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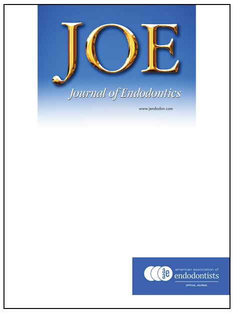

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PII: S0099-2399(20)30753-6
DOI: https://doi.org/10.1016/j.joen.2020.09.014
Reference: JOEN 4688

To appear in: *Journal of Endodontics*

Received Date: 10 April 2020
Revised Date: 12 August 2020
Accepted Date: 5 September 2020

Please cite this article as: Terauchi Y, Bakland LK, Bogen G, Combined Root Canal Therapies in Multirooted Teeth with Pulpal Disease, *Journal of Endodontics* (2020), doi: https://doi.org/10.1016/j.joen.2020.09.014.

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CONSORT CHECKLIST AND FLOW DIAGRAM

The submitted case series manuscript does not constitute or qualify as a randominized clinical trial and therefore the CONSORT Checklist and Flow Chart are not applicable.

Combined Root Canal Therapies in Multirooted Teeth with Pulpal Disease

Abstract

The types of pulpal disease found in multirooted teeth may vary from one root canal to the next. Current endodontic treatment strategies allow for ~~the~~ options such as regenerative endodontics, vital pulp therapy, or conventional root canal treatment depending on the disease status of the pulp in a specific root canal. A combination of procedures was employed in the three teeth ~~in~~ for this case series based on the assumed pulpal status in each canal. The follow-up ranged from 24 to 27 months and in each case the healing response was satisfactory. This report illustrates the use of a combination of treatment procedures, which can provide specific treatment benefits in various clinical situations.

Key Words

Caries detector dye; cone-beam computed tomography; dental operating microscope; mineral trioxide aggregate; pulpal diagnosis; regenerative endodontics; vital pulp therapy

Significance

Combining endodontic treatment procedures in multirooted teeth allows clinicians to choose treatment modalities based on the condition of the pulps in specific root canals.

INTRODUCTION

The diagnosis and classification of pulpal disease has changed over the years and continues to evolve[1].Treatment of teeth with pulpal disease is often based on the inflammatory condition of the pulp (as measured by responses to cold/hot stimuli), patients' chief complaints, presence and extent of pulpal necrosis, and the periapical radiographic images combined with clinical testing responses[2,3]. While valuable information is obtained by such clinical examinations, it is frequently not sufficient for an accurate determination of the pulpal condition[4,5]. It is possible, that treatment based only on routine examination procedures may lead to removal of vital pulp tissue that could otherwise survive after selective elimination of adjacent diseased tissues.

Expanding examination procedures to include direct visual observation of the pulp through a dental operating microscope (DOM), provides the opportunity to evaluate parts of the pulp that can potentially be preserved[6]. This has been illustrated by clinical cases of carious pulp exposures in which the healthy part of the pulp was protected and preserved following elimination of diseased tissue[7] and in cases of pulp chamber pulpotomies[8-10]. Cone-beam computed tomography (CBCT) is an additional method for obtaining important information prior to treatment planning as illustrated in the treatment of teeth displaying anatomical anomalies such as dens evaginatus[11] and dens invaginatus[12].

Teeth in young patients in which both pulpal disease and apical pathosis are present can often be treated with endodontic procedures that preserve healthy radicular pulp tissue resulting in both apical healing and continued root formation[11,13,14]. Accurate diagnostic evaluation of radicular pulps in some multirooted teeth can be difficult to achieve with current examination procedures[15,16]. This can prevent the opportunity to use treatments that could preserve *reversibly* inflamed radicular pulps in some canals even if adjacent ones are *irreversibly* involved[17,18]. With more precise diagnosis it could be advantageous to treat canals of multirooted teeth independently even if tissue conditions vary between canals. Conservative treatment of teeth with pulpal disease, in which healthy, reversibly inflamed pulp tissue can be preserved, the surrounding tooth structure maintained, and any apical lesions resolved may have advantages over conventional root canal therapy. In some select cases, canals with infected pulp necrosis can be managed by the technique introduced by Iwaya et al.[11] and which subsequently is referred to as regenerative endodontics treatment (RET)[19].

