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Review Article

Role of microsurgery in contemporary dental practice-A review

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Abstract

Endodontic surgery has evolved into endodontic microsurgery, leveraging advanced technology, specialized instruments, and biologically compatible materials to achieve predictable outcomes in healing endodontic lesions. This transition, marked by the advent of operating microscopes in the 1990s, has improved visualization, understanding of apical anatomy, and treatment success while reducing postoperative complications. This review highlights current concepts, techniques, flap designs, and materials, underscoring the significant advancements that have transformed endodontic surgery into a precise and reliable approach.

Keywords: Endodontic surgery, Endodontic microsurgery, Current concepts, Specialized instruments, Flap designs, Biologically compatible materials

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1. Introduction

Endodontic surgery is an essential aspect of comprehensive root canal treatment, addressing issues that cannot be resolved through nonsurgical methods.[1] Endodontic microsurgery is defined as a surgical procedure performed using an operating microscope to address highly small and intricate anatomical structures. This approach eliminates the uncertainties associated with traditional surgical methods, allowing for greater precision and predictability in treatment.[2]

By implementing the microscopic concept, which Prof. Kim first proposed in the 1990s, into surgical endodontics, it is possible to manage the bone structures better, perform atraumatic, more moderated bevel, apical resection procedures and permit coaxial ultrasonic preparation into the root.[3]

The triad of endodontic microsurgery consists of magnification, illumination, and specialized instruments. These three elements are indispensable, as microsurgery would not be feasible without them. Magnification and illumination, provided by the surgical operating microscope, have revolutionized the practice of endodontic surgery. By delivering bright, focused light and magnification ranging from 4x to 31x, the microscope enables the surgeon to visualize every detail of the apical structures and perform treatment with exceptional precision. Additionally, the enhanced magnification has facilitated the use of smaller osteotomies, further improving surgical outcome.[4]

Traditional surgical instruments are too large to be used effectively at higher magnifications. Endodontic microsurgery relies on specially designed microsurgical instruments to achieve the precision required for such procedures. The microsurgical approach is built on the triad of magnification, illumination, and instruments.[5]

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2. Discussion

2.1. Comparison of traditional and microsurgical endodontics

Traditional endodontic surgery is challenging due to the need to approximate anatomical structures like blood vessels, the mental foramen, and the maxillary sinus. Despite minimal risks, it is often viewed negatively because of its invasive nature and uncertain outcomes.

Microsurgical endodontics, however, offers benefits such as easier root apex identification, smaller osteotomies, and shallower resection angles, conserving bone and root length. Microscope magnification reveals detailed root anatomy, including isthmuses and microfractures. Ultrasonic instruments enable precise, conservative root-end preparations and fillings, improving surgical success. [13,23] (Table 1)

2.2. Microsurgical instruments

The first generation of microsurgical instruments was conceptualized and developed by Dr. Garry Carr.

1. Examination Tools: Mirror, periodontal probe, explorer, and micro explorer.
2. Incision & Elevation Instruments: Blades (15, 15C), mini scalpels/blades, periosteals (Molt 9, Prichard PPR3, PPB user, P145S, P9HM, P4 elevators).
3. Curettage Instruments: Mini jacquette 34/35 scaler, Columbia 13–14, minimolten, miniendodontic curettes.
4. Inspection Tools: Micro-mirrors. (**Figure 1**)
5. Miscellaneous Tools: Retrofilling carrier, plugging instruments, large ball burnisher, bone file, microrongeur.
6. Osteotomy Instruments: Impact Air 45 handpiece (**Figure 4**), H161 Lindemann Bone Cutting Bur.
7. Suturing Instruments: Laschal microscissors, small-beaked scissors, Castroviejo needle holder.
8. Tissue Retraction Instruments: Kim-Pecora, Rubinstein, and Prichard retractors.

2.3. Dental cart

A compact, all-in-one unit featuring sterilized water tank, high/low-speed handpiece ports, ultrasonic unit, and Stropko irrigator/drier—essential for modern microsurgery.

2.4. Ultrasonic units & tips

Popular ultrasonic units include EMS Miniendo, Spartan, and Satelec P-5. Surgical tips, pioneered by Dr. Garry Carr, are 1/4 mm in diameter.

