



Guidelines for Periradicular Surgery

2020

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Introduction

Apical periodontitis is predominantly managed by non-surgical root canal treatment with predictably high success rates.^{1,2} The presence of signs and symptoms such as pain, swelling and periapical radiolucency post-treatment may indicate persistence of microbial infection. In these cases, periradicular surgery may be required. Root-end resection and retrograde root-filling facilitate access and potential elimination of apical anatomical complexities.

The evolution in contemporary periradicular surgery has been fuelled by a greater understanding of the disease process, an appreciation of the limitations of non-surgical root canal treatment and the adoption of technological advances. Contemporary techniques allow us to address the biological concerns of intra-canal contamination and root-end sealing.

These guidelines are not a formal systematic review as such but provide a consensus document based upon best available evidence considered by a multidisciplinary group. They aim to take into account the range of current best practice and parameters of care for the guidance of patients, health care providers, and commissioners. [Appendix 1](#) summarises the evidence. [Tables 2–5](#) denote treatment outcomes.

Indications for periradicular surgery

1. When orthograde root canal treatment cannot be completed due to persistent exudation into the root canal despite repeated chemo-mechanical debridement.
2. When previous treatment has been carried out to guideline standards but symptomatic or progressing periradicular disease associated with an optimally root-filled tooth.
3. Symptomatic or progressing periradicular disease associated with a well root-filled tooth and in which root canal retreatment:
 - » has failed
 - » may be detrimental to the structural integrity of the tooth
 - » would be destructive to a restoration or fixed prosthesis
 - » would involve the removal of a post with a high risk of root fracture.
4. Symptomatic or progressive periradicular disease associated with a tooth in which iatrogenic or developmental anomalies prevent orthograde root canal treatment being undertaken.
5. When a biopsy of periradicular tissue is required. The sample should be sent in formalin for histopathological examination to the local head and neck pathology service.
6. When visualisation of the periradicular tissues and tooth root is required if perforation or root fracture is suspected.

Interestingly, reports on the effects of non-surgical root treatment quality on root-end surgery outcome are not consistent.

Contraindications to periradicular surgery

Outcomes are adversely affected when:

- » primary disease has not been stabilised
- » the coronal seal is poor
- » the tooth is unrestorable
- » when clinical and radiographic examination or surgical exploration suggests a diagnosis of a combined periodontal–endodontic lesion
- » the prognosis of the tooth is limited by compromised bone support or its root length should root-end resection be carried out
- » there is a root fracture
- » access to the root end and the associated lesion is difficult or the risk of access is considered to be greater than the potential advantages
- » there are medical history factors of relevance (precautions related to medical history are as for any other surgical procedure to be carried out under local anaesthesia)
- » the operator does not have the prerequisite skills, experience, equipment or materials.

Assessment

Assessment should include consideration of the hard tissues, soft tissues and the tooth itself.

General considerations

General considerations include:

- » whether stabilisation of primary disease is required
- » note taken of the contour of the alveolar bone (eg chronic swelling, exostosis) and adjacent anatomical structures (eg external oblique ridge, zygomatic buttress, maxillary sinus, nasal cavity, nerve foramen and canal)
- » soft-tissue inflammation related to the affected tooth (eg fistula, swelling, erythema)
- » gingival biotype
- » thickness of attached gingiva
- » patient's smile line
- » functionality and occlusion
- » existing restorations (fixed and removable) both related to the tooth in question and to the adjacent teeth.

Local considerations

For optimal outcomes, the following are prerequisites:

- » favourable tooth angulation and access to the root end
- » good restoration coronal seal with no recent history of repeat debonding of cemented restorations (eg veneers, inlays, overlays or crowns)
- » favourable periodontal attachment levels of the affected tooth
- » absence of a potentially traumatic occlusion
- » presence of a well-condensed root filling (although there is no clear evidence that this affects the surgical outcome).

Special tests

Special tests may include:

- » pulp tests using thermal and electric testing devices on neighbouring teeth
- » imaging.

Imaging

Contemporary radiology using digital imaging techniques has the potential for low doses of radiation in line with 'as low as reasonably practicable' principles.³ Most radiographical software has a facility for image enhancement to aid the operator in diagnosis and visualisation of the endodontic lesion, and therefore treatment planning.

