



MAGNIFICATION IN SURGICAL ENDODONTICS

Surgical endodontics has seen many developments since the time of its inception. One of the major developments was the introduction of magnification. Magnification devices used in dentistry are loupes and dental operating microscopes. These devices provide increased visibility, precision during surgery, and improve operator ergonomics. Furthermore, when used in conjunction with bioactive materials can render more predictable treatment outcomes. This has also led to the introduction of various microsurgical instruments exclusively for endodontic microsurgery. This book seeks to provide an evidence-based overview of the state-of-the-art procedures and outcomes of endodontic microsurgery with a prime focus on periapical surgeries while contrasting the differences with traditional or historical techniques.

Akshata Airsang
Adarsha M.S.
Meena N.

MAGNIFICATION IN SURGICAL ENDODONTICS

Dr Akshata J. Airsang is a Masters in Dental Surgery candidate in Conservative Dentistry and Endodontics from the Vokkaligara Sangha Dental College (VSDC).
Dr Adarsha M.S., Professor, Department of Conservative Dentistry and Endodontics from VSDC.
Dr. N. Meena, Professor, Department of Conservative Dentistry and Endodontics from VSDC.

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Adarsha M.S.
Meena N.**

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str. A.Russo 15, of. 61, Chisinau-2068, Republic of Moldova Europe

Printed at: see last page

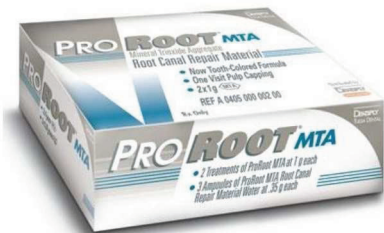
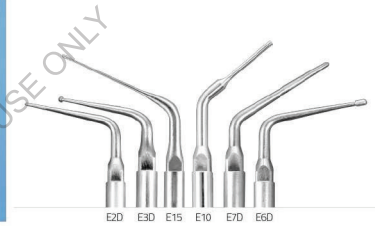
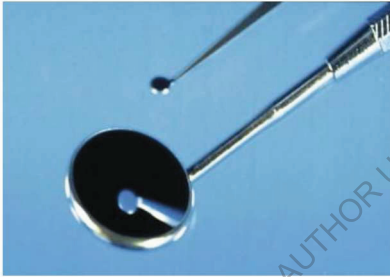
ISBN: 978-620-3-92532-6

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Dr Akshata J Airsang

Dr Adarsha M. S.

Dr. N. Meena

CONTENTS

Sl. No.	Title	Page No.
1	Introduction	1-2
2	Presurgical Considerations	3-16
	2.1 Indication	3-5
	2.2 Contraindications	6
	2.3 Objectives	7
	2.4 Classification of endodontic microsurgical cases	8-9
	2.5 Anatomical considerations	10-16
3	Surgical considerations and methods for endodontic surgery pertaining to maxillary teeth and mandibular teeth (Traditional techniques)	17-20
4	Surgical considerations and methods for endodontic surgery (Endodontic microsurgical techniques)	21-25
5	Endodontic microsurgical technique in comparison to traditional techniques.	26-45
	5.1 Anaesthesia and Hemostasis.	26-33
	5.2 Flap design.	33-37
	5.3 Incision and reflection	37-38
	5.4 Apical access	39
	5.5 Root end resection	39-43
	5.6 Root end cavity preparation	43-45
6	Microsurgical instruments	46-78
7	Magnification	79-96
8	Root end filling materials	97-100
9	Post surgical considerations	110-112
10	Advances in endodontic microsurgery	113-120
	10.1 Three dimensionally assisted surgical techniques (Static)	113-117

	10.2 Three dimensionally assisted surgical techniques (Dynamic)	117-118
	10.3 Guided tissue regeneration	119
	10.4 Lasers in endodontic microsurgery	119-120
11	Treatment outcomes	121-122
12	Bibliography	123-136

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I. INTRODUCTION

Surgical Endodontics deals with the diagnosis and treatment of lesions of endodontic origin that do not respond to non surgical endodontic therapy or those that cannot be treated by conventional endodontic therapy. In such cases, endodontic surgery is seen as the last resort that could address the objectives of endodontic therapy. The objectives of Surgical Endodontics are to achieve the three dimensional cleaning, shaping and obturation of the apical portion of the root canal system which is only accessible through the reflection of a surgical flap.¹

Endodontic surgery can be divided into periapical and periradicular surgeries. Periradicular surgery includes procedures such as root fracture management, root amputation, hemisections, intentional replantation and transplantation. Periapical surgery includes apicoectomy followed by retrograde filling of the apical root canal system. These are indicated in cases with persistent or refractory periradicular pathosis that have failed to heal after nonsurgical retreatment.

The standard approach for surgical endodontics, for many years, has been access and root-end resection with surgical burs and the use of amalgam as root-end filling material. However, this approach has seen three important developments over the past couple of decades: the ultrasonic root end preparation, biocompatible materials and the surgical operating microscope; which were introduced in the 1990s. This also was accompanied by advancements in instruments and materials used that made endodontic surgery today, to be performed with added accuracy and predictability of results. These have contributed to the evolvement of "Microsurgical Endodontics".

CAUSES OF REFRACTORY ENDODONTIC INFECTIONS:

For the majority of the situations the primary reason for failure of either non-surgical and surgical endodontic treatment is the persistence of intra- and/or extraradicular infection. The modes of recurrence of infections even after a non-surgical endodontic

therapy have been addressed to and are comprehensible. However, the same after a surgical intervention is unclear. Persisting intracanal infection will be a source of failure after surgery if the method and materials used did not provide an effective seal. This ineffective seal can further aggravate the disease process as an apicoectomy leaves open a large number of tubules and canal ramifications, through which microorganisms may penetrate and cause periapical inflammation. These were the limitations of the traditional surgical endodontics that have been taken care of by the newer concepts of endodontic microsurgery.

WHAT WERE THE NEWER CONCEPTS?

The surgical operating microscope gives high magnification and uninterrupted illumination. This reduces the need for beveling of the resected root and reduces the number of exposed dentinal tubules. Ultrasonic instruments for in-axis root-end cavity preparation limit damage and achieve better cleaning, and the use of biocompatible and stable root-end filling materials support healing processes better than conventional cements.

AIM OF THIS BOOK:

This book seeks to provide an evidence-based overview of the state-of-the-art procedures and outcomes of endodontic microsurgery with a prime focus on periapical surgeries while contrasting the differences with traditional or historical techniques.

II. PRESURGICAL CONSIDERATIONS

II.A INDICATIONS OF PERIAPICAL OR ROOT END SURGERIES

The indications for periapical or root end surgeries are:

1. Anatomical issues Anatomical issues:

- Pulp stones and extremely calcified canals, produced by aging, small traumas or big restorations, that prevent the operator's file from reaching the apical foramen of a tooth.
- Double-curved roots where the file can get through the first curve but not the second.
- Incomplete apical development - "blunderbuss-shaped apex"
- Apical external dentinal resorptions

2. Presence of Periapical Pathology :

- Nair et al. classified 35% of lesions on extracted teeth as periapical abscess, 50% as granuloma, and 15% as cysts. ²
- Periapical cysts may be pocket cysts, which have direct connection with the infected root canal system, or apical true cysts, which are separated from the root. Of all periapical lesions, 9% were described as apical true and 6% as apical pocket cyst. ² **True cysts are less likely to resolve by primary endodontic treatment or non-surgical retreatment. These cases may thus require surgical intervention.**
- If the initial size of the **periapical defect exceeds 5 mm** in diameter healing by non-surgical treatment may be impaired. ^{3,4}
- Scenarios less likely to be resolved only by non-surgical retreatment, may need endodontic surgery.

3. Altered Canal anatomy Impeding Non-surgical

Instrumentation:

- **Insoluble obturation materials**, such as hard resins.
- Many retreatment cases present with **complexities in the root anatomy of the tooth** making eradication of microbial component inconvenient.
- Moreover, as a consequence of the initial treatment, there may be **alterations to the original root canal anatomy** that may prevent instrument and irrigant access to all areas of the root canal system. These alterations include **transportations, ledges or perforations and separated instruments**.
- **Over-instrumentation/under-obturation**: iatrogenic modification of the root anatomy that makes non-surgical correction impossible.
- **Over-obturation**: foreign body reaction and/or bacteria inside the extruded obturation material, gutta-percha or contaminated paper points
- Some of these challenges may only be obvious upon initiating a conventional non surgical retreatment, while other may be apparent during the treatment planning stage as well such as instrument separations and perforations.
- The success rate of non-surgical retreatment cases with apical periodontitis together with altered root canal anatomy that could not be renegotiated is only about 40%.⁵
- Removal of the separated fragment of the instrument is necessary in case of evident periapical pathology.

4. Posts and Build-ups:

Irremovable obturation materials: Richmonds-type crown, big cast posts, broken instruments, etc.

Long, prefabricated metal posts, cast post and core build-ups and crowns may require a disassembly of the existing restoration that may carry risks of root

fracture, excessive tooth tissue loss or perforation, favouring a surgical approach.

5. **Resorptions, Perforations:**

- The healing of internal or external resorptions, as well as perforations, depends on their location within the root canal or the root.
 - The more coronal any resorptive defect is located, the more likely a non-surgical retreatment to succeed.
 - The more apical, a surgical approach would be preferred.
6. Peri-radicular disease in a root-filled tooth where nonsurgical root canal retreatment cannot be undertaken or has failed, or when it may be detrimental to the retention of the tooth.
 7. Where a biopsy of periradicular tissue is required.
 8. Where visualisation of the periradicular tissues and tooth root is required when perforation or root fracture is suspected.
 9. Where it may not be expedient to undertake prolonged nonsurgical root canal retreatment because of patient considerations.
 10. Restorative consideration that compromise treatment.
 11. Horizontal root fractures with apical necrosis.
 12. Procedural error during treatment.

II. B CONTRAINDICATIONS

There may be situations where endodontic surgery may be compromised or contraindicated. This may include:

1. Proximity of the surgical site to anatomical structures that could suffer severe or permanent damage, for example the mental and infra-alveolar nerves, the nasal or sinus cavities, or the palatal neurovascular bundle.
2. Teeth with unfavorable crown-to-root ratio, increased mobility or advanced periodontal disease will have a less favourable prognosis.
3. The tooth has no function (no antagonist, no strategic importance serving as a pillar for a fixed prosthesis).
4. Systemic diseases, such as cardiovascular disease prohibiting the use of vasoconstrictors with the local anesthesia, congenital bleeding disorders, a history of intravenous bisphosphonate therapy that puts the patient at high risk of bisphosphonate-related osteonecrosis of the jaws, may not allow a surgical procedures.
5. Other situations, such as diabetes, immune deficiencies, or anticoagulant therapy may put the patient at elevated risks of postoperative complications or impaired wound healing. Cooperation with the patient's physician is then mandatory.
6. Uncooperative patient .

II. C OBJECTIVES

1. To remove all necrotic tissues from the surgical site.
2. To eliminate and prevent microbial leakage from the root canal system into the periradicular tissues by completely sealing the root canal system.
3. To facilitate the regeneration of hard and soft tissues including the formation of a new attachment apparatus for subsequent healing.

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II.D CLASSIFICATION OF ENDODONTIC MICROSURGICAL CASES

Since the outcome of endodontic surgery depends on the pre-existing condition of the tooth, it is important to know that the probability of success depends on the given situation.

Kim and Kratchman classified periradicular lesions into 6 classes (A–F).⁶ Classes A, B, and C represent lesions of endodontic origin and are ranked according to increasing size of periradicular radiolucency. Classes D, E, and F represent lesions of combined endodontic-periodontal origin and are ranked according to the magnitude of periradicular breakdown.

Class A represents the absence of a periapical lesion, no mobility and normal pocket depth, but unresolved symptoms after nonsurgical approaches have been exhausted. Clinical symptoms are the only reason for the surgery.

Class B represents the presence of a small periapical lesion together with clinical symptoms. The tooth has normal periodontal probing depth and no mobility. The teeth in this class are ideal candidates for microsurgery.

Class C teeth have a large periapical lesion progressing coronally but without periodontal pocket and mobility.

Class D are clinically similar to those in class C, but have deep periodontal pockets.

Class E teeth have a deep periapical lesion with an endodonticperiodontal communication to the apex but no obvious fracture.

Class F represents a tooth with an apical lesion and complete denudement of the buccal plate but no mobility.

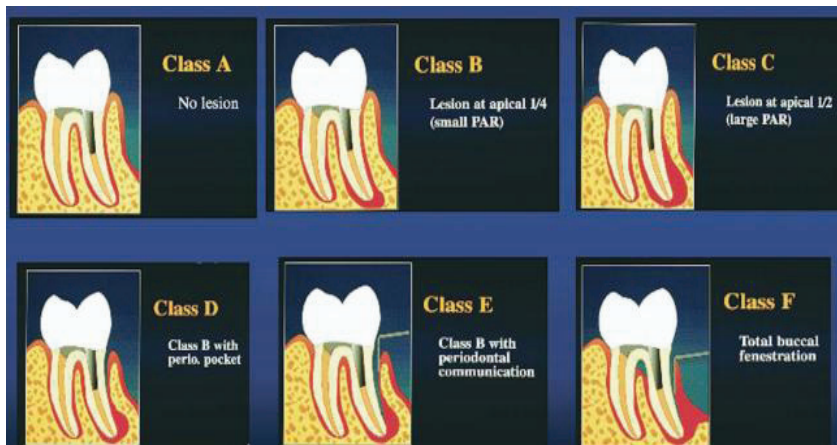


Figure 1: Classification of endodontic microsurgical cases according to Kim and Kratchman (2006).

©Kim and Kratchman et al, 2006

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II. E ANATOMICAL CONSIDERATIONS

1. MAXILLARY SINUS:

Maxillary sinus is located in the body of the maxilla. Size of the sinus varies from individual to individual, also between the two sides of the same person. It is approximately of dimensions 34×33×23 mm. It has an irregular pyramidal shape.

Anatomical relations of the sinus:

- i. **Apex:** zygomatic process of the maxilla
- ii. **Base:** lateral wall of the nasal cavity.
- iii. **Anterior wall:** Facial surface of maxilla
- iv. **Posterior wall:** Infraorbital surface of maxilla
- v. **Floor:** alveolar process of maxilla
- vi. **Roof:** the orbital surface of the maxilla
- vii. The maxillary sinus communicates with the middle meatus of the nasal cavity through the ostium in the superior part of its base.

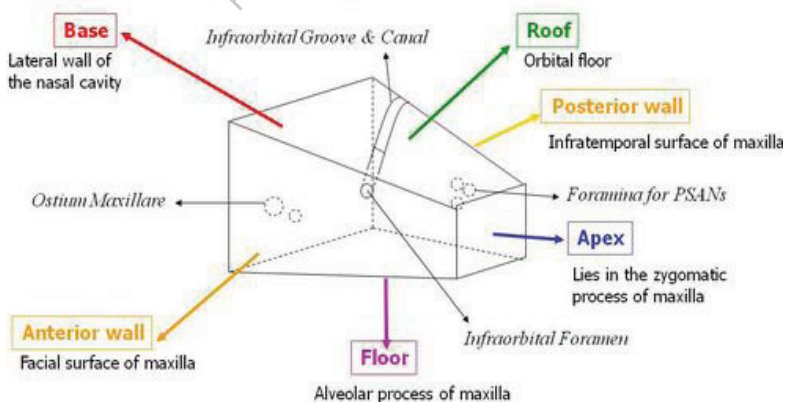


Figure2: Anatomical relationship of the sinus

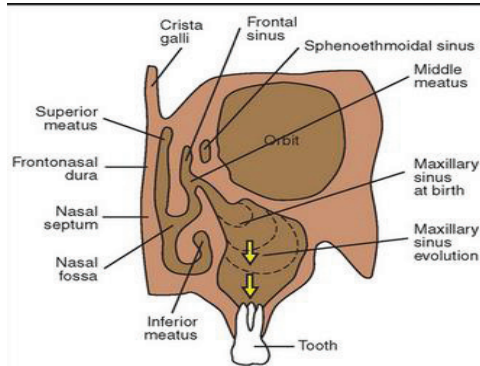
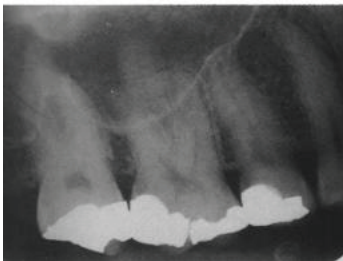


Figure 3: The maxillary sinus communicates with the middle meatus of the nasal cavity through the ostium in the superior part of its base.

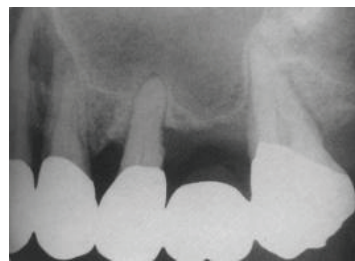
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In extreme cases, the sinus floor extends downward into the alveolar process between the roots of adjacent teeth or the radicular portion of a multirrooted tooth so that their sockets protrude into the sinus.

Usually there is a thin layer of bone present around these roots.



(a)



(b)

Figure 4 (a) Maxillary sinus extends downward into the alveolar process between the posterior teeth; (b) Maxillary sinus extends into the radicular portion of first molar

©Lin et al (1985)

The apices of maxillary premolars and molars are located below the floor of the antrum.

First premolar is commonly further away from the floor of the sinus than the second premolar and molars.

- **In maxillary first premolars with single root**, the socket is in close relation to the outer alveolar plate and is separated from the inner alveolar plate by spongy bone.
- **In maxillary first premolars with two roots**, buccal root is close to the outer alveolar plate whereas the socket of lingual or palatal root is located almost in the center of the retroalveolar spongiosa.

Second premolar:

- The floor of the maxillary sinus dips down into the immediate neighborhood of the second premolar .
- The socket is separated from the sinus only by a thin layer of compact bone.

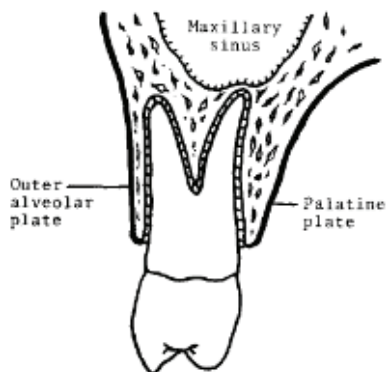


Figure 5 The buccal root of maxillary first premolar is close to the outer alveolar plate and the palatal root is almost in the center of the retroalveolar spongiosa.

© Lin et al. (1985). Oroantral communication in periapical surgery of maxillary posterior teeth. *Journal of Endodontics*

Molars:

- The sockets of the molars almost always reach the floor of the antrum and frequently protrude into it.
- The divergence of the molar roots, especially in the first molar, often permits extension of the extremely enlarged sinus downward into the furcation of these roots.
- The buccal roots of molars are generally situated between the anterolateral surface of the sinus and the outer alveolar plate, whereas the palatal roots are between the base of the sinus and the palatine plate of maxilla.

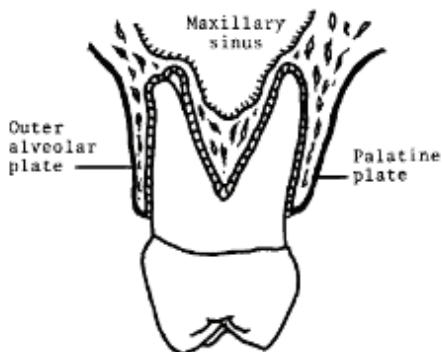


Figure 6 The buccal roots of maxillary molars are situated between the outer alveolar plate and the anterolateral surface of the sinus and the palatal root between the base of the sinus and the palatine plate.