1. Carr Tips (CT)
    a. CT 1 and CT 5: Used for anterior teeth; CT 5 is sharper.
    b. CT 2 and CT 3: Double-angled for posterior teeth.

2.5. Kim Surgical (KiS) Tips

Advanced zirconium nitride-coated tips with a 3 mm cutting edge and optimized irrigation ports for smoother, faster cutting with reduced microfractures.

1. KiS 1: 80° angled tip, 0.24 mm diameter, for anterior teeth and premolars.
2. KiS 2: Wider diameter tip for larger apex teeth, such as maxillary anteriors.
3. KiS 3: Designed for hard-to-reach posterior teeth, featuring a double end and a 75° angled tip for use on the maxillary left side or mandibular right side.
4. KiS 4: Similar to KiS 3 but with a 110° angled tip to access the lingual apex of molar roots.
5. KiS 5: Counterpart to KiS 3, intended for the maxillary right side and mandibular left side.
6. KiS 6: Counterpart to KiS 4, offering the same angulation and functionality.[6,7,8] (**Figure 2**)

2.6. Case selection for endodontic microsurgery

2.6.1. Indications

1. Persistent pain following previous endodontic therapy.
2. Anatomical deviations, such as tortuous roots, severe S- or C-shaped canals, sharp angle bifurcations, pulp stones, and calcifications, that prevent complete debridement and obturation.
3. Procedural errors, including ledge formation, canal blockage, perforation, instrument breakage, overfilling, or underfilling.
4. Exploratory surgery to identify unresolved issues.[9]

2.6.2. Contraindications

1. Proximity to vital anatomical structures, such as neurovascular bundles.
2. Presence of endodontic-periodontic lesions, as periodontal defects compromise surgical outcomes.
3. Patients who are very old, critically ill, or unable to endure the stress of a lengthy procedure.
4. Situations that exceed the clinician's skill level.

2.6.3. Relative contraindications

1. Active medical conditions, such as leukemia, neutropenia, or severe diabetes.
2. Patients recovering from recent heart or cancer surgeries.
3. Advanced age or poor general health may limit surgical tolerance but do not universally preclude treatment.[10,11]

2.6.4. Pre-assessment for microsurgery

1. Medical Evaluation: Assess the patient’s overall medical status and determine the need for antibiotic prophylaxis.
2. Radiographic Analysis: Conduct a detailed radiographic evaluation to gather vital information, such as the tooth's length, number of roots, degree of curvature, and any anomalies.[7]

Table 1: Comparison of traditional and microsurgical approaches in endodontics[23]

Parameter	Traditional approach	Microsurgical Approach
Magnification	Basic loupes	Advanced dental operating microscope
Flap Design	Semilunar flap	Papilla preservation
Apex Identification	Challenging	Highly precise
Osteotomy Size	Larger (8–10 mm)	Smaller (3–4 mm)
Inspection of Resected Root Surface	Not performed	Consistently performed
Bevel Angle	Steep (45°)	Minimal (<10°)
Isthmus Identification & Treatment	Rarely feasible	Routinely achieved
Root-End Preparation	Approximate (seldom inside the canal)	Accurate, always within the canal
Root-End Preparation Instrument	Dental bur	Ultrasonic tips
Root-End Filling Material	Less precise	Precisely placed
Sutures	4 × 0 Silk	5 × 0 or 6 × 0 Monofilament
Suture Removal Timing	7 days post-surgery	2–3 days post-surgery
Healing Success Rate (1 Year)	Moderate (40–90%)	High (85–96.8%)

Figure 1: Micromirror

Figure 2: KiS tips in the order of KiS 3, KiS4, KiS1, KiS 2, KiS5, KiS6

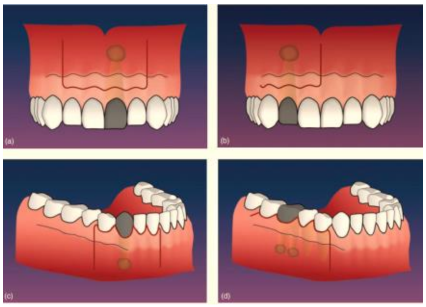

Figure 3: Flap designs in endodontic microsurgery: (**a**): Submarginal rectangular flap; (b): Submarginal triangular flap; (c): Sulcular rectangular flap; (d): Sulcular triangular flap. (Courtesy of Drs. Syngcuk Kim and Samuel Kratchman)