The three cases presented here demonstrate a conservative approach using combined treatment modalities in teeth with carious pulp exposures and initial diagnosis of pulp necrosis. The treatments were completed by one of the authors (YT).

CASE REPORTS

Several procedures were similar in all cases. On the first treatment appointment, the initial procedure was performed without using local anesthetic. The patient would raise his/her hand if there was any pain or discomfort. The purpose for removal of restorations and caries and necrotic pulp tissue was to identify any possibly vital tissues. All procedures involving vital tissues were completed with local anesthesia.

The dental operating microscope (DOM) was used for all clinical treatment procedures to ensure maximum ability to identify carious dentin and tissue remnants. In addition, a caries detector dye (Caries Detector, Kuraray Medical Inc, Osaka, Japan) was used to help identify and remove carious dentin.

Case 1

A 15-year-old male patient presented with a chief complaint of pain in the mandibular left first molar (tooth #19). His medical and dental histories were noncontributory. A sinus tract was present on the buccal tissues and the tooth had recurrent caries around a class II composite restoration. The tooth was painful to percussion and the surrounding tissues were painful to palpation. All periodontal probings were within normal limits (2-3mm). The tooth had normal mobility and did not respond to pulp vitality testing.

The preoperative periapical (PA) radiograph (Figure 1A) suggested possible bony changes in the furcation and apical areas. The preoperative cone-beam computed tomography (CBCT) examination, however, showed in the sagittal view a large bony lesion associated with the distal root and smaller one around the apical area of the mesial root (Figure 1B). The axial CBCT view showed single canals in each root and an absence of buccal cortical bone adjacent to the distal root (Figure 1C). The buccal sinus tract probably passed through the area showing no bone. Both the axial and sagittal views showed that the canal in the distal root had a larger diameter than that in the mesial root.

Based on the clinical examination and radiographic interpretation, the diagnosis for tooth #19 was pulp necrosis and a chronic apical abscess. A preliminary treatment plan was presented and accepted. An attempt would be made for RET for the distal canal along with conventional root canal therapy (RCT) for the mesial canal. The treatment plan could be modified if, after accessing the pulp chamber, the pulpal conditions in the canals were different than expected.

The first step in the treatment was to remove the composite restoration without the use of local anesthesia. The DOM was used throughout the procedure. After removal of the restoration, the pulp chamber was exposed, showing the pulp tissue to be necrotic and partially liquefied. With a

#6 carbide bur and copious water spray, all carious dentin was removed, augmented with caries detector dye. The distal wall was built up with bonded composite resin (Clearfil Majesty, Kuraray Noritake Dental Inc., Okayama, Japan.) before dental dam isolation and subsequent treatment steps. A spoon excavator along with copious irrigation with 5.25% sodium hypochlorite (NaOCl) were used to debride the pulp chamber. Both the distal and the mesial root canal orifices were easily located. The tissues in the distal orifice appeared necrotic and a #10 endodontic file was easily passed through to the apical opening without resistance and it provoked no painful sensation, confirming the presence of pulp necrosis. The working length was determined with an electronic apex locator and apical gauging with NiTi K-files showed the diameter at the working length to be more than 0.7 mm, indicative of an open apex. In contrast, when a file was introduced into the mesial canal, it provoked a painful sensation in the coronal part of the canal, indicating presence of vital tissue. The preliminary treatment plan was modified to combine vital pulp therapy (VPT) in the mesial canal and RET in the distal canal.

