Integrated Micro-Endodontic Surgical Management of a Persistent Periapical Lesion in a Maxillary Central Incisor: A Case Report

Tanty Permatasari Frima[1,*],Denny Nurdin[2],Opik Taofik Hidayat[2]

[1]Postgraduate Specialist Program in Conservative Dentistry, Faculty of Dentistry, Universitas Padjadjaran, Indonesia
[2]Department of Conservative Dentistry, Faculty of Dentistry, Universitas Padjadjaran, Indonesia

Corresponding Author: tanty23001@mail.unpad.ac.id

ABSTRACT

Background:
Managing persistent periapical lesions in anterior teeth of adolescent patient presents a clinical challenge. While conventional root canal therapy remains the first line of treatment, certain cases may not respond adequately, especially when the lesion involves extensive bone destruction. In such scenarios, a surgical endodontic intervention becomes a vital alternative to preserve the affected tooth.
Case Report:
A 15-year-old female patient presented with tooth 11 previously treated endodontically. However, the CBCT revealed a periapical radiolucency associated with possible apical root crack and cortical bone perforation. Given the lesion's extent and the limited prognosis of nonsurgical retreatment, a decision was made to perform a micro-endodontic surgical procedure. The procedure involved a submarginal Ochsenbein–Luebke flap, apical resection, curettage, root-end preparation, and retrograde obturation with mineral trioxide aggregate (MTA). To enhance healing, bone grafting and membrane placement were performed prior to wound closure. Histopathological analysis of the excised lesion confirmed a periapical cyst.
Objective:
This case underscores the critical role of accurate diagnosis using advanced imaging such as CBCT and highlights the value of a multidisciplinary approach in treating persistent lesions. The use of biocompatible regenerative materials like MTA and bone grafts can promote healing and maintains anterior aesthetics in adolescent patients.
Conclusion:
Micro-endodontic surgical management offers a predictable and conservative solution, especially for persistent periapical lesion in previously treated teeth, ensuring both functional preservation and aesthetic integrity.

Keywords
Apicoectomy, Bone graft, Cone-Beam Computed Tomography, Maxillary central incisor, Periapical cyst, MTA, Microsurgery.

INTRODUCTION

The success of nonsurgical root canal treatment is commonly determined by the absence of clinical symptoms such as swelling, pain, or the presence of a sinus tract, along with the preservation of normal tooth function and radiographic evidence of an intact periodontal ligament. The prognosis can also be confirmed radiographically by the resolution of apical radiolucency and the reappearance of the lamina dura, both of which indicate ongoing periapical healing. Among the clinical factors that play a decisive role in treatment outcome, the apical extent of the root canal filling is considered critical. If the filling material or bacterial biofilm extends beyond the apical foramen into the surrounding periapical tissues, it may act as a foreign body and trigger an inflammatory reaction, thereby prolonging the healing process or ultimately resulting in treatment failure.[1,2]

Although nonsurgical root canal treatments are often successful, a proportion of cases may still fail. Such failures are commonly linked to factors such as residual bacteria within complex root canal systems that are difficult to instrument, or the persistence of infection beyond the apical region. [3-8]

Conventional root canal therapy (RCT) is generally the first-line treatment and achieves high success rates in eliminating infection and promoting periapical healing.[9,10] Nevertheless, in cases with extensive periapical bone destruction or when conventional retreatment fails, the outcome may be unsatisfactory. In such cases, surgical endodontics serves as a valuable alternative to conventional retreatment, as it allows direct management of persistent periapical pathology that may not resolve with nonsurgical approaches. This intervention is particularly important for younger patients, where preservation of the natural tooth is critical not only for maintaining structural integrity and function but also for ensuring aesthetic outcomes during a formative stage of development. This report describes the integrated surgical-endodontic management of a persistent periapical lesion in a maxillary anterior tooth of an adolescent patient.[11,12]

Endodontic surgery has evolved into endodontic microsurgery, integrating high-magnification visualization, ultrasonic root-end preparation, and advanced biomaterials such as mineral trioxide aggregate (MTA) and guided tissue regeneration (GTR). This approach has increased long-term success rates to over 90% compared with 40–70% for traditional apical surgery. [13-15]

This case report describes the integrated micro-endodontic surgical management of a persistent periapical lesion in a maxillary central incisor of an adolescent, highlighting the role of cone-beam computed tomography (CBCT) in diagnosis, microsurgical techniques, and regenerative biomaterials in promoting predictable outcomes.[16-19]

CASE PRESENTATION

A 15-year-old female patient presented to the Department of Conservative Dentistry, Universitas Padjadjaran, with a referral for persistent apical pathology following root canal treatment on the maxillary right central incisor (tooth 11).

Figure 1. Preoperative intraoral photographs (a) right lateral view. (b) frontal view. (c) left lateral view.

History and Clinical Examination: The patient reported a large carious lesion two years prior, followed by endodontic treatment at the end of 2024. She denied any systemic illnesses, allergies, or significant medical history.

Chief complaint: no pain, but referred due to persistent radiographic lesion. Extraoral examination revealed no facial asymmetry, lymphadenopathy, or swelling. Intraoral examination showed good oral hygiene (OHI-S 2.6), Angle's Class I occlusion, no sinus tract, and negative responses to percussion and palpation.

Radiographic and CBCT Findings: Periapical radiographs and CBCT revealed root canal filling extending to the working length, apical radiolucency measuring approximately 2 mm, and CBCT periapical index score 3, a suspected crack or accessory lateral canal was noted in the apical third (figure 2).