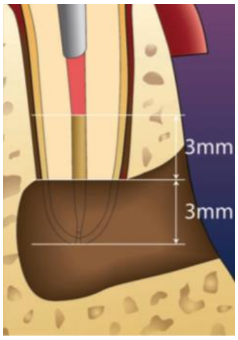

Figure 4: Resected root tip of 3 mm. (From Floratos et al.) (2017).

2.7. Procedure for microsurgery

2.7.1. Anesthesia and hemostasis

Anesthesia and hemostasis work together to ensure patient comfort and bleeding control during surgery.[1] A topical anesthetic (e.g., 5% Lidocaine ointment) is applied for 1–2 minutes, followed by a long-acting anesthetic like bupivacaine. Regional anesthesia is achieved with 1:50,000 epinephrine and lidocaine, injected along the flap area.[2,12] Slow submucosal injection of vasoconstrictors (e.g., 2% lidocaine with 1:50,000 epinephrine) 20–30 minutes before incision enhances hemostasis. Additional agents like Lidocaine, EMLA paste, epinephrine pellets, ferric sulfate, and Surgicel TM assist in pain relief and controlling bleeding.[13]

2.8. Soft tissue management and flap design

Effective flap design and soft tissue management are key to ensuring access and scar-free healing in endodontic microsurgery.[14] In surgical endodontics, two major categories of flaps are used:

1. Aesthetic-Oriented Flap: This flap is typically performed in the anterior region of the mouth. It involves a horizontal submarginal incision combined with one or two vertical releasing incisions. This approach prioritizes preserving the aesthetics of the soft tissue.
2. Functional-Oriented Flap: This flap is commonly used in the posterior region of the mouth or other areas where indicated. It consists of a horizontal sulcular incision paired with one or two vertical releasing incisions, focusing on functionality and adequate access.

In anterior surgeries, the goal is direct access to the apical lesion with a focus on soft tissue aesthetics. For molars, aesthetics is secondary, prioritizing convenient access for efficient surgery.

*2.9. Clinical indications for flap designs in endodontic microsurgery (**Figure 3**)*

1. Submarginal Rectangular Flap: (**Figure 3**a)
   a. Indication: Best for anterior teeth with long roots or crown-supported restorations, where preserving gingival margins is essential.
   b. Advantages: Maintains aesthetics, minimizes gingival recession, and allows good surgical access.
   c. Considerations: Requires adequate attached gingiva for proper healing.
2. Submarginal Triangular Flap: (**Figure 3**b)
   a. Indication: Suitable for anterior teeth with short roots and crown restorations when limited apical access is needed.
   b. Advantages: Single vertical incision simplifies flap repositioning, reducing trauma and improving healing.
   c. Considerations: Less access compared to the rectangular design but sufficient for small periapical lesions.
3. Sulcular Rectangular Flap: (**Figure 3**c)
   a. Indication: Recommended for uncrowned teeth or cases requiring full buccal root exposure, such as large periapical lesions or retreatments.
   b. Advantages: Provides maximum surgical access while preserving the periodontium.
   c. Considerations: Higher risk of gingival recession, especially in thin biotypes.
4. Sulcular Triangular Flap: (**Figure 3**d)
   a. Indication: Commonly used in posterior teeth where wide surgical access is required.
   b. Advantages: Simple design with minimal disruption to vascular supply, promoting healing by primary intention.
   c. Considerations: The vertical incision should be placed mesial to the mental foramen to preserve neurovascular structures.

