Endodontic surgery

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VERIFIABLE CPD PAPER

IN BRIEF

- Explains the role of surgery in managing endodontic failures.
- Reviews correct case selection and impact on surgical outcome.
- Provides an update on techniques and materials in endodontic surgery.

PRACTICE

A better understanding of endodontic disease and the causes of treatment failure has refined the role of surgery in endodontics. The advent of newer materials, advances in surgical armamentarium and techniques have also led to an improved endodontic surgical outcome. The aim of this article is to provide a contemporary and up-to-date overview of endodontic surgery. It will focus primarily on the procedures most commonly performed in endodontic surgery.

INTRODUCTION

The biological aim of endodontic treatment is to prevent or resolve apical periodontitis by controlled asepsis or through decontamination of the root canal system so as to create an environment in which periradicular healing can occur. However, if non-surgical root canal treatment is not possible or disease or symptoms persists following root canal treatment, endodontic surgery may be necessary in order to salvage a tooth.

There have been significant advances in endodontic surgery in the last two decades; gone are the antiquated, mechanistic procedures to be replaced by biological approaches, newer materials, aided by enhanced illumination and magnification, micro-surgical armamentarium and techniques. As a result, 'endodontic surgery' has evolved and is now often referred to as 'endodontic microsurgery'. These advances have helped improve the outcome of endodontic surgery, which was previously considered to be a rather unpredictable procedure, carried out in desperation and as a last resort. Indeed, contemporary micro-surgical techniques and newer root-end filling materials have reported a favourable healing outcome of 88–96%.^{1–4}

The aim of this article is to provide a contemporary and up-to-date overview of endodontic surgery. It is beyond the scope of this article to provide exhaustive coverage, including comprehensive technical details of every endodontic surgical procedure; therefore, it will focus primarily on the procedures most commonly performed – periradicular curettage, root-end resection, root-end cavity preparation and root-end filling; previously also referred to as periapical curettage, apicectomy, retrograde cavity preparation and retrograde filling respectively.

INDICATIONS FOR ENDODONTIC SURGERY

There used to be a plethora of indications for endodontic surgery; much of which were related to difficulties in (re-)gaining access to the root canal system for non-surgical retreatment. However, modern non-surgical retreatment techniques allow improved ability to gain coronal and radicular access; coupled with a better understanding of the causes of treatment failure, the preference is to carry out non-surgical root canal retreatment before considering endodontic surgery.^{5,6} Unless the root canal system is cleaned, shaped and filled, viable microorganisms may persist even after endodontic surgery constituting a potential risk factor for recurrence of periradicular pathosis. The idea that it is possible to contain microbes within the root canal system by carrying out endodontic surgery alone is not only untrue but dated and misguided (Fig. 1). As a result, the indications for endodontic surgery^{7,8} are reduced to the following:

- Persistent disease (with or without symptoms) in a previously root-filled

Fig. 1 Mandibular first and second molars, previously root filled. (a) Sub-optimal root fillings and poorly-fitting coronal restorations. Endodontic surgery carried out under general anaesthetic; root-ends incompletely resected and amalgam root-end fillings that are also incorrectly placed. Is it a surprise a second round of endodontic intervention also failed? (b) Non-surgical root canal retreatment should have been carried out instead; a favourable outcome in the end despite all the iatrogenic damage to the roots of both teeth

tooth where non-surgical root canal retreatment cannot be undertaken, is not feasible or has failed; for example, the presence of a post of significant size and

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length whose removal carries a high risk of root fracture

- Correction of iatrogenic errors not amenable to a non-surgical approach; for example, the removal or retrieval of extruded root filling material or a fractured instrument
- Biopsy or surgical investigation required; for example, a biopsy may be required for histopathological analysis of a suspicious-looking lesion or direct visualisation necessary to explore a suspected root fracture
- As a combined approach, in conjunction with non-surgical retreatment to resolve multiple technical problems; for example, a large periradicular lesion, a suspected radicular cyst, impossible to maintain a dry canal and a wide-opened apex in an immature permanent anterior tooth. A combined approach may also be part of anatomical redesigning (root amputation, tooth resection, bicuspidisation) with periodontal-endodontic cases
- Where patient factors dictate that it may be more expedient to consider a surgical rather than a non-surgical root canal retreatment approach.

CONTRA-INDICATIONS FOR SURGICAL ENDODONTICS

There are not many contraindications for endodontic surgery; they may be divided into general and local factors.

General

- Patient factors including psychological considerations and systemic disease for example, bleeding dyscrasias
- Clinician factors including the training, skill and experience of the operator, availability of equipment and facilities.