Courtesy: Lin et al. (1985).

MANDIBULAR CANAL, INFERIOR ALVEOLAR NERVE, AND ARTERY

- Radiographically: radiolucent band.
- The canal varies in size and in its relationship to the roots of the posterior teeth.
- The mandibular canal is anatomically, situated lingual to the roots of posterior teeth.
- Oftentimes it is close to or may even come in contact with the roots of the third molar. Sometimes, it is in the proximity of the roots of all mandibular molars.

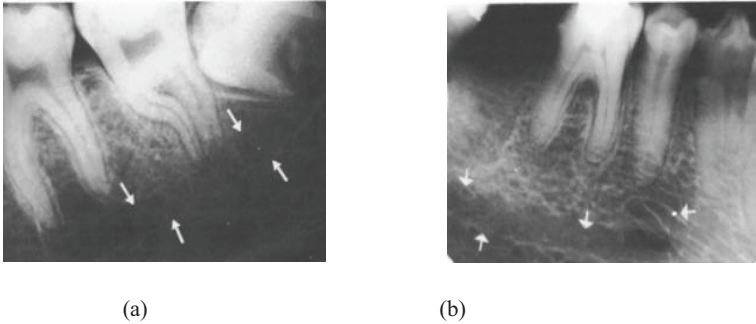
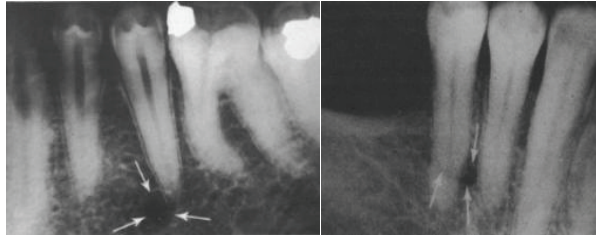


Figure 7(a) Mandibular canal (arrows) in proximity to the roots of mandibular molars; (b) Note the communication between mental foramen and mandibular canal (arrows).

Courtesy: Lin et al. (1983).

3. MENTAL FORAMEN, NERVE, AND ARTERY

- **Radiographically** : oval or round radiolucent area in the mandibular premolar region.
- Its location varies in relationship to the roots of the premolars: inferior to, at the same level as, or superior to the root apices; situated directly over the root of either premolar, or between them.
- Sometimes, the communication between the mental foramen and the mandibular canal can be seen.
 - i. The mental foramen is not always visible radiographically.



(a)

(b)

Figure 8 (a) Mental foramen (arrows) located at the apex of second premolar; (b) Mental foramen (arrows) situated in the periapical area between two premolars.

Courtesy: Lin et al. (1983).

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III. SURGICAL CONSIDERATIONS AND METHODS FOR ENDODONTIC SURGERY PERTAINING TO MAXILLARY TEETH

(TRADITIONAL TECHNIQUES)

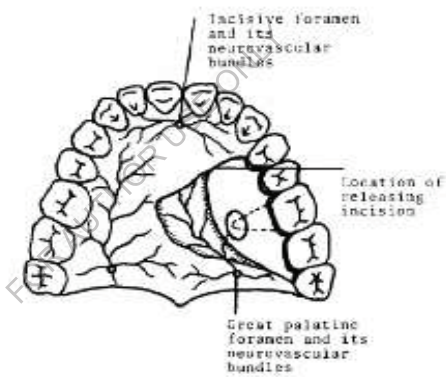
1. MAXILLARY POSTERIORES AND MAXILLARY SINUS:

- Diagnostic radiographs with distinct contrast and minimal distortion are imperative for the prevention of oroantral communication in periapical surgery of maxillary posterior teeth.
- The panoramic radiograph affords an excellent view of the entire antrum and its relationship with all of the maxillary teeth .
- To decrease the possibility of exposing the maxillary sinus, periapical surgery of bicrooted first premolars and the buccal roots of maxillary molars should be approached from the facial surface and the palatal root of molars via the palatal aspect .

MAXILLARY MOLARS:

- After the full-thickness flap has been reflected, a premeasured instrument is placed along the buccal alveolar plate or palatal plate covering the involved tooth to determine the approximate location of the root apex.
- If no periapical radiolucency is observed and/or if the cortical bone is still intact, the entry of the surgical bur at the outer alveolar plate or palatal plate is kept at least 4 mm short of the estimated root apex.
- The cortical bone was carefully removed until the apical third of the involved root surface is uncovered.
- The apex is then exposed, following the outline of the root apically.

- If difficulty is encountered in locating the root apex, a sterilized radiopaque material such as a piece of gutta-percha or lead foil from the X-ray packet can be placed in the bone cavity and a radiograph can be taken. This will guide the location of the root apex.
- Great care had to be taken while curetting the inflamed periapical tissues and also in resecting the apex because the maxillary sinus may lie closely behind the offending root.⁷
- Care must be taken not to sever the neurovascular bundles emerging from the great palatine foramen.
- The great palatine foramen is located between the second and third maxillary molars about 1 cm toward the midline of the palatal from the palatal gingival



margin

Figure 9 Note the palatal flap design to avoid injury of the great palatine neurovascular bundles.

Courtesy: Lin et al. (1985).

IN CASE OF EXPOSURE OF THE MAXILLARY SINUS:

- The use of overzealous irrigation and continuous probing of the exposure with instrument must be avoided to prevent ingress of bacteria from the periapical tissues into the sinus.

- If a root tip is displaced into the antrum and cannot be easily removed, it is advisable to immediately suture the wound.
- The patient should be referred to an oral surgeon for removal of the root tip via a sinusotomy procedure under optimal conditions.
- Postoperative management of a maxillary antral perforation includes the use of antihistamines and nasal drops such as 0.5% Neosynephrine to shrink the inflamed antral and nasal mucosa, thus improving drainage.⁷
- **Antibiotics:** treatment of an established, active infection with signs and symptoms of fever, malaise, abscess, cellulitis, lymphadenopathy, and elevated white cell count.

PERIAPICAL SURGERY OF PALATAL ROOTS OF BIROOTED MAXILLARY FIRST PREMOLARS

If their roots are greatly separated, a large portion of the buccal root may have to be resected in order to achieve adequate accessibility to and visibility of the palatal root. Otherwise, the maxillary sinus may be violated.

PERIAPICAL SURGERY OF PALATAL ROOTS OF BIROOTED MAXILLARY FIRST PREMOLARS

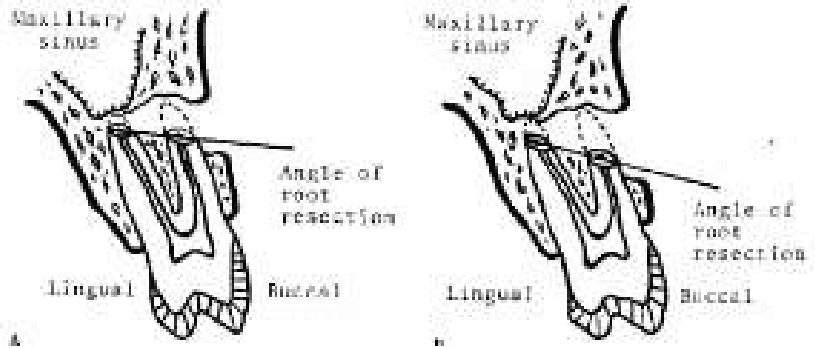


Figure 10 The angle and level of the buccal root resection is inadequate to achieve accessibility to and visibility of the palatal root in A. B shows adequate root resection of the buccal root.

©Lin et al. (1985).

**IV. SURGICAL CONSIDERATIONS AND METHODS FOR
ENDODONTIC SURGERY PERTAINING TO
MANDIBULAR TEETH
(TRADITIONAL TECHNIQUES)**

MANDIBULAR CANAL:

- The panoramic radiograph
- **Premeasured instrument** should be placed along the buccal alveolar plate covering the involved tooth to determine the **approximate location of the root apex**.
- **Entry of the surgical bur** at the outer alveolar plate or palatal plate should be kept at least **4 mm short of the estimated root apex**.⁸

MENTAL FORAMEN:

- A deep vertical releasing incision into the periapical area between two premolars is precluded because anatomically the mental foramen is frequently situated in this region.
- Careful exposure the mental foramen and its neurovascular contents.
- When reflecting the flap in the mental foramen area, there is a resistance to retraction of the flap due to its attachment to the neurovascular bundle.
- The patient may experience some temporary paresthesia.

VESTIBULAR FORNIX

- If the fornix of the vestibule is shallow, the accessibility to the periapical lesion will be limited.
- Therefore, the buccal cortical plate should be reduced before exploring for the periapical lesion.

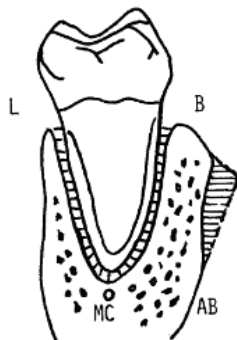


Figure 11 : Some of the alveolar bone (horizontal lines) should be reduced to overcome the accessibility to the periapical area during periapical surgery when the cortical plate is too thick.

Courtesy: Lin et al. (1983).

V. SURGICAL CONSIDERATIONS AND METHODS FOR ENDODONTIC SURGERY

(ENDODONTIC MICROSURGICAL TECHNIQUES)

Advancements that have made a positive influence on the technique are preoperative CONE-BEAM COMPUTED TOMOGRAPHIC (CBCT) IMAGING:

- Identify anatomic landmarks
- Proximation of vital structures to the apices of the offending tooth
- Accurate length measurements between structures
- Can be used to make surgical guides (3D Printing)

Use CBCT imaging in assessing the relationship of the maxillary posteriors and the maxillary sinus.

- **TYPE 0** : root is not in contact with cortical borders of the sinus
- **TYPE I**: Root is in contact with cortical border of the sinus
- **TYPE II**: Root is projecting laterally along the sinus cavity but apex is lying outside the sinus borders
- **TYPE III**: Root is protruding into the sinus cavity.⁹

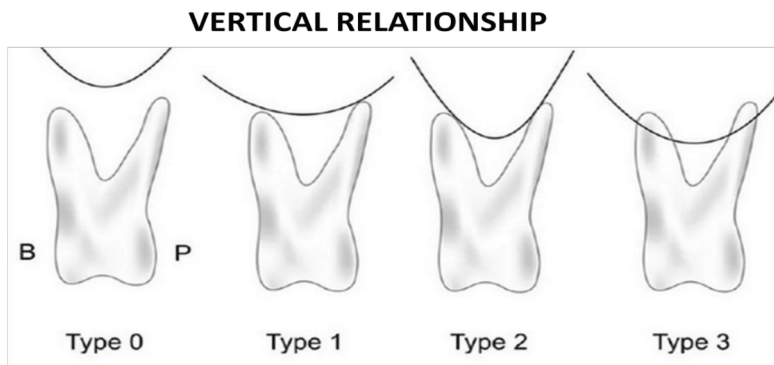


Figure 12: Vertical relationship of the roots of maxillary molars to the floor of the maxillary sinus.

© Katti G, Shahbaz S, Katti C, Rahman MS. The relationship between the roots and furcation of the maxillary first molar to the maxillary sinus: A cone-beam computed tomography study. *Journal of Indian Academy of Oral Medicine and Radiology*. 2018 Jul 1;30(3):260.

HORIZONTAL RELATIONSHIP

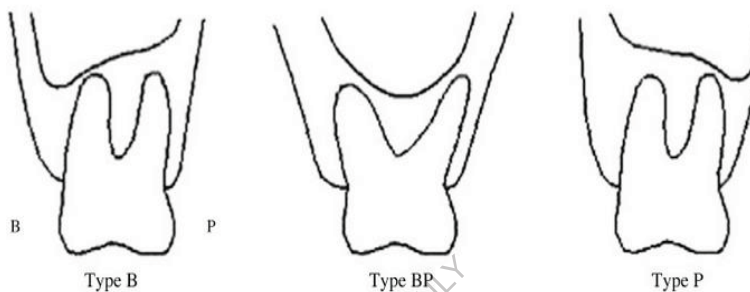


Figure 13: Horizontal relationship of roots of maxillary molar to the floor of the maxillary sinus.

© Kwak HH, Park HD, Yoon HR, Kang MK, Koh KS, Kim HJ. Topographic anatomy of the inferior wall of the maxillary sinus in Koreans. *International journal of oral and maxillofacial surgery*. 2004 Jun 1;33(4):382-8.

- **TYPE B:** the lowest point of the sinus floor located on buccal side
- **TYPE BP:** the lowest point of the sinus floor is located between the buccal and palatal roots.
- **TYPE P:** the lowest point on the sinus floor is located on the palatal root. ¹⁰

Use of CBCT imaging, 3-dimensional (3D) printing, and a 3D surgical guide:

- This allows the operator to create a small targeted wound to execute the entire surgical procedure in otherwise complex areas of the oral cavity.
- A successful and predictable outcome is dependent on good access to the apex of the tooth and the lesion.
- Provides an opportunity to surgically access inaccessible areas with a more predictable outcome.

(See Section on Targeted endodontic therapy)

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ENDODONTIC MICROSURGICAL TECHNIQUE COMPARED TO TRADITIONAL TECHNIQUES

1. Anaesthesia and Haemostasis:

Local anaesthetics used in dentistry are classified as esters or amides, based on their chemical structure. Among these the most commonly used anaesthetic agent is Lidocaine, which is an amide. Lidocaine has high diffusion rate, has a rapid onset, a prolonged action providing profound anaesthesia and is available in various concentrations with the vasoconstrictors.

The vasoconstrictors used in dental anaesthetics are nor-epinephrine, levonordefrin and epinephrine. Epinephrine is the most effective and widely used vasoconstrictor in dental anaesthetics. In non- surgical endodontic procedures the concentrations vary among, 1:80,000 ; 1: 1,00,000 or 1:2,00,000. However, these concentrations may not be effective in surgical endodontic procedures.

Local anaesthetics in surgical endodontic procedures should also provide localized hemostasis along with profound anaesthesia. This is of importance, since, it would provide hemorrhage control and a clear surgical field. Hence, there is a need for the use of higher concentrations of vasoconstrictors.

Buckley et al. demonstrated that the use of lidocaine containing 1:50,000 epinephrine produced more than a 50% improvement in homeostasis when compared to 2% lidocaine containing 1:100,000 epinephrine in patients undergoing periodontal surgery. ¹¹The technique of choice to obtain vasoconstriction and hemostasis is an infiltration of the surgical site with a local anesthetic containing 1:50,000 epinephrine.

To maximize postoperative analgesia and minimize intraoperative bleeding, a local anesthetic can be used with higher epinephrine concentrations (1:50,000) for the primary surgical anesthesia (Infiltration) and supplemented with one cartridge of long-acting local anesthetic (e.g., 0.5% bupivacaine with 1:200,000 epinephrine) immediately after surgery (Regional block). Long-lasting local anesthetics are particularly beneficial in mandibular surgery but much less so for surgery in the maxillary arch.

Systemic effects of vasoconstrictors:

Since, higher concentration of epinephrine containing anaesthetics is preferred in surgical endodontics, to obtain adequate vasoconstriction and hemostasis, it has raised concerns about its systemic effects. Injection of local anesthetic containing 1:50,000 epinephrine produces a transient tachycardia that returns to normal within 4 minutes.¹² Although, systemic effects such as blood pressure and heart rate are minimal, levels of epinephrine in the plasma may remain elevated when a high dose is used. The systemic effects of epinephrine appear to be dose dependent. The cardiovascular effects are minimal, short-lived and well tolerated by the majority of patients, except patients with severe cardiovascular disorders or who have had cardiovascular surgery. Thus, the use of 1:50,000 epinephrine with 2% lidocaine is recommended for local anesthesia in the majority of cases.⁶ In patients with severe cardiac illness, a consultation with his or her physician before the surgery is highly recommended and should be routine in the surgery protocol.

Many anesthetics are vasodilators. The use of anesthetics without vasoconstrictors, (e.g. plain mepivacaine i.e., 3% Carbo-caine), is not recommended as this will lead to excessive bleeding during surgery. Also, the use of norepinephrine causes marked tissue ischemia, it should not be used in surgical endodontics for the purposes of hemostasis.

Surgical Haemostasis:

Topical hemostats or local hemostatic agents are useful adjuncts in achieving hemostasis. They can be classified based on their mechanism of action as follows:

Mechanical agents	Bone wax
Chemical agents	Vasoconstrictors (epinephrine)
	Ferric sulphate
Biological agents	Thrombin
Resorbable agents	Calcium sulphate
	Gelfoam
	Absorbable collagen

	Microfibrillar collagen
	Surgicel

Table 1: Classification of different hemostatic agents

Bone Wax:

The use of bone wax (Ethicon, Somerville, NJ) as a local hemostatic agent was introduced by Horsley.¹³ Bone wax contains a large percentage of highly purified beeswax and a softening and conditioning agent (isopropyl palmitate). Bone wax presents a tamponade effect. The wax, when placed under moderate pressure, it plugs all vascular openings. The plug is formed partly of blood and partly of bone wax. This prevents further bleeding. The mechanism of action of bone wax is purely mechanical and does not affect the blood clotting mechanism.

While using bone wax for hemostasis it should first be packed into the entire cavity, firmly, and then the excess should be carefully removed to expose only the apex of the tooth. Following root-end filling, the wax should be removed.

It has been shown that bone wax causes a foreign body reaction if left in the surgical site.¹⁴ Bone wax residues have also been associated with sinus tracts development post surgery, suggesting that care must be taken to ensure the complete removal of this material from the surgical site. Consequently, bone wax is rarely used in endodontic microsurgery.

Epinephrine Cotton Pellet:

This is a mechanical as well as a chemical agent. Epinephrine causes local vasoconstriction by acting on the α -1 receptors present in the blood vessels wall, and the pressure applied supplements this hemostatic potential.

Racellets (Pascal Co., Bellevue, WA) are cotton pellets impregnated with racemic epinephrine hydrochloride. The amount of epinephrine in each pellet varies. For

example, each Racellet #3 pellet contains an average of 0.55-mg racemic epinephrine. Each Racellet #2 pellet contains 1.15 mg of racemic epinephrine hydrochloride.⁶

Other hemostatic cotton pellets with epinephrine are Epidri (Pascal Co.). These contain an average of 1.9 mg racemic epinephrine hydrochloride. Radri (Pascal Co.) has a combination of vasoconstrictor and astringent. Each pellet of Radri contains an average of 0.45-mg racemic epinephrine hydrochloride and 1.85 mg of zinc phenol sulfonate.⁶

All the granulomatous tissue should be removed from the bone cavity prior to the placement of the pellets. The first epinephrine pellet is placed against the bone. This is followed by packing the cavity with a sterile cotton pellet one at a time. Pressure is applied over these sterile pellets for about 2 to 4 min.

The procedure is repeated with a new epinephrine pellet until adequate hemostasis is achieved. The combination of both, epinephrine and pressure application, results in immediate and profound vasoconstriction.

Ferric Sulfate:

Ferric sulphate is a chemical agent used to achieve hemostasis and is commercially available as Stasis (Cut-Trol, Mobile, AL), Viscostat, and Astringent (Ultradent Products, Inc., UT). Agglutination of blood proteins occur as a result of reaction between blood and both ferric and sulfate ions and in the presence of acidic pH (0.21) of the solution.¹⁵ The agglutinated proteins form plugs that occlude the capillary orifices. Therefore, ferric sulfate affects hemostasis through a chemical reaction with blood.

