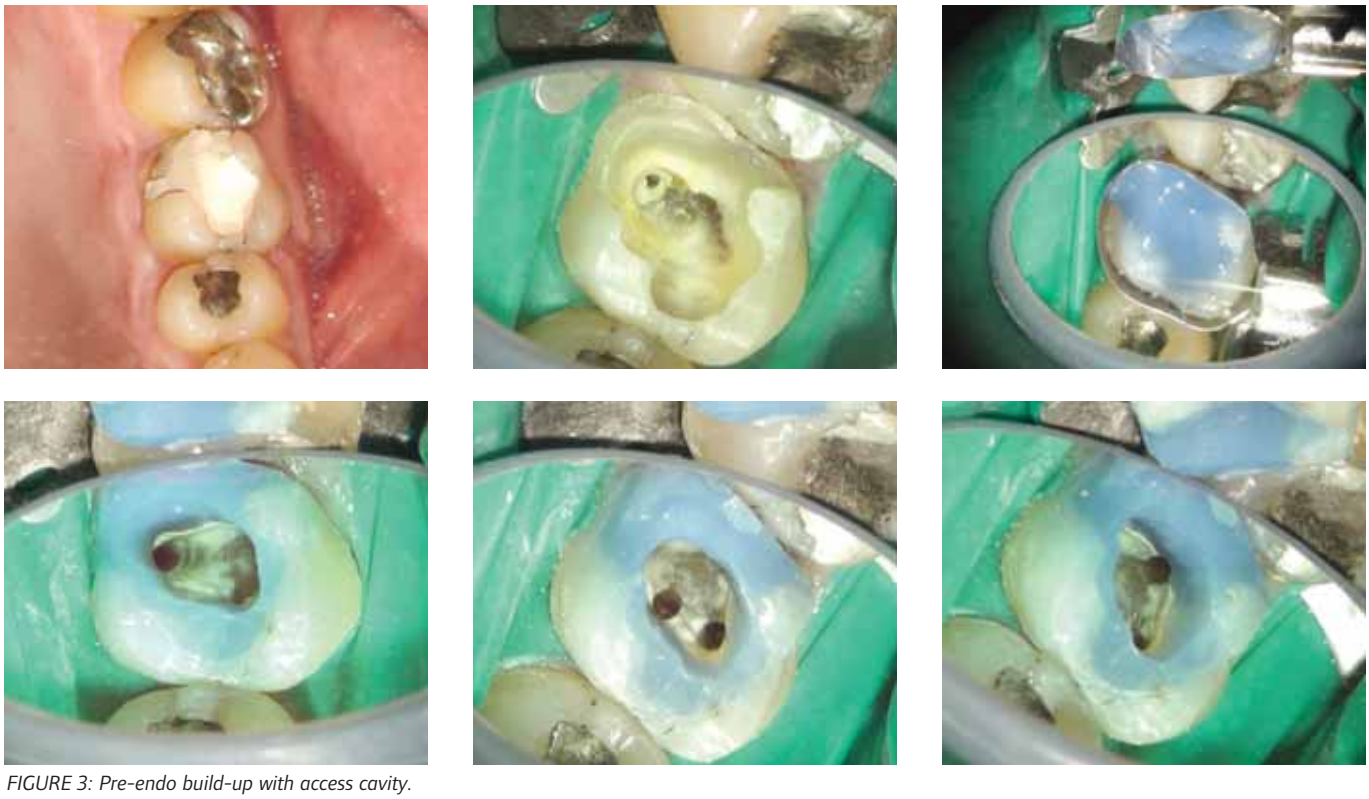

FIGURE 3: Pre-endo build-up with access cavity.