Local

- Dental factors including restorability of the tooth, root length, periodontal support and the patient's oral hygiene status
- Anatomical factors including the proximity of neurovascular structures. For example, the inferior alveolar and mental nerves may be at risk with surgery of mandibular molars and premolars; similarly, the palatal neurovascular bundle with a palatal flap
- Surgical access factors. For example, the ability of a patient to open their mouth wide, which will affect the operator's ability to easily see and access the surgical site. In the posterior region of the mandible the extended width of the external oblique ridge, when combined with lingually-placed root apices of

Fig. 2 Dental operating microscope, an invaluable tool in endodontic surgery

Fig. 3 Microsurgical instruments: (left to right) plugger, material carrier and periosteal elevator

molar teeth, may complicate visibility and access. Another example is the presence of a large bony exostosis, which may make incision and reflection of a flap considerably more difficult.

PRE-OPERATIVE ASSESSMENT

The pre-operative assessment includes a full medical and dental history, extra-oral and intra-oral examinations, and special investigations including radiographs. Radiographs should be taken using the paralleling technique with a beam-aiming device to provide the best views and good diagnostic yields. The full root/s and approximately two to three mm of the periradicular region should be included.⁹

Newer three-dimensional (3-D) imaging techniques such as cone beam computed tomography (CBCT) have been recommended for pre-operative planning of surgical cases to determine the exact location of root apices and to evaluate the proximity of adjacent anatomical structures.^{10,11} The need for a CBCT scan should be decided on a case-by-case basis. To keep the patient's radiation exposure as low as reasonably possible, a risk *versus* benefit analysis should be carried out beforehand. If deemed necessary, the CBCT scan should be of limited volume and high resolution.

Table 1 Example of a surgical kit

Incision, elevation and reflection of flap
Micro-scalpel holders and blades (for example, No. 11, 12 and 15/15C) Periosteal elevator Flap retractors Tissue forceps
Bone removal and root-end resection
Round and tapered fissure surgical burs High-speed, rear-venting surgical handpiece Slow-speed straight surgical handpiece
Periradicular curettage and biopsy
Straight and angled bone, and periodontal curettes and excavators Fine, curved artery forceps Small, curved surgical scissors Biopsy specimen container
Root-end cavity preparation and filling
Piezo-electric ultrasonic unit Micro-surgical ultrasonic root-end cavity preparation tips Stropko irrigator Haemostatic agents Methylene blue dye (1%) for differential staining Root-end filling materials and micro-placement carriers Miniature condensers, carvers & burnishers Micro-mirrors
Flap replacement and wound closure
Selection of suture types & sizes for example, metric size 0.7 or 1 (USP 5-0 or 6-0) Fine needle holders or artery forceps Toothed tissue forceps Surgical scissors
Miscellaneous
Front-surface mirror Endodontic and periodontal probes Local anaesthetic solution, syringe and needles Irrigating syringes, wide-bore needles and sterile saline
Surgical and micro-suction tips
Sterile gauzes

One of the aims of the pre-operative assessment is to anticipate and minimise procedural or healing complications. Potential risks, difficulties and complications should be discussed with the patient as part of the process of obtaining informed consent before surgery. Post-operative sequelae such as scarring, gingival recession, denudation of the interdental papilla may alter the anatomical contours and aesthetics of soft tissues and existing coronal restorations. Therefore, it is important to be aware that, among other considerations, different gingival biotypes will dictate the outcome of soft tissue healing. Patients with a thin gingival biotype are prone to suffer from gingival recession post-surgery while those with a thick gingival biotype may end up with pocket formation.¹² In addition,

Fig. 4 Semi-lunar flap design, no longer recommended

Fig. 5 Post-surgical scarring from inappropriate flap design

Fig. 6 Rectangular, full thickness flap

Fig. 7 Papilla base flap, designed to avoid and preserve the interdental papilla

marginal periodontitis and loss of cortical bone from the buccal or lingual aspect that denudes the root surface have a significant negative affect on surgical outcome.¹³ The proximity of the maxillary sinus does not automatically preclude a particular tooth from endodontic surgery but it is generally considered advisable to try and avoid perforating the antrum or displace infected debris or a resected root tip into the maxillary sinus.^{14,15}

SURGICAL EQUIPMENT

It is now routine for endodontic surgery to be carried out using an operating microscope¹⁶ (Fig. 2). Therefore, specially-designed

microsurgical instruments (Fig. 3) and techniques have been developed. Individual operators will have their own personal preferences when it comes to choice of instruments and equipment. An example of a surgical kit and a selection of suitable instruments are listed in Table 1.

ANAESTHESIA

In order to carry out endodontic surgery, profound anaesthesia and good haemostasis are essential. Lignocaine (lidocaine), combined with a vasoconstrictor, most commonly 1:80,000 adrenaline (epinephrine) in the local anaesthetic solution should fulfil these objectives.¹⁷ Felypressin, a non-catecholamine vasoconstrictor is less effective than adrenaline in achieving adequate haemostasis and should be avoided.