A dark brown or greenish brown coagulum forms on contact with blood and the source of any persistent hemorrhage can be located because of this color difference. Thus, new bleeding points can be identified .

Although ferric sulfate is known to be cytotoxic and causes tissue necrosis, systemic absorption of ferric sulfate is unlikely, as the coagulum isolates it from the vascular supply. However, ferric sulfate solution should not be left in the bone since it has significant adverse effects on osseous healing.¹⁶ Therefore, the surgical site has to be

thoroughly flushed with saline in order to remove the ferric sulfate completely to prevent any complication causing delay in healing.

Thrombin:

Topical thrombin USP (Thrombostat, Thrombogen) is a protein substance produced during a conversion reaction from bovine prothrombin. It is a potent dry powder which acts rapidly through the intrinsic pathway to clot the blood fibrinogen directly. Thrombin USP is used widely in the medical field for localized hemostasis. However, its use in endodontic surgery has not been investigated. The major disadvantages of topical thrombin include difficulty in handling and delivery to the bleeding site. It is also expensive.⁶

Calcium sulphate:

As a hemostatic agent, calcium sulfate acts as a physical barrier. The material is placed in the bony crypt, allowed to set, and then partly carved away to access to the root end.¹⁷ The material lining the crypt walls prevents bleeding. The residual calcium sulfate may be removed or left in situ. The presence of calcium sulfate in an osseous wound does not inhibit bone formation.¹⁸ It will be gradually removed from the site of implantation.¹⁹ Use of calcium sulfate during periradicular surgery does not significantly affect healing, and deposition of cementum and bone.²⁰

Gelfoam:

Gelfoam (Pharmacia, Peapack, NJ) is a gelatin-based sponge that is insoluble in water and can be resorbed. It stimulates the intrinsic clotting pathway by promoting platelet disintegration and the subsequent release of thromboplastin and thrombin.¹⁵ The Gelfoam in the surgical site, decreases the rate of healing. Extraction sockets containing foam have shown to have a greater inflammatory cell infiltrate, marked reduction in bone ingrowth, and a foreign-body reaction.²¹ However, these effects were found to be transitory and did not impair long-term bone healing.²²

Absorbable collagen:

The mechanisms by which collagen products achieve hemostasis is by stimulation of platelet adhesion, platelet aggregation and release and activation of factor XII²³ and mechanical tamponade by the structure that forms at the collagen-blood/wound interface. Collagen shows minimal interference in the wound healing process, and limited foreign body reaction.²⁴ Commercially available collagen based products include CollaCote (Integra Life Sciences, Plainsboro, NJ), CollaStat (American Medical Products Corp, Freehold, NJ), Hemocollagene (Septodont, Kent, UK), and Instat (Ethicon, Piscataway, NJ). Studies of wound healing with collagen-based hemostatic agents have shown favorable results.^{25,26}

Cautery/Electrosurgery:

Cautery causes coagulation of blood and tissue protein, leaving an eschar which leads to sloughing.²⁷ When used in periodontal surgery, tissue destruction was greater in areas exposed to electrosurgery, and healing was delayed compared with surgical sites not exposed to electrosurgery. Twelve hours post-surgery, further inflammatory reaction and greater destruction of periosteum were noted.²⁸ At 24 hours, numerous empty lacunae in the bone associated with electrosurgery were observed, and this necrosis became more extensive by 48 hours. At 96 hours, the electrosurgical connective tissue wounds were still lined by coagulum, whereas the scalpel wound began to repair.²⁹ This detrimental effect of applying heat to bone is proportional to both temperature and the duration of application and hence, not recommended.

Recommended Clinical Steps for Achieving Hemostasis:

A good agent should achieve hemostasis within a short period of time, should be biocompatible, should not impair healing, and work best for the particular surgical procedure and lastly, be relatively inexpensive. Hence, the following sequence has been recommended to achieve effective hemostasis during endodontic microsurgery.⁶

Presurgical:

Inject two carpules (maximum three carpules in special situations) of 1:50,000 epinephrine containing local anesthetic into multiple infiltration sites buccal/lingual and palatal throughout the entire surgical field. Wait at least for 15 to 20 min before making the first incision.

Surgical:

- a. Remove all granulosomatous tissue, quickly and completely, as it is highly vascularized, it would cause profused bleeding.
- b. Place an epinephrine pellet against the walls of the bone crypt followed by dry sterile cotton pellets until the crypt is filled. Apply pressure for 2 min.
- c. Remove all cotton pellets except for the first epinephrine pellet. Continue with the surgical procedure and remove the epinephrine pellet just before final irrigation and closure.
- d. Small bleeders from the bone can be stilled by dabbing them with a cotton pellet soaked with ferric sulfate solution. All of the ferric sulfate deposits must be carefully removed by saline flush.
- e. A large osteotomy site is filled with freshly mixed calcium sulfate paste. After setting it is carved out around the root. The calcium sulfate paste can then be left in the crypt as it is resorbable.

Postsurgical

Application of moist gauze compresses should be applied to the tissues before and after suturing to remove blood clots between the bone and soft tissues. This assures proper alignment of the flap and reduces stress on the suture. ⁶

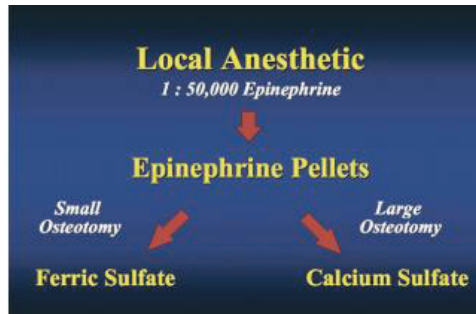


Figure 14 Schematic diagram illustrating hemostatic techniques employed at the University of Pennsylvania.

Courtesy: Kim et al (2006)

2. Flap design:

In surgical endodontics, the surgical site is exposed by reflecting a full-thickness tissue flap. Knowledge of regional anatomy and prevailing periodontal conditions must be considered when deciding the type and design of the flap. Of the flap designs been suggested, some have become obsolete and newer techniques have introduced. It is important that incisions, tissue elevations and reflections be performed in a way that facilitates healing by primary intention.

Types of incisions:

Vertical Incision :

The general principles for placement of a vertical relieving incision are:

- The incision should be made parallel to the suprapariosteal vessels in the attached gingiva and submucosa.
- No cuts should be made across frenum and muscle attachments.
- The incision should not be placed superior to a bony eminence.

- The dental papilla should be included or excluded but not dissected.
- The incision should extend from the depth of the vestibular sulcus to the midpoint between the dental papilla and the horizontal aspect of the buccal gingival sulcus. (cohen 30)

A vertical releasing incision severs fewer vessels, maintaining the blood supply to the tissue coronal to the incision, preventing localized ischemia and sloughing of the tissues. Consequently, incisions at an angle are contraindicated in periradicular surgery.

Horizontal incision:

There are three types of horizontal incisions that can be used to gain access to a surgical site: (cohen 30)

- An intra-sulcular incision including dental papilla:** It extends from the gingival sulcus and terminates at the crest of the alveolar bone. The incision then passes in a buccolingual direction adjacent to each tooth of the dental papilla and includes the mid-col region. The entire dental papilla is then completely mobilized.
- An intra-sulcular incision excluding dental papilla (papillary-based incision):** A shallow first incision at the base of the papilla and a second incision directed to the crestal bone is made. The dental papilla is not mobilized here.
- An incision made in the attached gingiva (a submarginal or Oxsenbein-Luebke flap):**
 - In this technique, at least 2 mm of attached gingiva is retained to prevent mucogingival degeneration.
 - The incision is placed at least 2 mm from the depth of the gingival sulcus.

- iii. It generally is recommended for use in the maxilla, where the esthetics is of concern.

These vertical and horizontal incisions can be used to achieve various flap designs. Soft tissue flaps used in surgical endodontics can be classified as:

a. Full mucoperiosteal flaps:

- i. Triangular: one vertical relieving incision
- ii. Rectangular: two vertical relieving incisions
- iii. Trapezoidal: two angled vertical relieving incisions
- iv. Horizontal: no vertical relieving incision

b. Limited mucoperiosteal or submarginal flaps:

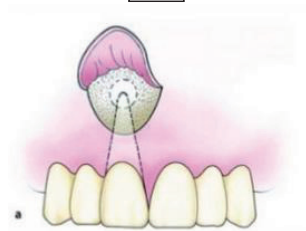
- i. Curve submarginal (semilunar)
- ii. Freeform rectilinear submarginal (OchsenbeinLuebke)³⁰



(a)



(b)



(c)



(d)



Figure 1(A) and (B) triangular flap; (C) Semilunar flap; (D) trapezoidal flap; (E) Rectangular flap; (F) and (H) Luebke- Ochsenbein flap or limited periosteal flap ; (G) Papilla based flap

© Holliday R. Cohen's pathways of the pulp. British Dental Journal. 2011 Mar;210(5):242-

The following management procedures have substituted the traditional techniques: ⁶

- i. The semilunar incision is no longer recommended because of inadequate access and scar formation.
 - a. it does not allow for an adequate access to the surgical site.
 - b. It is related to prolonged inflammation and scar formation on healing of the wound.³¹
- ii. The papilla base incision has been developed to prevent loss of interdental papilla height with sulcular incisions.³²

The Lu'ebke-Ochsenbein submarginal flap is the most commonly used esthetic flap design.

- a. It is performed within the attached gingiva and results in almost zero recession of the gum margins and the interdental papillae postoperatively.
- b. Crown margin exposure and formation of “black triangles” in anterior teeth as well as food impaction in posterior teeth is prevented.
- iii. In microsurgical technique, vertical incisions should be 1.5 to 2 times longer than in the traditional technique, this does not obstruct the path of light from the microscope.
- iv. In both the sulcular full-thickness flap and the mucogingival flap designs, creates a lasting scar as a result of cutting the mucosal tissue across the fiber lines. In the current method, the base of the flap is made as wide as the top, and the vertical incisions follow the vertical blood vessel alignment. This facilitates nearly scar-free healing.

3. Tissue reflection and retraction:

- a. Force should be applied so that the periosteum and superficial tissues are reflected together as a one unit. As underlying cortical plate is irregular, efforts should be made to avoid damage to the tissues during elevation.
- b. An elevation of **0.75 cm of the flap apical to the estimated apex** of the root provides adequate accessibility.³⁰

c. The main goals of tissue retraction are

- to provide a clear view of the surgical site
- to prevent further soft-tissue trauma.

Trauma to the soft tissues leads to more postoperative swelling and ecchymosis.

- d. Slippage of the retractors over soft tissues may also cause post operative swelling. This is also the major cause of transient parasthesia in the mandibular molar/ premolar region.

- e. To address this problem, retractors of several shapes and sizes have been developed to permit stable and non traumatic retraction. These retractors have wider (15 mm) and thinner (0.5 mm) serrated working ends. Some are concave while others are convex to accommodate the irregular contours of the cortical plates. The serrated tips provide better anchorage on the bone and are designed to prevent slippage during retraction.⁶ (See Section: **Microsurgical instruments**).
- f. A new procedure has been developed to protect the mandibular nerve. A **15-mm long horizontal groove** is cut into the bone with a **Lindemann bur** or a **#4 round bur**. This groove is placed beyond **the apex to** provide access for osteotomy and subsequent apicoectomy. The groove allows secure anchoring of the serrated retractor tip and steady retraction of the flap.⁶

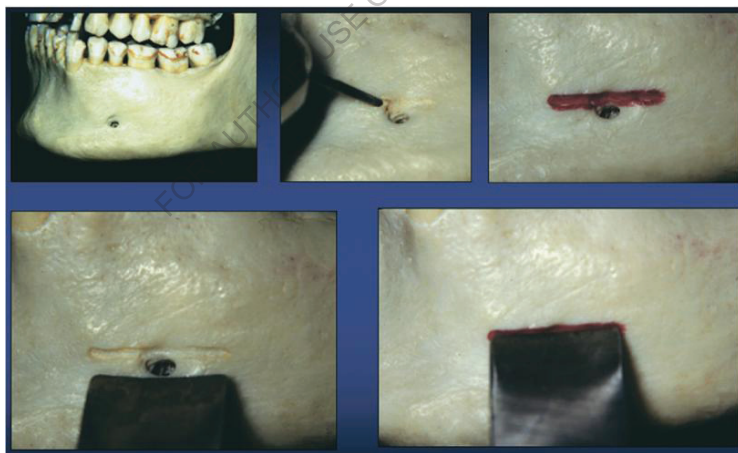


Figure 16 The Groove Technique: a small narrow horizontal groove is made just above the mental foramen. A KP#1 retractor is firmly seated in the groove protecting the nerve during the osteotomy.

Courtsey: Kim et al (2006)

4. Apical access:

- a. In microsurgery, the diameter of the osteotomy is only **3 to 4 mm**, allowing a 3-mm ultrasonic tip to vibrate freely within the bone cavity. A small-sized osteotomy leads to **reduced postoperative discomfort and faster rate of healing.**
- b. A lesion smaller than 5 mm would take an average of 6.4 months, a 6-mm to 10-mm-size lesion takes 7.25 months, and larger than 10 mm requires 11 months to heal. Therefore, the osteotomy size should be as small as possible, and large enough to accomplish the clinical objective.³³
- c. A tendency during surgery to enlarge the osteotomy towards the coronal margin, away from the apex would result in excessive removal of healthy bone around the neck of the crown which can predispose the tooth to perio-endo communication.

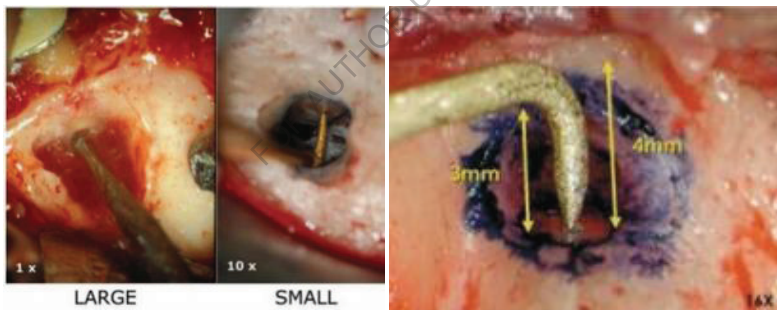


Figure 2 Osteotomy in endodontic microsurgery : diameter of the osteotomy is only 3 to 4 mm, just enough to allow for a 3-mm ultrasonic tip

Courtesy: Kim et al (2006)

5. Root end resection:

After complete removal of the granulation tissue, 3 mm of the root tip is resected perpendicular to the long axis of the root. A Lindemann bur should be used in any angled handpiece using copious water spray.

How Much Should be Resected?

- a. An anatomic study of the root apex conducted at the University of Pennsylvania revealed that a resection level of 3 mm from the anatomic apex will eliminate 93% of lateral canals and 98% of any other ramifications such as deltas, fins, and so forth.³⁴ Root-end amputation of 3 mm is advisable since this leaves on average of 7 to 9 mm of the root, providing sufficient strength and stability.
- b. A root end amputation of less than 3mm does, most likely, not remove all of the lateral canals and apical ramifications, therefore, posing a risk of re-infection and eventual failure.

Reasons for resection of the apical part of the root during periapical surgery:

- Removal of pathologic processes.
- Removal of anatomic complexities (apical deltas, accessory canals, apical ramifications, severe curves).
- Removal of iatrogenic mishaps (ledges, blockages, perforations, strip perforations, separated instruments).
- Enhanced removal of the granulation tissue.
- Access to the apical canal system when the coronal access is blocked or when coronal access with nonsurgical retreatment is impractical, time-consuming or too invasive.
- Evaluation of the apical seal.
- Creation of an apical seal.
- Reduction of fenestrated root apices.
- Evaluation for complete or incomplete vertical root fractures

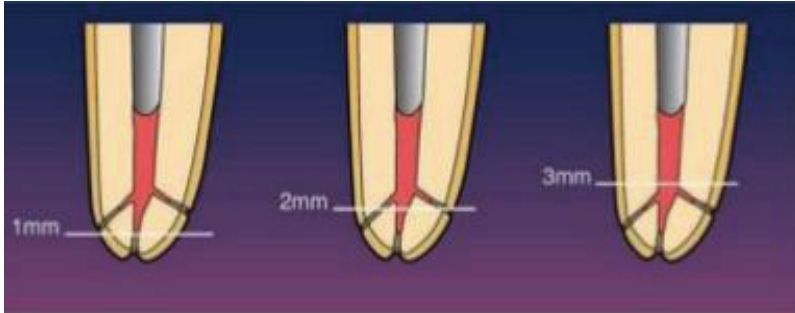


Figure 18 Resection level of 3 mm from the anatomic apex will eliminate 93% of lateral canals and 98% of any other ramifications such as deltas, fins, and so forth

©Kim et al, 2006

Root-End Resection: Long Bevel Versus Short Bevel

1. With the traditional rotary bur, the steep bevel angle of 45 to 60 degrees was recommended. This was to improve accessibility and visibility to the surgical site. Also, beveling to this degree was inevitable, since the surgical instruments were large.
2. Steel bevel would lead to one of the following:
 - Unnecessary removal of buccal supporting bone
 - Incomplete root resection which can occur particularly in roots that extend deep lingually (mandibular molar).
 - Root canal anatomy can be missed on the lingual/palatal aspect of the root.⁶
3. On the contrary, microsurgery suggests a zero degree bevel, perpendicular to the long axis of the tooth.

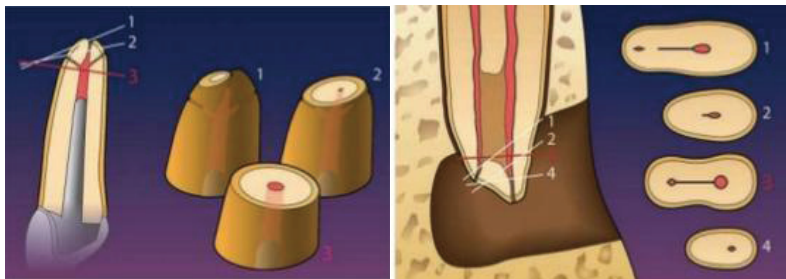


Figure 19: 45 degree bevel on broad or oval shaped root may reveal buccal canal (cut level 1) whereas the lingual or accessory canals emerging from the main canal to a lingual direction may be missed. Ideal cut should be at level 3.

©Kim et al, 2006

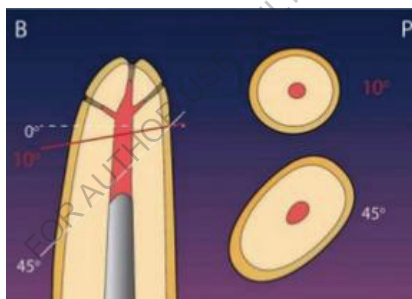


Figure 20: 45 degree bevel is associated with more exposed dentinal tubules on the cut root surface, which can be associated with a high risk of bacterial microleakage post operatively.

©Kim et al, 2006

A Zero degree bevel fulfils the following requirements:

- Preservation of root length
- There is less chance of missing lingual anatomy and multiple accessory canals.