Mandibular nerve block anesthesia was administered with 2% mepivacaine without a vasoconstrictor (Nagase Medicals Co. Ltd., Itami, Japan). The distal root canal was debrided with a #70 K-file, irrigated with 5.25% NaOCl, and dried with paper points. This was followed by saline and 17% EDTA irrigations and drying with coarse paper points. A #25 K-file was used to pierce the periapical tissues to promote bleeding into the canal to a level about 3 mm below the cementoenamel junction (CEJ). After waiting approximately 10 minutes, blood coagulation was observed (Figure 1D). A scaffold of CollaCote (Zimmer Biomet Dental, Warsaw, IN, USA) was placed on the clot followed by a 3 mm thick layer of mineral trioxide aggregate (MTA) (Gray ProRoot MTA, (Dentsply Tulsa Dental, Tulsa, OK). A moist cotton pellet was then placed over the MTA plug and the distal access area was sealed with unbonded Clearfil Photocore (Kuraray

Co. Ltd, Osaka, Japan). The inflamed and necrotic tissues from the coronal part of the mesial canal were removed with a water-cooled high-speed round diamond bur followed by flooding the chamber with 5.25% NaOCl for 10 minutes, and again for 5 minutes, to control hemorrhaging and obtain hemostasis. MTA was placed over the exposed pulp tissue, slightly compressed and shaped with a moist cotton pellet to create a uniform layer. Another moist cotton pellet was placed over unset MTA and covered with unbonded Clearfil Photocore.

The patient was asymptomatic when he returned after one week. Following dental dam isolation, the temporary seal and cotton pellet were removed. A bonded composite restoration was placed after checking the MTA for proper setting (Figure 1E). The 3-month follow-up axial CBCT view revealed advancing remineralization of the bony defects (Figure 1F). At the 18-month recall visits, the sagittal and axial 18-month CBCT images (Figures 1G and 1H) showed progressive healing of the periapical lesions, evidence of apical closure and re-establishment of the cortical plate. A two-year radiographic review shows normal supporting bone and absence of pathosis (Figure 1I). The tooth was asymptomatic, and responded to cold, heat, and electric pulp tests.

Case 2

A 43-year-old female patient presented with a chief complaint of pain in the maxillary right first molar (tooth #3). Her medical history was noncontributory. A sinus tract was noted buccal to the tooth which had a distal-occlusal composite restoration. It showed a class 2 mobility along with a 5-8 mm circumferential osseous defect and did not respond to pulp vitality tests. Percussion and soft tissue palpation elicited discomfort.

Preoperative PA radiographic examination demonstrated combined periapical and periodontal lesions (Figure 2A). The preoperative CBCT showed large periapical lesions communicating with the periodontal lesions around all 3 roots on sagittal, coronal, and axial views (Figures 2B, C, D). The axial view showed 2 canals in the mesiobuccal (MB) root and single canals in the distobuccal (DB) and palatal roots. The canal in the palatal root appeared larger than those in the other roots and displayed a wide apical opening. The CBCT also revealed cortical bone loss around the coronal one third of each root, indicating endodontic-periodontal involvement. Based on the above findings, the clinical endodontic diagnosis was pulpal necrosis and chronic apical abscess. The periodontal diagnosis was moderate to advanced periodontitis. The patient accepted and approved the preliminary plan of RET treatment of the palatal canal and conventional RCT of the other canals. After pulp chamber access, modifications to the treatment plan could be made if unanticipated pulpal conditions in the canals were encountered.

The first treatment procedure was to remove the composite restoration under dental dam isolation and without the use of local anesthetic. A DOM was used throughout the procedure. The patient would raise her hand if she felt any discomfort or pain during the procedure. After removal of the restoration and the roof of the pulp chamber, the chamber appeared to be empty except for a few tissue fragments. Augmented by caries detector dye guidance and using a #6 carbide bur with water coolant, all the carious dentin was removed and the pulp chamber was debrided with 5.25 % NaOCl irrigation. All four root canals were explored with a #10 K-file and no vital tissue was detected. As noted above, the wide apical opening of the palatal canal indicated a possible RET procedure for that canal.