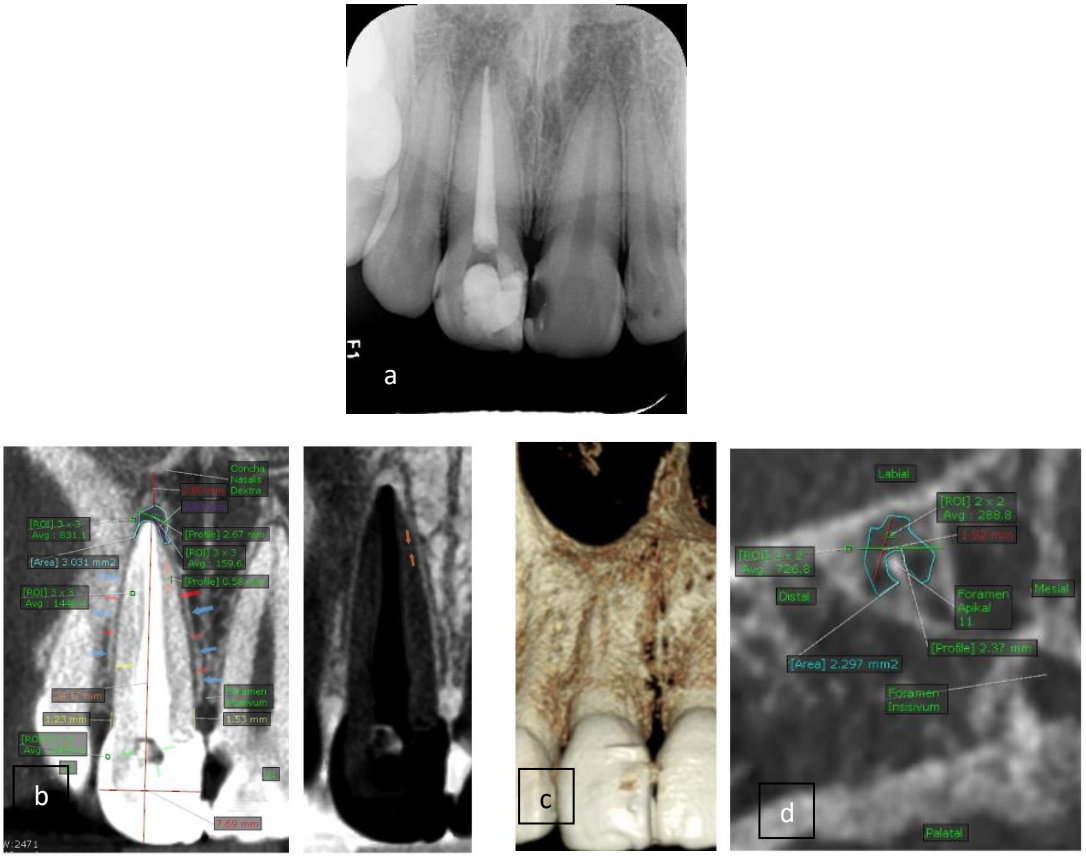

Figure 2.Preoperative radiograph of tooth 11 (a) Periapical radiograph, showing a filling along the root canal up to the apical of the tooth. (b) CBCT frontal view, there is a radiolucency at the apical of the tooth with an area of 3 mm^2 and radiolucent line overlaying a crack (red arrow) in the apical third of the mesial part of root. (c). Image of the cortical bone in the frontal area. (d). Image of the palatal area with a lesion size of 2.2 mm^2.

Table 1. Periapical tissue evaluation of 1st CBCT. Periapical and Endodontic Status Scale

Tooth		**11**
	CBCTPAI	3
PESS	Skor COPI	S1 – R1 – D1
	Skor ETTI	L1 – H1 – CS1 – CF5

Diagnosis: Tooth 11 – previously treated, with a persistent periapical lesion and a suspected apical root crack. The patient was observed for two months. She reported no pain and exhibited a negative response to percussion testing. Follow-up treatment was performed, which included the insertion of a fiber post and crown on tooth 11.

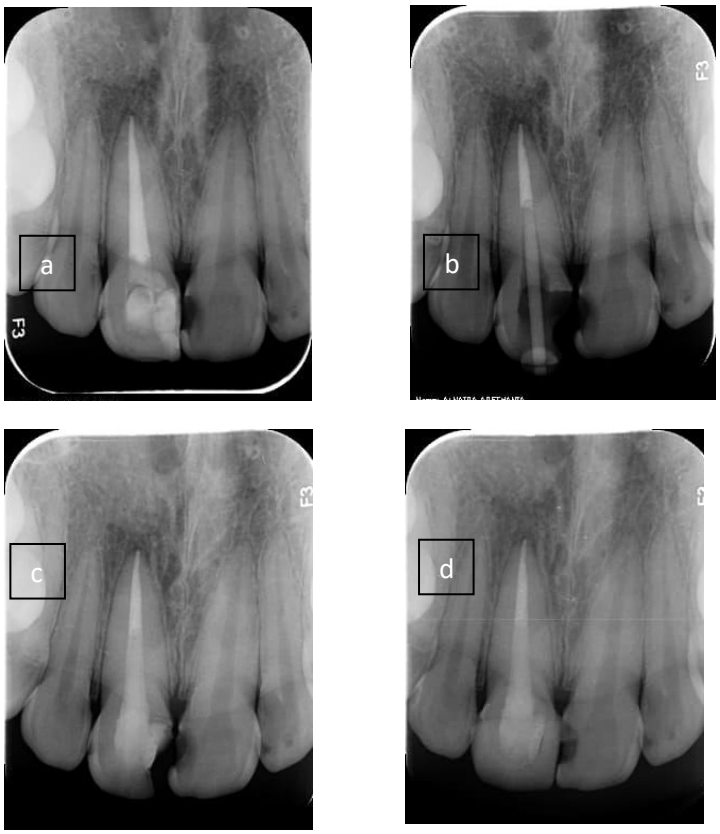

Figure 3. Radiographic image of the fiber post insertion process. (a). Preoprative post and crown procedure, (b). Removal of a sufficient amount of gutta percha as preparation for the fiber post space. (c). Cementation of fiber post use dual cure cement. (d). Cementation of lithium disilicate crown.