Periapical radiography

- » In the majority of cases, conventional periapical radiographs provide sufficient information for assessment of a periapical lesion and treatment planning.
- » Radiographs should be taken with a holding device for consistency in imaging and parallelism, and should encompass at least 3–5 mm of the apical anatomy around the root apex. Parallax radiographs using 2 periapical images with a horizontal beam angulation shift of around 20 degrees is appropriate for multi-rooted or multi-canal teeth.
- » If the lesion is larger than can be captured on a conventional sized receptor then it may be necessary to use alternatives, such as occlusal views or panoramic (ideally sectional panoramic) views and any radiologically apparent lesion. The use of cone beam computed tomography (CBCT) may be indicated in such cases.

Cone beam computed tomography

- » If conventional radiographs have failed to provide adequate diagnostic information to manage the patient for surgery and where there is a reasonable evidence-based justification, then a scan will aid in diagnosis or treatment, especially in locations in which there is a risk of iatrogenic damage to important structures, such as the mandibular canal and its branches and the maxillary and nasal sinuses. Current CBCT devices produce volumes of images that can be restricted to as low as 40 x 40 mm (cylindrical diameter multiplied by length) or less. This gives detailed and accurate three-dimensional information that hitherto was impossible to obtain from conventional radiography.⁴
- » Other indications for a CBCT related to endodontic surgery may include the need for information related to resorption, iatrogenic damage to the root surface or root fractures with non-metallic posts.
- » A position statement representing the consensus of an expert committee and based on current scientific evidence provides the clinician with criteria on when to use CBCT in endodontics.⁴ It was concluded that every image involving ionising radiation should be justified and optimised.
- » It is mandatory that all CBCT scans are clinically evaluated by a competent person in line with the Ionising Radiation (Medical Exposure) Regulations 2017.

Special anatomical considerations

Maxillary sinus and the nasal cavity

When communication of either the root apex or periradicular lesion is likely to involve either the maxillary sinus or nasal cavity, risks and consequences should be discussed with the patient prior to the procedure and documented.

Mental foramina and inferior alveolar nerves

When endodontic surgery and periradicular curettage is in close proximity or is likely to encroach on the mental foramen, there is a risk of temporary or permanent change in feeling to the lip, chin, gums and teeth, which could manifest as pain, numbness or other altered sensation. This should be discussed at the consultation appointment and preoperatively, so that the patient and clinician can weigh up the risks and benefits of surgical endodontics compared with other treatment options.

Vasculature

Endodontic surgery should be undertaken with respect to the surrounding vascular anatomy and tissues.

When should an orthograde over a surgical approach be considered?

- » When there are patient factors including medical conditions (eg haematological disorders), medication (eg intravenous bisphosphates, anticoagulant therapy) or ability of the patient to tolerate an extended treatment session.
- » When the coronal restoration and marginal seal are suboptimal and could be improved.^{5,6}
- » If there is potential for improvement of the quality of the root treatment.
- » If removal of the coronal restoration poses minimal risk to the remaining tooth structure.
- » If the operator does not have sufficient surgical experience and/or expertise.
- » If the appropriate surgical armamentarium (eg ultrasonic devices, microsurgical instruments) is not available.

When should a repeat surgical procedure be considered?

- » A second surgical episode should not be considered lightly, given the consistently reported lower probability of periapical healing after a second surgical procedure.⁷
- » The integrity of the coronal seal should be ascertained.
- » The reason for failure of the first surgical procedure should be determined.
- » The potential for rectifying errors in the first surgical approach (eg root-end resection, retrograde cavity preparation and filling) and the risks associated with repeated surgery (eg further gingival recession, loss of papilla height, scar tissue formation, further loss of root length) should be balanced against the benefits of extraction and replacement with a tooth or implant supported prosthesis.

How should an extensive lesion be managed?

- » Teeth with extensive lesions present the need for a more extensive assessment and are likely to require multidisciplinary involvement.
- » Where lesions are close to vital structures such as nerves, sinuses or even major blood vessels, CBCT examination can provide further useful information.
- » Larger lesions may also present with challenges in anaesthesia. Enucleation can be painful, and general anaesthesia may be needed to fully manage the lesion. In such cases, input from colleagues in oral surgery or maxillofacial surgery may be prudent to fully appraise the issues. Any subsequent treatment may be best achieved with the input of two operators: the oral surgeon managing the lesion and the endodontist managing the root end. Reduction in size of the lesion prior to the surgery may be achieved by decompression via an orthograde approach.

When should an implant be considered over a surgical approach?