Two cartridges of 2% mepivacaine without a vasoconstrictor was injected for local anesthesia and the working lengths of all four canals were established with an electronic apex locator (Root ZX II, J. Morita Corp, Tokyo, Japan). The MB, MB2 and DB canals were cleaned and prepared with NiTi files to size 30/.06 taper (Vortex Blue, Dentsply Tulsa Dental Specialties, Johnson City, TN, USA) and 5.25% NaOCl irrigation. The palatal canal was debrided using a #60 K-file and 5.25% NaOCl irrigation. All the canals were dried with paper points followed with a rinse with saline solution, then dried and re-irrigated with 17% EDTA and again dried with paper points. A #20 K-file was used to penetrate the apical tissues and stimulate bleeding into the palatal canal (Figure 2E) resulting in clot formation 4 mm below the CEJ (Figure 2F). A cotton pellet was placed on the blood clot and the pellet was temporarily covered with Cavit (3M, St. Paul, MN, USA). The buccal canals were then obturated using Gray ProRoot MTA with a combination of a modified Auger technique combined with endodontic plugger compaction[20]. The Cavit and cotton pellet were removed from the orifice of the palatal canal and a fitted CollaCote pellet scaffold was placed over the blood clot (Figure 2G). A layer approximately 3 mm thick of MTA was placed over the scaffold (Figures 2H, I). The MTA was covered with a moist cotton pellet and the access cavity was closed with unbonded Photocore (Figure J).

On the next visit one week later, the Photocore temporary and cotton pellet were removed under dental dam isolation. The MTA had cured (Figure K) and a bonded composite restoration was placed over the set MTA. A 3-month radiographic control showed evidence of healing of the periapical lesions (Figures 2L, M, N, O). At the 27-month control visit, both the CBCT and the PA radiographs showed continued improvement of the periradicular alveolar bone and evidence of palatal canal apical narrowing and remineralization with re-establishment of the cortical plate (Figures 2P, Q, R, S). The tooth was asymptomatic and presented with minimal (1+) mobility and all periodontal probings were within normal limits (2-3 mm).

Case 3

A 19-year-old male patient presented with a chief complaint of tenderness to chewing on the maxillary left second molar (tooth #15). The patient was in good health with no contributory medical conditions. The periodontal probings were 2-3 mm and the tooth mobility was normal (Class 1). While the tooth was not sensitive to percussion, it did give a mild response to cold testing. The preoperative radiograph showed a radiolucent area associated with the palatal root apex and the MO composite restoration in close proximity to the mesial pulp horn appeared to be defective (Figure 3A). CBCT sagittal imaging confirmed the presence of secondary caries in the composite/dentin interface (Figure 3B). Also noted were a large radiolucency associated with the DB root apex and a smaller apical lesion at the MB root apex (Figure 3C). A lesion apically to the palatal root was observed on the coronal view (Figure 3D). The preoperative clinical diagnosis was pulpal necrosis and chronic apical periodontitis. The patient accepted a preliminary treatment plan of RCT and also the possibility of treatment change if the pulpal condition was different than initial expectations.

The treatment was initiated without local anesthetic and under dental dam isolation and a DOM. After removing the composite restoration, carious dentin was removed using a #6 carbide bur with water coolant using caries detector dye guidance. A high-speed diamond bur was used for exposing the pulp chamber and removing the necrotic tissues. Exploratory insertion of a # 10 K-file into the four canals verified necrotic tissue in the DB and palatal canals. The patient, however, felt pain in the MB/MB2 canals when the #10 K-file reached the middle third of the canals, which induced hemorrhaging and indicated potentially reversibly inflamed tissues remaining (Figures 3E, F). The canal length was measured to the area of remaining vital pulp tissues with the same #10 K-file.