The patient returned to the clinic for an evaluation 3 months later. Subjective and objective examinations revealed no complaints of pain, clinical findings were satisfactory, with negative responses to percussion testing (figure 4). A follow-up radiographic examination was then performed. Six months after treatment, a second evaluation was performed using CBCT radiography.

Figure 4. Intraoral image after lithium disilicate crown insertion

Radiographic and CBCT Findings: Periapical radiographs and CBCT revealed radiopaque image along the root canal, apical radiolucency measuring approximately 4 mm, cortical bone perforation at the labial aspect, and CBCTPAI score 4, suggestive of a persistent periapical lesion (figure 5).

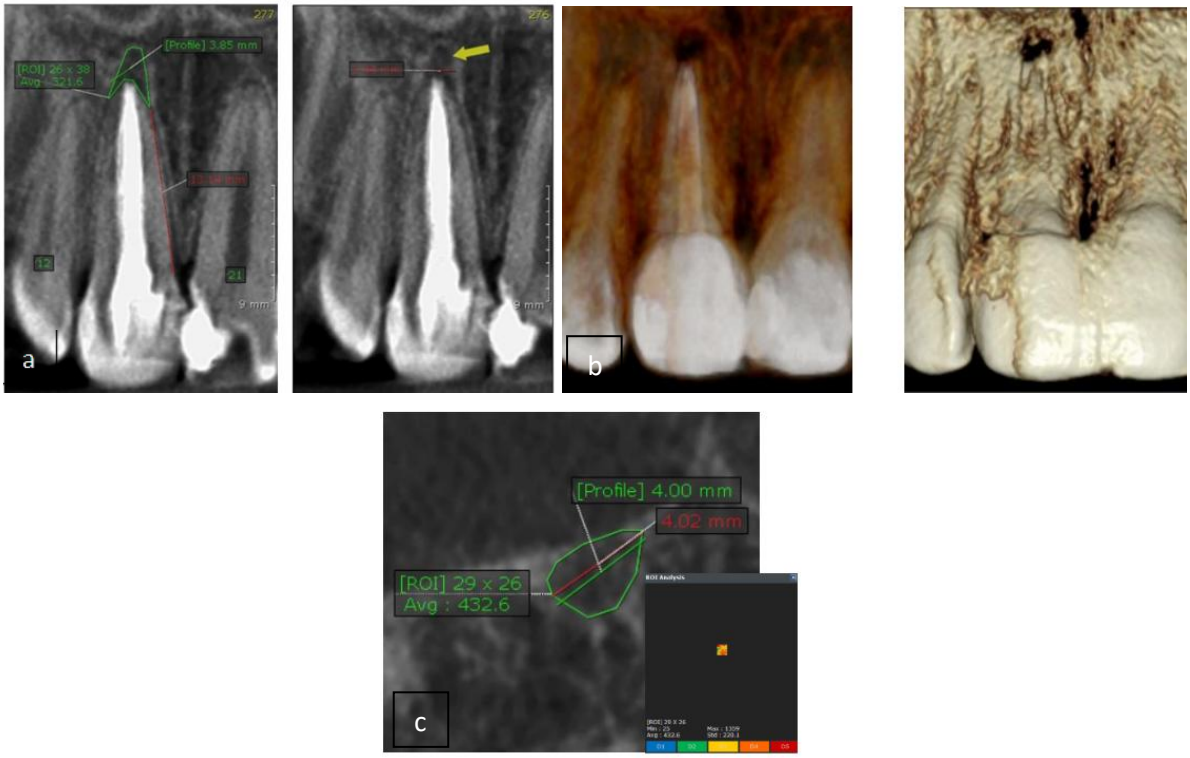

Figure 5. Evaluation CBCT radiograph of tooth 11 (a) CBCT radiograph, showing a filling along the root canal up to the apical of the tooth. (b) CBCT frontal view, there is a radiolucency at the apical of the tooth with diameter an area of 4,02 mm and destruction of the cortical bone in the frontal area. (c). Image of the lesion area, size of 4.00-4.02 mm.

Table 2. Periapical tissue evaluation. Periapical and Endodontic Status Scale from based on the second CBCT image.

Tooth		**11**
	CBCTPAI	4D
PESS	Skor COPI	S2 – R1 – D3
	Skor ETTI	L1 – H1 – CS1– CF5

Diagnosis: Tooth 11 – previously treated, persistent periapical lesion with suspected apical root crack. Histopathology confirmed a periapical cyst.
Treatment Plan: Given the extent of the lesion and poor prognosis of nonsurgical retreatment, a micro-endodontic surgical procedure with a regenerative approach was planned.[18,20,21]
Surgical Procedure: Endodontic microsurgery of tooth 11 was carried out. For preoperative pain control, an analgesic (Ibuprofen 400 mg) was administered orally 30 minutes before the surgery. Local anaesthesia was achieved with 2% lidocaine with 1:80,000 epinephrine for haemostasis. A submarginal Ochsenbein–Luebke flap was raised to preserve marginal gingiva and aesthetics. The gingiva and mucosa were incised using a 15c blade. At the sulcus and base of the papilla, a partial thickness flap was initially raised followed by a full thickness mucoperiosteal flap extended apically. The flap included two vertical releasing incisions, extending from the distal of tooth 12 to the distal of tooth 21 (figure 6).