- » Surgical endodontics may result in both soft- and hard-tissue changes that could have a negative effect on the soft-tissue aesthetics and the implant integration outcomes. If at the time of surgical treatment it is clear that the prognosis of the tooth is to be poor then extraction and implantation could be considered. Other imaging techniques such as CBCT can aid decision making in this instance.
- » When a tooth proves to be unrestorable or the presence of a crack is revealed during surgical endodontics, the clinician needs to decide whether closure, extraction or indeed extraction and placement of an implant are options. The latter would depend on the competency of the clinician providing the treatment and their ability to assess the outcome of such an approach.

How should the coronal aspect of the tooth be managed?

- » The integrity of the coronal seal of the restoration is paramount for the success of treatment.
- » For surgical endodontic management, the presence of a suboptimal restoration should preclude treatment unless the replacement of the restoration is factored into the overall treatment plan for the patient.

How should perforations be managed?

The rationale behind the surgical management of perforations is to seal a pathogenic or iatrogenic communication between the root canal system and the periodontium or oral cavity. Indications for surgical management of a perforation include:

- » persistent periradicular disease subsequent to orthograde management
- » when concomitant management of the periodontium is indicated
- » if the defect is inaccessible from a non-surgical approach or where a non-surgical approach may introduce further risk to the tooth/patient
- » an extensive apical perforation if this cannot be managed non-surgically.

Success depends on:

- » absence of contamination and associated periodontal breakdown
- » the size of the perforation
- » the location of the perforation for accessibility and vicinity to the bone and gingival margin
- » the bone level of the neighbouring teeth
- » the duration of time since the perforation was created.

Risks and consent

In law, consent is a voluntary agreement with an action proposed by another. The person giving consent must be of sufficient mental capacity and be in possession of all essential information. In the context of endodontic surgery, consent implies permission for the procedure to take place.

Key considerations

- » The decision about whether to undertake surgery will follow informed discussion of risks and benefits of the proposed surgery compared with no treatment, a period of further monitoring or extraction.
- » When assessing the appropriateness of periradicular surgery, due consideration should be given to the patient's medical, social, psychological status, general oral status and the patient's personal preference.
- » The patient must be fully aware of:
 - » the purpose and nature of the procedure
 - » the probable effects and consequences
 - » the potential risks of the surgical procedure, including pain, swelling, bleeding, post operative infection, gingival recession, loss of papilla height, damage to the tooth, adjacent teeth or vital anatomical structures (maxillary sinus, nasal cavity, nerves)
 - » in the event of loss of the tooth, the replacement options.

The final decision as to whether or not to go ahead with treatment ultimately rests with the patient once they understand the indications, procedure and potential outcomes. This is valid consent.

It is often useful to supplement the consent process with adjunctive patient information in the form of a hard-copy leaflet or links to online resources. There should be an opportunity for questions.

Referral

Periradicular surgery is considered to necessitate the skills of a specialist or a clinician with a special interest in surgical endodontics.

Consideration should be given to the appropriate setting for treatment. This will be determined by the competence and training of the clinical and support staff, facilities and the patient's medical history. If appropriate, referral should be made to a suitably trained colleague.⁸ The referring clinician should provide relevant information and should forward radiographs. An indication should be made as to the plans for the proposed restorative treatment of the tooth.

Operative management

Any signs of acute dental conditions should be managed with urgency and may involve immediate surgical drainage via the soft tissues, or even extraction of the offending tooth if coronal access is not immediately achievable.

Anaesthesia

Most surgical endodontic treatment can be undertaken using local anaesthesia with a vasoconstrictor alone and where necessary with adjunctive use of intravenous sedation. The vasoconstrictors in local anaesthesia are of value in achieving per operative haemostasis.

Antibiotics

The benefit of routine use of prophylactic antibiotics to prevent postoperative infection has not been evidenced in the literature and use of such antimicrobials must be balanced with the risk of widespread growing bacterial resistance. In certain circumstances, however, it may be relevant to seek advice from the patient's medical specialist.⁹

Magnification

The impact of magnification on the outcome of endodontic surgery has been demonstrated.¹⁰ Magnification in the form of loupes or use of an operating microscope can be used for:

- » preoperative soft and hard tissues examination
- » microsurgical flap management (design, incision, elevation, replacement and suturing)
- » conservative osteotomy and surgical access to the periradicular lesion
- » radicular assessment (microanatomy, fractures)
- » root-end resection
- » root-end cavity (ultrasonic) preparation and filling.