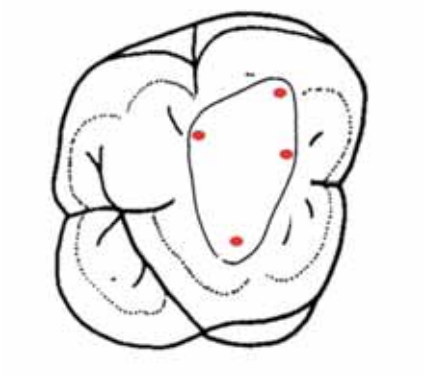

FIGURE 4: Direct vision.

FIGURE 5: Calcified canals.

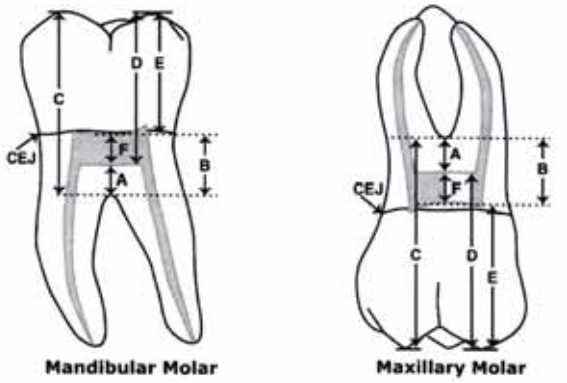

FIGURE 6 (above and tables below): Mean measurements for consideration when accessing molars according to Deutsch and Musikant.[5]

Table 1: Mean measurements (mm) for maxillary molars

n = 100	A*	B	C	D = (C – A)	E = (C – B)	F = (B – A)
Mean	3.05	4.91	11.15	8.08	6.24	1.88
SD	0.79	1.06	1.21	0.88	0.88	0.69
% variance	25.8	21.6	10.9	10.9	14.11	36.5

**Values A-F refer to measurement distances illustrated in Figure 6 (above) (%CV = [SD/Mean]) and are a measure of the percent variance observed in the sample.*

Table 2: Mean measurements (mm) for mandibular molars

n = 100	A*	B	C	D = (C – A)	E = (C – B)	F = (B – A)
Mean	2.96	4.57	10.9	7.95	6.36	1.57
SD	0.78	0.91	1.21	0.79	0.93	0.68
% CV	26	20	11.1	9.94	14.6	43

**Values A-F refer to measurement distances illustrated in Figure 6 (above) (%CV = [SD/Mean]) and are a measure of the percent variance observed in the sample.*

FIGURE 7: Munce Discovery Burs from www.cjmengineering.com.

FIGURE 8 (above and right): Ultrasonic tips from www.eie2.com.

2 Access preparation

The ideal access preparation will:

1. Allow for removal of the entire contents of the pulp chamber.
2. Allow for direct vision of the pulpal floor and canal orifices (**Figure 4**).
3. Facilitate the introduction of instruments into the root canal.
4. Provide straight-line access to the apical third of the canal.
5. Provide a positive support for the temporary filling.
6. Prevent excessive removal of the tooth with consequent reduction in strength of the remaining tooth.

In order to achieve these objectives it is important to appreciate the anatomy of the tooth under treatment. The shape of the crown is generally a reflection of the shape of the pulp chamber; however, oftentimes we are dealing with heavily restored teeth, or teeth that have been crowned, and the natural anatomy has been altered. In some cases it may be advantageous to commence access without the rubber dam to improve orientation.[4] However, once the pulp chamber is accessed the dam is immediately placed.

Radiographic examination will provide a certain amount of information, e.g., size and position of the pulp chamber, angulation of the crown of the tooth, presence of pulp stones or calcifications, or difficulty in locating the canal (**Figure 5**). Knowledge of the mean measurements and the use of radiographs may give an idea of the depth of the pulp chamber from occlusal landmarks and also the distance to the furcation area in molars (**Figure 6**). Knowing these may reduce the possibility of furcal perforations, as there is no reason why the bur should advance beyond the distance to the pulpal floor.