Figure 6. Flap design: Full Thickness flap Submarginal Ochsenbein-Lubke Incision

Based on the CBCT measurement, the distance from the alveolar crest to the lesion was determined. The location of the lesion was estimated using the aid of k-file (figure 7).

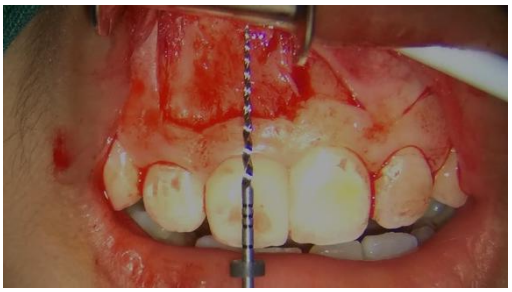

Figure 7. Measurement of lesion location at the apex of the tooth based on working length in root canal treatment.

Any remaining debris was rinsed with normal saline, the lesion was clearly visible at the apex of the tooth. The lesion attached to the apical part of the tooth with apicoectomy aim to remove the tissue, followed by periapical curettage (figure 8). To ensure debridement of the apical region while preserving healthy surrounding tissue, the periapical lesion along with the apical third of tooth #11 was excised, and approximately 3 mm of the root apex was resected. Apical resection and periapical curettage were subsequently performed. Root-end preparation was performed using ultrasonic tips, followed by retrograde filling with MTA to achieve a hermetic seal.

Figure 8. The lesion is visible directly attached to the apex of tooth 11.

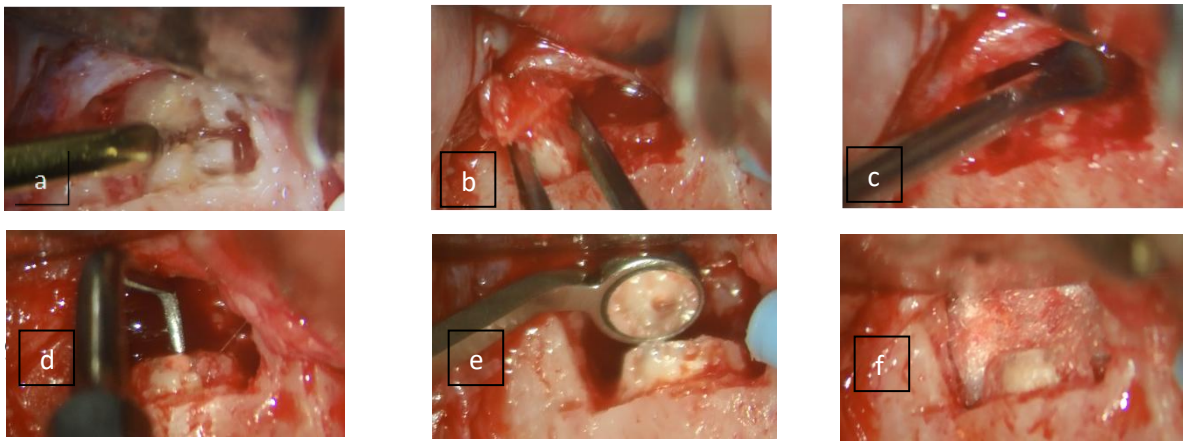

Figure 9. Clinical picture during surgery: (a). root resection. (b). lesion removal. (c). curettage. (d). root-end preparation. (e). post preparation. (f). steril gauze applied, preparation root end filling-MTA.

Guided tissue regeneration was applied using a xenograft bone substitute and resorbable membrane. This helps accelerate the healing process. The flap was repositioned and sutured with 5-0 monofilament sutures.[22, 23, 24,]

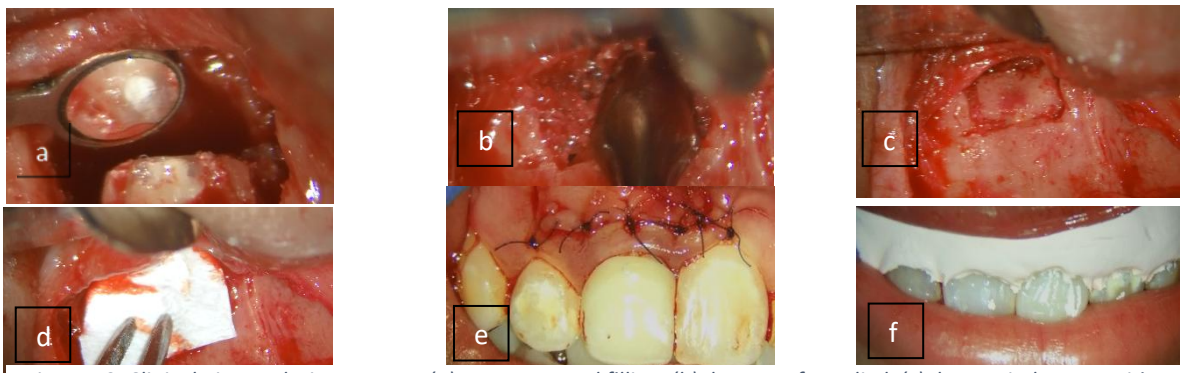

Figure 10. Clinical picture during surgery: (a). MTA-root end filling. (b). bone graft applied. (c). bone window reposition. (d). resorbable membrane applied. (e). suturing. (f). surgical and periodontal dressing applied.