Depending on the surgical site, nerve block, infiltration or a combination of both local anaesthetic techniques may be necessary. Local anaesthetic in volumes of 0.5 ml is also normally deposited slowly at a rate of one to two ml per minute into numerous infiltration sites around the relevant tooth. The local anaesthetic solution should be delivered into the loose connective tissue of the alveolar mucosa near to the root apices. Placement too deep and into suprapariosteal tissues or frenal attachments may result in increased bleeding due to the predominance of β -2 receptors in skeletal muscle. The anaesthetic solution will be dispersed more rapidly and the duration of anaesthesia will, therefore, be reduced. Sometimes, an infra-orbital infiltration may be required for surgery in the maxillary canine or premolar region. Occasionally, in addition to local anaesthesia, conscious sedation or general anaesthesia may be necessary if the surgical procedure is complicated, significant discomfort or pain is anticipated or if the patient is anxious.

PRE-EMPTIVE ANALGESIA

Pre-emptive analgesia, in simple terms, is the concept of stopping pain before it starts. It involves the administration of a pain management regime, commonly pharmacological, before anticipated noxious stimuli, thereby preventing or reducing central sensitisation of the nervous system to pain. Pre-emptive analgesia is a practice particularly suitable for any intervention in which the timing of the noxious stimuli is known; hence it is beneficial in endodontic surgery. A therapeutic dose of an analgesic drug is taken before pain developing rather than being required in response to it. This strategy has been shown to be effective in reducing pain during the post-operative period and results in fewer analgesics being required. Paracetamol (acetoaminophen)

or non-steroidal anti-inflammatory drugs (NSAIDs) such as Ibuprofen have been advocated for pre-emptive analgesia.^{18–20} Similarly, the administration of a nerve block injection of a long-acting anaesthetic drug such as bupivacaine, which lasts for up to eight to ten hours, may be of value in reducing post-operative pain.²¹

PRE-OPERATIVE DISINFECTION

A pre-operative chlorhexidine gluconate (0.2%) mouthrinse for one minute has been recommended as this reduces the intra-oral microbial load intra and improves post-operative healing by preventing the risk of infection.^{22,23}

FLAP DESIGN

There are many different flap designs that have been used in endodontics.^{8,24} The flap design chosen will usually and mainly be dependent on the surgical access required; however, it will also affect the post-surgical probing depth, gingival margin level and clinical attachment.²⁵ Regardless of the design chosen, it should always follow the basic principles of ensuring that there is an adequate blood supply, and these days preservation or avoidance of the interdental papilla is preferred.

Semi-lunar flap

The semi-lunar flap design (Fig. 4) is inadequate in terms of providing good surgical access and is also associated with many post-operative complications including pain, swelling and scarring (Fig. 5). Therefore, the semi-lunar flap is contra-indicated for use in periradicular surgery.^{7,8,24}

Full thickness marginal flap

A primary incision is made in the gingival sulcus and follows the contours of the teeth. Relieving incisions crossing any bony defects should be avoided as this may hinder healing. The relieving incision is made with firm pressure starting at the gingival margin and extended through the attached gingiva in as vertical direction as possible to avoid severing supra-periosteal vessels and collagen fibres; this will reduce bleeding and improve healing. Extension deep into the sulcus is not normally required and can lead to increased bleeding into the operative site. One relieving incision (triangular flap) may provide sufficient visibility. However, two relieving incisions (rectangular flap) (Fig. 6) will provide greater surgical access. Healing is normally by primary intention and provided there is good oral hygiene, post-operative complications are rare.²⁶

A papilla-base incision has been advocated to preserve the interdental papilla and reduce

post-surgical recession.^{27,28} The papilla-base flap (Fig. 7) consists of two different incisions at the base of the papilla; a perpendicular incision of the epithelium and a second sub-epithelial incision of the connective tissue resulting in a split thickness flap.

Submarginal (Luebke-Ochsenbein) flap

The submarginal flap (Fig. 8) is useful in the anterior maxilla especially if preservation of the gingival contours adjacent to crowned teeth is needed.²⁹ The horizontal, scalloped incision is made approximately three mm from, and follows, the contours of the gingival margin, with one or two relieving incisions.³⁰ Disadvantages of this flap design include the risk of flap shrinkage, delayed healing and scarring; it is also not suitable for use in the mandible.

Palatal flap

On occasions, in the maxilla, a palatal flap may be necessary. This full-thickness flap design with one or two relieving incisions will provide good access, for example, the palatal root of a maxillary molar. The anterior relieving incision is made at the mesio-palatal line angle of the first premolar and extended two-thirds of the distance to the apex of the palatal vault. If a distal relieving incision is required this should be made from the distal line angle of the last molar and is extended posteriorly. There is high risk of severing the palatine neurovascular bundle if a palatally-inclined relieving incision is used in the posterior region. Reflection of the flap can be difficult as the tissues are thicker and more firmly bound.