Most dentists have their standard burs that are used for access preparation. Surgical length burs can be useful as the head of the handpiece can be further away from the occlusal surface so as not to obstruct the view into the tooth. Munce Discovery Burs (**Figure 7**) can be very useful in trying to locate calcified canals as their extra length (34mm) and thin shaft facilitates improved vision.

Ultrasonic instruments (**Figure 8**) are also invaluable in allowing for improved vision and for cleaning up debris in the pulp chamber, removal of pulp stones and smoothing off the walls of the access preparation. There are many brands available for the Satelec, NSK and EMS or MiniEndo piezoelectric ultrasonic units.

FIGURE 9: Mirrors from www.eie2.com.

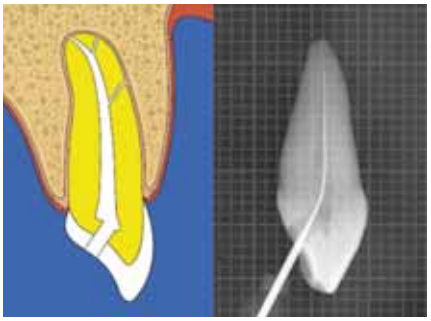

FIGURE 10: Cingulum-placed access.

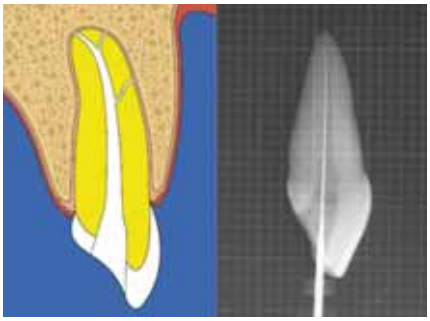

FIGURE 11: Straight-line access.

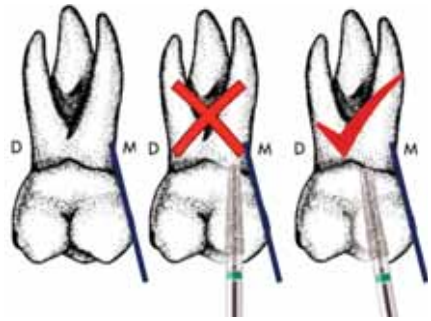

FIGURE 12: Bur orientation.

FIGURE 13: EndoZ bur.

FIGURE 14: Maillefer micro-opener.

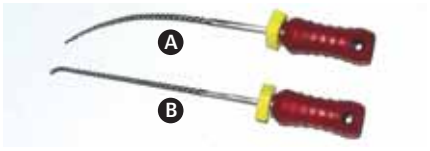

FIGURE 15: Pre-bent files.

FIGURE 16 (right): Dentsply Maillefer Glyde.

FIGURE 17 (below): Premier RC-Prep.

The use of smaller mirrors, particularly in posterior areas or where access is restricted due to limited mouth opening, provides better visibility of the working field, i.e., the pulp chamber (**Figure 9**).

In anterior teeth, cingulum-placed access cavities (**Figure 10**) create file restrictions, which lead to more procedural errors and file breakages and are more likely to lead to labial perforations. The access preparation should be placed as incisally as possible (**Figure 11**) to give straight-line access to the canal. This minimises constriction of the files and allows for increased tactile awareness of the tip of the file. This increased tactile awareness allows for better negotiation of the canal with reduction in ledging and blockages, and minimises the risk of broken instruments.

When designing the access preparation care should be taken not to remove excessive dentin in the cervical area. Orienting the bur towards the centre of the tooth is recommended (**Figure 12**), i.e., take note of the slope of the mesial wall and the initial orientation of the bur should reflect this. This will hopefully reduce the possibility of a subgingival perforation mesially and reduce excessive dentin removal in the cervical area.