The histopathological examination results showed that the lesion was a cyst. The macroscopic image obtained from the specimen was a brownish tissue measuring 0.4 cm in cross-section, hard. And microscopic image was a cyst without lining epithelium. Fibrocollagenous connective tissue stroma infested with mononuclear inflammatory cells, PMNs, and histiocytes. Lamellar bone trabeculae were visible. No malignancy was apparent (figure 11).

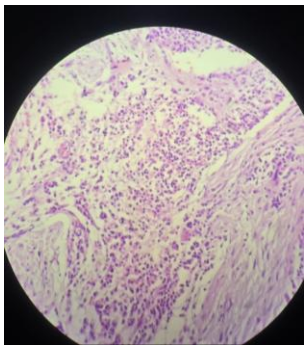

Figure 11. Histological picture of the lesion

Postoperative: The patient was prescribed antibiotic, analgesics, and instruction in postoperative care. At a week follow-up, soft tissue healing was satisfactory. Radiographic follow-up at a month revealed progressive bone fill.

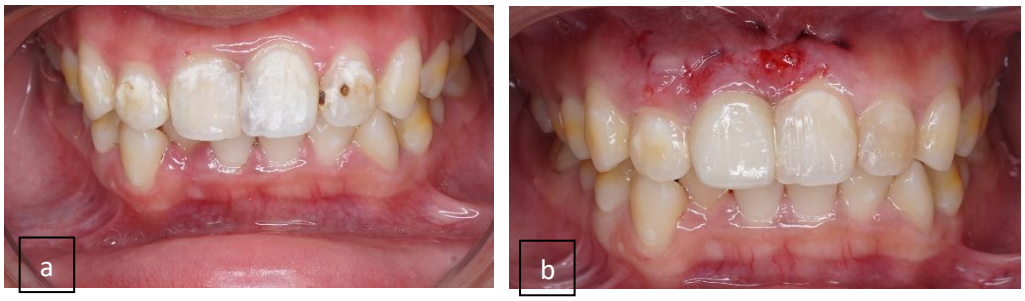

Figure 12. (a) Preoperative intraoral photographs. (b) Aff hecting after five days. The gingival mucosa was healing.

Figure 13. After a month post microsurgical endodontic, The central right incisor was to be healed. And will be follow up after 6 months.

DISCUSSION

This case highlights the value of micro-endodontic surgery in managing a persistent periapical lesion in an anterior maxillary tooth. Although nonsurgical retreatment is usually prioritized before considering surgical intervention, its success depends on the thorough elimination of intraradicular infection and achievement of an adequate apical seal. The persistence of the lesion may result from several possible causes. The complexity of the apical anatomy of the tooth, such as the presence of an untreated accessory lateral canal, may callow bacterial penetration into the periapical tissue or extrusion of the root canal filling into the periapical tissue.

Such conditions can only be identified through follow-up radiographic examination, even when clinical evaluation and objective findings appear satisfactory. This is the importance of radiography, especially CBCT, which can provide detailed and accurate three-dimensional images. Conventional two-dimensional radiography cannot offer this level of information. Therefore, CBCT is considered a modern and sophisticated examination. Cone-beam computed tomography enables precise evaluation of each slice, yielding valuable insights regarding treatment success or failure and aiding in the accurate diagnosis of complex cases.
In this case, the second CBCT showed destruction of the buccal cortical bone of tooth 11 and an increase in lesion size, indicating progression rather than mere persistence. This is assessed using the Periapical and Endodontic Status Scale (PESS), a diagnostic evaluation system that utilizes CBCT imaging to assess periapical conditions and the status of endodontically treated teeth.

However, when periapical pathology persists despite adequate root canal therapy, as seen in the present case, surgical intervention becomes a predictable and necessary alternative. Previous studies indicate that nonsurgical retreatment achieves success rates ranging from 60–80%, whereas endodontic microsurgery with contemporary protocols can achieve outcomes exceeding 90%.[12,17,25] These findings emphasize the importance of case selection and the incorporation of advanced surgical protocols when nonsurgical approaches are unlikely to succeed.

A critical factor in this case was the use of CBCT, which enabled precise three-dimensional evaluation of the lesion's extent, cortical plate involvement, and suspected apical crack. Compared to conventional radiographs, CBCT provides superior diagnostic accuracy for periapical pathology and anatomical complexities, improving both diagnosis and treatment planning. In this patient, CBCT not only facilitated accurate diagnosis but also guided a conservative yet effective microsurgical approach, allowing for a conservative yet effective intervention. [26-28]

Through various considerations, the complexity of the root canal in the form of a lateral accessory canal or suspicion of a crack in the apical third, as well as limitations in areas that cannot be visually accessed during root canal treatment, and given that tooth 11 has follow-up restoration in the form of a post crown, even with signs of deterioration in the lesion area, and the patient is about to move out of town where access to dental care will be difficult to obtain, the treatment decision is micro-surgical endodontic treatment for tooth 11 as the available option. Of course, this is with the consent of the patient and their family. Micro-surgical endodontic treatment is supported by evidence as a predictable procedure with a favourable prognosis in young patient. [29-32]

The microsurgical approach significantly improves prognosis. Magnification through a dental operating microscope enhanced visualization of root-end anatomy, facilitated perpendicular apical resection, and enabled the detection of apical cracks that might otherwise be missed. Combined with ultrasonic root-end preparation, this approach minimized osteotomy size and maximized the likelihood of achieving a hermetic seal. Numerous studies confirm that microsurgical techniques under magnification yield superior healing outcomes compared with traditional apical surgery, with success rates consistently reported above 90% .[13,26-29]