FLAP REFLECTION

The periosteal elevator should have a keen, undamaged blade to ensure atraumatic reflection of the flap. The instrument should not be inserted into the interdental papilla; the starting point for flap reflection should be at the relieving incision at the level of the alveolar mucosa.⁸ From this starting point (Fig. 9), it is advanced under the periosteum to undermine the tissues and moved gently in a lateral direction, maintaining contact with the cortical bone as the flap is reflected.²⁹ Once the flap is fully reflected, a tissue retractor is used to protect and keep the flap in position. Newly designed retractors are better contoured; they have wider (15 mm) and thinner (0.5 mm) working ends compared to standard oral surgery retractors (Fig. 10). The retractor should rest on bone and not pinch the soft tissues to avoid damaging them. Occasionally it may be necessary to make a shallow locating groove in the cortical bone to prevent slippage of

the retractor. Retractors with serrated ends, which are designed to improve anchorage, are also available.

BONE REMOVAL AND ROOT-END IDENTIFICATION

Once the flap is reflected, the root-end has to be located and uncovered. If there is a periradicular lesion of significant size the overlying cortical bone may have already been perforated; in this case, the root-end is easy to locate (Fig. 11). A sharp excavator can be used to remove the thin cortical bone around the fenestration to enlarge the bony crypt.

If there is no bony fenestration then the approximate location of the root-end may be estimated using pre-operative radiographs. The overlying bone will then have to be removed in order to uncover the root-end. Bone removal may be carried out using a round surgical bur in a slow-speed handpiece with sterile saline irrigation. However, a specially-designed, rear-vented high-speed handpiece (Impact Air 45, Palisades Dental LLC, Eaglewood, NJ, USA or Phatelus 45, NSK, Kanuma, Tochigi, Japan) may also be used. Tungsten carbide or steel burs, for example, Lindemann bur (Fig. 12), work best as they are less likely to be clogged with bone fragments and lead to heat generation. Bone is carefully removed using a light brush stroke action. The osseous window is then enlarged until there is sufficient space to see and access the root-end and the periradicular lesion.

PERIRADICULAR CURETTAGE

Periradicular curettage involves the removal of reactive soft tissue from around the root-end. Most periradicular lesions are the result of an inflammatory response to microbial infection within the root canal system or a foreign body reaction to any extruded material/irritant.

Periradicular curettage is normally carried out with a straight or angled surgical bone or periodontal curette (Fig. 13). The curette is first worked around the margins of the lesion with the convex surface innermost to reflect the lesion from the surrounding bone. The curette is then reversed to scoop out the soft tissue lesion.²⁹ A biopsy if needed will entail either taking the whole or part of the curetted lesion for histopathological analysis. Any lesion that is removed should be immediately placed in formal saline and sent for histopathological examination.

Sometimes even with profound anaesthesia the patient may be aware of discomfort when a lesion is being curetted. This may be due to increased neural budding within the centre of a lesion that has been stimulated by inflammatory mediators.³¹ Injecting local

Fig. 8 Submarginal (Luebke-Ochsenbein) flap

Fig. 9 Flap reflection. Begin at the vertical relieving incision at the level of the alveolar mucosa (1); the flap is slowly undermined (2) and reflected (3, 4)

Fig. 10 Micro-surgical (top) and standard surgical (bottom) retractors

Fig. 11 Overlying cortical bone lost, root-end easily uncovered and identified

anaesthetic into the lesion over a few minutes will normally help resolve this problem.

In some instances, it may not be always possible to remove all the reactive tissues

Fig. 12 Impact Air 45 high-speed handpiece with a Lindemann bur

Fig. 13 Periradicular curettage of a large lesion

Fig. 14 Micro-surgical mirrors, significantly smaller than the conventional mouth mirror in the background, essential for examining the root-end after resection and cavity preparation

surrounding the root-end. Clinical evidence indicates no statistical significant difference in outcome between cases where complete and incomplete removal of reactive tissues has been achieved; therefore the priority should be given to preserving vital structures.³²

ROOT-END RESECTION

Unless accessible to root canal instruments, medicaments and irrigants, the complex apical architecture of infected teeth will harbour microbes. Resection of an apical two to three mm portion of the root end removes this nidus of infection;³³ however, care must be taken not to remove an unnecessary amount of root as this will compromise the crown-to-root length ratio.