- Complete root end resection
- Reduced exposure of dentinal tubules
- Dentinal tubules are more perpendicularly oriented to the long axis of the tooth and therefore, a perpendicular bevel will expose a fewer tubules.
- Easier to perform a root end preparation coaxial to the root. This will avoid perforation. The longer the bevel, the more difficult it is to orient and perform a coaxial preparation. ⁶

6. Root end cavity preparation:

- a. Inspection under high magnification is crucial for microsurgery that is missing from the traditional surgical technique. Magnification of the microscope should be set at the range of 14 X to 25X, higher than the rest of the surgical steps.
 - b. During inspection, the resected root end is rinsed and dried with a Stropko Irrigator (Vista Dental, Racine, WI).
 - c. The dried surface is then stained with 1% methylene blue, which is applied to the root surface with a microapplicator tip.
 - d. The anatomy of the root outline varies greatly. It's shape can be oval, ovoid, reniform and various other irregular forms. The oval or ovoid shapes are frequently found in single roots while the more complex shapes are found in fused premolar or molar roots.
- e. Clinical Significance and Management of Isthmus:**
- i. An isthmus is a narrow, ribbon-shaped communication between 2 root canals. It contains pulp derived tissues and after instrumentation, necrotic pulpal and dentinal debris along with microorganisms.
 - ii. Isthmuses are present in premolars and molars in approximately 80% to 90% of cases at the 3 mm level from the apex.³⁴
 - iii. The isthmus tissue appears to be the “Achilles’ heel” of conventional endodontic treatment.

- iv. According to Hsu and Kim , isthmi can be classified into five different types.

Type I was defined as either two or three canals with no noticeable communication.

Type II was defined as two canals that had a definite connection between the two main canals.

Type III differs from the latter only in that there are three canals instead of two. Incomplete C-shapes with three canals were also included in this category.

Type IV isthemi have canals extending into the isthmus area.

Type V was recognized as a true connection or corridor throughout the section.³⁵

- v. This is one of the reasons why apical root resection alone, without root-end preparation and root-end filling of canals and the isthmus, usually fails. Identification of unnegotiated canals and isthmuses is the first and most important step after root-end resection.
- vi. It is essential that the entire canal and isthmus be prepared to a depth of 3 mm.

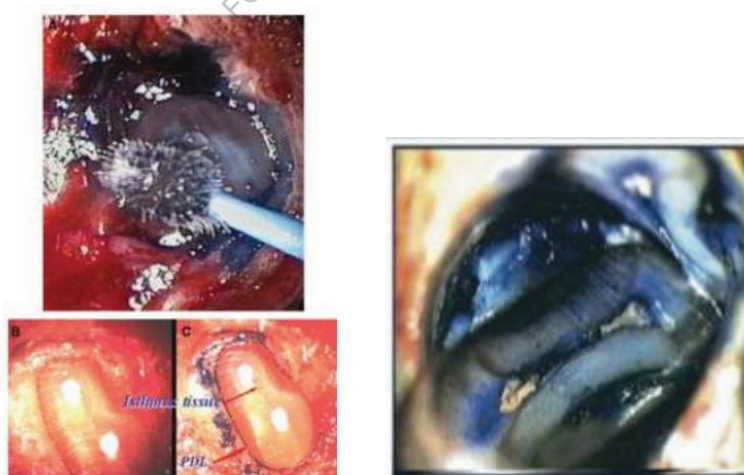


Figure 21: Use of methylene blue to detect pulp tissue remnants and isthmi.

©Kim et al ,2006

- f. The ideal root-end preparation is a class I cavity at least 3 mm into root dentin with walls parallel to and within the anatomic outline of the root canal space.³⁰ This clinical demand can no longer be satisfied by use of rotary burs in a micro-handpiece, which was the common practice in traditional surgical techniques.

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VI. MICROSURGICAL INSTRUMENTS

An increased visibility is obtained with the use of dental operating microscopes, endoscopes, and oroscopes. This would be of limited value without microsurgical instruments. Traditional surgical instruments are simply too large for working in magnification. Some microsurgical instruments are miniaturized versions of traditional surgical instruments, but many more are specifically designed for the precision needs of endodontic microsurgery, including ultrasonic tips, the Stropko irrigator/drier, pluggers, carriers for root end filling material, and micromirrors.

Stainless steel is the material of choice for microsurgical instruments because it provides greater degree of hardness and flexibility.

Microsurgical instruments can be classified as follows:

I. Examination Instruments:

The examination instruments include the dental mirror, periodontal probe, endodontic explorer, and microexplorer.

The dental mirror, periodontal probe, and endodontic explorer are standard instruments in endodontic practice.

Micromirrors are available in many different shapes. An important feature of the mirror neck is flexibility. Without the ability to bend the micromirror neck to accommodate the angle, the resected root surface cannot be viewed clearly or completely.

- Rectangular mirrors with 2 mm, 3 mm, and 4 mm widths on a flexible stainless handle are the micromirrors of choice.
- A round mirror has limited usage on a round resected root surface, e.g., central incisor



Figure 22: Rectangular mirrors showing the entire resected area

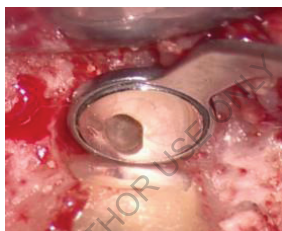


Figure 23: Round micromirrors

Courtesy : Castellucci A. *The State of the Art in Surgical Endodontics: Nessa J Oral Care and Dentistry*

Only the microexplorer is specifically designed for microsurgery. It has a 2-mm tip bent at 90 degrees on one end and 130 degrees on the other. The short tip makes it particularly easy to manoeuvre inside the small bony crypt.

Uses:

- Locating an area of leakage on the resected root surface
- Distinguishing a fracture line or canal from an insignificant craze line.

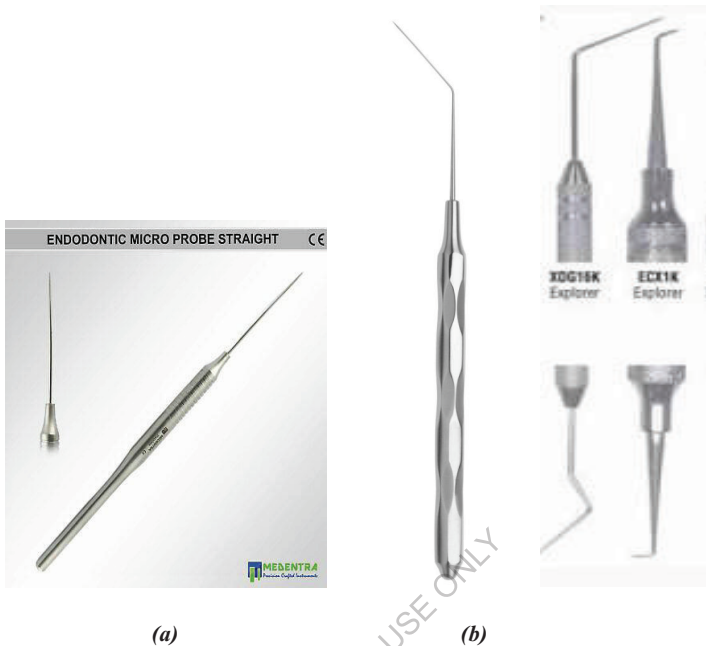


Figure 24 : (a) Endodontic micro probe straight; (b) Endodontic micro probe
Courtesy: Medentra and Denma

II. Incision and Elevation Instrument:

Instruments used for incision and elevation include a 15C blade and handle and soft tissue periosteal elevators.

The ideal scalpel blade for microsurgery is a 15C blade, microblades are useful only when the interproximal spaces are tight.

Microblades:

- Microblades are useful only when the interproximal spaces are tight.
- Offer precision and bidirectional cutting which enhances the efficiency and ease of use.

- The scalpels are double-ended and curved to conform to all areas of the mouth.



Figure 3: (a) KeVo Kerr microblades and microhandles for endodontic use; (b) Micro blades, Bluedent, India

© *Microsurgical Instruments, SeungHo Baek and Syngcuk Kim*



Figure 4 Bidirectional usage of microblades; Microblades are useful when the interproximal spaces are tight.

© *Feather Microsurgical Blades, Morita*

III. Soft Tissue Elevators:

The soft tissue elevators exclusively made for microsurgery are designed to elevate the gingiva and tissue from the underlying cortical bone producing minimal trauma to the tissue.

One end of the instrument has a thin, sharp, triangular beak and the other end has a sharp, rounded beak that varies in size. ³⁶



Figure 5: Elevation instruments. Enlarged view of the tips of soft

© *Microsurgical Instruments, SeungHo Baek and Syngcuk Kim*



(a)



(b)



(c)



(d)

Figure 6: a) Periosteals Molt 9 ; b) Prichard PPR3 ; c) Buser elevator ; d) KiS set: Elevation instruments

© *Microsurgical Instruments, SeungHo Baek and Syngcuk Kim*

The new design of these retractors incorporates thin edges and points that allow the soft tissue to be elevated from the bone cleanly and completely.

IV. Tissue Retraction Instruments:

The new retractors developed for microsurgery eliminate many deficiencies of previous traditional retractors, which are basically unfit to microsurgery.



Figure 7: (a) Examples of endodontic tissue retractors (Top—Arens Tissue Retractor; Middle—Seldin retractor; Bottom—University of Minnesota retractor); (b) Retractors used in periradicular surgery. Top to bottom, EHR-1, ER-2, and ER-1 (equivalent to Carr #2 and #1 retractors)



Figure 8: *KimTrac-M5 retractor with a plastic protector and its application intra-orally.*

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KimTrac retractors (B&L Biotech) have more variable widths than other conventional retractors (from 8 mm to 14 mm compared with conventional 10 mm).³⁶

- **KimTrac P1 and P2** retractors have wings to separate the elevated soft tissue from the area of surgery. Additionally a plastic protector is provided for safe soft tissue elevation.
- KimTrac can be used with and without the plastic protector flap retraction with highly improved visibility and accessibility to the operating field.
- The KimTrac anchors against the cortical plate precisely and stably, regardless of the shapes, due to its serrated end.
- The KimTrac retractor is one-third the thickness of other retractors. This makes them an ideal retractor which can be used the bone grooving technique on mandibular posterior surgery.³⁶



Figure 9: Tissue retraction instruments (KimTrac) with various mouth widths and shapes from 8 to 14 mm. These retractors have the thinnest serrated blade available.

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The **Kim/Pecora** (KP 1, 2, and 3) retractors (Obtura/Spartan) have wider tips than conventional retractors (15 mm compared with 10 mm) and are 0.5 mm thinner.³⁶

- Again, their serrated ends anchor the retractors securely on to the bone.
- The KP 4 retractor is a small, all-purpose retractor with a blade width of 10-mm.
- The KP retractor tips are modelled to the concavities and convexities of the cortical bony plate.



(a)

(b)

Figure 10: (a) Kim/Pecora (KP) retractors. Left to right, KP 1, KP 2, KP 3, and KP 4 retractors; (b) Enlarged views of serrated blade widths. Middle (B) is the KimTrac blade and A and C are KP retractor blades. The KimTrac blade width is one-third that of the KP retractor

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The full contact of the retractor tip on the bone provides a secure, stable hold, eliminating sudden slippage that results in traumatized tissue, swelling, and painful healing.

Many retractors are available on the dental market, but only the KimTrac retractors and Kim/Pecora retractors are designed especially for endodontic microsurgery.

V. Osteotomy Instruments:

The instrument of choice for osteotomy is a 45 degree surgical handpiece with a Lindemann bur is for this procedure (Brasseler NSK and Morita)

- It is designed to direct water on to the cutting surface. Water is channelled along the surface of the bur while the air is ejected through the back of the handpiece.
- This reduces the chance of emphysema and pyemia and creates less splatter than a conventional handpiece. The handpiece's 45 degree angled head makes it easier to work in and visualize difficult to reach areas.

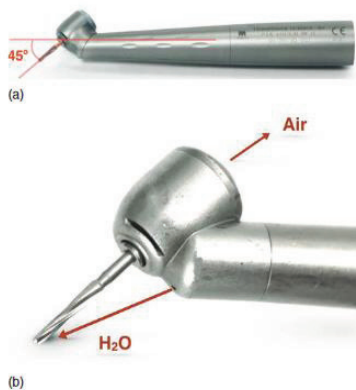


Figure 11: A 45 degree surgical handpiece (a) is designed to irrigate the surgical site while ejecting air from the back of the handpiece, eliminating water splatter and air emphysema (b).

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(a) & (b)



(c)

Figure 12; (a) Lindermann bur; (b) Lindemann Side Cutting bur internally irrigated; (c) Lindemann Side cutting aerator burs

The Lindemann bone cutting bur is used for osteotomies and has fewer flutes than conventional burs, resulting in less clogging and frictional heat and more efficient cutting.

The Lindemann side cutting bur has fine cross cuts and optimum flute depth ensures efficient cutting of hard tissue or bone tissue and expels waste material. The side cutting bur can be used efficiently for enlarging the osteotomy size. This bur is also available in the latchtype form with internal irrigation.

VI. Curettage Instruments:

Curettage instruments include periodontal curettes, surgical curettes, and miniendodontic curettes. Any periodontal curette can be used for curettage.



Figure 13: Curettage instruments.

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Figure 14: Enlarged view of the specially designed minicurettes and mini-molt curettes

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VII. Ultrasonic Units and Tips for Root End Preparation:

Ultrasound:

Ultrasound is sound energy that has a frequency above the human range of hearing, that is 20 kHz. For clinical purposes, it is generated using transducers that convert electrical energy into ultrasonic waves. This can be achieved either by magnetostriction or piezoelectricity.

Magnetostriction:

Magnetostrictive dental scaler devices undergo changes in their physical dimensions when placed within a magnetic field. Magnetostrictive instruments operate between 18 and 25 kHz. As the electric current passes through a wire coil present inside the handpiece, a magnetic field is created around the stack or rod transducer, causing it to constrict. Alternating current then produces an alternating magnetic field causing the tip to vibrate.^{37,38}

Piezoelectricity:

Piezoelectric electric effect was first described in 1880 by Jacques and Pierre Curie, who claimed that some ceramics and crystals deform when an electric current is passed across them. This resulted in oscillations of ultrasonic frequency without producing heat. Currently, lead zirconate titanate is the most widely used piezoelectric material.³⁷

The resultant vibration produces tip movement that is primarily linear in direction and generally allows only 2 sides of the tip to be active at any time.

Differences between magnetostrictive and piezoelectric handpieces:

Sl. No		Magnetostrictive handpiece	Piezoelectric handpiece
1	Mechanism/ Transducer	Metal Stack or Ferrite rod	Aligned ceramic discs
2	Tip Movement	Elliptical	Linear (Back and forth; Piston type)
3	Active surfaces	All surfaces active (Back, Face and Lateral)	Lateral surfaces more active
4	Optimal Frequency	20-40 kHz	29-50 kHz

Table 2: Differences between magnetostrictive and piezoelectric handpieces:

Advantages and Disadvantages of Magnetostrictive and Piezoelectric handpieces (Surgical):

Sl.No.		Advantages	Disadvantages
1	Piezoelectric	Variety of tips for accessing multiple areas	High initial cost

		Light weight and ergonomic handpiece	Short working length of handpiece
		Increased tactile sensitivity with low to no vibration in handpiece.	
		Coaxial root end cavity preparation.	
		Active only on hard / mineralized tissues.	
2	Magnetostrictive	Variety of tips for accessing multiple areas	Elliptical movement of the tips is not ideal for root end cavity preparation.
		Longer working length of the handpiece	

Table 3: Advantages and Disadvantages of Magnetostrictive and Piezoelectric handpieces (Surgical)

Piezosurgery:

Piezosurgery uses piezoelectric ultrasonic vibrations to Italian oral surgeon Tomaso Vercellotti.

The unique feature of the piezosurgery technique is that cutting occurs when the tool is applied to mineralized tissue but stops when soft tissue is encountered.

The vibrations are amplified and transferred to a vibration tip. On application of the tip to bone surface, cavitation occurs which is a mechanical cutting effect that occurs in only mineralized tissue. Piezosurgery is useful when bone must be cut close to vital tissues, such as nerves, vessels, etc. The cavitation effect and constant irrigation provides a bloodless procedure. The flow rate of the cooling solution must be regulated to prevent the bone from overheating. Therefore, the main advantages of piezosurgery include:

- a. protection of soft tissues,

- b. optimal visualization of the surgical field,
- c. decreased blood loss,
- d. reduced vibration and noise,
- e. increased comfort for the patient, and protection of tooth structures .

Magnetostrictive units rely on an elliptic movement of the ultrasonic tip, which is not ideal for either surgical or nonsurgical endodontic use. Another drawback of magnetostrictive units is that the excessive heat generation, necessitating adequate cooling.

In the past, root end Class I cavity preparations or slot type cavity preparations were prepared by a miniature contra-angle handpiece with small burs or a straight slow speed handpiece. Hence, coaxial root end preparation, along the root canal was not possible. Furthermore, it caused frequent perforation on the lingual aspect of the root.

Conventionally, root-end cavity preparation was done using rotary burs in a micro-handpiece which posed several problems:

- a. Access to the root-end was difficult, especially with limited working space.
- b. There is a high risk of a perforation of the lingual root-end
- c. There is insufficient depth and retention of the root-end filling material.

The root-end preparation is done to remove the intracanal filling material and irritants from the apical root canal and to create a cavity that can be filled with an appropriate restorative material in order to re-establish an apical seal. The ideal root-end preparation is a class 1 cavity with a depth of 3 mm into root dentine, cavity walls parallel to and coincident with the anatomic outline of the root canal space.³⁹

Wuchenich et al. compared the root-end cavities prepared with conventional handpieces with ultrasonic tips in cadavers using SEM. They found that ultrasonics tips made cleaner and deeper root-end cavity preparations, aiding retention of the root-end filling material and disinfecting the canal space by removing infected dentin.⁴⁰

Ultrasonic units:

- Ultrasonic units create vibrations in the range of 30 to 40 kHz by exciting quartz or ceramic piezoelectric crystals in the handpiece.
- The energy created is carried to the ultrasonic tip, producing forward and backward vibrations.
- Continuous irrigation along the cutting tip cools the surface and maximizes debridement and cleaning.
- The three most widely used ultrasonic units are the EMS, the Spartan (Spartan/Obtura), and the P-5 (Acteon).

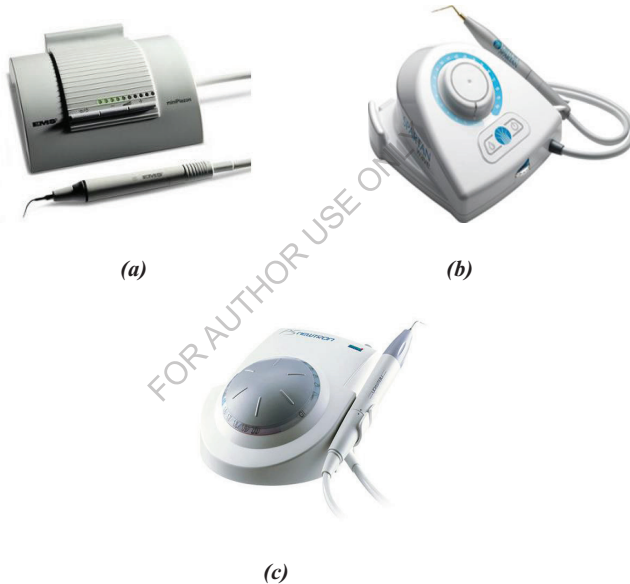


Figure 15: a) EMS Miniendo (Analytic Endo); b) the Spartan (Spartan/Obtura); c) the P-5 (Acteon)

- It is strongly advised to have a unit that has both Piezotome for Groove preparation and ultrasonic root end preparation. Currently, Acteon P-5 has both capabilities.