2.10. Special considerations

For patients with high smile lines or thin-scalloped biotypes, esthetics requires careful attention. Flap design should always prioritize adequate access, functional outcomes, and minimal tissue disruption.[7,15,16,17]

2.11. Osteotomy and apical surgery

2.11.1. Osteotomy

Osteotomy, involving the removal of the cortical plate to expose the root end, should be performed with precision and care to ensure it is made directly at the root apices. Precise radiographs are essential to assess root length, curvature, apices position, and proximity to critical structures like the mandibular nerve or sinus. The cortical bone is carefully removed using a Lindemann bone cutter or Impact Air 45 handpiece with copious water spray to minimize heat and tissue damage. Smaller osteotomies (3–4 mm) promote faster healing. Curettes such as Columbia #13/14 and Jacquette 34/35 are used to remove granulation tissue efficiently.[7]

2.11.2. Apical root resection

The recommended apical resection length is 3 mm, followed by a 3 mm root-end cavity preparation, addressing 93% of apical ramifications and 98% of lateral canals. Adjustments may be required for curved or resorbed roots to optimize root-end preparation and filling. [18]

2.11.3. Bevel angle

A major benefit of microsurgery is the reduction or removal of the bevel angle. Traditional rotary burs recommended a steep bevel of 45–60° for access and visibility, but this angle caused significant tissue damage to buccal bone and root. Studies show that: (1) increased bevel slope led to more leakage, (2) deeper retrograde fillings reduced microleakage, and (3) the optimal retrograde depths were: 0° = 1 mm, 30° = 2.1 mm, and 45° = 2.5 mm.

2.11.4. Apical curettage with resection

Periapical lesions result from a leaky apical seal, allowing microorganisms and toxins to enter. Periradicular curettage removes the diseased tissues, but it addresses only the effect of the leakage, not the underlying cause. Apical surgery combines tissue removal, root resection, and retrofilling to eliminate both the cause and effect of the lesion, ensuring comprehensive treatment.[7]

2.11.5. Inspection of the root end in microsurgery

High-magnification inspection of the root end, absent in traditional techniques, is crucial in microsurgery to identify causes of treatment failure. Unlike traditional methods, which lack magnification, microsurgery employs 16× to 25× magnification for detailed inspection. After resection, the root end is rinsed, dried, and stained with methylene blue to reveal anatomical details.[19] Findings are categorized into macrofindings (e.g., isthmuses, missed canals) and microfindings (e.g., craze lines).

A fused, oval-shaped root often contains a web-like connection between two canals, referred to as an isthmus. This connection can be either complete or partial. Traditional apical surgery largely neglected the identification and treatment of isthmuses.

At 3 mm from the apex, isthmuses are present in:
1. 90% of mesiobuccal roots of maxillary first molars
2. 30% of maxillary and mandibular premolars
3. Over 80% of mesial roots of mandibular first molars[13]

2.11.6. Root end preparation in microsurgery

The primary objective of root-end preparation is to clean and shape the apical canal, creating a cavity that allows for a hermetic apical seal with the filling material. Ideally, the root-end preparation can be defined as Class I cavity extending at least 3 mm into the root dentine, with walls parallel to and aligned with the canal's anatomic outline.[2]

2.11.7. Challenges with conventional techniques
Traditional rotary burs used in a micro-handpiece present several difficulties:

1. Limited access to the root-end in confined spaces.
2. Risk of perforating the lingual root-end or creating a cavity misaligned with the canal path.
3. Inadequate depth and retention for root-end filling materials.
4. Exposure of dentinal tubules during resection.
5. Inability to remove necrotic isthmus tissue effectively.

2.11.8. Ultrasonic root-end preparation (USREP)
The USREP technique, performed under a microscope at 4× to 16× magnifications, addresses these limitations.

1. For single canal roots, the ultrasonic tip is centered in the canal, energized with coolant to prevent overheating, and allowed to passively advance to a depth of 3 mm.
2. In multi-canal roots with an isthmus (e.g., mesiobuccal root of maxillary first molars), each canal is prepared separately to ensure correct angulation before shaping the isthmus. Care is taken to avoid overheating during the process.

Ultrasonic techniques enhance precision, reduce risks, and improve treatment outcomes, making them the preferred choice for root-end preparation in modern microsurgery.[20]

2.12. Retrograde filling materials in endodontic microsurgery

2.12.1. Amalgam

Amalgam is an alloy containing mercury and has been widely used as a retrograde filling material. It is durable, less technique-sensitive, and easy to manipulate, with minimal placement time compared to other materials. Additionally, its corrosion products help seal the tooth-restoration interface, preventing bacterial leakage. However, its disadvantages include the potential for local allergic reactions, concerns about mercury toxicity, and the fact that it does not bond to the tooth structure.