The root-end resection is normally carried out with a slow-speed or a specially-designed

Fig. 15 Micro-surgical mirror used to examine the cut root face

Fig. 16 Ultrasound and specially-designed surgical tips are used to prepare the root-end cavity

Fig. 17 Angled micro-surgical ultrasonic tip

high-speed handpiece, same as for bone removal. It is no longer considered appropriate or necessary to cut the root down to the coronal edge of the bony crypt.²⁹ In multi-rooted teeth it may be necessary to reduce the buccal roots slightly to provide adequate access to a lingually-placed root. If the bony crypt is small, or the soft tissues restrict reflection of the flap and access, then further reduction of the root may be necessary to make enough space for root-end cavity preparation. Alternatively, the bony crypt may be enlarged but unnecessary destruction and leaving less than one mm of crestal bone on the buccal aspect of the root may seriously affect treatment outcome. Once resected, an inspection is carried out of the cut root-end with the operating microscope, aided by micro-mirrors (Fig. 14), for smoothness, cracks and canal irregularities.¹⁶ Sometimes

small knife-edges of root may be retained on the lateral borders, or if the root is angled, it may not have been adequately resected to expose the main root canal system. Methylene blue (1%) dye may be used to highlight the periodontal ligament, canal orifices, cracks and missed canals to ensure that resection is adequate and complete.³⁴

Historically, when the root-end is resected, bevelling was always carried in order to improve access for preparation of a cavity with a round bur for the root-end filling.³⁵ However, current biological evidence and advances in preparation techniques, such as the use of surgical ultrasonic tips (see later) aided by an operating microscope, has meant that the root-end should be resected perpendicular to the long axis of the root and not bevelled.^{8,33} Apart from preserving more root length, a near horizontal resection avoids exposing more dentinal tubules on the cut root face, which can allow the leakage of microbial by-products and irritants from the root canal system even in the presence of a root-end filling.^{36,37}

ROOT-END CAVITY PREPARATION

Root-end cavity preparation should always be carried out with the aid of magnification, as it is easy to miss subtle root canal system features such as isthmuses and additional canals with the naked eye. Polished stainless steel and sapphire glass micro-mirrors are available to improve visualisation of the surface of the cut root-end (Fig. 15).

Root-end cavity preparation is carried out with specially-designed surgical ultrasonic tips (Fig. 16), which are available in different shapes, angles and configurations. Some are coated with diamond or other industrial coating (Fig. 17) and many have irrigant channels for improved cutting efficiency and debris removal. Normally, a root-end cavity is prepared to a depth of two to four mm.^{38,39} The root-end cavity preparation is angled along the long axis of the root and the lateral borders are dictated by the cross-sectional shape of the main root canal system following resection.

Apart from being used to prepare the root-end cavity, ultrasonic tips are also used to debride and enlarge any canal anastomoses and isthmuses effectively; they help achieve a better shape and cleaner root-end cavity compared with using burs.^{34,39-41} After the root-end cavity is prepared it is cleaned with sterile saline and then gently dried with paper points, or preferably a Stropko irrigator (Fig. 18), a specially modified micro-surgical three-in-one syringe tip.

HAEMOSTASIS

Good haemostasis must be achieved before placement of the root-end filling.^{42,43} An

aspirating micro-tip will help control small, localised bleeds. However, placement of a haemostatic agent within the bony crypt may be necessary for more effective control of bleeding; these include:

Gauzes and adrenaline

Pure surgical gauze that is fabricated from non-cotton fibres (therefore less likely to initiate post-operative inflammation) and soaked in 1:1,000 adrenaline or local anaesthetic solution containing 1:80,000 adrenaline may be packed firmly into the bony crypt. If 1:1,000 adrenaline is used it should not be left in the bony crypt for a prolonged period; normally 30 seconds should suffice.

Cellulose-based, collagen-based and absorbable gelatine products

Surgicel (Ethicon, Johnson & Johnson, Wokingham, Berks, UK), a cellulose-based material, encourages clot formation. However, it has been recommended that the material is removed following root-end filling as it is not absorbable and may initiate a foreign body inflammatory response.^{44,45}

Hémocollagène (Septodont, Saint-Maur-des-Fossés, France) (Fig. 19) and Collacote (Colla-Tec Inc. Plainsborough, NJ, USA) are lyophilised collagen-based materials. Absorbable collagen-based agents can be left in the bony crypt and should not interfere with healing.²⁶

When used as a haemostatic agent, Spongostan (Ethicon), an absorbable gelatine sponge, has been reported to elicit no adverse tissue reaction but delayed healing was observed.⁴⁶

Ferric sulphate

Ferric sulphate solution, for example, Astringedent or ViscoStat (Ultradent, South Jordan, UT, USA), Cut-Trol (Ichthys Enterprises, Mobile, AL, USA) or Stasis (Gingi-Pak, Camarillo, CA, USA) causes agglutination of blood proteins on contact; this in turn results in plugging of opened capillaries. However, the solution should be used sparingly as it has been associated with post-operative complications.⁴⁶ Therefore, the bony crypt should be gently curetted and any remnant washed out following use.