Table 3. Differences between traditional and microsurgical approaches[33]

Parameter	Traditional	Microsurgery
Identification of the apex	Difficult	Precise
Osteotomy size	Approx. 8–10 mm	3–4 mm
Inspection of resected root surface	None	Always
Bevel angle	Large (45°)	Small (<10°)
Isthmus identification and treatment	Impossible	Always
Root-end preparation	Approximate (seldom inside canal)	Precise (always within canal)
Root-end preparation instrument	Bur	Ultrasonic tips
Root-end filling material	Imprecise	Precise
Sutures	4 × 0 Silk	5 × 0, 6 × 0 monofilament
Suture removal	7 days post-op	2–3 days post-op
Healing success (over 1 year)	40–90%	85–96.8%

The choice of retrograde filling material is another determinant of prognosis. Mineral Trioxide Aggregate was used in this case because of its well-documented sealing ability, excellent

biocompatibility, and capacity to promote periradicular healing and hard tissue formation. Compared with amalgam or intermediate restorative material (IRM), MTA demonstrates significantly better biological and clinical performance. [33-37] Additionally, the use of GTR with xenograft bone substitute and resorbable membrane supported osseous healing, particularly critical in anterior maxillary teeth where aesthetics is a major concern. Literature strongly supports the adjunctive use of regenerative techniques in cases with large bony defects or cortical perforations, as these approaches improve long-term prognosis. [19,26,34,38,39]

Despite the favourable outcome, several limitations must be acknowledged. First, the complexity of apical anatomy and the presence of a suspected apical root crack presented significant diagnostic and therapeutic challenges. Without magnification, such anatomical variations may easily be overlooked, potentially resulting in incomplete treatment and recurrence of pathology. This highlights the necessity of high-magnification visualization as a standard of care in contemporary endodontic surgery.[8,21,40] Second, although CBCT provided invaluable diagnostic detail, its use must always be weighed against radiation exposure, especially in adolescent patients. Finally, as this is a single case report, the findings cannot be generalized; long-term follow-up and larger studies are required to confirm the predictability of similar management approaches.

This case demonstrates that the integration of advanced imaging modalities, microsurgical techniques, and modern biomaterials is indispensable in the management of complex periapical pathology. Cone-beam computed tomography enhances diagnostic accuracy and surgical planning; the dental operating microscope ensures precision and minimizes surgical trauma, and MTA combined with regenerative adjuncts, provides a biologically favourable environment for healing. For adolescent patients, where tooth retention and aesthetics are critical, micro-endodontic surgery offers a conservative and highly effective treatment option when conventional approaches fail.

CLINICAL IMPLICATION

This case reinforces the paradigm shift in modern endodontics, where advanced imaging, magnification, and biomaterials have redefined the prognosis of persistent periapical pathology. For clinicians, CBCT should be considered in complex cases to improve diagnostic accuracy, while the use of high-magnification visualization enhances precision and ensures complete management of root-end complexities. The adoption of MTA and regenerative adjuncts such as bone grafts and membranes further supports predictable osseous and periapical healing. Especially in adolescent patients, where functional and aesthetic preservation are equally critical, micro-endodontic surgery represents a conservative yet highly effective treatment modality when nonsurgical options are no longer sufficient.

This case illustrates the value of micro-endodontic surgery in managing persistent periapical lesions. While nonsurgical retreatment is often considered before surgery, its success may be compromised by apical transportation, inaccessible anatomy, or the presence of true periapical cysts, which rarely resolve with nonsurgical therapy alone. [8,9,18]

Role of CBCT: CBCT enabled precise evaluation of lesion size, cortical plate perforation, and potential root fracture, essential for surgical planning. [17,26,27]

Microsurgical approach: The use of a dental operating microscope improved visualization, allowing minimal osteotomy, perpendicular root-end resection, and detection of apical cracks. Current evidence demonstrates superior outcomes with microsurgery compared with conventional apical surgery. [25, 41-44]

Biomaterials: MTA is considered the gold standard retrofilling material due to its sealing ability, bioactivity, and promotion of periradicular healing. Bone graft and resorbable membranes support guided tissue regeneration, enhancing osseous healing and preserving aesthetics in anterior teeth. Mineral Trioxide Aggregate has become a widely favoured material in endodontics because of its reliable sealing properties, high level of biocompatibility, and its ability to promote hard tissue regeneration. Its formulation includes dicalcium silicate, tricalcium silicate, and bismuth oxide as filler for radiopacity. [28,33,34,45-49]

Prognosis: The combination of modern microsurgical techniques and regenerative biomaterials achieves success rates exceeding 90%. This aligns with the positive healing outcome observed in the present case.[34,50,51]

CONCLUSION

Micro-endodontic surgical management provided a predictable and conservative solution for a persistent periapical lesion in a previously treated adolescent maxillary central incisor. The integration of CBCT imaging, microsurgical techniques, and regenerative materials ensured both functional preservation and aesthetic integrity. This case reinforces the role of microsurgery as a viable option when nonsurgical approaches are insufficient.