Next, local anesthetic was administered with two cartridges of 2% mepivacaine without vasoconstrictor. NiTi files from a size 15/.06 taper to a size 40/.06 taper were placed to the level of surviving pulp tissues and rotated to remove the overlying necrotic/inflammatory tissues in the MB/MB2 canals; 5.25% NaOCl was used to irrigate those canals. The canals were soaked in 5.25% NaOCl for 10 minutes and rinsed with saline solution. A size 15 K file was then used to penetrate the vital pulp tissues and induce bleeding to a level 4 mm below the CEJ (Figures 3G, H). A few minutes after clot formation, RetroMTA (BioMTA, South Korea) was placed over the area, gently compacted, and shaped with a moist cotton pellet to establish a uniform thickness of approximately 4 mm (Figure 3I). A moist cotton pellet was placed directly over the MTA and covered with unbonded Clearfil Photocore.

The DB and palatal canals were negotiated and working lengths established with the electronic apex locator. The canals were irrigated with 5.25 % NaOCl and prepared to working length with NiTi files. Then both canals were rinsed with saline solution, dried and re-irrigated with 17% EDTA. A #25/.03 taper file, one size smaller than the apical diameter, was used together with mixed RetroMTA, and placed to the working length and turned counterclockwise (reverse) while connected to an apex locator compacting the MTA into the canals using a push and pull motion (Figure 3J). The cavity floor was cleared of excess MTA with a two-way syringe and Cavit placed over a wet cotton pellet as the provisional restoration. One week later, local anesthetic was administered with two cartridges of 2% mepivacaine without a vasoconstrictor and the tooth was isolated with dental dam. The Cavit and Photocore were removed and RetroMTA hardening was confirmed in the obturated canals and pulpotomy sites. The crown was restored with bonded composite resin.

The 6-month CBCT and PA radiographic control showed remineralization of the periapical areas (Figures 3K, L, M). The patient was asymptomatic and the electronic pulp testing elicited a positive response. The 2-year radiographic view showed an absence of periapical lesions and CBCT scans in two planes confirmed restitution of supporting bone and absence of periapical lesions. The patient was asymptomatic and the tooth had normal mobility (Class 1) and periodontal probings within normal limits (2-3mm) (Figures 3N, O, P).

DISCUSSION

Bacterial invasion of the dental pulp through caries is a compartmentalized process resulting in a peripheral area of liquefactive pulp tissue with subjacent inflamed tissue next to healthy tissues[18,21]. Anatomically, the pulpal conditions can vary from the coronal to the radicular areas and are dependent on the extent and location of bacterial intrusion, the time of exposure, and the innate and adaptive defense mechanisms[22,23]. Based on the various pulpal conditions in a tooth, treatment can be modified to take advantage of such variations and combine treatment procedures in a multirooted tooth.

The treatment provided for the three cases was based on the modified clinical diagnosis that could be made by direct observation of the pulpal conditions in each of the root canals after removal of caries and necrotic tissues, and the judicious use of CBCT. Presence or absence of vital tissues was confirmed with the use of an endodontic file; control of bleeding was used as a guide to differentiate between reversible or irreversible pulpal inflammation[24-26]. Use of the DOM was both essential in evaluating pulpal tissues and for accurate placement of dental materials.

Since the suggested treatment for the teeth included a combination of procedures rather than the conventional single procedure for a given tooth, it was important to use CBCT to enhance the ability to diagnose, evaluate, treat and monitor the patients. The benefit to the patients of a positive outcome from this unusual combination of treatment procedures, necessitated employing the CBCT even with a small increase in total ionizing radiation. In the future as more experience with the treatment combination described, the outcomes can be monitored using conventional radiographs with less radiation exposure[27].

Combining treatment procedures for a multirooted tooth, as exemplified in case #1, illustrates how two different procedures could be applied based on the pulpal condition in each root canal[26]. In the mesial canal the pulp tissues were vital and reversibly inflamed, so vital pulp therapy was applicable. In the distal canal the content was liquefactive necrotic tissue, so RET was an option. Complete canal debridment with NaOCl disinfection was provided in RET using caries detector dye staining with normal hemorrhaging and clot formation confirmed under the DOM. This may suggests that long-term intracanal medications may not be required in every case if meticulous canal debridment is observed. Radiographic follow-up indicate that both the diagnosis and treatment choices were sound (Figures 1G, H, I)[28,29].