ROOT-END FILLING

Every dental restorative material and cement ever formulated has, at one time or another, been suggested for root-end filling. The requirements of an ideal root-end filling material are well documented (Table 2) but, currently, there does not appear to be a material that fulfils all these requirements.⁴⁷

Traditionally amalgam, ubiquitous in dentistry, was the root-end filling material

Fig. 18 Stropko irrigator, useful for drying the root-end cavity

Fig. 19 Collagen-based haemostatic sponge

Table 2 The requirements of an ideal root-end filling material

Root-end filling materials should:

Adhere or bond to tooth tissue and 'seal' the root end three-dimensionally

Not promote, and preferably inhibit, the growth of pathogenic microorganisms

Be dimensionally stable and unaffected by moisture in either the set or unset state

Be well tolerated by periradicular tissues with no inflammatory reactions

Stimulate the regeneration of normal periodontium

Be non-toxic both locally and systemically

Not corrode or be electrochemically active

Not stain the tooth or the periradicular tissues

Be easily distinguishable on radiographs

Have a long shelf life, be easy to handle

of choice. However, amalgam can no longer be considered an appropriate root-end filling material and should be permanently consigned to history. Amalgam is prone to corrosion and disintegration; excess amalgam and the release of metal particles into the surrounding tissue and gingiva can result in amalgam tattooing. The presence of mercury in amalgam may also be a concern to patients. In addition, the healing characteristics following root-end filling with amalgam are questionable.⁴⁷ Newer root-end filling materials have better sealing ability and are

Fig. 20 Buccal roots of a maxillary first molar sealed with IRM and polished

Fig. 21 Lee Block, useful for forming pellets of MTA

Fig. 22 Micro-carriers for easier placement of MTA root-end filling

Fig. 23 Completed MTA root-end filling

more biocompatible. There is good evidence for the use of the following,⁴⁷ commonly available, newer root-end filling materials:

Zinc oxide-eugenol (ZOE) cements

Reinforced zinc oxide eugenol cement, such as intermediate restorative material (IRM)

Table 3 Sutures types

Suture material	Example/s
Polyglactin 910	Vicryl, Ethicon, Johnson & Johnson, Wokingham, Berks, UK
Polyamide/nylon	Supramid, B. Braun Medical Ltd., Sheffield, UK or Ethilon, Ethicon
Polypropylene	Prolene, Ethicon
Polyethylene/polyester	Mersilene, Ethicon
Expanded polytetrafluoroethylene (ePTFE)	Gore-Tex, W. L. Gore & Associates Inc., Flagstaff, AZ, USA
PTFE (Teflon)-coated polyester	Tevdek, Deknatel, Teleflex Medical, Research Triangle Park, NC, USA

Fig. 24 Sutures: polyglactin 910 (top) and polypropylene (bottom)

and ethoxybenzoic acid (EBA) cement, has been advocated as a root-end filling material for many years.⁴⁷ The biological properties of ZOE cements are dependent on their formulation. Unmodified ZOE cements that are not reinforced are weaker and have a longer setting time and hence they are not suited as root-end filling materials.

IRM and EBA cement are acceptable for root-end filling. A micro-apical carrier or fine carver for example, half Hollenback, may be used to place, and micro-pluggers used to pack, IRM or EBA cement into the root-end cavity. The filling is burnished and when set it may be finished with an ultra-fine fluted tungsten carbide bur to leave a smooth surface (Fig. 20). Reinforced ZOE cements, such as IRM, produce a better seal than amalgam and following its use as a root-end filling material, periradicular healing has generally been shown to be good.^{1,48}

Mineral trioxide aggregate (MTA)

MTA is a fine powder with a similar basic chemical composition to Portland cement. Unsurprisingly, it has a sand-like consistency when hydrated not unlike building mortar. The material has a long setting time (two hours 45 minutes), which may be the reason for its superior sealing ability.^{47,49} Various other versions of accelerated setting MTA have now appeared on the market; for example, a Brazilian version, MTA-Angelus (Angelus Dental Solutions, Londrina, Parana, Brazil), is claimed by the manufacturer to have an initial setting time of ten minutes while MM-MTA (Micro-Mega, Besançon Cedex, France), with the addition of calcium carbonate, has a reduced setting time of 20 minutes.

MTA has consistently shown to be an excellent root-end filling material; it is hydrophilic and biocompatible.⁴⁹ Given its consistency and long-setting time, MTA can be challenging to manipulate; pellets may be formed using the Lee MTA block (Fig. 21). Alternatively, MTA is placed using some form of micro-carrier system (Fig. 22). Excess material is removed using a periodontal curette or carver and the surface

of the filling finished with a damp sponge or cotton pellet (Fig. 23).