Ultrasonic tips:

The first ultrasonic tips for endodontic surgery were stainless steel Carr Tips (CT 1–5) in 1990.³⁶

- They are 1/4 mm in diameter and about 1/10 the size of a conventional microhead handpiece.
- The CT 1 and CT 5 have the same design except that the CT 5 tip is more sharply pointed.
- The hook-shaped tip, known as a back-action or CK tip, is very effective for cleaning the buccal wall of a canal. The CT 1 and CT 5 tips are used mainly for maxillary and mandibular anterior teeth.
- The CT 2 and CT 3 have a double angle to facilitate work in posterior teeth.



Figure 16: Carr ultrasonic tips.

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In 1999 Spartan/Obtura introduced KiS (Kim Surgical) tips.

- The KiS ultrasonic tips have a better cutting ability and a more efficient irrigation port.
- They are coated with zirconium nitride and have an irrigation port near the tip rather than along the shaft. The enlarged view of a KiS tip, which has a 3-mm cutting tip.
- These tips cut faster and smoother and cause fewer microfractures because of the improved positioning of the irrigation port.

- **The KiS 1 tip**, which has an 80 degree angle and is 0.24 mm in diameter, is designed for the mandibular anterior teeth and premolars.
- **The KiS 2 tip** has a wider diameter tip and is designed for wider teeth (e.g., maxillary anteriors).
- **The KiS 3 tip** is designed for posterior teeth. It has a double bend and a 75 degree angled tip for use in the maxillary left side or the mandibular right side.
- **The KiS 4 tip** is similar to the KiS 3 except that the tip angle is 110 degrees, to reach the lingual apex of molar roots.
- **The KiS 5 tip** is the counterpart of the KiS 3 for the maxillary right side and the mandibular left side. The KiS 6 tip is the counterpart of the KiS 4 tip.
- **The KiS 6 tip** is the counterpart of the KiS 4 tip.

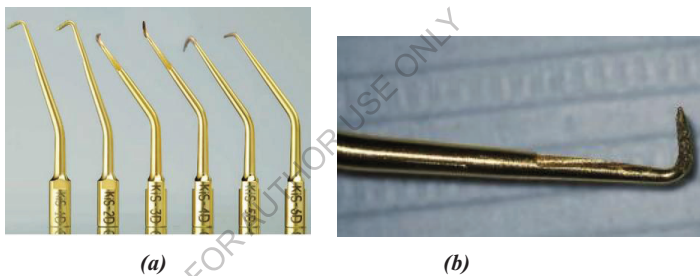


Figure 17: (a) KiS tips 1, 2 for anterior teeth and KiS 3, 4, 5, and 6 for posterior teeth (Image courtesy of Obtura Spartan, Algonquin, IL © 2017) ; (b) KiS 1 tip is 3 mm long and has an 80 degree angle. The tip is coated with zirconium nitride.



Figure 18: KiS tips Modifications: KiS 1D2 , KiS 1D4, KiS 3 D2 and KiS 5D2

Image courtesy of Obtura Spartan, Algonquin, IL © 2017

- **KiS-1D2:** Angled 80 degrees at the working end, with a 0.5mm diameter x 2.0mm cutting surface. Designed as a general purpose tip for anterior and posterior areas with a cutting surface smaller than the KiS-1.
- **KiS-1D4:** Angled 80 degrees at the working end, with a 0.5mm diameter x 4.0mm cutting surface. Designed as a general purpose tip for anterior and posterior areas with a cutting surface larger than the KiS-1.
- **KiS-3D2:** A double angled, 90 degree instrument designed for use on the buccal root of the mandibular right molar and mesial buccal of the maxillary left molar. 0.5mm diameter x 2.0mm cutting surface.
- **KiS-5D2:** A double angled, 80 degree instrument designed for use on the buccal roots of the mandibular left molar and mesial buccal of the maxillary right molar. 0.5mm diameter x 2.0mm cutting surface.

Recently Jet Tips were introduced.

- These tips have microprojections on the cutting surface allowing quick and complete removal of gutta percha from the canal.
- They are bendable (B&L Biotech) which can be bent in any direction to improve access.
- JETips are available with 2 mm, 3 mm, 4 mm, 5 mm, and 6 mm tips

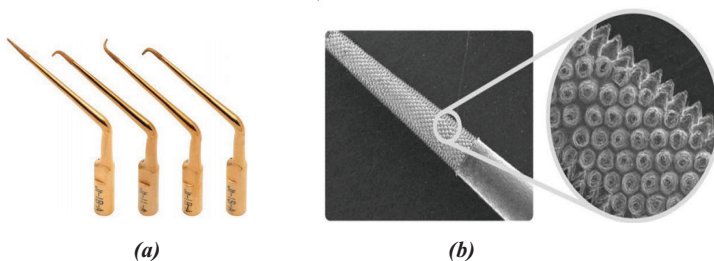


Figure 19: (a) : JETip 1B, JETip 1L, JETip 1R, and JETip 1S; (b) JETip with metal microprojection (enlarged).

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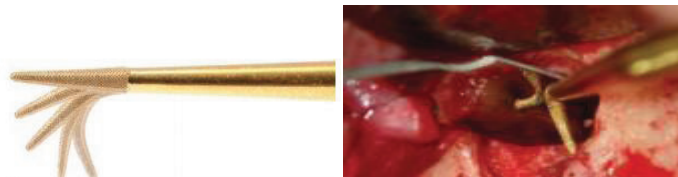


Figure 20: (a) JETips for bending that provides a customized tip angle; (b) Retropreparation with a JETip

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Ultrasonic retrotips by Dentsply Maillefer :

SURG 1: Universal instrument with a single 80 deg angle intended for more narrow canals of anterior teeth

SURG 2: Universal instrument with a single 80 deg angle intended for wider canals of anterior teeth (larger diameter than SURG 1).

SURG 3: This instrument has a double 75 deg angle and is typically used for preparing the roots of mandibular left and buccal roots of maxillary right posterior teeth

SURG 4: This instrument has a double 110 deg and is used for preparing the more lingual roots of mandibular left and maxillary right posterior teeth.

SURG 5: a Double 75 deg angle and used for preparing the roots of mandibular right and buccal roots if maxillary left posterior teeth.

SURG 6: Double 110 deg and used for preparing more lingual roots if mandibular right and maxillary left posterior.

Advantages of ProUltra Tips:

- Longer length improve access to posterior roots
- Multiple angles promote safety during radicular preparations
- Abrasive coating reduces the risk of microfractures
- Abrasive coating improves cutting efficiency and restorative retention.



Figure 21: Ultrasonic retrotips by Dentsply Maillefer

Dr. Khayat designed longer ultrasonic tips diamond coated of 3, 6, and 9 mm of length.

- Particularly useful in case when the surgical procedure is performed in root canals partially empty.⁴¹



Figure 22: Longer ultrasonic tips designed by Dr Khayat

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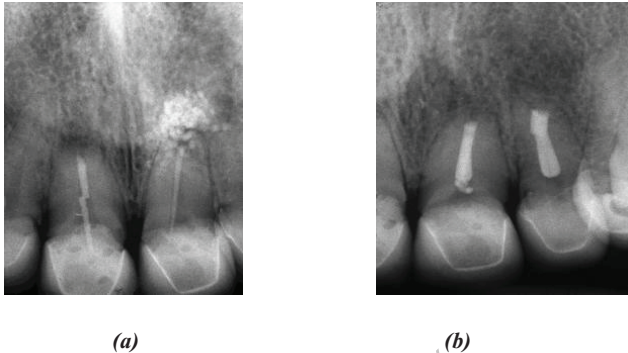


Figure 23: (a) Pre-operative radiograph of the upper central incisors. The root canals have been obturated with a surgical approach during the previous surgical procedure. (b) The root canals have been prepared using in sequence the long tips and obturated with thermoplastic gutta-percha and white MTA in the apical 3 mm.

Courtesy: Castellucci A. The State of the Art in Surgical Endodontics: Nessa J Oral Care and Dentistry

Advantages of Ultrasonic root end preparation compared to the conventional techniques:

- a. A 360° cleaning of the apical root canal is possible
- b. The preparation is along the main axis of the root canal.
- c. The retroprep is smaller, retentive and is easier to seal.
- d. The osteotomy size is smaller
- e. It allows preparation of the isthmuses.
- f. The access is comfortable even in canals difficult to be reached.
- g. Lessens the chances of lingual perforation.⁴¹

Disadvantages of Ultrasonic tips:

- a. The tips are fragile.
- b. Number of instruments required is more, like tips, ultrasonic units, and many micro-instruments, like mirrors, pluggers, carriers etc.
- c. The cost is relatively higher.⁴¹

The tips in stainless steel with no coating are the less effective.

The tips chemically coated (zirconium or titanium nitride) are more efficient.

The diamond coated are definitely the most efficient.

VIII. Stropko irrigator/drier :

This device fits on a standard air/water syringe and uses blunt 0.5-mm diameter microtips (Ultradent Co.)

- It is easy to use and highly effective for irrigating and drying retropreparations and resected root surfaces.
- It supplants the use of paper points to dry the preparation, which provides no certainty that the preparation is completely dry.



Figure 24: Stropko Irrigator by Kerr Endodontics

Normal air pressure to a dental syringe is 30-50 lbs. This pressure needs to be reduced to 4-10 pounds for safe use of the Stropko Irrigator. The air pressure can be reduced by using an in-line regulator.

For irrigation, only notched, or side-vented needles of minimum gauge of 27 are recommended.⁴¹

IX. MTA Carriers:

The first carrier that became available was the **Dovgan Carrier** (Quality Aspirators, Duncanville, TX, USA), but even though the needles were bendable, its use was not comfortable during surgery, especially in posterior teeth.⁴²



Figure 25: Dovgan Carrier

© *Seedat HC, Van der Vyver PJ, De Wet FA. Micro-endodontic surgery-Part 1: Surgical rationale and modern techniques. South African Dental Journal. 2018 Apr;73(3):146-53.*

In the year 2000 another carrier was proposed by **Edward Lee**, the MTA Pellet Forming Block.

After being properly mixed to a putty-like consistency, the MTA is pressed into the previously selected groove of the Lee block, then a small spatula slides into the groove to take the selected length of material, this adheres to the tip of the spatula and it is ready to be easily placed into the retroprep.⁴³



Figure 26: the MTA Pellet Forming Block by Pearson Dental

Manufactured by Produits Dentaires SA (Vevey, Switzerland) in cooperation with Dr. Bernd Ilgenstein, called **The MAP (Micro Apical Placement) System**

It is also called the “**universal**” **carrier** as it has applications both in clinical and in surgical endodontics.

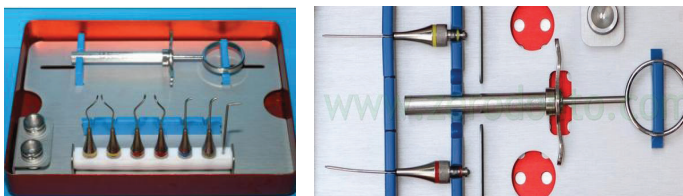


Figure 27: The MAP System

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The system consists of a stainless steel applicator, with a bayonet catch for several exchangeable applicators cannulas (needles).

The straight and curved needles are for non-surgical endodontics, while the triple angled developed in cooperation with Dr. Bernd Ilgenstein, and single angle needles are best indicated for surgical endodontics.



Figure 28: Triple angled needles and single angle needles best indicated for surgical endodontics

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The surgical needles are available in two variants, right-angled and left-angled, each with two external diameters, 0,9 mm (yellow) and 1,1 mm (red).

The internal diameter of the cannulas is 0,6 mm (yellow) and 0,8 mm (red), which allows for sufficient portions of the retro-filling material to be applied successively.

The intra-cannular plungers of the angled needles are made of PEEK (Polyether Ether-Ketone), a polymer used for medical purposes and the plungers of the straight and curved needles are made of NiTi.

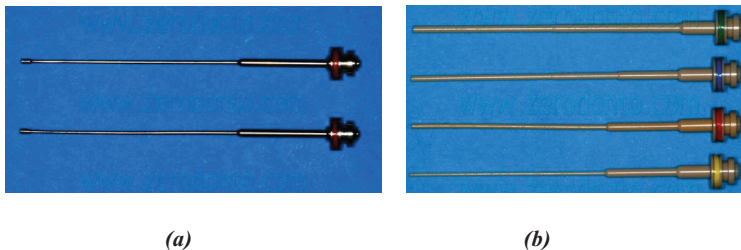


Figure 29: Intra cannular plungers : (a) NiTi Plungers ; (b) PEEK Plungers

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Residues of material in inside the cannulas can be easily removed with a cleaning curette.

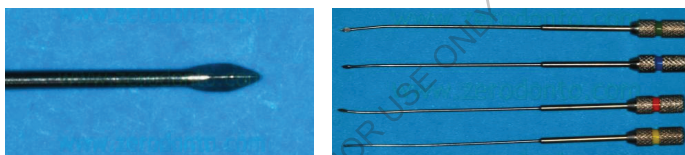


Figure 30: Cleaning Curettes

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The intra-cannular plunger inside the needle is intentionally longer than the needle itself, so that it will not only deliver the MTA in the retro-preparation, but will also act as a plugger and thus begin to compact the material in the deepest portion of the prepared cavity.

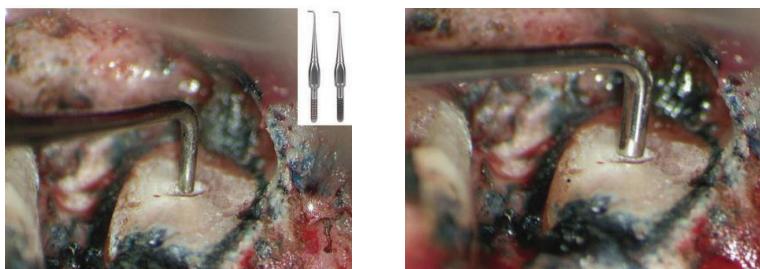


Figure 31: The needle acts as a carrier and also as a plugger, condensing the material inside the cavity.

Courtesy: Castellucci A. The State of the Art in Surgical Endodontics: Nessa J Oral Care and Dentistry.

X. Microplugger Instruments:

After placement of MTA or Bioceramic putty into the root end preparation using the Lee carver, the filling materials need to be gently condensed to fill the whole root end preparation length of 3 mm or a longer length. This procedure is done using micropluggers, one a thin 2-mm diameter and another a thick 4-mm diameter, depending on the size of root end preparation.



(a)

(b)

Figure 32: (a) Small diameter (2 mm) microplugger ; (b) Larger diameter (4 mm) microplugger

Courtsey: Castellucci A. The State of the Art in Surgical Endodontics: Nessa J Oral Care and Dentistry

XI. Suturing Instruments:

The function of sutures is to position and stabilize the flap during wound healing and provide initial hemostasis.

The suture should secure the flap without imposing needless traction.

A microscopic approach provides clear visualization, which aids in precise work and passive wound closure.

ADVANTAGES OF MICROSUTURING:

- Direct vision provides resolution as low as 0.2 mm. at this level of visual acuity, fine hand movements have precision of only about 1mm. Physiologic tremor can further reduce precision.
- Primary wound closure that is without tension.

Castroviejo needle holder: (14,16 and 18 mm)

- Locking device is near the handgrip area.
- Diamond coating of the internal surfaces of the jaws provides solid grip on the needle and prevents it from slipping or rotating.

Straight and curved are available.

The Laschal microscissors: Spring loaded, have curved blades with rounded tips.



Figure 33: (a) Castroviejo needle holder; (b) Laschal microscissors

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Suturing needles:

Suturing needles for microsurgery must be:

- Stable in the needle holder
- Able to pass through the tissue with minimal trauma.
- Sharp enough to penetrate the tissue with low resistance
- Rigid enough to resist deformation

Shape and thickness of the needle is selected based on the tissue biotype:

- Thin biotype: The round bodied or cylindrical needles as they cause less tissue tearing .
- Thick tissue biotypes: a reverse cutting needle as they reduce tearing while piercing the tissue and provide a stable base for the needle holder.

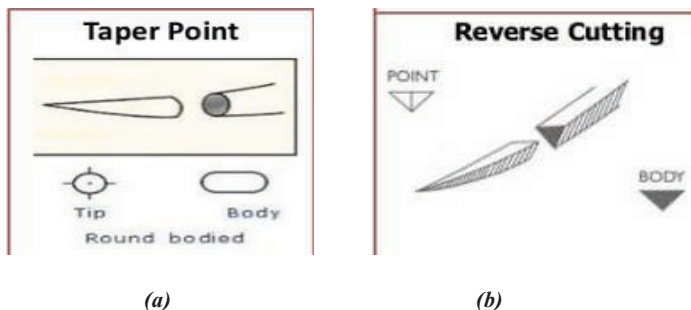


Figure 34: (a) Round bodied or cylindrical needles for thin biotype; (b) Reverse cutting needle for thick tissue biotype

© *Suture Materials – Types, Materials used and Techniques in Oral Surgery*
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XII. Suturing material:

Before the advent of microsurgery, 4-0 silk sutures were the standard for endodontic surgery, but they are no longer recommended. Because silk sutures are braided and thick, plaque, food debris, and bacteria readily accumulate on them, resulting in secondary inflammation at the suture site.

To prevent this inflammation and associated delayed healing, 6-0, 7-0, and 8-0 monofilament sutures of nylon or polypropylene are now used.

Monofilament produce less friction while passing through tissue and are less traumatic. However, they are more prone to untying, so they must be secured with multiple knots. Also, are more prone to damage.

Nylon is colonized more slowly, but is too rigid and often patients complain because the suture is irritating the lip or the cheek.

Tevdek is a newly introduced suture made of a polytetrafluoroethylene impregnated polyester material. It is very resistant to bacterial colonization and is non-irritating. The suggested size of the suture is 6-0.

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Figure 35: Tevdek sutures

©*Tevdek Polyester Suture from Teleflex Medical OEM*



(a)

(b)

Figure 36: (a) Immediate post operative image of Tevdek suture placement; (b) The suture was removed after 24 hours and the image taken after 2 years. shows no scars.

Courtesy: Castellucci A. The State of the Art in Surgical Endodontics; Nessa J Oral Care and Dentistry.

XIII. Miscellaneous Instruments:

A large ball burnisher and a bone file are used to smooth the bone and root surface and to mold bone augmenting material to the boney contours

A small rongeur is used to remove granulation tissue. The beaks of these rongeurs are miniaturized to fit into the hard to reach areas deep inside the bony crypt

Other instruments that may be used during an endodontic microsurgery are:

- Diamond peet forceps 30°, 70° and 90°.
- Stieglitz forceps 45° and 90°
- Fragment forceps: straight and curved (90°) with 125mm beak length.
- MC Condensers
- LC- 1 and LC – 2 microcondensers
- Burnishers



(a)

Figure 37: Miscellaneous instruments

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VII. MAGNIFICATION

The use of magnification improves precision, illumination and the quality of work. Magnification increases the focal length in order to see small objects accurately. This increases the working distance between the eye and the object allowing, extra-ocular muscles to remain relaxed reducing eye fatigue. This also improves the dentist's posture.

The optical magnification instruments that can be used by an endodontist are:

- I. Loupes,
- II. Dental operating microscope,
- III. Endoscopes, and
- IV. Orascopes

SURGICAL OPERATING MICROSCOPE:

Dr. Apothecker and Dr. Jako in 1978 introduced the concept of magnification in dentistry in the form of the dental operating microscope (DOM). The advantages of using a DOM are as follow:

1. **Increased visualization of the surgical field:**

The surgical field can be inspected at high magnification, hence, anatomical details, such as isthemus, extra apex, lateral canals, can be identified and managed. The integrity of the root can be examined with great precision for fractures, perforations, or other signs of damage.

Bone and root tip can be easily distinguished under this high magnification using methylene blue staining.

