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Evolution Of Periapical Surgery From Conventional To Microsurgical Approaches: A Review

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Abstract

Periapical surgery has undergone a remarkable transformation from conventional, technique-oriented procedures to modern, precision-based microsurgical approaches. Conventional periapical surgery, though effective in eliminating pathology, often involved large osteotomies, limited visualization, and variable healing outcomes. The advent of Endodontic Microsurgery (EMS), driven by magnification, illumination, and microsurgical instrumentation, has redefined surgical standards with smaller osteotomies, enhanced accuracy, and improved biological healing. The introduction of technologies such as Cone Beam Computed Tomography (CBCT), ultrasonic retro-tips, and biocompatible materials like Mineral Trioxide Aggregate (MTA) and Biodentine has further advanced diagnostic precision and regenerative outcomes. Integration of digital guidance, dynamic navigation, and biologic adjuncts supports minimally invasive, predictable procedures with high success rates. This evolutionary progression reflects a paradigm shift toward biologically centered, technologically integrated, and patient-friendly surgical endodontics, enhancing both clinical efficiency and long-term prognosis.

Keywords: Periapical Surgery, Microsurgery, Cone Beam Computed Tomography, Ultrasonics, Oral and Maxillofacial Surgery.

Introduction

Periapical pathology encompasses a range of inflammatory and infectious conditions that affect the tissues surrounding the apex of a tooth, primarily resulting from pulpal necrosis or bacterial invasion of the root canal system. These pathologies, including periapical granulomas, cysts, and abscesses, arise when microorganisms and their byproducts induce periapical inflammation, leading to bone resorption and radiographically visible periapical radiolucencies.[1] Clinically, patients may present with pain, swelling, sinus tract formation, or may remain asymptomatic with lesions detected incidentally. The underlying etiology typically involves pulp necrosis secondary to dental caries, trauma, or restorative procedures, while the pathogenesis is characterized by persistent microbial infection within the root canal that extends to the periapical tissues.[2] Although nonsurgical root canal therapy remains the first line of treatment for managing periapical lesions, certain cases demonstrate persistent radiolucencies or recurrent infection due to complex root canal anatomy, inaccessible areas, or procedural complications such as perforations or separated instruments. In such scenarios, periapical surgery serves as a valuable treatment option, aiming to eliminate pathological tissue, achieve apical sealing, and promote periradicular healing through surgical access, root-end resection, and retrograde filling.[3] Indications for surgical intervention include failure of nonsurgical retreatment, persistent lesions unresponsive to conservative management, large cystic or granulomatous pathologies, and anatomical variations such as dilacerated or ankylosed roots that limit orthograde access. Over the past century, periapical surgery has evolved remarkably from conventional methods focused on lesion removal and simple retrograde sealing to advanced microsurgical techniques emphasizing precision, biological compatibility, and minimally invasive intervention.[4] Early 20th-century procedures relied on direct excision with limited visualization, while mid-20th-century developments introduced refined flap designs and root-end management strategies. Conventional approaches often employed large osteotomies (8–10 mm), steep bevels (45–65°), and retrograde preparations using burs, typically restored with materials such as silver amalgam or IRM, yielding moderate success rates (40–90%) and considerable postoperative morbidity.[5] The advent of endodontic microsurgery revolutionized the field by integrating high-magnification surgical microscopes or endoscopes, enhanced illumination, micro-instrumentation, and ultrasonic retro-tips that allow conservative osteotomies (3–4 mm), minimal bevels (0–10°), and precise isthmus detection and management. This transition from conventional to microsurgical periapical surgery represents a paradigm shift toward evidence-based, minimally invasive, and biologically driven endodontic care.[6]