MTA is one of the few materials that were found to encourage the formation of cementum at the root-end surface.^{50,51} The formation of 'a double seal' incorporating both a physical and biological covering over the resected root end is a desired result of periradicular surgery.⁴⁷ In the first randomised prospective clinical study on the use of MTA as a root-end filling material it was reported that the highest number of teeth with complete healing was observed with MTA.¹ When the numbers of teeth with complete and incomplete (scar) healing were combined, although the results for MTA were higher (92%) compared with IRM (87%), there was no significant statistical difference in outcome between the two materials. The good results with both materials may be due to the strict entry requirements, the surgery carried out by specialists and the stringent, established criteria for assessing treatment outcome.

Recently a number of calcium silicate-based materials, such as Biodentine (Septodont, Saint-Maur-des-Fossés, France) and BioAggregate (Innovative BioCeramix, Vancouver, Canada), with similar properties to MTA have been marketed as alternatives. A drawback of Biodentine is that it is of similar radio-opacity to dentine, which makes it difficult to discern radiographically. It is anticipated that many new calcium silicate-based root-end filling material, formulated to overcome the disadvantages of MTA, will become available in due course.

GUIDED TISSUE REGENERATION PROCEDURES

The post-operative outcome for endodontic surgery is much poorer when there is loss of cortical bone overlying the root.¹³ Guided tissue regenerative procedures that are commonly used in periodontal surgery may be useful in endodontic surgery.⁵²

CHECK RADIOGRAPHS

It is good practice to take a radiograph following placement of the root-end filling

and before surgical closure. If necessary, any adjustments or revisions may be made without risking the need to re-access the surgical site.

The radiograph should show:

- An adequate root-end resected and no remnants of the root tip
- The root-end filling material well condensed and correctly adapted within the root-end cavity
- No excess root-end filling material or other foreign bodies lodged in the bony crypt.

FLAP REPLACEMENT

The flap is gently eased back into place and gentle pressure applied using saline-moistened gauze to aid close approximation for flap re-attachment. Pressure is again applied for five to ten minutes after suturing to prevent haemorrhage occurring and to reduce the coagulum, a potential nidus for infection.^{53,54}

SUTURES

Sutures are required to hold the re-approximated tissue flap in position and prevent dislodgement allowing healing to occur by primary intention. Sutures may be braided or monofilament, absorbable or non-absorbable. Braided or multi-strand silk sutures can become infected with bacterial plaque through the 'wicking' effect so they are no longer recommended. Instead, single strand or monofilament sutures (Table 3) should be used (Fig. 24). According to operator preference the minimum number of interrupted or sling sutures required to retain the flap should be placed. Sutures are normally removed after 48-72 hours at which point early epithelialisation would have occurred.^{29,54}

POST-OPERATIVE CARE

When surgery has been carried out efficiently with minimum trauma, post-operative healing is usually uneventful. Patients should be provided with post-operative instructions both verbally and in writing.^{7,8,55}

Ice pack

The patient should be instructed to rest; strenuous activity should be avoided for at least 24 hours. An ice pack should be applied on the external area of the surgical site for two to four hours immediately following the procedure to help reduce the risk of swelling and resultant post-operative discomfort.⁵⁵ Since the external area around the surgical site may still be numb it is important to warn the patient not to leave the ice pack in place for too long; intermittent application, 15–20 minutes on and 15–20 minutes off, should be adequate. The patient should also be instructed to avoid being overly inquisitive and retract the lip to have a look as this may dislodge the flap or apply unnecessary tension and pull out the sutures.

Wound care

Eating and drinking is best avoided while the area is still numb. Alcohol and smoking should be avoided. Tooth brushing can be omitted on the day of surgery, but recommenced the following day and in all areas apart from the surgical site. The cleanliness of the surgical site is maintained using chlorhexidine mouthwash; this is swilled for one minute, twice daily until the sutures are removed to help suppress plaque formation.⁵⁶ Antibiotics are seldom required, should not be routinely prescribed and only indicated when there is, for example, suggestion of post-operative infection.

Pain and swelling

Although there may be mild discomfort following root-end surgery, severe pain is not usually a feature. The post-operative pain after root-end resection and filling is, normally, of a relatively short duration; it is at its maximum intensity early in the post-operative period, three to five hours afterwards, but progressively decreases with time.⁵⁷ The maximum pain experienced is during the first day and the maximum swelling between the first and second day post-operative; patients with poor oral hygiene, smokers and those with pain before surgery may experience more pain and swelling.⁵⁸

The benefit of pre-emptive analgesia has already been discussed and if practised should reduce the need for post-operative pain control. However, if necessary, post-operative pain can normally be controlled using NSAIDS such as Ibuprofen.⁵⁵ Paracetamol may be used for patients unable to tolerate NSAIDS. Combining paracetamol and NSAIDS have also been shown to provide additive analgesia.⁵⁹ Oral analgesics are more effective if taken regularly as this will ensure that a therapeutic dose of the drugs is maintained in the blood stream.