Once the pulp chamber is penetrated the use of the Endo-Z bur (**Figure 13**) is recommended to un-roof the pulp chamber and refine the access preparation coronally. This is a tungsten carbide multi-fluted bur with a non-cutting tip so it smooths the walls of the access preparation while reducing the possibility of perforation. The size of the access is to a large extent dictated by the size of the pulp chamber and the position of the canal orifices.

Exploration of the pulp chamber can be carried out with a sharp DG16 endodontic probe or the use of a Maillefer Micro-Opener (**Figure 14**).

We have to recognise that the more tooth structure we remove the weaker the tooth; however, we need sufficient access to allow for proper preparation and disinfection of the canals and also to allow us to locate all the canals present. Minimally invasive, so-called ninja access cavities, restrict our vision and instruments, and are more likely to lead to procedural errors and untreated areas of the root canal system. The use of magnification and enhanced illumination significantly improve our ability to locate all the canal orifices while reducing the amount of tooth removal necessary for access. The more you can see the more you can treat.

3 Negotiation and shaping of the canal

Once the canal orifice has been located the initial penetration of the canal should be carried out with a small file, usually size 10 in posterior teeth, which has a gradual bend in the body of the file. There are two general types of bends that can be placed in files. One is a gradual curve in the body of the file (**Figure 15, A**) and the other is an acute bend more apically placed (**Figure 15, B**). The gradual curve is more useful initially. This facilitates placement of the file in restricted areas. The apical curve is more useful when attempting to probe and negotiate a canal to the apical foramen.

Negotiation of the canal is carried out in the presence of a viscous ethylenediaminetetraacetic acid (EDTA) gel such as Glyde (**Figure 16**) or Premier RC-Prep (**Figure 17**), which acts as a lubricant and an emulsifier.

FIGURE 18: Access cavity prepared and resistance encountered in narrow canals.

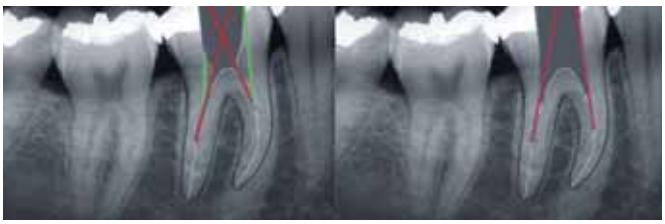

FIGURE 19: Gates Gliddens used to remove triangles of dentin restricting access into the canals.

FIGURE 20: Proglider has a progressive taper from 2-8%.

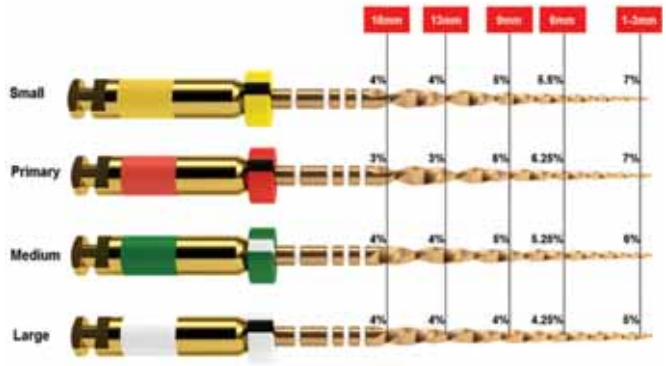

FIGURE 21: Dentsply Sirona WaveOne Gold files.

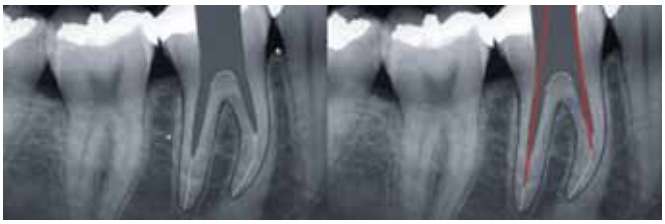

FIGURE 22: Coronal enlargement allows further penetration of the canals.

FIGURE 23: Negotiation of canals to apical constriction and glide path allow use of WaveOne Gold to the apical constriction.