3. **Improved quality**

4. **Precision of treatment :**

Precise removal of infected or granulation tissue can be done.

5. **Better evaluation of the surgical technique:** whether the granulomatous tissue was completely removed from the bone crypt.

6. **Enhanced ergonomics and ease of proper digital documentation**

6. Increased communication ability

7. Better predictability of long term results:

At higher magnification the osteotomy can be made small (3-4 mm) and this results in faster healing and less postoperative discomfort.

8. Occupational and physical stress is reduced since using the microscope requires an erect posture.

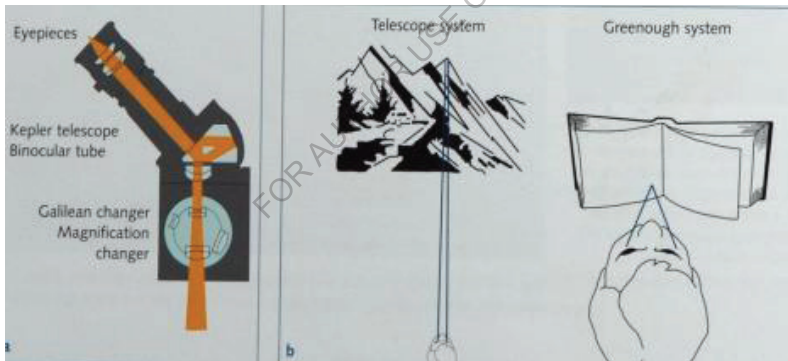
Sl. No.	Magnification	Procedures	Provides
1.	Low (x3 to x8)	Orientation , inspection of the surgical site, osteotomy, alignment of surgical tips, retrocavity preparation, and suturing.	Wider surgical field view Great depth of field despite movements
2.	Midrange (x8 to x16)	Most of the microsurgical procedures are done in this range, including hemostasis, removal of granulation tissue, detection of root tips, apicoectomy, rinsing, drying, retrocavity preparation and obturation.	Moderate surgical field view Moderate depth of field
3.	High (x16 to x30)	Inspection or resected root surface and retrocavity obturation, observation of fine anatomical details like cracks or crazy lines, isthmus, final inspection before suturing.	Small surgical field view Extremely shallow depth of field Focus lost with small movements On ly used for inspection

Table 4: Magnifications for different surgery stages

- a) The surgical operating microscope has a range of magnifications from 2.5x to 25x and the illumination is always perfectly coaxial with the line of sight. Coaxial illumination refers to the illumination beam that has a maximum 2-6-degree divergence from the axis of observation.⁴⁴ The coaxial illumination is made possible because the operating microscope uses Galileian optics. Galileian optics focus at infinity and send parallel beams of light to each eye, the operator's eyes are also focusing at infinity and every procedure can be performed without any eye fatigue.⁴⁴

The coaxial illumination has two advantages:

- b) The clinician can look into the surgical field without any shadows
 c) Every procedure can be performed without any eye fatigue.



(a)

(b)

Figure 60: (a) and (b) With no objective lens on, all microscope lenses are focused to infinity in a telescope system . This means that the microscope is already focused to infinity, so ocular muscles do not need to work to produce a sharp image. Lengthy operations can be performed without eye fatigue. In contrast, loupes are mounted angled inward (convergent optics), so ocular muscles have to work to get a sharp image.

Courtesy: Enrique M. Merino; Endodontic microsurgery, 2009.

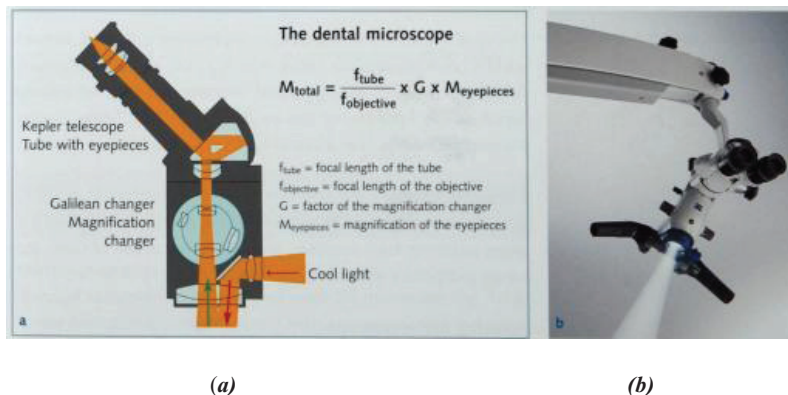


Figure 381: (a) and (b) Coaxial light (red arrow) has only 2--6-degree divergence from the optical axis of the microscope (green arrow) and allows light to be put into the deepest part of roots. Less than 2-degree divergence could reflect the light on a liquid surface or metallic instrument in the surgical field back into the binoculars and surgeon's eyes. More divergence than 60 could prevent light entering into deep spaces, only producing shadows.

Courtesy: Enrique M. Merino; *Endodontic microsurgery*, 2009.

Color:

The standard built-in light is a halogen yellow source with 3200 K color temperature. If a pure white, more powerful light is required, as with digital microphotography, an external xenon strobe light source can be used. Some modern microscope models have a xenon light source built in.

Focusing the microscope:

Gross focus adjustments are made by moving the microscope up and down. Fine focusing is by a manual knob or an electric motor.

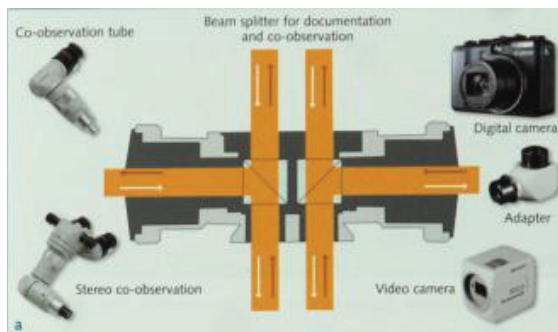


Figure 392: Microscope accessories are essential for producing documentation in a professional manner.

Courtesy: Enrique M. Merino; Endodontic microsurgery, 2009.



Figure 403: Knobs for manual fine focus control (yellow arrow) and manual magnification change (red arrow) (photo: ©Carl Zeiss). (a) Inner ring or (b) handle controls for both fine motorized focus and magnification (photo: © Carl Zeiss).

Courtesy: Enrique M. Merino; Endodontic microsurgery, 2009.

Microscope Parts:

Eyepieces:

There are three types of eyepiece, depending on quality and optical aberration correction properties:

- Huygens (H),
- Wide-field (WF),
- Plössl (PL).

They are available with 6.3, 10, 12.5, 16 and 20 magnification powers. They have an adjustable diopter setting and rubber cups.



Figure 64: Oculars differ in magnification, but basically they all have a diopter scale and rubber cups. Users wearing spectacles can adjust them or introduce their own eye data into the diopter scale, so they work at the microscope without glasses. A wide ocular is advised in order to have a greater field view

Courtesy: Enrique M. Merino; Endodontic microsurgery, 2009.

Binoculars:

Binoculars come with different focal lengths; the longer the focal length, the greater the magnification. Inclined binoculars are adjustable for positions up to and sometimes beyond 180 degrees. Other ergonomic tools are the C-code beam splitter

and the Carr extender. These bring the binoculars away from the microscope and closer to the surgeon.⁴⁴

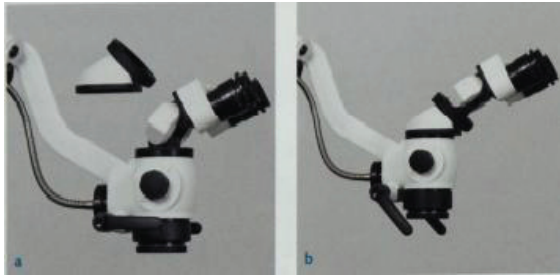


Figure 6541: (a) The Carr extender, for (b) the Global operating microscope

Courtesy: Enrique M. Merino; Endodontic microsurgery, 2009.

Magnification Changer:

Located in the microscope body, the changer holds the lenses that magnify the image in three or five steps manually, or progressively if motorized. Total magnification M_r is determined by the combination of the eyepiece magnification M_e , the focal length of the binoculars f_t , the magnification changer M_c , and the focal length of the objective lens f_o :

$$M_r = (f_t / f_o) M_e M_c$$

Focusing Knob:

The manual focusing knob changes the distance between the microscope lens and the surgical field. Motorized focusing is controlled by the inner ring and moves the objective lens closer to or away from the surgical field.

Objective Lens:

The focal length of the objective lens determines the distance between the lens and the surgical field. The closer the objective lens to the surgical field, the higher the final magnification at each step, and the smaller the diameter of the surgical field will be but also, the smaller the space for passing instruments, and the greater likelihood of the objective lens being splashed.

In contrast, objective lenses with longer focal lengths have smaller magnifications at each step, but allow more room for cords and instruments passing between the operating field and the lens, and reduced splashing possibility.

Typical working distances are: 8 inches (20 cm) for a 200-mm lens; 10 inches (25 cm) for a 250-mm lens; and 14 inches (35 cm) for a 300-mm lens. State-of-the-art optics today allow a wide focal length range with a fixed objective lens.

Lenses from 200 mm to 250 mm are recommended for endodontic microsurgery because they provide a comfortable working distance and enough room for passing instruments.

Microscope support is provided by two systems: springs or electromagnetic clutches. A free-floating magnetic clutch system offers the easiest way to move the microscope and - more important - a totally stable position regardless of the weight of the microscope.

Beam Splitter:

Its function is to supply light to accessories:

- Real time images can be shared with the assistant through an external LCD monitor or a co-observation tube
- Pictures can be taken with a digital camera
- Video can be taken with a one- or three-chip digital video camera

A straight beam splitter or a C-code splitter can be inserted into the pathway of the light, as it returns to the operator's eye, between the binoculars and the magnification changer.



Figure 426: (a) This straight beam splitter between the microscope body and binoculars sends the surgical field image to documentation accessories; (b) This 45-degree inclined C-splitter between the microscope body and binoculars sends the surgical field image to documentation accessories.

Courtesy: Enrique M. Merino; Endodontic microsurgery, 2009.

External Monitor or Co-observation Tube :

The image signal can be shared to an external monitor situated at the surgeon's back, in front of the assistant, so the assistant can view the surgical field on the monitor without moving his or her head, and can help the surgeon by passing instruments ("four-handed dentistry").

ADVANTAGES AND DISADVANTAGES OF USING A MICROSCOPE

ADVANTAGES:

- **Increased diagnostic power**
- **Broader therapy treatment spectrum :**

The microscope has widened the spectrum of conditions an endodontist can treat with higher predictability: perforations, managing mesiolingual canals of mandibular molars or mesiopalatal canals of maxillary molars, isthmuses, removal of broken instruments, etc.

- **Reduced trauma:**

All microsurgical techniques and instruments are designed to reduce tissue trauma. The healing process is speeded up dramatically.

DISADVANTAGES:

- **Learning curve:**

The learning curve duration may be around 9 months, while the loupe learning curve typically takes 1-4 weeks. However, this depends on your past experiences in several areas (including indirect vision working) and on whether you have already taken a microscope hands-on course.

- **Skills aquisition :**

With the microscope you can develop better surgical skills, so the only limitations you have to deal with then are biological ones.

- **Longer sessions:**

To begin with, sessions are longer. Later on, the time will be reduced .

- **Expensive armamentarium**

ERGONOMIE SURGICAL WORKING POSITIONS

1. Surgeon's stool position:

Head and back straight and balanced (not bent forward or to either side); thighs parallel or slightly elevated to the floor; feet parallel to the floor; arms bent at the elbows (slightly extended) and properly supported in order to keep shoulders and arms relaxed, allowing fine motor joints like wrists and fingers to make precise movements.



Figure 437: (a)- (c) Spine, arms and legs are in neutral spatial positions. Courtesy: Enrique M. Merino; Endodontic microsurgery, 2009.

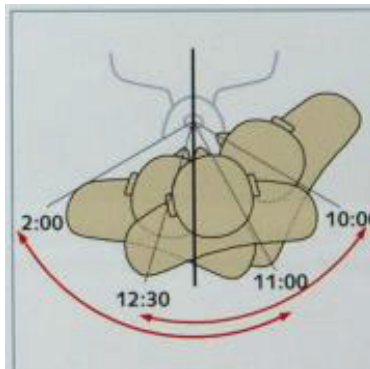


Figure 68: The surgeon must be able to move freely between the 10 o'clock and 2 o'clock positions. Courtesy: Enrique M. Merino; Endodontic microsurgery, 2009.

2. Dental chair position:

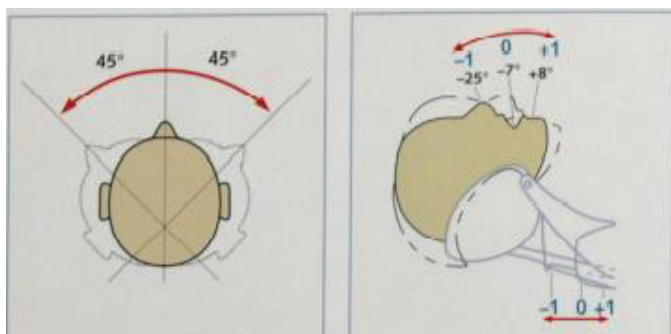
Maxillary teeth should be in the range of the operator's fingers, with sufficient space for the legs below, and for the microscope above. The seated surgeon should be able to see the surgical field through the binoculars without straining.

3. Microscope position:

Unlike with traditional dentistry, where the dentist moves when a better view is needed, when working with the microscope the operator should remain still. Whenever possible it is best to keep the operating microscope vertically positioned and not tilted off the vertical axis; but this is not always possible when looking for a direct view of the surgical field.

4. Patient's head and body positions:

The patient's head or body is adjusted according to the surgical area, because the patient can more easily move his or her head or entire body than the surgeon can. The patient's head is tilted to the opposite of the working side: if working on the right side, the patient's head is tilted to the left; if working on the left side, the patient's head is tilted to the right. For long procedures it is more convenient to tilt the whole of the patient's body instead of just the head.



(a)

(b)

Figure69: (a) and (b) With short surgery, the patient can move his or her head right to left and back and forth to permit better access to the surgical field. Courtesy: Enrique M. Merino; Endodontic microsurgery, 2009.

WORKING POSITIONS:

➤ UPPER RIGHT PREMOLARS AND MOLARS :

Dental chair: slightly elevated; surgical field is low to the operating microscope

Surgeon position: 11-12 o'clock

Microscope position : angled down the axial plane of the roots

Patient head position: facing slightly to the left for premolars and lying on his left side for molars; mandible right lateral extrusion.

➤ MAXILLARY INCISORS AND CANINES:

Dental chair: 45 degrees elevated; surgical site is low to the operating microscope

Surgeon position: 11-12 o'clock

Microscope position: angled down the axial plane of the roots

Patient head position: occlusal plane 45 degrees to the floor; patient looking ahead

➤ MAXILLARY LEFT PREMOLARS AND MOLARS:

Dental chair: slightly elevated; surgical field is low to the operating microscope

Surgeon position: 11-12 o'clock or 12-1 o'clock

Microscope position: angled down the axial plane of the roots

Patient head position: facing slightly to the right for premolars and lying on his right side for molars (for surgeon position at 11 o'clock); or facing slightly to the right for premolars and molars (for surgeon position at 1 o'clock); mandible left lateral extrusion.

➤ **MANDIBULAR RIGHT PREMOLARS AND MOLARS:**

Dental chair: slightly elevated; surgical field is low to the operating microscope

Surgeon position: 8-9 o'clock

Microscope position: angled up the axial plane of the roots

Patient head position: facing slightly to the left.

➤ **MANDIBULAR INCISORS AND CANINES:**

Dental chair: slightly elevated; surgical field is slightly higher to the operating microscope.

Surgeon position: 8-9 o'clock.

Microscope position: angled up the axial plane of the root

Patient head position: looking straight ahead.

➤ **MANDIBULAR LEFT PREMOLARS AND MOLARS:**

Dental chair: horizontal; surgical field is low to the operating microscope

Surgeon position: 8-9 o'clock

Microscope position: angled up the axial plane of the roots

Patient head position: Lying on the right side with the head turned up.(44)

THE MICROSCOPE AND THE LOUPE COMPARED

Sl. No.		LOUPES	MICROSCOPE
1	Principle	<p>Convergent lens system (Greenough system):</p> <p>Because the lens is fixed in a convergent beam path, the user's eyes must converge to view a sharp image. 50 the work of ocular muscles can cause eyestrain, fatigue and even vision changes, if the loupe is not properly adjusted.</p>	<p>Galilean principles (telescope system)</p> <p>They are already focused to infinity. Stereoscopic lenses focused at infinity send parallel beams of light to each eye, allowing the viewing of objects in three dimensions with an excellent impression of depth.</p>
2	Range of Magnification	Each loupe has its fixed magnification power that cannot be changed.	Wide range of magnification. (X6(-) X24(+))

3	Illumination	Most loupes have no coaxial integral light.	With coaxial light, the illumination beam has a maximum 2-6-degree divergence from the axis of observation. Coaxial light renders a shadow-free surgical field with no annoying reflections, and the light reaches deep parts of the roots.
4	Documentation	There is no way to take good quality pictures and video for reporting clinical cases, lecturing and archiving.	Possible (Photos and Videos)
5	Focusing	At the beginning, focus is achieved by moving the dental chair up or down, but then focusing is faster when the surgeon moves his or her head up and down - eventually causing neck pain	Gross focus adjustments are made by moving the microscope up and down. Fine focusing is by a manual knob or an electric motor.
6.	Instruments used	Standard surgical instruments with an additional light source from a fiber-optic cable that ends on the active part of the retractor	Standard instruments cannot be used under the microscope. A new dedicated armamentarium is necessary when using the microscope, to complete the triad of magnification-illumination-microinstrumentation.

		instrument is required	No additional external light source with a fiber-optic tip attached to a retractor instrument is necessary
7	Surgical Setup	Surgeon and assistant have to advance, tilt and rotate their spines. This leads to fatigued dorsal muscles	There are straighter spines for both surgeon and assistant (no diaphragm collapse), with arm support provided by the microsurgical stool.

Table 5: Comparison of Loupes and DOM

FIBRE OPTIC ENDOSCOPE

A recent addition to the field of visualization devices in endodontic surgery is the fibre –optic endoscope. Endoscopy is clinically advantageous compared to surgical microscopy in endodontic microsurgery.

Endoscopes provide a non-fixed field of vision. Hence, they allow the treatment field to be viewed at various angles and distances without losing depth of the field and focus. Therefore, endoscope is more versatile than the microscope. The use of an endoscope was associated with a high success rate in endodontic surgery (88.9-94.9%).⁴⁵ The endoscope accurately identified microstructures following root-end resection and root-end preparation and could be considered for intraoperative diagnostics in endodontic surgery.⁴⁶ von Arx *et al.* compared the microscopy and endoscopy with scanning electron microscopy, and the endoscopy x64 proved the most accurate visual aid for the identification of dentinal cracks after root-end resection in extracted human teeth; however, it also provided the most false identifications.⁴⁷

Orascopy involves using the Orascope, a modified medical endoscope, for treatment in the oral cavity. It uses fiber optics, making the instrument lightweight and flexible.

In the past, fiber-optic imaging provided superior ergonomics but suffered from poor image quality.