Review of Literature

The evolution of periapical surgery from traditional to microsurgical approaches marks a pivotal advancement in endodontic treatment, significantly improving precision, visualization, and healing outcomes. Early conventional techniques, though effective in lesion removal, often involved extensive osteotomies, steep root-end bevels, and limited illumination, resulting in greater tissue trauma and variable success rates. With the introduction of dental operating microscopes, microsurgical instruments, and ultrasonic tips, procedures such as apicoectomy have become more conservative and predictable, offering superior clinical outcomes and reduced postoperative morbidity (Budacu et al., 2025; Krastev & Filipov, 2020).[7,8] The advent of micro-instruments and micro-tips has enhanced the quality of root-end cavity preparation, enabling better control and minimizing structural compromise (Arx, 2011).[9] Diagnostic innovations, particularly Cone Beam Computed Tomography (CBCT), have further refined case selection and treatment planning by providing three-dimensional visualization of periapical anatomy, lesion extent, and adjacent structures, thereby reducing surgical risks and improving accuracy (Kale et al., 2024; Budacu et al., 2025). In parallel, the incorporation of bioactive materials such as Mineral Trioxide Aggregate (MTA) and Biodentine has transformed the biological outcomes of periapical surgery by promoting cementogenesis, osteogenesis, and sealing integrity, ultimately facilitating true tissue regeneration rather than mere repair (Kale et al., 2024; Budacu et al., 2025). Recent trends also point toward the integration of nanotechnology, digital workflows, and artificial intelligence to enhance surgical precision, automate diagnostic interpretation, and optimize preoperative planning (Budacu et al., 2025). Nonetheless, despite these advances, some clinicians emphasize that conventional approaches continue to hold clinical relevance in select scenarios where microsurgical resources, expertise, or case complexity may limit the application of advanced techniques. This balanced perspective underscores the importance of individualized treatment planning, where the choice between conventional and microsurgical methods is guided by lesion characteristics, operator proficiency, and patient-specific factors to achieve optimal therapeutic outcomes in periapical surgery.[10]

Conventional Periapical Surgery

Conventional periapical surgery comprises a sequence of well-defined surgical procedures aimed at eliminating periapical pathology and achieving apical sealing when nonsurgical endodontic treatment fails or proves inadequate. The procedure begins with careful flap design and reflection, where a mucoperiosteal flap—triangular, trapezoidal, or semi-lunar—is created to access the periapical area while minimizing trauma to the periosteum and surrounding tissues.[11] Following flap elevation, an osteotomy is performed by removing the cortical bone overlying the root apex using rotary instruments such as round burs under copious irrigation, thereby exposing the pathological site. Root-end resection, or apicoectomy, involves removing approximately 3 mm of the apical portion at a 45-degree bevel angle to eliminate the apical delta and infected segments while facilitating subsequent sealing.[12] Once the root tip is resected, a retrograde cavity is prepared at the root end using small burs or ultrasonic tips to establish a clean and retentive space for retrofilling. The prepared cavity is then sealed with retrograde filling materials such as amalgam, Intermediate Restorative Material (IRM), or Super-EBA to ensure a hermetic seal and prevent microbial leakage into the periapical tissues.[13] The armamentarium traditionally includes low-speed fissure and round burs, curettes, elevators, and retractors, designed for efficient tissue management and access. Despite its clinical utility, conventional periapical surgery is associated with several limitations. The absence of magnification hinders visualization of the resected root surface, isthmuses, and accessory canals, increasing the likelihood of incomplete debridement.[14] Furthermore, the need for large osteotomies (typically 8–10 mm) results in greater bone removal, tissue trauma, and delayed healing, contributing to increased postoperative discomfort and inflammation. Consequently, these factors, along with the use of non-biocompatible or less durable root-end filling materials, have contributed to historically moderate success rates ranging between 40% and 70%.[15] In summary, conventional periapical surgery effectively addresses periapical infections through lesion excision and root-end sealing but remains constrained by limited precision, higher morbidity, and variable healing outcomes—challenges that have ultimately driven the evolution toward microsurgical techniques offering enhanced accuracy, reduced trauma, and superior prognoses.[5,9]

Microsurgery

Endodontic Microsurgery (EMS) represents a transformative evolution in periapical surgery, founded on the principles of achieving procedures that are "smaller, cleaner, and more predictable." It emphasizes precision through the integration of magnification, illumination, and advanced microsurgical instrumentation.[16] EMS is defined as a minimally invasive surgical intervention performed at the root apex to manage persistent periapical pathologies that fail to resolve through conventional endodontic therapy. The core philosophy focuses on tissue preservation, minimal surgical trauma, and enhanced predictability of healing outcomes. The introduction of the Surgical Operating Microscope (SOM) has been a pivotal advancement, offering superior visualization and illumination of the operative field, thereby allowing clinicians to identify root apices, accessory canals, and microanatomical details with exceptional accuracy.[17] This improvement facilitates conservative osteotomies (approximately 3–4 mm in diameter) compared to the larger access windows of traditional surgery, enabling sharper and more controlled root-end bevels while minimizing tissue disruption. Ultrasonic instruments have further refined EMS by replacing conventional burs for root-end cavity preparation, allowing for conservative, centered preparations that align with the canal's long axis, reduce unnecessary dentin removal, and improve access to isthmuses for optimal sealing.[18] In parallel, the adoption of modern biocompatible root-end filling materials such as Mineral Trioxide Aggregate (MTA), Biodentine, and Calcium Enriched Mixture (CEM) cement has dramatically improved clinical outcomes due to their superior sealing ability, biocompatibility, and capacity to induce cementogenesis and periapical tissue regeneration. Moreover, EMS often integrates regenerative adjuncts through Guided Tissue Regeneration (GTR) techniques, employing bone grafts to fill osseous defects, resorbable membranes to direct selective cellular growth, and biologically active agents or growth factors to promote enhanced bone and soft tissue healing.[7,11]