Fig. 25 Maxillary central incisor. (a) Radiograph showing extruded root filling material, which proved impossible to remove and tooth remained symptomatic even after non-surgical root canal retreatment; (b) Post-operative radiograph following periradicular surgery showing a well-adapted MTA root-end filling; (c) Recall radiograph six months post-surgery, evidence of bony healing and tooth is symptom-free

Table 4 Overview comparing older and newer periradicular surgery concepts and techniques

	Then	Now
Magnification	Eyes or loupes (1–4×)	Microscope (4–24×)
Illumination	Dental light	Enhanced and integral with microscope
Armamentarium	Conventional oral surgery instruments	Specially-designed micro-surgical instruments
Flap design	Semilunar or full thickness, interdental papilla involved, angled relieving incisions	Full thickness, interdental papilla preservation or avoidance, more vertical relieving incisions
Flap reflection	Begin at interdental papilla	At relieving incision
Osteotomy wound size	Large (7–10 mm diameter)	Smaller (3–5 mm diameter)
Root-end resection	Slow-speed, angled & bevelled (45–60°), often apical ramifications and extra canals missed	High-speed, near horizontal angle (0–10°), usually 3 mm, lateral canals and apical ramifications included
Root-end surface	Not inspected, isthmuses and other apical anatomy often missed	Cut root-end inspected with micro-mirrors
Root-end cavity preparation	Burs, 1–2 mm depth & non-axial	Ultrasonic micro-surgical tips, >3 mm depth and along long axis
Root-end filling material	Amalgam	MTA or ZOE cements
Sutures	Braided silk, metric size 2 or 1.5 (USP 3–0 or 4–0), removed after 7–14 days	Monofilament, metric size 0.7 or 1 (USP 5–0 or 6–0), removed after 2–3 days
Post-operative healing	Delayed and often painful	Faster and usually minimum pain
Outcome (over one year)	<50%	>90%

Bleeding

Excessive bleeding is unusual following surgery unless the flap or sutures have been dislodged. However, the patient may taste blood in their mouth and slight bleeding when mixed with saliva will always appear worse than it really is. An emergency telephone number should have been made available should the patient wish to make contact.

Bruising

Bruising can occur following surgery and is usually worse approximately three to four days following surgery. It may take some time to resolve and can look rather alarming even though the patient may not be in pain.

ENDODONTIC SURGERY OUTCOME

Within two to three days after surgery an initial review appointment is required to

remove the sutures and assess healing. If healing is uneventful the patient may be seen again for another review 6–12 months later (Fig. 25); although at that stage the treatment outcome may be inconclusive. Longer follow-up periods may be necessary as there can be cases of favourable and unfavourable outcomes over time.^{9,60–62} The radiographic classification of treatment outcome following endodontic surgery described by Molven *et al.*⁶³ is often used as there is good correlation with histological assessment. The four categories are:

- Complete healing
- Incomplete healing (scar)
- Uncertain healing
- Failure.

Some cases may initially appear to fall into the uncertain healing category but can, in due course, improve. Equally, late failures (>10 years) have been reported in cases that appeared to be initially responding well, although in this particular study⁶⁴ the root-end filling material was amalgam.

REFERRALS

It is good practice to consider referring patients for endodontic surgery if it is better carried out by a colleague with specialist knowledge or training.⁶⁵ Specialists in endodontics have spent many years training in microsurgical endodontic techniques and are best placed to help.^{66,67} A retrospective study on periradicular surgery carried out in endodontic and in oral surgery units of a teaching dental hospital reported a difference in the rate of complete healing in patients treated in the two different units.⁶⁸ A recent meta-analysis of the literature concluded that the use of a microscope for endodontic surgery improves treatment outcome.⁶⁹ Another meta-analysis concluded that treatment-related, patient-related, and tooth-related factors influenced the prognosis of periradicular surgery. The clinician may be able to control treatment-related factors but, unfortunately, not patient-related or tooth-related factors.⁷⁰

CONCLUSIONS

In the past endodontic surgery was often viewed as a procedure of desperation and last resort with an unpredictable outcome. There was also limited understanding of endodontic disease and the causes of treatment failure. The concept that it is possible to confine microbes within the root canal system purely by placement of an apical plug, which led to poor case selection and the unquestioned practice of performing endodontic surgery first, is obsolete. The development of newer surgical armamentarium, the

implementation of microsurgical techniques, the use of enhanced illumination and magnification, and the advent of newer root-end filling materials have revolutionised endodontic surgery (Table 4) and improved surgical outcome.

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