Passive penetration of the canal is carried out with gentle reciprocating motions with outward cutting strokes and no great apical force. In some cases the file can be advanced to the apical third of the canal. In many narrow canals the taper of the canal is less than the taper of the file and if resistance is felt then the file is withdrawn and then small filing motions are carried out short of this length until the file feels loose (**Figure 18**). Once there is increased space in the coronal third of the canal, the file will often have the freedom to advance more apically. Enlargement of the coronal two-thirds of the canal greatly facilitates access to the apical third.

The canal orifice can be enlarged or modified to remove areas of restriction coronally. Gates Gliddens or the SX ProTaper files can be used for this (**Figure 19**). The size 10 file is then replaced and the canal again negotiated until resistance is felt. Filing motions are carried out until the file is loose and a smooth path exists to this area of resistance. A measurement is taken of the distance to this point. We can now enlarge the canal coronal to this with the use of larger files or we can take advantage of NiTi glide path instruments such as the Proglider from Dentsply Sirona (**Figure 20**). The use of glide path instruments has been shown to be a safe and efficient means of enlarging the canal with a reduction in canal curvature modification and canal aberration as compared to stainless steel hand files.[6]

The gel EDTA is replaced with sodium hypochlorite (NaOCl) prior to the use of rotary instruments. Once the Proglider has enlarged the glide path we are now ready to use whatever NiTi system is preferred, such as the WaveOne Gold (**Figure 21**), to shape the canal. Copious irrigation with NaOCl is carried out during this.

Once the canal is prepared to the area of restriction (**Figure 22**), the NaOCl is replaced by the gel EDTA so that the apical third of the canal can be explored. A size 10 file is reintroduced into the canal, this time with a small radius curve at the tip of the file.

The file is used in a probing fashion to find a path beyond the previous area of restriction/resistance. By gently rotating the file in the canal and using it as a probe, a path beyond the restriction can usually be negotiated. At this stage the electronic apex locator can be used to check the position of the file as it approaches the apical constriction or apical foramen. If the file can be negotiated to the terminus, small amplitude movements in an up and down motion will smooth irregularities.

Increasing the range of motion eventually creates a smooth pathway. Notice should be taken of the curve in the file and the orientation of the file in the canal so it can be replicated with larger files. Once this glide path is created and the 10 file is loose we can now reintroduce the Proglider, this time to the full length of the canal. The apex locator can be used to check the length and a file length radiograph can confirm correct length measurement. The EDTA gel is replaced with NaOCl prior to the use of the Proglider and NiTi shapers. If we have been able to use the Proglider to full length we can now prepare the canal to full length with our WaveOne Gold rotary files (**Figure 23**).

If a smooth pathway cannot be created with these small files then rotary files cannot be used to full length.

Attempting to do so is likely to lead to ledging and blockages making further instrumentation more difficult.

FIGURE 24: Dentinocemental junction and apical constriction.

FIGURE 25: Root ZX Electronic apex locator.

FIGURE 26: File length radiograph confirms accurate reading.

4 Use of the apex locator or electronic measurement devices

The ideal termination of our canal preparation is the dentinocemental junction or apical constriction.[7] Neither the dentinocemental junction or apical constriction (**Figure 24**) can be determined by radiographs or clinically. Traditionally these points were estimated to occur at 0.5-1mm short of the radiographic apex.[8] However, these measurements were found as average measurements in studies examining the apical areas of root canals histologically. It has also been shown that the foramen can be as much as 2.5mm short of the radiographic apex;[9] hence, working to 0.5-1mm short can lead to over preparation in some cases. Working long can increase the irritation to the apical tissues, is more likely to extrude infected material apically and can alter the shape of the foramen.

Overextension of the gutta percha in these cases may further cause apical irritation and increase postoperative symptoms.