In case #2, the canals in the two buccal roots were managed with RCT and filled with MTA, while RET was the selected treatment for the palatal canal because the large apical opening[20,29]. The outcome was apparent from the observed thickening of the root canal walls. In case #3, the combined treatment consisted of conventional RCT for the DB and palatal canals and vital pulp therapy for the MB canals. The incorporation of pulp tissue assessment under the DOM, removal of necrotic tissues, NaOCl hemostasis and the placement of bioceramic materials with bonded restorations contributed to predictable outcomes in all three cases.

CONCLUSION

Combining treatment approaches for multirooted teeth provides the opportunity to select procedures that may have specific benefits, such as maintaining pulp vitality where possible. Treatment that combines different therapies may ultimately benefit the patient and increase tooth survival.

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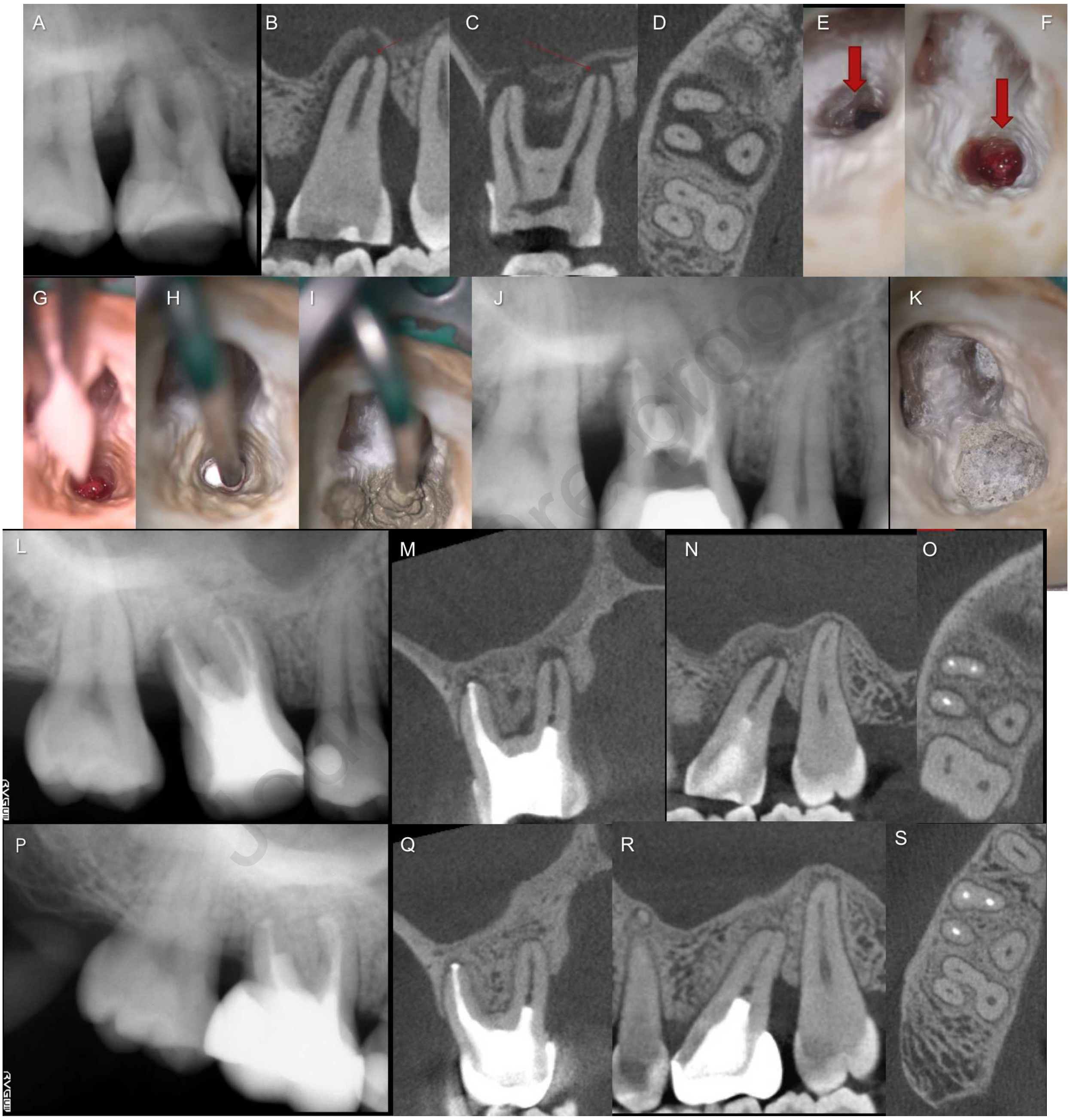
FIGURE 1