2.12.2. Gutta percha

Gutta percha is primarily used in conjunction with root canal cement, as it does not adhere to the canal walls. One of its main advantages is that it provides a tight apical seal, as noted by Woo et al. (1990). However, its lack of adhesion to dentinal walls necessitates the use of an additional sealing agent, such as root canal cement, as recommended by Olson et al. (1989).

2.12.3. Gold foil

Gold foil has long been regarded as a premier restorative material due to its longevity, biocompatibility, smooth surface, and excellent marginal adaptability. Despite these advantages, its use has declined due to the need for high technical skill, the cost of the material, and the risk of root fracture under excessive condensation pressure.

2.13.4. Silver cones

Silver cones were historically used for root-end fillings but have significant limitations. They do not effectively obturate the root canal space in three dimensions, particularly in the coronal areas exposed during resection. Additionally, silver cones cannot be burnished to improve the apical seal, making them less effective than other materials.[21]

2.13.5. Glass ionomer cement

Glass ionomer cement is a hybrid material that combines the properties of silicate and polycarboxylate cements, offering physicochemical bonding to dentin and enamel along with anti-cariogenic properties. It has good biocompatibility and sealing ability (Chong et al., 1995), and it bonds chemically to dentin. However, freshly mixed glass ionomer cement has been reported to exhibit cytotoxic effects, and it's setting time ranges between 5-10 minutes. Additionally, it is highly sensitive to moisture and drying in its initial setting stage, which may lead to insufficient filling and the formation of voids (Khoury & Staehle, 1987).[22]

2.13.6. Zinc oxide eugenol

Zinc oxide eugenol is a material that forms a plastic mass when mixed with clove oil, originally described by Chisholm in 1873. It is dimensionally stable, offers good surface detail, and is easy to manipulate. However, it has certain disadvantages, including potential allergic reactions to eugenol, low mechanical strength, and high solubility, making it less durable than other materials.

2.13.7. Composite resins

Composite resins have been less commonly used as retrograde filling materials due to their cytotoxic effects on pulpal and periapical tissues. Despite concerns regarding their biocompatibility, selected products have shown promising results, with periodontal fiber reattachment observed in some cases (Andreasen et al., 1953) and long-term clinical success reported for specific formulations (Rud et al., 1996). However, composite resins remain moisture- and technique-sensitive, and concerns persist regarding their monomer content and initial cytotoxicity, which may last for over a month (Bruce et al., 1993).

2.14. IRM (Intermediate Restorative Material)

IRM is a reinforced zinc oxide eugenol cement that contains 20% polymethacrylate by weight. Retrospective studies have shown that IRM has a higher success rate compared to amalgam as a retrograde filling material. The addition of hydroxyapatite to IRM improves its sealing ability. Despite its advantages, IRM has some limitations, including condensation difficulties, radiopacity similar to that of gutta percha, and variations in setting time based on temperature and humidity. It also requires refrigeration to delay the setting process.[21]

2.15. Retroplast

Retroplast is a dentin-bonding composite resin system developed in 1984 for retrograde filling applications. In 1990, its formulation was modified by replacing silver with ytterbium tri-fluoride and ferric oxide. Some studies suggest that Retroplast promotes hard tissue formation at the root apex, with limited case reports indicating regeneration of the periodontium and cementum formation over the root-end restoration. However, its clinical effectiveness requires further investigation.[23]

2.16. Geristore (Resin Ionomer Suspension)

Geristore is a resin-based glass ionomer designed to combine the best properties of composite resins and glass ionomers. Its advantages include self-adhesion, eliminating the need for retentive cavity design and reducing chair time. It bonds effectively to enamel, dentin, cementum, metals, and old amalgam, making it a versatile restorative material. Additionally, it has low polymerization shrinkage, excellent marginal integrity, resistance to marginal leakage, and proven biocompatibility. However, it is technically challenging to place in root-end cavities, requiring light activation and a resin bonding agent.[24]