The use of the electronic apex locator (**Figure 25**) has been shown to be highly accurate in locating the position of the foramen or constriction.[10] It is more accurate than radiographs and can reduce the need for additional radiographs.[11] There are a number of different brands on the market and the modern devices are all highly accurate.

It may be of interest to note that the apex locator is not a modern device. L.E. Custer from Dayton, Ohio, presented, at the Michigan State Dental Society in April 1918, a paper titled 'Exact Methods of Locating the Apical Foramen'. In this he described his method of using an electrical device using the difference between the conductance of the canal and that of the periodontal tissues to locate the foramen. He recognised the importance of eliminating necrotic tissues and bacteria from the apical region of the root canal for a successful outcome and the necessity to know where the foramen was to achieve this.

Although apex locators are highly accurate, there are a few areas to be mindful of that can lead to inaccurate or misleading readings:

1. Poor isolation and salivary contamination.
2. The presence of sodium hypochlorite in the pulp chamber in multi-rooted teeth.
3. Contact of the file with metallic restorations.
4. Contact between sodium hypochlorite and metallic restorations.
5. Instrument too small.
6. Obturating materials limiting contact of the instrument with the canal wall.
7. Presence of a perforation.
8. Instrument passing through a lateral canal.

The accuracy will be improved if the pulp chamber is dry and there is definite contact of the instrument with the canal wall. One thing to note is that the apex locator will not give a reading indicating the file is at the constriction. It can tell the operator when the instrument is long and when it is short of the constriction. The file must go beyond the constriction and is then withdrawn until the reading indicates that the file is short and a little skill is required to determine the point when the file goes from long to short. It is safest to prepare the canal 0.5mm short of this provided patency filing is carried out.

Radiographs are necessary to confirm that the apex locator is giving an accurate reading (**Figure 26**). However, the correct use of the apex locator will go some way to improving the accuracy of our working length determination, while minimising the need for excessive radiographs.

5 Disinfection

Once a canal has been shaped with either hand or rotary files, it is not necessarily ready for obturation. Disinfection of the canal is a very important part of our preparation and failure to pay sufficient attention to this aspect of treatment is likely to increase failures even in cases where the final result, the obturation, appears good.

Irrigants are used to:

a) flush out debris;
b) dissolve tissue;
c) kill bacteria and disrupt the biofilm;
d) lubricate the canal to reduce friction during instrumentation; and,
e) remove the smear layer.

No single solution will accomplish all of these objectives so we need combinations in the correct order to maximise their effects. We also want to avoid negative properties such as cytotoxicity, staining and weakening of tooth structure.

At present, NaOCl appears to be our best irrigant as it is a potent antimicrobial agent against both planktonic- and biofilm-containing bacteria and also has the ability to dissolve pulpal remnants. The antibacterial effect of a 1% solution of NaOCl is as good as that of a 5% solution. However, a 5% solution of NaOCl has a much better ability to dissolve tissue in a shorter time. NaOCl is a toxic solution and it cannot be emphasised sufficiently that great care needs to be taken in using it. There have been a number of reports over the years of the consequences of extrusion of NaOCl into the periapical tissues.[12] There is nothing comparable to it for endodontic irrigation but there are risks involved. An endodontic safe-ended needle should be used (**Figure 27**). It should never be wedged into the canal. Light force should be used with the syringe and a measurement taken of the position of the needle in the canal. It's not a powerwasher!

FIGURE 27: Safe ended endodontic irrigating needle.

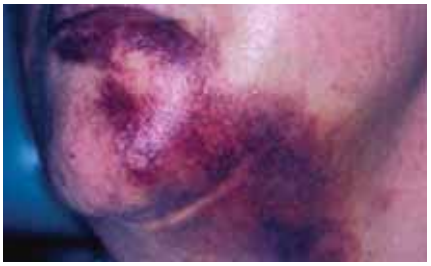

FIGURE 28: Sodium hypochlorite accident.[14]

FIGURE 29: The Endoactivator increases the effectiveness of sodium hypochlorite.