Soft tissue management

The flap design depends on:

- » access to the periradicular lesion
- » the periodontal status
- » the restorative status of the coronal tooth structure
- » aesthetics
- » adjacent anatomical structures
- » the tissue biotype.

Key points

- » In the 'aesthetic' zone where post-surgical gingival recession and loss of interdental papillae is critical for a patient's appearance, a papilla-base incision is recommended.^{11,12}
- » The horizontal extent of the flap and position of relieving incisions is based on the extent of the underlying intraosseous lesion, anatomical structures and restorative margins.

- » The sub-marginal incision design may be appropriate in cases where there is absence of periodontal loss of attachment, sufficient width of the attached gingivae (3–5 mm), a non-thin biotype of the attached mucosa and sound cortical bone (ie flap margins should be on sound cortical bone and not directly over the intraosseous lesion).
- » The size of the flap is a prognostic factor in terms of healing. If vertical relieving incisions at either ends of the flap follow the lines of muscular attachment, they tend to be parallel to the vasculature in the buccal vestibule. Incising along these lines will reduce intraoperative haemorrhage and afford the operator better visibility during the procedure and reduce eventual scarring in the unattached mucosa.
- » Microsurgical (full radius) blades are recommended for precise incisions that are essential for the papilla-base and sub-marginal incision flaps.
- » Reflection of the flap should start at the top of a relieving incision(s) with careful elevation of the full thickness of mucoperiosteum along the horizontal incision (eg base of each interdental papilla and gingival sulcus in the case of the papilla-base incision flap) using a small sharp elevator instrument and without shredding the margins of the flap.
- » Careful retraction of the flap is essential to good postoperative wound healing. It could be achieved by placing the retractor firmly on bone avoiding pinching of any soft tissue.
- » Contemporary sutures use short 3/8 circle needles (11–13 mm), reverse-cutting needles are recommended. Contemporary suture materials are 6/0 or 7/0 grade and monofilament polypropylene (eg Prolene®) or braided polyglactin (eg Vicryl Rapide®). It is important to ensure that the flap is not under tension.
- » Sutures are left in place to secure positioning and initial healing of the flap, and should then be removed after five to seven days when the wound strength is sufficient to withstand stresses/tension induced in function.

Hard tissue management

The osteotomy should be performed under magnification and the operator should be mindful of the information derived from the preoperative images including the size and position of the intraosseous lesion and of nearby anatomical structures that need to be avoided. There is often pathological fenestration of the cortical bone if there has been a chronic apical abscess draining via a fistula into the overlying soft tissues. Alternatively, the cortical plate may be fragile ('egg shell') due to inflammatory resorption from the lesion and the bone can be easily penetrated and lifted with a sharp curette.

Bone cutting should be performed with light pressure and copious irrigation to avoid excessive heating of the bone. An 'Impact Air 45' high-speed reverse exhaust turbine or contrangled speed-increasing surgical handpieces with coolant-only streams and safe retrograde air exhaust can be used for efficient osteotomy. Lindemann bone-cutting tungsten-carbide burs should be used for efficient bone cutting and reduce clogging resulting in heat build-up.

Modern devices use piezosonic energy for efficient and 'atraumatic' bone cutting.¹⁴ Piezosurgery offers advantages of reduced bleeding for optimal visualisation of the surgical site, precise cutting of the hard tissue and less risk to soft tissues. It also reduces vibration and noise and is therefore more comfortable for the patient.¹⁵

The osteotomy should be sufficient to allow access to the full extent of the lesion. Once the lesion has been accessed, identification and exposure of the affected root structure is required.

It is prudent to remove the pathological tissue first; this enables visualisation of the root end and establishes obvious aetiological factors such as foreign material, cracks, missed

canals or anastomoses, or contaminated root filling. The soft tissue should be removed with curettes to allow accurate visualisation of the root apex. If other anatomical structures are likely to be damaged then this tissue should be left. Any tissue should be sent in formalin for histopathological examination to the local head and neck pathology service as this should be routine standard of care.

Haemostasis follows. Resection of the root end allows visualisation of the full depth of the lesion and the osteotomy margins can be modified as necessary. Once the entire defect is accessible, all inflammatory/infected tissue should be excised and sent for histological examination.¹⁶

Root resection

It is recommended that 3 mm of the apical root is resected perpendicular to the long axis of the tooth. A more conservative resection should be considered in cases with short root length if there has been previous resection or if a post is present.