2.17. MTA (Mineral Trioxide Aggregate)

Developed at Loma Linda University by Torabinejad, MTA is a hydrophilic powder that sets in the presence of moisture. Initially, its pH is 10.2, rising to 12.5 within three hours. It is considered the least toxic of all retrograde filling materials and exhibits excellent biocompatibility. MTA forms a strong marginal seal, is non-resorbable, and stimulates cementum formation. However, it is difficult to manipulate, has a long setting time (2 hours 45 minutes), and is relatively expensive. Additionally, it lacks antimicrobial properties and may dissolve in acidic environments.[25,26]

2.18. Viscosity-enhanced root repair material (VERRM)

VERRM is a newer retrograde filling material formulated using Portland cement as the base material. To improve its radiopacity and handling characteristics, bismuth oxide and other compounds have been added. Studies by Hut Kheng Chng et al. have shown that VERRM shares similar physical properties with MTA and is biocompatible with periradicular tissues, making it a promising alternative.[27]

2.19. Biodentine

Biodentine™ was developed by Septodont's Research Group as a high-performance dental material that combines mechanical strength, biocompatibility, and bioactivity. It has been demonstrated to be among the most biocompatible biomaterials in dentistry, as confirmed by various ISO standard tests and research studies. Additionally, preclinical and clinical studies have shown that Biodentine™ promotes reactionary dentin formation, exhibiting both high quality and quantity of protective dentin stimulation in indirect pulp capping procedures.[28]

Clinicians should select retrograde filling materials that provide a hermetic seal, biocompatibility, and dimensional stability while being non-toxic, non-cariogenic, and cost-effective. Based on the literature, Biodentine and MTA are the most effective root-end filling materials due to their excellent sealing properties, biocompatibility, and clinical reliability.

2.20. Flap repositioning and suturing

The aesthetic outcome of soft tissue manipulation depends on multiple factors, including tissue type, incision design, choice of instruments for incision, elevation, and retraction, as well as precise reapproximation and appropriate suturing techniques.

To maintain tissue integrity during the procedure, it is essential to rehydrate the soft tissue to restore its natural elasticity, facilitating easier re-approximation.

2.20.1. Suturing techniques

1. Continuous Sling Suture:
    a. Often employed in microsurgery, providing efficient and secure tissue closure.
2. Single Knot (Interrupted) Suture:
    a. Offers precise and stable closure.
    b. Facilitates primary closure of the flap.

c. Requires careful and time-intensive application, particularly for submarginal flaps in the anterior region.

By selecting the right suturing method and ensuring proper tissue handling, a favorable esthetic and functional result can be achieved.[13]

2.21. Prognosis of endodontic microsurgery

The primary goal of endodontic microsurgery is the resolution or improvement of apical periodontitis. Modern advancements, such as the use of dental operating microscopes, ultrasonics, specialized microsurgical instruments, and biocompatible root-end filling materials, have significantly improved treatment outcomes.

2.21.1. Clinical success rates

1. Short-term success (1 year): 96.8%
2. Long-term success (5–7 years): 91.5%

Regular clinical and radiographic follow-ups for at least one year, as recommended by the European Society of Endodontology (ESE), are essential for assessing treatment outcomes. The majority of healing occurs within approximately 7.1 months, which suggests that a 6-month follow-up may be insufficient.

2.21.2. Factors influencing prognosis

1. Lesion Size: Larger lesions require more time to heal.
2. Case Selection: Strict and proper case selection is crucial for achieving successful outcomes. Kim and Kratchman proposed a surgical classification (A–F) to guide case selection for optimal results.

2.21.3. Radiographic evaluation

Molven's radiographic classification system aids in reducing bias and variability during follow-up assessments by categorizing healing into four groups, Success is defined as either group 1 (complete healing) or group 2 (incomplete healing with scar tissue), and clinically by the absence of pain, swelling, percussion sensitivity, or sinus tract. Failure includes group 3 (uncertain healing with reduced lesion size) and group 4 (unsatisfactory healing with no change or increased lesion size).

2.21.4. Comparison with traditional techniques

Studies published in the Journal of Endodontics demonstrate that microsurgical approaches:

1. Achieve higher clinical success rates at 1-year follow-ups.
2. Exhibit reduced postoperative sequelae compared to traditional methods.