REFERENCES

1. Ng Y -L., Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature – Part 2. Influence of clinical factors. Int Endodontic J. 2008 Jan;41(1):6–31.
2. De Sousa Gomide Guimarães MRF, Samuel RO, Guimarães G, Nalin EKP, Bernardo RT, Dezan-Júnior E, et al. Evaluation of the relationship between obturation length and presence of apical periodontitis by CBCT: an observational cross-sectional study. Clin Oral Invest. 2019 May;23(5):2055–60.
3. Kerblom A, Hasselgren G. The prognosis for endodontic treatment of obliterated root canals. Journal of Endodontics. 1988 Nov;14(11):565–7.
4. Ng Y -L., Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature – Part 1. Effects of study characteristics on probability of success. Int Endodontic J. 2007 Dec;40(12):921–39.
5. Setzer FC, Kratchman SI. Present status and future directions: Surgical endodontics. Int Endodontic J. 2022 Oct;55(S4):1020–58.
6. American Association of Endodontists. Contemparary Endodontic Microsurgery: Procedural Advancements and Treatment Planning Consideration. Colleagues for Excellence (Endodontics). Fall 2010.
7. Neville BW, Damm DD, Allen CM, Chi AC. *Oral and maxillofacial pathology*. 4th ed. St. Louis: Elsevier; 2016.
8. Microsurgical Endodontics, Arnaldo Castellucci, Edra S.p.A., 1st Edition 2019 -TLS (Arnaldo Castellucci) (z-lib.org).pdf.
9. Ng YL, Mann V, Gulabivala K. A prospective study of the factors affecting outcomes of nonsurgical root canal treatment: part 1: periapical health: Outcome of nonsurgical root canal treatment. International Endodontic Journal. 2011 Jul;44(7):583–609.
10. Nair PNR. P ATHOGENESIS OF A PICAL P ERIODONTITIS AND THE C AUSES OF E NDODONTIC F AILURES. Critical Reviews in Oral Biology & Medicine. 2004 Nov;15(6):348–81.
11. Nair PNR. On the causes of persistent apical periodontitis: a review. Int Endodontic J. 2006 Apr;39(4):249–81.
12. Setzer FC, Shah SB, Kohli MR, Karabucak B, Kim S. Outcome of Endodontic Surgery: A Meta-analysis of the Literature—Part 1: Comparison of Traditional Root-end Surgery and Endodontic Microsurgery. Journal of Endodontics. 2010 Nov;36(11):1757–65.
13. European Society of Endodontology. Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. Int Endodontic J. 2006 Dec;39(12):921–30.
14. Kim S, Kratchman S. Modern Endodontic Surgery Concepts and Practice: A Review. Journal of Endodontics. 2006 Jul;32(7):601–23.
15. Wang H, Xu X, Bian Z, Liang J, Chen Z, Hou B, et al. Expert consensus on apical microsurgery. Int J Oral Sci. 2025 Jan 2;17(1):2.
16. Rubinstein RA, Kim S. Short-Term Observation of the Results of Endodontic Surgery with the Use of a Surgical Operation Microscope and Super-EBA as Root-End Filling Material.
17. Tsesis I, Rosen E, Taschieri S, Telishevsky Strauss Y, Ceresoli V, Del Fabbro M. Outcomes of Surgical Endodontic Treatment Performed by a Modern Technique: An Updated Meta-analysis of the Literature. Journal of Endodontics. 2013 Mar;39(3):332–9.

18. Teh LA. Endodontic Microsurgery on a Persistent Periapical Lesion. Cureus [Internet]. 2023 Jul 1 [cited 2025 Aug 25]; Available from: https://www.cureus.com/articles/162543-endodontic-microsurgery-on-a-persistent-periapical-lesion
19. Tsesis I, Rosen E, Tamse A, Taschieri S, Del Fabbro M. Effect of Guided Tissue Regeneration on the Outcome of Surgical Endodontic Treatment: A Systematic Review and Meta-analysis. Journal of Endodontics. 2011 Aug;37(8):1039–45.
20. Venskutonis T. Periapical tissue evaluation: analysis of existing indexes and application of Periapical and Endodontic Status Scale (PESS) in clinical practice. Giornale Italiano di Endodonzia. 2016 Jun;30(1):14–21.
21. Kim S, Kratchman S. Microsurgery in Endodontics [Internet]. 1st ed. Wiley; 2017 [cited 2025 Aug 28]. Available from: https://onlinelibrary.wiley.com/doi/book/10.1002/9781119412502
22. Flynn R, Foschi F, Maloney B, Creavin G, Duncan HF. The impact of bone grafting with/without barrier membrane placement on the outcome of apical surgery: A systematic review and meta-analysis. Int Endodontic J. 2024 Aug;57(8):1006–20.
23. Suleiman M. The Effect of Flap Design on Wound Healing after Periapical Surgery: A Comparative Study. RDENTJ. 2008 May 1;8(1):120–7.
24. Fan J, Bi L, Jin D, Wei K, Chen B, Zhang Z, et al. Microsurgical Techniques Used to Construct the Vascularized and Neurotized Tissue Engineered Bone. BioMed Research International. 2014;2014:1–7.
25. Setzer FC, Kohli MR, Shah SB, Karabucak B, Kim S. Outcome of Endodontic Surgery: A Meta-analysis of the Literature—Part 2: Comparison of Endodontic Microsurgical Techniques with and without the Use of Higher Magnification. Journal of Endodontics. 2011 Nov;S0099239911011460.
26. Bieszczad D, Wichlinski J, Kaczmarzyk T. Factors Affecting the Success of Endodontic Microsurgery: A Cone-Beam Computed Tomography Study. JCM. 2022 Jul 10;11(14):3991.
27. Patel S, Durack C, Abella F, Shemesh H, Roig M, Lemberg K. Cone beam computed tomography in E ndodontics – a review. Int Endodontic J. 2015 Jan;48(1):3–15.
28. Kim S, Pecora G, Rubinstein RA. *Color atlas of microsurgery in endodontics*. Philadelphia: W.B. Saunders; 200.
29. Pinto D, Marques A, Pereira JF, Palma PJ, Santos JM. Long-Term Prognosis of Endodontic Microsurgery—A Systematic Review and Meta-Analysis. Medicina. 2020 Sep 3;56(9):447.
30. Sperou C, Tepperman A, Ben Suleiman A, Malkhassian G, Shah PS, Azarpazhooh A. Evaluating Outcomes and Prognostic Factors in Endodontic Microsurgery: A Retrospective Cohort Study. Journal of Endodontics. 2025 Jun;S0099239925003255.
31. Pallarés-Serrano A, Glera-Suarez P, Tarazona-Alvarez B, Peñarrocha-Oltra D, Peñarrocha-Diago M, Peñarrocha-Diago M. Healing of 295 Endodontic Microsurgery Cases After Long-Term (5-9 Years) Versus Middle-Term (1-4 Years) Follow-up. Journal of Endodontics. 2022 Jun;48(6):714–21.
32. Alawadhi A. Outcome of Endodontic Microsurgery: Success and Survival Rates at Virginia Commonwealth University.
33. Ananad S, Soujanya E, Raju A, Swathi A. Endodontic microsurgery: An overview. Dent Med Res. 2015;3(2):31.
34. Parirokh M, Torabinejad M. Mineral Trioxide Aggregate: A Comprehensive Literature Review—Part I: Chemical, Physical, and Antibacterial Properties. Journal of Endodontics. 2010 Jan;36(1):16–27.