A resection with minimal bevel (0–10 degrees) minimises the surface area of dentinal tubules that could be exposed to potential microleakage.^{17,18} Anatomical studies have also demonstrated that the complexity of the canal anatomy, major portal of exits and biofilm is most apparent within the apical 3 mm of failed root-filled cases.^{19,20}

Once resected, examination of the root end should be performed under magnification, to visualise the resected root outline, the root filling material, accessory canal anatomy (eg isthmuses between major canals, lateral canals) and microfractures. Methylene blue dye can be applied sparingly over the root dentine to enhance such microdefects.²¹

Retrograde canal preparation

Ultrasonic devices are the recommended technology to prepare the canal space after root-end resection.

Retrograde tips are widely available in diamond-coated or serrated stainless steel designs and in various orientations. Tips of 3 mm and longer allow sufficient retrograde preparation of the majority of resected roots. The piezoelectric power setting to activate these tips is typically in the range of 50–70%. Sufficient coolant with copious sterile saline irrigation should be used.

Care must be taken to ensure cutting along the canal without deviation from the canal path. In certain cases, instrumentation of the root canal system from a retrograde approach can be achieved using stainless steel files²² or long (6–9 mm) ultrasonic root-end tips.

Haemostasis must be achieved at the end of the procedure prior to suturing. It is largely established preoperatively with an adrenaline containing local anaesthetic, although this will lose its effectiveness if surgery is prolonged.

Soft- and hard-tissue bleeding can generally be controlled well using 2% lignocaine with 1 : 80,000 adrenaline concentrations.

Occasionally, electrosurgery, epinephrine-impregnated pellets, ferric sulphate or suturing of severed blood vessels may be necessary.

Any non-resorbable agents used should be subject to counting in and counting out procedures to ensure that no foreign body is retained at the surgical site unintentionally.

Root-end filling

Amalgam has been widely used in the past but it is no longer recommended because of its poor biocompatibility and poor success rates.^{23,24}

The use of moisture-sensitive materials such as resin composites and glass ionomer cement may compromise potentially successful outcomes, although there is insufficient evidence to conclude or refute the efficacy of glass ionomer cements as a retrograde material.

Robust clinical evidence for determining the most superior root-end filling material does not yet exist.²⁵ Retroplast, a Bis-GMA (2,2'-bis-[4-(methacryloxypropoxy)-phenyl]-propane)/TEGDMA (tri (ethylene glycol) dimethacrylate)-based resin composite used in combination with a dentine bonding agent as retrograde material has shown promising results.

Reinforced zinc oxide–eugenol cement or ethoxy–benzoic acid can be used but they need relatively good moisture control. They may be preferable to mineral trioxide aggregate (MTA) because of their handling properties. MTA is promising and sets in the presence of moisture and blood. Other hydraulic calcium silicate cements may be considered as clinical evidence emerges.

The root-end preparation should be isolated from fluids. A suitable haemostatic agent should be placed in the bony crypt and the root-end cavity dried with a paper point.

The surgical crypt should be lined with a retrievable material to control excess root-end filling material. The root-end filling material should be compacted into the cavity with a small plugger. Excess material of the resected root face should be removed.

There should be careful debridement of the bony crypt to ensure that any excess filling material has been retrieved.

Radiographic verification of the quality of the root-end filling prior to wound closure is recommended.

Guided tissue regeneration

To date, there is a lack of strong evidence to support the use of guided tissue regeneration procedures related to endodontic surgery. In general it appears that guided tissue regeneration procedures do not negatively affect outcome of endodontic surgery. Based on limited evidence, a systematic review and meta-analysis demonstrated that if a large or through and through lesion exists, guided tissue regeneration procedures may favour a positive result and that the outcome is better using resorbable rather than non-resorbable membranes.²⁶ It is clear that there is a need for well-designed prospective clinical studies to be carried out to allow for a precise recommendation or otherwise for its use.²⁷

Follow-up

Non-resorbable sutures should be removed five to seven days postoperatively, provided that the wound is stable.

Patients whose teeth have undergone root-end surgery should be followed up clinically and radiographically annually up to four years postoperative.

Management of complications

Postoperative pain can normally be controlled with non-narcotic analgesics and the use of long-acting local anaesthetics at the end of the procedure. Long-term pain as a result of surgical damage to peripheral nerves is rare.