In summary, endodontic microsurgery provides predictable and superior treatment outcomes, with strict case selection and proper follow-up being vital to ensuring long-term success.

2.22. Recent advancements in endodontic microsurgery

Endodontic microsurgery has seen significant advancements in recent years, enhancing precision, patient outcomes, and expanding the scope of treatment options. These developments are largely attributed to technological innovations and refined surgical techniques.

2.23. Piezoelectric surgery

The evolution of piezoelectric surgery has introduced thinner, more powerful piezoelectric blades, facilitating procedures like the bone window technique. This method involves temporarily removing and preserving a section of the cortical bone to access underlying structures, which is then repositioned post-surgery. The primary benefits include preserving bone integrity and minimizing trauma, leading to improved healing outcomes. Studies have demonstrated that ultrasonic instruments used in piezoelectric surgery result in less intraoperative bleeding, better visibility, and faster bone healing compared to traditional rotary instruments.[29,30]

2.24. Laser technology

Laser technology has also been incorporated into endodontic microsurgery, offering benefits such as reduced bleeding, less swelling, and decreased postoperative pain. Lasers can be used to make incisions, remove diseased tissue, and sterilize the surgical area, all while causing minimal trauma to the patient. The precision of laser technology ensures that the surgery is not only effective but also promotes quicker healing and recovery times.[31]

2.25. Advanced imaging and healing assessment

The integration of Cone Beam Computed Tomography (CBCT) has revolutionized pre-surgical planning and postoperative assessment in endodontic microsurgery. Its detailed three-dimensional imaging enables precise evaluation of periapical lesions, optimal surgical path selection, and differentiation between healing outcomes, such as scar tissue formation versus incomplete healing. By minimizing invasiveness and improving clinical decision-making, CBCT enhances treatment success and patient management.[3]

2.26. Guided surgical techniques and artificial intelligence

The advent of guided surgical techniques, utilizing 3D-printed templates or stents, has improved the accuracy of osteotomies and root resections.[32] These guides are designed based on CBCT data and intraoral scans, ensuring precise surgical interventions.[3] Additionally, the incorporation of artificial intelligence (AI) in endodontics is emerging, with applications in automated detection of periapical lesions and treatment planning. AI has the potential to enhance diagnostic accuracy and predict treatment outcomes, thereby improving patient care.[33]

2.27. Robotics in endodontic treatment

Robotic systems have begun to make their way into the endodontic microsurgery arena as well. These systems provide a level of precision that is difficult to achieve manually, with steadier instrument handling and the ability to perform complex movements that are challenging for human hands. Robots can also minimize fatigue and increase the consistency of surgical procedures, which is particularly advantageous in microsurgical environments where small errors can have significant consequences. The development of robotic systems, such as DentiBot, which features real-time monitoring and hybrid position/force control, represents a significant step forward. These systems adjust to patient movements and provide consistent, precise manipulations during endodontic treatments, reducing the risk of procedural errors and improving patient outcomes.[34,35,36]

2.28. Augmented reality in surgical navigation

The continued development of these technologies suggests a future where endodontic microsurgery will become even less invasive and more patient-friendly. Innovations such as augmented reality (AR) for surgical navigation and the further refinement of robotic systems are likely to push the boundaries of what is currently possible. AR could overlay critical information directly onto the surgeon's field of view during the operation, enhancing decision-making and surgical precision. Meanwhile, advancements in robotic technologies could lead to more autonomous procedures, potentially increasing the accessibility and standardization of treatments.[37]

2.29. Biocompatible materials

The introduction of advanced biocompatible materials, such as bioactive ceramics, has improved the success rates of endodontic surgeries. These materials promote better sealing of the root canal system and facilitate faster healing, reducing the likelihood of postoperative complications. Their properties have made them a preferred choice in modern endodontic microsurgical procedures.[37,38,39]

3. Conclusion

Endodontic microsurgery with advanced tools, materials and modern techniques ensures predictable and effective healing of endodontic lesions. Continued research will further improve its effectiveness and address future challenges, establishing it as a leading approach in contemporary dental practice.

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None.

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7. References

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