Extrusion of NaOCl through the apical foramen or through a perforation can cause a severe reaction with excruciating pain, swelling and haematoma formation. In some cases nerve damage can occur, particularly in the mandibular premolar or molar regions, leading to paraesthesia and chronic facial pain (**Figure 28**).

It is important to confirm the length and integrity of the root canal prior to irrigating with NaOCl solutions.

The use of negative pressure irrigation with devices such as the EndoVac minimises the risks involved as it reduces the apical pressure during irrigation. Alternatively, filling the pulp chamber with NaOCl and aspirating the solution down the canal with the tip of the needle close to the working length can be employed to draw the solution into the canal.

The use of devices such as the EndoActivator (**Figure 29**) agitates the irrigants in the canal creating turbulence that increases the penetration of the solutions into the irregularities of the canal systems and increases their effectiveness. The EndoActivator tips are designed for single use and are disposable.

The IrriSafe is an ultrasonic file designed for passive ultrasonic irrigation. Unlike the plastic EndoActivator tip the IrriSafe is metallic. It is advantageous in that there may be a flushing effect during its use; however, it may also alter the shape of the prepared canal.

The IrriSafe can be used in multiple teeth; however, it will eventually fracture.

Another method of agitating the irrigant in the canal is the manual dynamic activation technique. This involves the use of a well-fitting master cone of gutta percha, moving it in small 2-3mm strokes up and down in the canal in the presence of an irrigant. This produces an effective hydrodynamic effect and improves the displacement and exchange of the irrigant. Approximately 100 strokes are carried out to maximise the effect.

Any filing or shaping procedure produces a layer of organic and inorganic material called the smear layer and our instruments do not reach all areas of the root canal systems. The smear layer may contain infected material and may also block dentinal tubules, lateral canals, fins and apical deltas containing bacteria. Removal of the smear opens up these areas to allow our disinfectants to have better access and therefore more effectiveness. NaOCl will dissolve the organic parts of the smear layer but we need something additional, such as EDTA or citric acid, to remove the inorganic components. EDTA is commonly used in a 17% solution.

The method of choice for removal of the organic and inorganic components of the smear layer appears to be the alternate flushing of the canals with EDTA and NaOCl.[13]

As previously stated, the antibacterial effect of a 1% solution of NaOCl appears to be as good as a 5% solution. However, further dilution of the NaOCl and acidifying it to reduce its pH can lead to a more effective disinfectant.[15]

A homemade solution of Sterilox can be made by the addition of 1ml of 5% NaOCl and 1ml of distilled vinegar to 100ml of distilled water. This is an excellent and very safe antibacterial solution, but unlike 5% NaOCl it has no tissue-dissolving properties.

Another irrigant to be considered is chlorhexidine digluconate (CHX). This is a good antimicrobial irrigant; however, it does not possess any tissue-dissolving capability and will not disrupt the biofilm. It is recommended in a 2% solution for endodontic disinfection. It will form an orange-brownish precipitate if used directly following NaOCl, which will cause staining, so the solutions should not be mixed.

Sterile water and local anaesthetic solutions have been used as irrigants but apart from flushing debris out of the canal they have no antimicrobial properties and have a very limited use.

Summary

The use of the rubber dam, creation of good access, negotiation of canals to the apical constriction or dentinocemental junction (particularly in cases of necrosis with apical periodontitis), shaping the canals to allow our disinfectant solutions to reach all areas of the root canal system, use of combinations of disinfectant solutions to eliminate bacteria and necrotic tissue, obturation of the canals, and adequate restoration of teeth together should allow us to maximise the opportunity for a successful outcome (**Figure 30**).

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FIGURE 30: Negotiating canals to the apical constriction, adequate shaping to allow disinfectant solutions access to all areas and good three-dimensional obturation maximises the opportunity for successful outcomes.

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