Postoperative swelling can be minimised with the use of anti-inflammatory analgesics such as non-steroidal anti-inflammatories for 3 to 5 days postoperatively (eg ibuprofen 400–600 mg) or paracetamol 1,000 mg. Cold compresses for the immediate four to six hours after surgery may be helpful.

Patients should be made aware that bruising is a normal sequela to endodontic surgery and that it should normally resolve by two weeks postoperatively.

Infection of the soft tissues may result in secondary haemorrhage, local abscess formation or cellulitis. It is best prevented by maintenance of good oral hygiene measures. Antimicrobials (in combination with surgical drainage if appropriate) should be prescribed when signs of systemic involvement are present in the form of pyrexia and regional lymphadenopathy. Such patients should be reviewed within 24–48 hours. Patients who are non-responsive may need to be referred to the emergency services.

Outcomes related to periradicular surgery

Outcomes of periradicular surgery can be measured based on periapical healing, tooth survival and quality of life impact.

Periapical healing data

Clinical and radiographic parameters are used to define treatment success and therefore periapical health. In the absence of clinical signs and symptoms (pain, swelling or presence of a sinus), the radiographic healing categories are outlined in [Table 1](#).

Table 1 Radiographic healing categories (adapted from Rud *et al* 1972)²⁷

Healing category	Definition
Complete	Resolution of the periapical radiolucency. The presence of a continuous periodontal ligament space.
Incomplete	Reduction in periapical radiolucency size.
Scar tissue	An intact periodontal ligament space is seen apically with the radiolucency separated from the apex. There may be some bony infill, but the characteristic is the presence of an irregular border with the radiolucency possibly being asymmetrical around the apex.
Unsatisfactory	The radiolucency has increased in size or remained the same for 4 years.

A range of success rates has been reported in the literature. In an attempt to collate the data, the results of two systematic reviews with meta-analyses that include teeth treated with a contemporary technique only can be found in [Table 2](#). Both of these meta-analyses define success as a combination of complete or incomplete radiographic healing.

Table 2 Periapical healing rates reported in two systematic reviews of periradicular surgery

Study (year)	Studies (n)	Duration after treatment (months)	Pooled periapical healing rate (%)
Setzer <i>et al</i> (2010) ²⁹	9	6–60	94
Tsesis <i>et al</i> (2013) ³⁰	18	12	89

A number of prognostic factors for periradicular surgery have been reported in systematic reviews. These factors are summarised in [Table 3](#).

Table 3 Prognostic factors for periapical healing highlighted by systematic reviews

Prognostic factor	Study (year)
Preoperative:	
Absence of preoperative pain or signs	von Arx <i>et al</i> (2010) ³¹
Dense root-fillings (existing root canal treatment)	
Radiolucency less than 5 mm	
First time surgery was better than repeat surgery	
Intraoperative:	
Use of high-magnification	Setzer <i>et al</i> (2010) ²⁹
	Tsisis <i>et al</i> (2013) ³⁰
	von Arx <i>et al</i> (2010) ³¹
	Del Fabbro and Taschieri (2010) ³²
Root-end preparation with ultrasonics	von Arx <i>et al</i> (2010) ³¹
Use of mineral trioxide aggregate	Tsisis <i>et al</i> (2013) ³⁰
	von Arx <i>et al</i> (2010) ³¹

Tooth survival data

Survival is defined as the retention of an asymptomatic tooth regardless of the clinical and radiographical status of the tooth. Minimal data exist on tooth survival. A survival rate of 98% was found when teeth were followed up 4–10 years after periradicular surgery.³³

Quality of life assessment

With the emphasis on periapical healing outcomes, very few studies have investigated impact of periradicular surgery on the patients' quality of life. In one study, the perioperative experience was questioned in comparison with non-surgical root canal treatment.³⁴ Just less than half (46%) of the included patients reported less pain following periradicular surgery. In addition, the experience was more pleasant than expected for 67%.

Short-term outcomes (0–12 months)

Quality of life impact studies looked at the immediate short-term outcomes in relation to postoperative comfort.^{34,35} The following outcomes were noted:

- » Little postoperative pain for most, although this was variable among the cohorts.
- » When pain or swelling was present, it lasted for up to three days with subsequent reduction. In most cases, postoperative symptoms were completely resolved by week two.
- » There was a more rapid reduction in pain levels when a papilla-based incision was used over a sulcular incision.

