Targeted Endodontic Microsurgery: A Retrospective Outcomes Assessment

Buniag, Arianne G, DDS; Pratt, Allen M, DMD; Ray, Jarom J, DDS

ABSTRACT

Introduction: Targeted Endodontic Microsurgery (TEMS) replaces freehand carbide or diamond bur osteotomy and root end resection with a guided approach using an end-cutting trephine bur rotated within a guide tube. TEMS departs from traditional EMS in osteotomy size, control of resection level and bevel, surgical time and resection method, yet the impact of these departures upon clinical outcomes has yet to be assessed. The aim of this study is to assess clinical outcomes of TEMS surgeries at least one year after treatment.
Methods: Potential cases were retrospectively identified from a secure database of all patients that received TEMS in the Air Force Postgraduate Dental School from June 2017 to May 2019 with a postsurgical recall exam at 1 year or beyond (23 patients with 24 teeth). Two board certified endodontists completed a calibration exercise prior to assessing radiographs. A retrospective outcomes assessment was conducted considering recall clinical and radiographic findings to assign one of three healing designations: *complete healing*, *reductive healing*, or *failure*.
Results: Combined clinical and radiographic data led to 20 designations of *complete healing*, 2 designations of *reductive healin*g and 2 *failures (*91.7% success rate). Considered alone, radiographic criteria for *complete healing* were met for 20 cases, *reductive healing* by 3 cases with 1 radiographic *failure*.
Conclusions: This limited retrospective outcomes assessment is an early indication that TEMS guided trephine bur root end resection leads to similar success as is established for freehand carbide and diamond bur resection. Controlled clinical trials with long-term follow-up are warranted.

KEY WORDS

Targeted Endodontic Microsurgery, TEMS, endodontic microsurgery, apical surgery, surgical guide, trephine, outcomes, 3D printed

SIGNIFICANCE

TEMS departs from traditional endodontic microsurgery (EMS) in osteotomy size, control of resection level and bevel, surgical time and resection method. The impact of such departures upon clinical outcomes is assessed in this study.

INTRODUCTION

Targeted Endodontic Microsurgery (TEMS) replaces freehand carbide or diamond bur osteotomy and root end resection with a guided approach using an end-cutting trephine bur rotated within a guide tube (1). After trephine resection, root ends receive ultrasonic preparation and fill with a biocompatible material under the surgical operating microscope (2).

TEMS customizes osteotomy diameter and root end resection level and bevel with a preoperative digital design that is transferred to the surgical field with a 3D printed surgical guide (3). In a mannequin simulation study, TEMS resulted in constricted osteotomies with more appropriate root end resection level and bevel accomplished in significantly less time, as compared to free-hand osteotomy and resection (4). Reduced surgical time and osteotomy size may result in better healing outcomes (2, 5). As new endodontic surgical techniques and armamentaria become available, it is important to assess the resulting clinical outcomes. TEMS departs from traditional endodontic microsurgery (EMS) in osteotomy size, control of resection level and bevel, surgical time and resection method, but the impact of these departures upon clinical outcomes has yet to be assessed.

Rud et al. proposed that outcomes be assessed at least one year after surgery by radiographically assigning cases to one of four categories: *complete healing, incomplete healing, uncertain healing* or *unsatisfactory healing* (6). They also correlated radiographic designations with subjective and objective clinical findings. Subsequently, Molven et al. added an "observer strategy" to the radiographic criteria proposing systematic training using illustrations and radiographs prior to performing an individual outcomes assessment (7). After individual assessment, examiners viewed radiographs together resulting in a 94% agreement for radiographic healing designations. The principles of these two studies are widely applied to contemporary endodontic surgical outcomes assessments (8-13).

In a cone beam computed tomography (CBCT)-based investigation, Curtis et al. adapted these principles to establish three outcomes categories based upon clinical and radiographic findings (14). *Complete healing* was defined as the absence of pain, absence of percussion and palpation tenderness, no probing depths indicative of endodontic failure, and CBCT periapical radiolucency (PARL) of 3.6 mm^3 or less. *Reductive healing* was defined as the absence of pain, the absence of percussion and palpation tenderness, no probing depths indicative of endodontic failure and a CBCT PARL that had reduced in volume but was greater than 3.6 mm^3. *Failure* was defined by the presence of pain, percussion or palpation tenderness, probing depths indicative of endodontic failure, or CBCT periapical lesion volume unchanged or enlarged. This classification eliminates possible confusion that can arise from the Rud et al. (6) categories of *incomplete healing* and *uncertain healing*, both of which allow for a reduction in radiolucency without complete resolution.