FIGURE 2



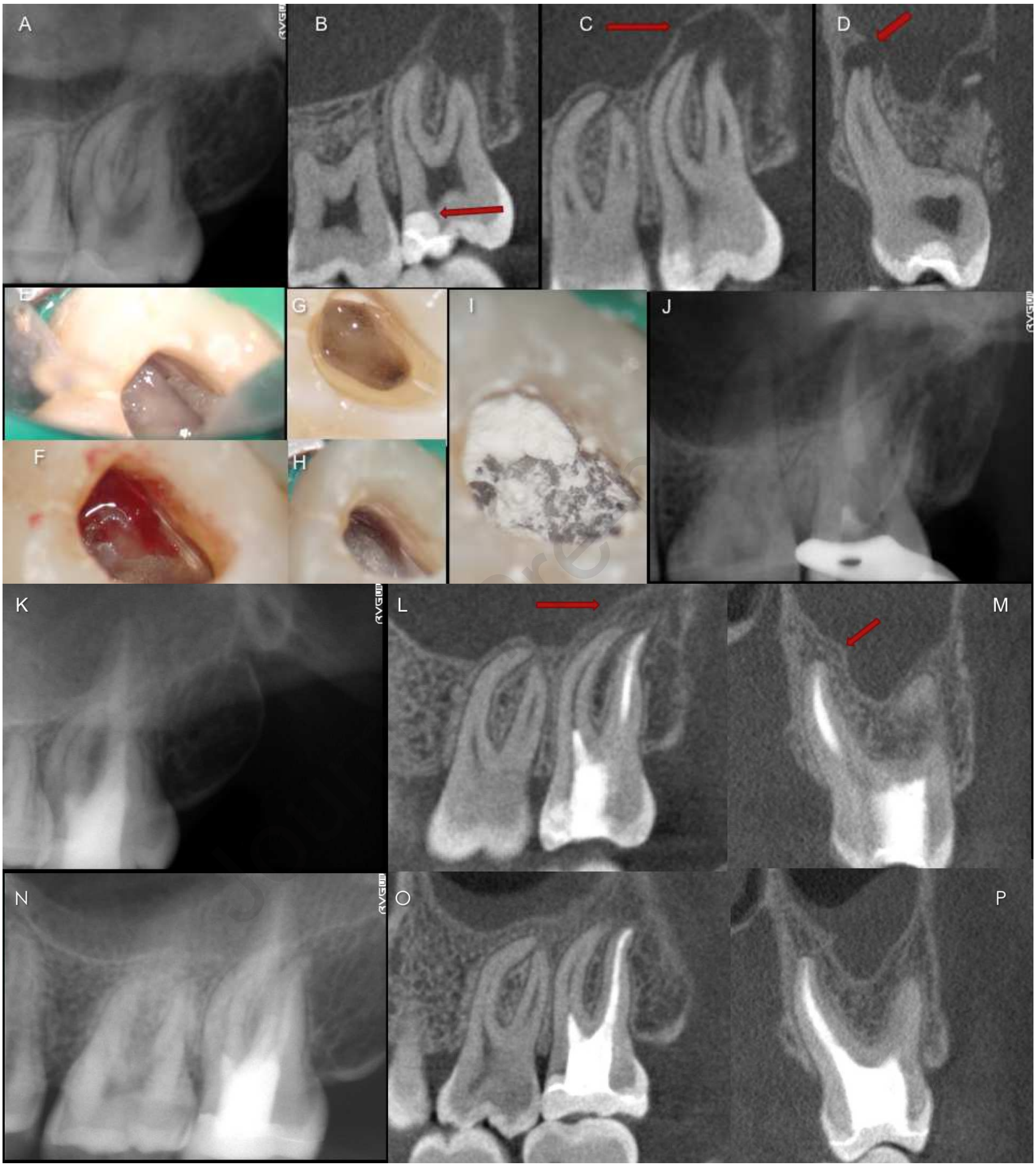


FIGURE 3

Figure 1. (A) Preoperative radiograph shows deep carious lesion on the distal aspect of the mandibular left first molar (tooth #19). (B) Preoperative CBCT sagittal view shows large periapical

lesion around the distal root and smaller one apical to the mesial root. (C) Preoperative axial view shows absence of buccal cortical bone proximal to the distal root (arrow). (D) Vital pulp exposure in the mesial canal (right) and blood clot in the distal canal (left). (E) Postoperative radiograph after MTA placement. (F) Three-month follow-up CBCT axial view shows remineralization of the bony defects. (G,H) Eighteen-month postoperative CBCT sagittal/axial views show resolution of the periapical lesions and new bone in the pretreatment buccal cortical defect. (I) Two-year radiographic review.

Figure 2. (A) Preoperative radiograph shows periapical lesions around the maxillary right first molar (tooth #3). (B-D) CBCT sagittal, coronal and axial views show an open apex in the palatal root, extensive periapical pathosis, loss of supporting bone and presence of four canals. (E,F) Necrotic pulp tissues, induced bleeding (arrows) and blood clot formation in palatal canal. (G-I) CollaCote placed over the blood clot followed by MTA placement. (J) Postoperative radiograph shows MTA plug as part of regenerative endodontic treatment of palatal canal, and MTA obturation of MB1, MB2, and DB