The majority of the published literature reported periapical healing rates at 12 months post-treatment. A meta-analysis of studies limited to those adopting a contemporary technique found an 89% healing rate when complete and incomplete healing were combined.³⁰

Medium-term outcomes (12–48 months)

Few studies fulfilled the recommended 48-month follow-up.³⁶ Among the systematic reviews, a 78% periapical healing rate was found; however, the authors pooled data from traditional and contemporary technique studies.³⁷ Data from individual studies were limited to those using contemporary techniques. The outcomes for two to four years can be seen in [Table 4](#).

Table 4 Periapical healing at 12–48 months post-treatment

Study (year)	Sample size (number of teeth)	Duration after treatment (months)	Periapical healing rate (%)
Villa-Machado <i>et al</i> (2013) ³³	93	48	84
Taschieri <i>et al</i> (2013) ³⁸	86	48	91
Li <i>et al</i> (2014) ³⁹	82	24	93

Longer-term outcomes (more than 48 months)

A limited number of studies follow up clinical outcome in the longer term. These are summarised in [Table 5](#). A trend towards a slight reduction in success rates can be seen with time.

Table 5 Outcomes over 48 months post-treatment

Study (year)	Sample size (number of teeth)	Duration after treatment (months)	Periapical healing rate (%)	
			Over 48 months	At 12 months
Rubinstein & Kim (2002) ⁴⁰	59	60–84	91.5	96.8
von Arx <i>et al</i> (2012) ⁴¹	170	60	76	84
Villa-Machado <i>et al</i> (2013) ³³	62	48–120	79	–

Appendix 1: Summary of evidence for the best available care in periradicular surgery

Use of magnification: dental operating microscope or surgical loupes

- » Improved diagnostic accuracy *in vitro* and *in vivo*.
- » Higher success rate compared with no magnification.²⁹

Soft-tissue management

- » Choice of flap design should be influenced by the individual case.
- » Depending on the amount of surgical access required, triangular or rectangular/trapezoidal flaps with sulcular incisions or submarginal flaps can be used.
- » Use of a papilla-base flap resulted in rapid predictable recession-free healing compared with the marked loss of papilla height associated with the full-thickness sulcular incision.⁴²
- » Semilunar flaps are no longer indicated due to limited access to the apical tissues and scarring post-treatment.^{12,43}

Osseous management: small osteotomy wherever possible

- » A significant reduction in success rate was seen (80–53%) in crypts greater than 10 mm, compared with less than 10 mm.⁴⁴
- » Faster healing with a smaller osteotomy.⁴⁰
- » Although the effect of method of osteotomy on success rate was not reported *per se*, a back-exhaust high-speed air rotor was used in almost all of contemporary outcome studies. This is in preference to a surgical slow-speed motor.

Perpendicular root-end resection of 3 mm

- » An increased bevel resulted in a greater number of exposed dentinal tubules, *ex vivo*,⁴⁵ and significantly greater dye leakage, *in vitro*.¹⁷
- » Based on these principles, perpendicular resection is recommended.
- » Clinical data indicates higher success rates with perpendicular versus bevelled resection.^{33,46–48}
- » Resection of 3 mm allows elimination of lateral canals and apical ramifications.^{21,49,50}
- » Root-end preparation using ultrasonic retreatips.
- » Preparation should be as deep as possible to facilitate placement of root-end filling for sealing and prevention of leakage.¹⁷
- » Allows preparation of the canal parallel to the long axis of the root with better visibility than burs.⁵¹
- » Superior clinical outcomes when compared with bur preparations.^{31,33,46–48}

Root-end filling with biocompatible materials

- » Animal studies have demonstrated superior periapical bone regeneration in association with mineral trioxide aggregate (MTA) root-end fillings⁵² compared with amalgam and Super-EBA.
- » A number of clinical studies highlight MTA's superiority over other materials.^{31,41,53,54}
- » Systematic reviews support these findings.^{30,31}

- » These findings are consistent with the bioactive and biocompatible properties of MTA.⁵⁵
- » Despite the number of studies supporting the use of MTA, randomized controlled trials also support the use of zinc oxide eugenol based materials such as IRM and Super-EBA when compared with MTA.^{54,56}

Closure of the surgical site: monofilament 5–0 to 8–0

- » Monofilament sutures induce a smaller inflammatory reaction compared with multifilament.⁵⁷
- » 5–0 to 8–0 suture sizes will reduce the risk of papilla necrosis.^{58,59}

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