35. Montero-Miralles P, Ibáñez-Barranco R, Cabanillas-Balsera D, Areal-Quecuty V, Sánchez-Domínguez B, Martín-González J, et al. Biomaterials in periapical regeneration after microsurgical endodontics: A narrative review. J Clin Exp Dent. 2021;e935–40.
36. Çalışkan MK, Tekin U, Kaval ME, Solmaz MC. The outcome of apical microsurgery using MTA as the root-end filling material: 2- to 6-year follow-up study. Int Endodontic J. 2016 Mar;49(3):245–54.
37. Umbach JM, Phillips MB, Dutner JM, Otterson SW, Jones J. Surface Integrity of Orthograde MTA Obturation Following Targeted Endodontic Microsurgery.
38. Karabucak B, Setzer F. Criteria for the ideal treatment option for failed endodontics: surgical or nonsurgical? Compend Contin Educ Dent. 2007 Jun;28(6):304–10; quiz 311, 332.
39. Taschieri S, Del Fabbro M, Testori T, Weinstein R. Efficacy of Xenogeneic Bone Grafting With Guided Tissue Regeneration in the Management of Bone Defects After Surgical Endodontics. Journal of Oral and Maxillofacial Surgery. 2007 Jun;65(6):1121–7.
40. Kim S, Kratchman S. Modern Endodontic Surgery Concepts and Practice: A Review. Journal of Endodontics. 2006 Jul;32(7):601–23.
41. Ramachandran Nair PN. Non-microbial etiology: periapical cysts sustain post-treatment apical periodontitis. Endodontic Topics. 2003 Nov;6(1):96–113.
42. Von Arx T, AlSaeed M. The use of regenerative techniques in apical surgery: A literature review. The Saudi Dental Journal. 2011 Jul;23(3):113–27.
43. Hirsch V, Kohli MR, Kim S. Apicoectomy of maxillary anterior teeth through a piezoelectric bony-window osteotomy: two case reports introducing a new technique to preserve cortical bone. Restor Dent Endod. 2016;41(4):310.
44. Lee SM, Yu YH, Wang Y, Kim E, Kim S. The Application of “Bone Window” Technique in Endodontic Microsurgery. Journal of Endodontics. 2020 Jun;46(6):872–80.
45. Christiansen R, Kirkevang L -L., Hørsted-Bindslev P, Wenzel A. Randomized clinical trial of root-end resection followed by root-end filling with mineral trioxide aggregate or smoothing of the orthograde gutta-percha root filling – 1-year follow-up. Int Endodontic J. 2009 Feb;42(2):105–14.
46. Chong BS, Pitt Ford TR, Hudson MB. A prospective clinical study of Mineral Trioxide Aggregate and IRM when used as root-end filling materials in endodontic surgery. Int Endodontic J. 2003 Aug;36(8):520–6.
47. Torabinejad M, Parirokh M. Mineral Trioxide Aggregate: A Comprehensive Literature Review—Part II: Leakage and Biocompatibility Investigations. Journal of Endodontics. 2010 Feb;36(2):190–202.
48. Ashi T, Bourgi R, Cuevas-Suárez CE, Hardan L, Nahat C, Altaqi Z, et al. Healing Ability of Endodontic Filling Materials in Retrograde Treatment: A Systematic Review of Clinical Studies. Applied Sciences. 2025 Jun 8;15(12):6461.
49. Aust Endodontic J - 2022 - Angerame - Root-end resection with or without retrograde obturation after orthograde filling.pdf.
50. Kim D, Ku H, Nam T, Yoon TC, Lee CY, Kim E. Influence of Size and Volume of Periapical Lesions on the Outcome of Endodontic Microsurgery: 3-Dimensional Analysis Using Cone-beam Computed Tomography. Journal of Endodontics. 2016 Aug;42(8):1196–201.
51. Vonarx T, Hanni S, Jensen S. Correlation of Bone Defect Dimensions with Healing Outcome One Year after Apical Surgery. Journal of Endodontics. 2007 Sep;33(9):1044–8.