canals. (K) Set MTA in all canal orifices. (L) Three-month radiographic recall. (M-O) Three-month CBCT coronal, sagittal, and axial views show emerging resolution of the periapical lesions and advancing reformation of supporting bone. (P) Twenty-seven month radiographic recall showing new ceramic restoration. (Q-S) Twenty-seven month CBCT coronal, sagittal, and axial views reveal resolution of the periapical lesions and reformation of furcation bone.

Figure 3. (A) Preoperative radiograph of maxillary left molar (tooth #15) with a periapical radiolucent region. (B) Preoperative sagittal CBCT shows close proximity of restoration to the mesial pulp horn (arrow). (C,D) Preoperative sagittal and coronal view of distobuccal and palatal root radiolucencies (arrows). (E) Initial view of coronal necrotic tissues in MB canals and (F) hemorrhaging after No. 10 file insertion. (G) 5.25% NaOCl 5-minute immersion and (H) vital pulp tissues detected in the MB canal after hemostasis. (I) Clinical photograph of RetroMTA placement. (J) Postoperative radiograph showing MB canal pulpotomy and obturation of DB and P canals. (K) Six-month radiographic control shows progressive remineralization of apical lesion. (L, M) Six-month sagittal and coronal CBCT views showing remineralization of buccal and palatal periapical lesions (arrows). (N) Two-year radiographic recall. (O,P) Two-year sagittal and coronal CBCT views showing advanced resolution of the periapical lesions.