Parameter	Conventional Periapical Surgery	Endodontic Microsurgery (EMS)
Surgical Philosophy	Focused on lesion removal and root-end sealing; technique-oriented.	Biologically driven and precision-oriented; aims for tissue preservation and regeneration.
Visualization	Performed with the naked eye or loupes; limited visibility of fine structures.	Uses surgical operating microscope (SOM) or endoscope for high magnification and illumination.
Access and Osteotomy	Large osteotomy (8–10 mm) to access the root apex; more bone removal.	Small, conservative osteotomy (3–4 mm); minimal bone removal and trauma.
Root-End Resection	45° bevel; greater removal of root structure; limited control of angulation.	0–10° bevel; precise and conservative root resection preserving root integrity.
Root-End Preparation	Done with burs; limited centering and control; less adaptation of filling.	Done with ultrasonic micro-tips; centered and conservative preparation following canal axis.
Bone and Tissue Management	Greater tissue trauma, bleeding, and postoperative swelling.	Minimal trauma, precise tissue handling, faster healing, less inflammation.
Use of Regenerative Techniques	Rarely incorporated; limited to lesion curettage and filling.	Often includes Guided Tissue Regeneration (GTR), bone grafts, and biologics (PRF, membranes).
Healing and Prognosis	Healing by scar tissue; moderate success (40–70%).	True tissue regeneration; high success rates (85–96%).
Surgical Precision and Control	Limited by poor visibility and instrumentation.	Highly precise with controlled, minimally invasive procedures.

Technological Innovations and Digital Integration in Periapical Microsurgery

Technological innovations have revolutionized periapical microsurgery by enhancing diagnostic precision, surgical accuracy, and treatment predictability, with Cone Beam Computed Tomography (CBCT) standing at the forefront of this evolution. CBCT provides high-resolution, three-dimensional imaging of the maxillofacial region, allowing clinicians to assess root morphology, proximity to vital anatomical structures, and the extent of periapical pathology with unparalleled clarity. This enables meticulous preoperative planning, minimizes unnecessary bone removal, and enhances surgical outcomes. Complementing this advancement, dynamic navigation and digital guidance systems have introduced real-time tracking and precise instrument placement, ensuring minimally invasive access and reduced operative trauma.[18] The refinement of microsurgical instruments—such as micro-mirrors, micro-scalpels, and micro-curettes has further improved tactile precision, enabling delicate dissection and accurate root-end preparation under the surgical microscope. Additionally, endoscopic visualization and laser-assisted techniques contribute to superior illumination, enhanced microbial decontamination, and faster postoperative healing. The integration of digital dentistry combining CBCT data with computer-aided design (CAD), 3D printing, and navigation-guided surgical workflows has created a seamless continuum from diagnosis to execution, facilitating highly predictable and efficient outcomes.[19] Looking ahead, emerging frontiers such as robotic-assisted microsurgery promise unprecedented precision and consistency, while artificial intelligence (AI) algorithms may soon analyze CBCT datasets for lesion characterization, prognosis prediction, and surgical pathway optimization. Concurrently, advancements in biomimetic and bioengineered materials aim to accelerate periapical tissue regeneration and enhance biocompatibility, marking a transformative future for microsurgical endodontics within the broader realm of oral and maxillofacial surgery.[20]

Conclusion

The evolution from conventional periapical surgery to microsurgical approaches marks a paradigm shift from extensive, invasive procedures to minimally traumatic, precision-driven interventions. Enhanced visualization, refined instrumentation, and biocompatible materials have redefined surgical accuracy and predictability. This transition emphasizes tissue preservation, reduced morbidity, and accelerated healing. Ultimately, periapical microsurgery embodies the integration of technology and biology for superior clinical and regenerative outcomes.

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