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VIII. ROOT END FILLING MATERIALS

The ideal retrograde filling material should have the following characteristics:

- a) easy to carry and to manipulate
- b) relatively fast setting time
- c) dimensionally stable and non resorbable
- d) capable to guarantee a perfect seal of the cavity
- e) biocompatible
- f) non-toxic
- g) insoluble in tissue fluids
- h) bacteriostatic
- i) sterile or easily sterilizable before use
- j) radiopaque
- k) easily removable if necessary.⁴⁸

Various materials have been used as root-end filling materials over the past few years: amalgam, gold foil, zinc oxide eugenol cements, Diaket (ESPE GmbH, Seefeld, Germany), glass ionomer cements, composite resins, intermediate restorative material (Caulk/Dentsply, Milford, DE), SuperEBA (Bosworth, Skokie, IL), and mineral trioxide aggregate (MTA; ProRoot MTA; Dentsply, Tulsa, OK). Although none of these satisfy all the requirements of an ideal repair material, MTA has been the material of choice for root-end filling.

AMALGAM:

Amalgam had been used as a retrograde filling material as it is easy to manipulate, radiopaque and non-resorbable. Farrar (1884) was the first one to place it as a root-end filling subsequent to resection.

Biologic response to amalgam:

The biological effects of amalgam are dependent on the composition of the alloy.⁴⁹

- Zinc is known to be cytotoxic. Zinc-free amalgam are less cytotoxic than zinc-containing amalgam.⁵⁰

- There is no significant elevation of blood-mercury levels in humans following the placement of freshly mixed amalgam root-end fillings.⁵¹

The tissue response to amalgam root-end fillings has been shown to be unfavourable. Inflammation in short-term studies has been noted., from 2 weeks to 5 months following placement.^{52,53}

Freshly mixed conventional silver amalgam is very cytotoxic due to the presence of unreacted mercury. The cytotoxicity decreases there after rapidly as the materials hardens.⁵⁴ The stability of amalgam and the migration of metallic particles into the tissues have raised concerns as, they have been associated with inflammation.⁵⁵ Some larger particles of amalgam have been encapsulated by collagen and persist almost unchanged.

Overall, studies show that the biocompatibility of amalgam is poor in the early period. However, it seems to improve over a period of time.

In the presence of metallic posts or crowns, a galvanic current may be produced when in contact. Also, amalgam tattoos may arise due to corrosion of amalgam/silver cones.

Advantages of Amalgam:

1. Inexpensive
2. Readily available
3. Easy to handle and manipulate
4. Good radiopacity.
5. Non-soluble in tissue fluids and
6. Marginal adaptation as well as sealing improves as amalgam ages due to formation of corrosion products.

Disadvantages of Amalgam:

1. Initial marginal leakage
2. Secondary corrosion
3. Induction of inflammation of adjacent peri-radicular tissues
4. Amalgam tattoo formation
5. The need for an undercut in cavity preparation- Technique sensitivity.
6. Zinc toxicity
7. Delayed expansion
8. Moisture sensitivity

9. Safety issues due to mercury toxicity
10. Tin and mercury contamination of periapical tissues

Amalgambond was introduced in 1990, which contained 4-META resin. It has shown to have lesser microleakage compared to the conventional amalgam.⁵⁵ However, the use of amalgam as a retrograde filling material in endodontics microsurgery has been reduced to almost nil currently.

GUTTA PERCHA:

Gutta percha is inexpensive, adapts to the canal walls, and is inert. Until the development of thermoplasticized gutta-percha, the placement of gutta percha as a root-end filling material was not advocated. Orthograde gutta-percha root canal obturation that is associated with apical surgery should be burnished after apicoectomy with either cold or hot burnisher. Heat-sealed gutta-percha has shown significant marginal defects, and pull-aways, absorbs moisture from periapical tissues and also results in dimensional changes due to contraction and expansion.⁵⁶

Biologic response to Gutta Percha:

The tissue response to gutta-percha with zinc oxide root canal sealer was presented with little or no inflammation. In contrast, more severe inflammation was observed in tissues related to gutta-percha softened with Kloropercha.⁵⁷ Also, the low degree of toxicity associated with gutta percha has been thought to arise due to the presence of Zinc oxide in the composition.⁵⁸

Gutta-percha is considered to have acceptable biocompatibility.

Use of gutta-percha as a root end filling material is no longer recommended owing to the advent of newer materials with significantly enhanced properties

ZINC OXIDE EUGENOL CEMENTS:

These cements contain Eugenol which, in contact with tissue fluids, is hydrolyzed and released. Free eugenol acts as an allergen. Newer modifications of ZOE compounds, such as IRM and Super EBA provide a better apical seal.

INTERMEDIATE RESTORATIVE MATERIAL (IRM) :

Intermediate Restorative Material is a modified ZOE cement that has been reinforced by the addition of 20% polymethacrylate in the powder, eliminating the absorbability show a better biocompatibility and higher clinical success rate than amalgam.

The osteoid formation was not seen within 1 mm of the IRM retrofilling at 15 weeks. This could be due to eugenol leaching from the retrograde filling, slowing the healing potential.⁵⁹

SuperEBA:

Super ethoxybenzoic acid cement is an improved IRM. Super-EBA contains only one-third as much eugenol as IRM.⁶⁰ It also adheres well to itself and the canal walls in moist conditions. There is a substitution of part of the eugenol liquid with ortho-ethoxybenzoic acid (EBA) and addition of alumina to the powder to alter the setting time and increase the strength of the mixture. Super EBA is pH neutral, has low solubility, and has less leakage than amalgam. It produces minimal chronic inflammation in the apex. It has excellent adaptation to sectioned dentin edges, and collagen fiber apposition over the material has been observed.⁶¹

The toxicity of Super-EBA is maintained even after a week of placement.⁶⁰

SuperEBA (Bosworth)	IRM (Caulk)
Powder	
Zinc oxide, 60%	Zinc oxide, 80%
Alumina, 34%	Polymethylmethacrylate, 20%
Natural resin, 6 %	
Liquid	
Eugenol, 37.5%	Eugenol, 99%
Ortho-ethoxybenzoic acid, 62.5%	Acetic acid, 1%

Figure 44: Composition of Super EBA and IRM

Dorn and Gartner examined the results of amalgam, IRM and EBA as root-end fillings from 6 months to 10 years. An outcome of 95% was found with EBA, 91% with IRM and 75% with amalgam. The difference between EBA and IRM was not statistically significant.⁶²

Super-EBA seems to be more biocompatible than IRM.

CAVIT:

Cavit was introduced as a temporary filling material made of zinc oxide and zinc sulphate without eugenol. Cavit undergoes a hygroscopic set a, resulting in a high linear expansion (18%). This defends its use as a root-end filling material. Cavit has been shown to exhibit greater leakage than IRM. It is found to be soluble and quickly disintegrates in tissue fluids. Evaluation of the sealing ability of amalgam, Cavit and glass ionomer cement was done to reveal that Cavit had a better seal than amalgam but the seal was inferior to that of GIC. Biocompatibility studies with Cavit are conflicting, showing it to be both toxic and nontoxic. Hence, the use of Cavit as a root-end filling material cannot be advised .⁶³

GOLD FOIL:

Gold foil as a retrograde filling material was advocated by Schuster in 1913 and Lyons in 1920. It exhibits perfect marginal adaptability, surface smoothness and biocompatibility. When compared to IRM, composite resin, amalgam and glass ionomer, goldfoil was least toxic. Leakage studies in root- end preparations have indicated minimal or no leakage. However, routine use of gold foil as a root-end filling material is not practical due to its technique sensitivity and cost.⁶³

ZINC PHOSPHATE CEMENT:

Zinc phosphate cement was also considered as a retrograde filling material. As discussed before, the root-end filling material should be nonirritating, not inhibit healing, and exhibit minimal leakage or solubility. Since zinc phosphate does not fulfill these criteria, it is not indicated as a root- end filling material. ⁶³

POLYCARBOXYLATE CEMENT:

Polycarboxylates placed in relation to the periapical tissues showed varied response. Apical leakage studies have indicated that the leakage levels are significantly higher than amalgam or gutta-percha. Due to their poor sealing ability and uncertain periradicular tissue response, the use of polycarboxylate as root-end filling material is highly questionable.⁶³

GLASS IONOMER CEMENTS:

Biocompatibility studies revealed initial cytotoxicity with freshly prepared samples, and decrease in toxicity as setting occurred.⁶⁴ Both inhibitory and stimulatory effects of fluoride ions released from GIC have been observed. This depends upon ion concentration and culture conditions.⁶⁵ It has been reported that GIC inhibits the growth of gingival fibro-blasts and periodontal ligament cells.⁶⁶ Ketac Silver (GIC) exhibited higher levels of cytotoxicity due to the presence of silver. Also, silver content lead to discoloration and possible corrosion leading to cytotoxicity.⁶⁷ Also, GIC was damaged by exposure to moisture early in the setting reaction, futher affecting the sealing ability.⁶⁸

GERISTORE (RESIN IONOMER SUSPENSION):

Geristore is a dual-cure, self-adhesive, resin glass ionomer formula that contains fluoride. Since its hydrophilic, it bonds to the tooth structure and gingiva even in the presence of moisture and blood. Geristore is biocompatible for soft tissue and teeth

Advantages of Geristore:

- Hybrid ionomer composite - Combines best properties of both types of materials
- Self-adhesive properties make Geristore exceptionally easy to use with no need for retentive cavity design, eliminating chair time usually devoted to cavity preparation
- Quick and easy to use
- Bonds to all surfaces including enamel, dentin, cementum, precious and non-precious metal, and old set amalgam - eliminates the need for multiple products
- Low polymerization shrinkage and low coefficient of thermal expansion - excellent marginal integrity
- Radiopaque

Disadvantages of Geristore:

Technical difficulty of placement.

Requires light activation and resin bonding agent to bond to tooth surface.⁶³

COMPOSITE RESINS :

Composite resins due to their cytotoxic or irritating effects on pulp tissue have received minimal attention as root-end filling materials.

Biologic effects:

The release of formaldehyde from composite resins can cause allergic reactions.⁶⁹ The presence of cytotoxic monomers EGDMA and TEGDMA along with their tendency to promote microbial growth, also contribute to tissue injury.⁷⁰ Composite resin and amalgam have produced an inflammatory responses and were also accompanied by the formation of a fibrous tissue capsule.⁷¹

It was reported that composite retrograde material exhibited complete healing in 74% of the cases when compared to amalgam (59%).⁷² The success of the composite is dependent on excellent moisture control.

Dentine-bonding agents alone have been proposed for achieving apical seal after root resection. Two polymerised dentine-bonding agents tested produced adverse effect on the viability of monocytes. Hence, they should be used with caution.⁷³

COMPOMERS:

The compomer group has shown greater inflammation compared to amalgam. Dyract has been shown to have good anti-bacterial effects against *P.gingivalis*, *P.intermedia*, *P.endodontalis* and *F.nucleatum*, owing to the release of residual monomers and additives after polymerization. The results of an electrochemical study of the sealing ability of super-EBA, MTA and Dyract-flow showed that the sealing ability of Dyract-flow is equal to that of super-EBA and MTA.⁷⁴

RETROPLAST(DENTINE-BONDED RESIN COMPOSITE):

A BISGMA/TEGDMA-based resin composite (Retroplast, RP) in combination with a dentine-bonding agent (GLUMA) was developed in 1984. Retroplast can promote hard tissue formation at the root apex and form cementum.⁷⁵

The cavity design for retroplast placement is advocated to be shallow, concave and saucer shaped, with a cavosurface angle close to 180 degrees. This is particularly advantageous in roots with challenging access. This reduces the volume of composite against the dentine surface and prevents contraction gaps forming. EDTA is used to

remove the smear layer after preparation of the root-end prior to the application of Gluma.

MTA:

MTA is extremely biocompatible, capable of stimulating healing and osteogenesis, promotes tissue regeneration when placed in contact with the periradicular tissues and is hydrophilic.⁷⁶⁻⁷⁹

Biologic effects:

Calcium hydroxide released by MTA is biocompatible with tissue. The initial pH of MTA is 10.2, with an increase to 12.5, 3 hours after mixing.⁷⁶ MTA offers a biologically active substrate for bone cells as a result of its alkaline pH and calcium ion release.⁸⁰ The high pH is also responsible for coagulation necrosis and dystrophic calcification that follow its sub-cutaneous implantation.⁸¹ It was found that the Saos-2 cells (the human osteoblast-like cell line) on the MTA were viable and able to proliferate, even at 72 hours.⁸² The cell metabolism and growth was reduced dramatically on Super-EBA and amalgam surfaces.⁸² GIC, Super-EBA and amalgam showed higher levels of cytotoxicity when compared to MTA.⁸³ Based on these studies, the use of MTA as a root-end filling material appears favourable.

Advantages :

- 1) Excellent seal and hard tissue repair
- 2) It is found to be more opaque than EBA and IRM.
- 3) The marginal adaptation of MTA was better with or without finishing when compared to IRM and Super EBA.
- 4) Showed evidence of healing of the surrounding tissues.
- 5) Bioactivity
- 6) Potential to stimulate cementogenesis.
- 7) Biocompatibility and its osteogenic and regenerative potential
- 8) Since it sets in the presence of moisture, it is not moisture sensitive and is not affected by blood contamination.

Disadvantages:

- 1) Difficulty to handle: Prepared MTA has the consistency of a moist, granular paste, and it may be difficult to place it in a root-end cavity. MTA may also be prone to washout in the presence or excessive bleeding or other tissue fluids compromising its sealing ability.

Gray MTA (gMTA) and White MTA (wMTA):

When biocompatibility of gMTA and wMTA was evaluated in terms of cell attachment and osteogenic behavior, it was found that there was no initial difference in the cell attachment, but the cells on wMTA did not survive as long as on the gMTA.⁸⁴ In majority of studies wMTA and gMTA have not been directly compared. However, it was concluded that WMTA is biocompatible and has the potential to induce osteogenic behavior.⁸⁵

Recent studies have demonstrated the formation of a hydroxyapatite (HA) layer on the MTA surface when in contact with tissue fluid during which was described as “biomineralization”. It was proposed that this layer creates a biologic seal between MTA and the dentin interface enhancing the long-term sealing ability of MTA.⁸⁶

A number of new bioactive materials based on tricalcium silicate cement have been introduced as potential root-end filling materials due to their ability to release calcium hydroxide in solution.

CERAMICRETE:

Ceramicrete is an inorganic phosphate ceramic binder. It is a self-setting phosphate ceramic. Its mechanical properties were improved by adding calcium silicate whiskers to produce a phosphosilicate ceramic material. A ceramicrete based dental or bone material was introduced containing hydroxyapatite powder and cerium oxide radioopaque fillers. This material is biocompatible and radioopaque and releases calcium and phosphate ions during setting. Ceramicrete as an retrograde filling material demonstrated higher sealing ability compared to a SuperEBA and ProRoot MTA group.⁸⁷ Ceramicrete also formed Dicalcium phosphate dihydrate (DPCD) or hydroxapatite on its surface.⁸⁷ Thus, ceramicrete has shown potential bioactivity.

ACTIVE BIOSILICATE TECHNOLOGY:

The Active Biosilicate Technology™ is a proprietary technology developed according to the state-of-the-art pharmaceutical background applied to the high temperature ceramic mineral chemistry. This technology ensured the purity of the calcium silicate content of the formulation and the absence of any aluminate and calcium sulfate in the final product. Based on this technology, Septodont introduced Biodentine™ and BioRoot™ RCS.⁸⁸

BIODENTINE:

A systematic review on Biocompatibility and sealing ability of mineral trioxide aggregate and biodentine as root-end filling material was carried out. It was found that Biodentine had good sealing ability and favorable biological properties.⁸⁹ In a Spectrophotometric study evaluating the apical microleakage in GIC, MTA and Biodentine when used as retrograde filling materials, it was concluded that Biodentine and MTA showed less microleakage as compared to GIC. There is no significant difference between mean microleakage of MTA and Biodentine.⁹⁰ This justifies its use in clinical practice as a retrograde filling material.

BIOAGGREGATE:

The sealing ability of Bioaggregate was found to be superior to gutta percha, amalgam, IRM, and wMTA. The results showed that microleakage was significantly less in Bioaggregate when compared to amalgam, IRM and White MTA. Bioaggregate's excellent hermetic seal can be attributed to its nano-sized particles that adhere to the dentinal wall, and its hydrophilic nature.⁹¹ Bioaggregate was shown to be non-toxic to osteoblast cells and it was also shown to enhance expression of genes for collagen type 1, osteopontin and osteocalcin, which are genes associated with mineralization in osteoblast cells.⁹² Bioaggregate showed a significantly better inflammatory reaction and foreign body reaction than the MTA group.⁹³ Therefore, Bioaggregate is more biocompatible than MTA.

The effect of Bioaggregate and MTA on human pulp and PDL cell growth was determined by examining the cells grown on this cement using a phase microscope. An inhibition zone was detected in the pulp and PDL cell culture grown with MTA. Bioaggregate showed no inhibition zone around the material. Bioaggregate was found to be nontoxic to human pulp and PDL cells.⁹³

ENDOSEQUENCE (ROOT REPAIR MATERIAL / ROOT REPAIR PUTTY):

Endosequence presents exceptional dimensional stability, high mechanical bond strength, high pH, and radiopaque and hydrophilic setting properties.⁹⁴ Both ERRM and ERRP have statistically similar levels of cytotoxicity to MTA, thus rendering them biocompatible.^{86,94} The bioceramic RRM's possess antibacterial properties and sealing ability similar to those of MTA.⁹⁵ RRM also achieved a better tissue healing response adjacent to the resected root-end surface histologically compared with MTA.⁹⁶ An in vivo study concluded that there was no significant difference in the clinical outcomes of EMS using MTA or using BP-RRM as the root-end filling material. Hence, RRM is a suitable root-end filling material.⁹⁷

All the calcium silicate based cements are hydrophilic, vary in setting time and methods of preparation. The calcium silicate cements offer significant improvement over zinc oxide/ eugenol cements, showing reduced cytotoxicity, increased biocompatibility, increased cell attachment, cemento-, and osteoinductive properties as well as increased pH values.

CAPASIO:

Capasio (Primus Consulting, Bradenton, FL, USA) is composed primarily of bismuth oxide, dental glass, and calcium alumino-silicate with a silica and polyvinyl acetate based gel. A recent study found that Capasio and MTA promote apatite deposition when exposed to synthetic tissue fluid thus had the mineralization capacity. The same researchers also concluded that when used as a root-end filling material, Capasio is more likely to penetrate dentinal tubules.⁹⁸

ENDOBINDER :

EndoBinder is new cement which has calcium aluminate as the chief ingredient. Studies have shown endobinder to have good tissue response and biocompatibility. It has superior mechanical properties than MTA, no dental staining, and increased flowability.⁹⁹

GENEREX A :

Generex A is bismuth oxide, tricalcium silicate, dicalcium silicate, and tricalcium aluminate with a mixing gel containing sodium lauryl sulfate and other undisclosed ingredients. It is the only new generation endodontic material which allowed osteoblast growth as compared to MTA. It is considered to have superior resistance to washing, compressive strength and good radiopacity .⁹⁸

BONE CEMENT:

Bone cement is common in the orthopaedic practice. The cement exhibits low cytotoxicity and also delivers high antibiotics locally. It has also been found to be effective in inhibiting bacterial growth. It can also a moist environment such as blood that results in a slight decrease in shear strength and no difference in mechanical penetration of the cement interface has been observed. These characteristics potentially make it a suitable for retrograde filling.¹⁰⁰

Drawbacks of bone cement:

- One of the major drawbacks of bone cement is cement fragmentation and foreign body reaction to wear debris
- Bone cement generates heat as it cures and contracts and later expands due to water absorption. It is neither osteoinductive nor osteoconductive and does not remodel.
- The monomer is toxic and there is a potential for allergic reactions to cement constituents.

CASTOR OIL POLYMER:

It is obtained from a common tropical plant Ricinus Communis, it is widely used in medicine for prostheses to replace bone. It is biocompatible, non- toxic and easy to handle. This biopolymer has high interaction capacity with human cells. It presents a chain of fatty acids whose molecular structures are also present in lipids of human body. Therefore, it doesn't get recognized as a foreign body.¹⁰¹ The sealing ability of COP was significantly better than MTA and GIC.¹⁰¹

CALCIUM PHOSPHATE CEMENT (CPC):

It was developed by ADA-Paffenbarger Dental Research Center at the United States National Institute of Standards & Technology. CPC is a mixture of two calcium phosphate compounds, one acidic and the other basic. It is commonly known as hydroxyapatite cement and is composed of tetracalcium phosphate and dicalcium phosphate reactants. When combined by dissolution in moisture, even blood, CPC sets into hydroxyapatite. It demonstrates excellent biocompatibility, does not cause a sustained inflammatory response or toxic reaction.¹⁰² CPC implants are resorbed slowly and are replaced by natural bone in an approximate 1:1 ratio in an osteoconductive manner.¹⁰³ CPC seems to be promising as a retrograde filling material.

CALCIUM-ENRICHED MIXTURE (CEM):

The hydration reaction of powder creates a colloidal gel that solidifies in less than an hour and forms hydroxyapatite. CEM is alkaline cement (pH~11) that releases calcium hydroxide (CH) during and after setting. This cement is biocompatible, able to produce hydroxyapatite with endogenous and exogenous ion sources and induces formation of cementum, dentin, bone and periodontal tissues.

IX. POST OPERATIVE CONSIDERATIONS:

Application of pressure:

The surgical area is covered with a sterile gauze and pressed with firm and constant finger pressure for 5-10 minutes. After this, the patient is advised to either bite the gauze (occlusive pressure) or press with the tongue on the gauze (palatine and lingual pressure). The surgical site is re-evaluated. A new dry gauze is put back and should remain in place completely still for 1 hour.¹⁰⁴

Cold dressing :

A cold dressing has to be applied firmly on the site at intervals of 20 minutes, resting 20 minutes, and so on for 8 hours. The immediate reduction in temperature and the pressure application slows the blood flow and stimulates intravascular clotting. It also intercepts and counteracts "the hemorrhagic rebound effect".¹⁰⁵ This decreases postsurgical bleeding and swelling. Cold also acts as an analgesic as it desensitizes the peripheral nerve endings. It is discontinued after 8 hours as it may impede tissue healing by interfering with the inflammatory response.

Analgesics:

Non-narcotic Analgesics: Magnesium metamizol (Nolotil) - An oral ampule (2 g) or a tablet (575 mg) can be given immediately post operatively. This drug is contraindicated during the first and last trimesters of pregnancy nor during breastfeeding. There can be cross-sensitivity in patients who have had asthma symptoms, rhinitis or hives after being given acetylsalicylic acid, paracetamol or NSAIDs. **44**

Paraminophenol derivates: Acetaminophen (Paracetamol, Tylenol, APAP) is an analgesic and antipyretic. The dose is 1000 mg initially and then 650 mg every 4 h. The maximum adult dose is 4 g/day. The combined use of acetaminophen (1000 mg) and ibuprofen (600 mg) has proved to be as effective for pain as the narcotics, without their undesirable secondary effects.¹⁰⁶

Non-steroidal Anti-inflammatories: Ibuprofen has become the drug of choice for managing dental pain. The dosage is 600 mg every 8 h.

Narcotic Analgesics:

- Opium alkaloids: codeine 30-60 mg every 3-4 h.
- Synthetics: meperidine 50 mg every 6-8 h (extremely addictive with unpredictable effect and with many side-effects)
- Semisynthetics: hydrocodeine 5-10 mg every 4-6 h (Vicodin is a combination of 5 mg hydrocodeine + 500 mg acetaminophen (1 or 2) every 4-6 h).⁴⁴

Antibiotics:

Transient bacteremia can occur after endodontic surgery. This is well tolerated by healthy patients. However, certain high-risk patients must have prophylactic antibiotic coverage following AHA recommendations.

This group consists of patients with:

- prosthetic cardiac valves
- previous bacterial endocarditis
- cardiac transplantation with valvulopathy
- specific congenital heart disease:
 - unrepaired cyanotic conditions with or without palliative shunts/conduits, or other prostheses;
 - within 6 months of repair using prosthetic material;
 - repair of any duration with residual adjacent defect or shunt.

Patients who no longer require prophylactic antibiotic are those with :

- mitral valve prolapse
- rheumatic heart disease
- bicuspid valve disease
- calcific aortic stenosis

- ventricular septal defect or atrial septal defect (except within 6 months of repair or with a residual peri-prosthetic defect)
- hypertrophic cardiomyopathy
- intracoronary stents.⁴⁴

Disinfectant Solutions: Chlorhexidine (CHX) mouth rinses play an important role in pre- and postsurgical disinfection and rapid healing.⁴⁴

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X. RECENT ADVANCES IN ENDODONTIC MICROSURGERY

1. 3D PRINTED SURGICAL GUIDES: STATIC GUIDANCE

Locating the root end without damaging the surrounding structures poses challenge during surgical endodontic therapy. This is tougher in scenarios in which lesions have not yet perforated the cortical plate or when vital structures are in close proximity. These anatomic challenges have an impact on the success of endodontic surgical procedures. In addition, minimizing the size of the osteotomy has been correlated with favorable postoperative healing outcomes.

Modern technology including magnification, illumination, microinstruments, and cone beam-computed tomographic (CBCT) scans has modelled endodontic surgery more precise.

Recent case reports have advocated the use of 3-dimensional (3D)-printed guides to aid in nonsurgical endodontic access. CBCT Digital Imaging and Communications in Medicine (DICOM) files converted into stereolithography files have been used in the production of 3-dimensional-printed surgical guides (3DSGs).^{107,108} Targeted EMS produces a single-step osteotomy; root-end resection; and biopsy with a defined perforation site, angulation, depth, and diameter.¹⁰⁴

Preoperative Treatment Planning and Procedure:

A preoperative CBCT scan is required and a polyvinyl siloxane (PVS) impression is made and poured. To overcome restoration associated artifacts, a digital 3D scan of the poured model is made and merged with the preoperative DICOM files.**(105)** Using CBCT scans and STL files, a 3D model is generated. In order to precisely reach the root apex the dimension and direction of the surgical trephine bur are defined. According to the digital plan, a 3D surgical guide is printed.¹⁰⁵

Surgical Procedure:

Under profound anesthesia, and dental operating microscope, a soft tissue flap design is made after placement of the 3DSG on the teeth and stabilizing it by pressing down on the soft tissue. The vertical incision line is marked on the mucosa by double pinching it with a dental probe with the surgical stent in place. The guide is removed, and the incision is made along the markings in a straight line from the vestibule to the attached gingiva, terminating 3 mm short of the margin.¹⁰⁵ After flap reflection, the guide is replaced directly onto the exposed bone, and its stabilized. The osteotomy is performed by drilling with a trephine bur at a speed of 1000 rpm and to the depth of 1.5 mm with copious irrigation with sterile saline. After the cortical bone is punched out, it is stored away. The same drill is used to drill to the planned depth to resect 3 mm of the apex and the surrounding granulation tissue. The retrograde cavity preparation, filling n removal of granulation tissue is done. The osteotomy is first closed with the cortical bone disc, which was obtained in the beginning of the procedure. . The flap is reapproximated and closed with 6.0 nylon sutures.¹⁰⁵

Using deviation as a measurement from the apex of the root, a study showed that the distance from the apex was 0.79 mm (0.33 standard deviation) using guidance and 2.27 mm (1.46 standard deviation) using freehand drilling. An error >3 mm occurred more than 22% of the time freehand but never occurred when using the guide.¹⁰⁵

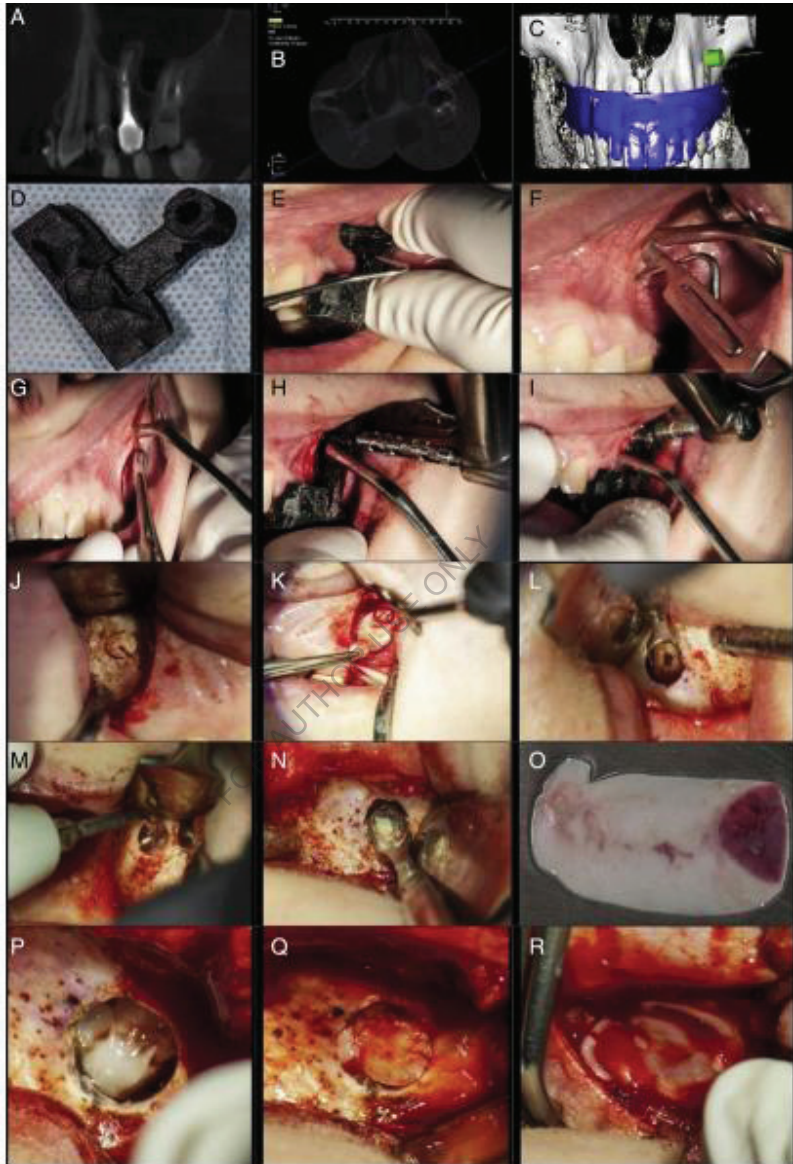


Figure 70: (A) CBCT preoperative sagittal view of the maxillary left second premolar with a low radiodensity area at the apex and the pneumatized maxillary sinus cavity around it. (B and C) Images of the diameter and

direction of a 3DSG visualized with DDS-Pro planning software. (D) The printed 3D surgical stent (3DSG). (E) The 3DSG in place to mark the incision line with a dental probe. (F and G) The incision and reflection of the flap. (H) The 3DSG stabilized over the exposed bone. (I) Hollow trephine bur osteotomy through the 3DSG port. (J and K) The bone disc created and elevated after the trephination of the cortical plate. (L) Inspection of the resected root surface with a dental operating microscope (10 \times magnification [Leica M320; Leica Microsystems, Wetzlar, Germany]). (M) Root-end preparation with ultrasonic tip E11D EMS. (N) Observation of root-end filling with MTA1. (O and P) Images (8 \times) of PRF obtained from the centrifuged patient's whole blood and placement on the osteotomy site as a graft. (Q and R) Images (8 \times) of the bone disc in place and covered with the PRF membrane covering it. (S) 6-0 nylon sutures. (T) A postoperative radiograph with adequate resection and root-end filling. (U) Fourday postoperative soft tissue healing after suture removal. (V–X) Bone healing visible on a CBCT control scan

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However, there are some limitations to this technique. Many of the teeth that require surgical intervention may have fullcoverage restorations, which could produce artifacts in the CBCT study and would decrease the accuracy of superimposing 3D intraoral images on the CBCT images. Another aspect to consider is that the superimposition of the optical impression may be more challenging when using a small field of view CBCT scan. Additionally, considering that a printed guide has inherent thickness and can provide only 1 straight trajectory to the target, using this technique may pose difficulty with positioning the handpiece. Another challenge in using the guides is to obtain optimal irrigation during the osteotomy procedure. In a clinical scenario, irrigation

could be accomplished via an irrigation port or with traditional irrigation in a larger osteotomy window

The advantage is to be minimally invasive, allowing for targeted access, making previously inaccessible areas now being accessible for endodontic surgery.

2. DYNAMIC NAVIGATION SYSTEM:

Dynamic navigation integrates surgical instrumentation and radiologic images using an optical positioning device controlled by a dedicated computerized interface. A clinical real-time interface displays and guides users to drill into the targeted position through the prefixed trace according to the output of the preoperative planning software.¹⁰⁹ The dynamic navigation system can be used in endodontic procedures for locating calcified canals, minimally invasive access cavity in orthograde endodontics, and surgical endodontics.¹¹⁰ In surgical endodontics, it can be used to perform osteotomy, identifying the root apices, and in retrograde access cavity preparation. The rest of the surgical procedure was performed with a traditional microsurgical approach. The Navident system, a dynamic navigation system used majorly in implant dentistry, shows real time deviation between the planned path and the orientation of the bur in operation.¹⁰⁹ The tip of the bur is directed to the root apex, and the progression is visually controlled by checking the planned cavity simultaneously with 2 different CBCT views. Once the tip of the root is reached, root end resection is performed. The clinical advantage of using dynamic navigation system in endodontic microsurgery is to give clinicians an easy-to-use, accurate, and portable way to carry out the desired treatment plan.¹⁰⁹



Figure 71: (A) Treatment planning using the patient's previous CBCT scan. (B) Tracing: the system calibration phase is performed by selecting 6 different points on software reconstructions. (C) A fixed support is mounted on the patient's mouth, which can be recognized by the Navident's cameras, after which the 6 preselected points are traced using a tool that presents a support that can be recognized by the Navident to create matching between the CBCT scan and the patient's jaw. (D) Tracing is completed by an accuracy check view. (E) Before use, the handpiece and burs must be calibrated. (F) Drilling under dynamic guidance: the direction and the angulation of the bur during the surgical procedure can be checked on 3 different CBCT views.

3. GUIDED TISSUE REGENERATION:

The use of guided tissue regeneration (GTR) technique or the use of bone grafting materials and/or membranes, has been proposed as an adjunct to endodontic surgery in order to promote bone healing. The use of guided tissue regeneration (GTR) techniques has been proposed as an adjunct to endodontic surgery in order to promote bone healing.¹¹¹ The placement of any grafting materials or membranes is done prior to wound closure. These separate bones healing from connective tissue healing. Common materials include polytetrafluoro ethylene (ePTFE, Goretex), collagen or polylactide for membranes; freeze-dried bone allografts, demineralized freeze-dried bone allograft, hydroxyapatite, tricalcium phosphate, bioglass or calcium sulfate for grafts.¹¹² GTR effectively excludes epithelial ingrowth into lesions and permitted bone regeneration. No differences were seen in the healing rate with or without membrane placement in uncomplicated defects i.e., endodontic lesions without periodontal communication.^{113,114} Endodontic lesions with complicated defects may benefit from GTR techniques. In through and through lesions, buccal and lingual barriers resulted in complete healing of the defects.¹¹⁵ Lesions sizes that exceeded 10 mm in diameter demonstrated heal faster and have better outcome when GTR techniques were utilized.¹¹⁶ The final type involves cases where a defect of the supporting alveolar bone is present, such as a denuded root where no buccal plate is present initially or following degranulation or resection.¹¹⁷

GTR techniques appear beneficial in situations of complicated and periodontally involved defects.

4. LASERS:

The CO₂ or Nd:Yag lasers are not suitable as they do not cut bone and dentin effectively.¹¹⁸⁻¹²⁰ Er:YAG laser causes no vibration and discomfort while cutting bone and dentin. It causes less damage to soft tissues and bone. The Er:YAG system can be used for osteotomies and root resections. However, this procedure requires more time than a preparation with burs. While the Er:YAG laser may promote faster healing and more comfortable postoperative results according to

the manufacturer, the root-end preparation cannot be done with the laser and the procedure still requires microsurgical ultrasonic preparation and filling.¹²¹⁻¹²³

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XI. MICROSURGICAL TECHNIQUE: PROGNOSIS AND TREATMENT

OUTCOMES

The classification system to assess the outcome of endodontic surgery is based on the criteria put forth by Rud and Molven. Success is defined radiographically as complete healing or incomplete healing in the form of scar formation. Clinical success is defined by the absence of pain, swelling, percussion sensitivity, or a sinus tract. In the first year following the surgical intervention, asymptomatic cases with complete or incomplete healing are considered success, whereas situations with uncertain healing should be re-evaluated for up to 4 years.^{124,125}

Traditional Methods:

The clinical success of traditional surgery, based on the absence of symptoms and on radiographical healing, ranged from 44 to 90%.¹²⁶⁻¹²⁹

Modern microsurgical periradicular surgery uses such as the dental operating microscope, ultrasonics, modern microsurgical instruments, and biocompatible root-end filling materials and has obtained highly successful treatment outcomes. These higher success rates were attributed to a superior inspection of the surgical site and to precise preparation of root-ends with microinstruments using high magnification and enhanced illumination.¹³⁰⁻¹³² The clinical success of microsurgically approached cases is reported to be as high as 96.8% and 91.5% at the short-term follow-up after 1 year and the long-term follow-up after 5 to 7 years, respectively.¹³³⁻¹³⁴

the strict case selection is of paramount importance. Kim and colleagues³⁴ found a successful outcome of 95.2% for cases classified as A to C, compared with a success rate of 77.5% for classes D to F.¹³⁵

Comparison of Ultrasonic versus Traditional Method:

The ultrasonic technique healing success of 95% was compared with 65% success with the traditional techniques in a study conducted by Bader and Lejeune.¹³⁶ Testori et al. reported that of 68% of the teeth treated with the traditional techniques healed in 4.5 yr versus 85% with the ultrasonic technique.¹³⁷ Both authors found a difference of 17% between the two techniques. It is apparent from these results that ultrasonic root-end preparation provides a significantly higher treatment success, perhaps in the range of 17 to 30%, than the traditional bur techniques.

Ultrasonic Without Microscope:

Von Arx et al. reported 88% success after 1-yr follow-up, using ultrasonics and SuperEBA.¹³⁸ Zuolo et al reported that healing after a 1 to 4 yr follow-up was 91.2% of 102 cases included. This study did not include the use of a microscope, but fiberoptic light was used to transilluminate the root.¹³⁹ Maddalone and Gagliani used 4 loupes, ultrasonic tips and SuperEBA root-end fillings, showing overall healing of 92.5% for 120 teeth.¹⁴⁰ These studies show that the treatment outcome can be significantly improved with the use of ultrasonic tips and biologically acceptable root-end filling materials, even when not all microsurgical techniques are being used.

Ultrasonics and the Microscope: The Complete Microsurgical Approach:

After 1 yr, 96.8% of the cases reported had healed in a retrospective study by rubinstein and Kim using only Super EBA as the retrograde filling material.¹⁴¹ Chong and Pitt Ford (19) compared IRM versus MTA with the same technique and reported healing rates of 92% with MTA and 87% with IRM.¹⁴²

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