The aim of this study is to assess outcomes of TEMS at least one year after treatment, adapting the Curtis et al. (14) CBCT-based assessment to a periapical (PA)-radiograph-based outcomes assessment.

MATERIALS AND METHODS

The 59th Medical Wing Institutional Review Board approved this study.

TEMS Clinical Technique

Endodontic faculty and residents performed surgical procedures using the TEMS technique described previously (1). Immediate postsurgical and one-year postsurgical periapical radiographs were taken using an external positioning device and a size 2 sensor (RGV 6100, Kodak, Rochester, NY). An x-ray machine (Planmeca Intra, Helsinki, Finland) exposed the sensors with kVp, mA and exposure time, adjusted for patient size and location in the dental arch. After full-thickness flap reflection, clinicians seated a surgical guide and tapped a guided trephine bur through bone and root end at 9,000-10,000 r.p.m. with copious irrigation. Surgeons elevated the tissue core of bone and root end, then (in all but two cases) ultrasonically prepared and filled the root end with EndoSequence Root Repair Material (Brasseler USA, Savanah, Georgia) under the surgical operating microscope. In two cases, presurgical orthograde-placed white ProRoot MTA (Dentsply, Tulsa, OK) was deemed serviceable and no root end preparation or fill was carried out. All root ends were stained with methylene blue dye prior to final inspection.

Clinical Data Collection and Interpretation

Potential cases were retrospectively identified from a secure database of all patients that received TEMS in the Air Force Postgraduate Dental School, Lackland AFB, TX from June 2017 to May 2019. All initial or re-surgery TEMS cases with a one year or greater postsurgical clinical and radiographic exam were included. Intraoperative and recall data was entered into a secure database to include: American Association of Anesthesiologists (ASA) classification, age, sex, tooth type, grafting materials (if used), root end filling type, subjective report at recall, mobility, probing depths, presence of a sinus tract and percussion and palpation responses.

Outcomes Designations

Complete healing was defined as the absence of pain, absence of percussion and palpation tenderness, no probing depths indicative of endodontic failure, and complete resolution of immediate postsurgical radiolucency with periodontal ligament (PDL) width up to twice that of non-involved parts of the root (6). *Reductive healing* was defined as the absence of pain, the absence of percussion and palpation tenderness, no narrow, deep probing depth characteristic of endodontic failure, and incomplete reduction of immediate postsurgical radiolucency. *Complete healing* and *reductive healing* were considered successful outcomes. *Failure* was defined as the presence of pain, percussion or palpation tenderness, probing depths characteristic of endodontic failure, and/or a radiolucency of the same size or enlarged over the immediate postsurgical size.

Examiner Calibration and Radiographic Assessment

Two board certified endodontists completed a calibration exercise that included a detailed review of the radiographic outcomes criteria described by Rud et al. and the modified outcomes categories adapted by Curtis et al (6, 14). The raters then graded a series of 40 paired immediate postsurgical and recall radiographs that were unrelated to the study sample, using radiographic appearance alone to assign one of the outcomes designations (*complete healing*, *reductive healing* or *failure*). Next, de-identified immediate postsurgical and recall radiographs of each TEMS case were assessed by individual examiners to assign one of the three outcomes assessment designations based on radiographic appearance alone. When individual assessments were not in agreement, examiners viewed and discussed the radiographs together in an attempt to achieve consensus. This process of individual and consensus assessment was repeated 7 days later.

Final Outcomes Assessment

Radiographic classifications were combined with clinical data (pain, percussion or palpation tenderness, probing depths characteristic of endodontic failure) to form the final outcomes assessment of *complete healing*, *reductive healing* or *failure*.

Statistical Analysis

Intra-rater agreements were calculated by using the Cohen's kappa statistic. Significance was set to $p<0.05$. Statistical analyses were performed using SAS version 9.4 (Statistical Analysis Software, Cary, NC).

RESULTS

Twenty-four teeth from twenty-three patients (15 female, 9 male, all ASA I or II) met inclusion criteria with recall occurring between 12-28 months after treatment. The mean patient age was 42 years (range 23-67). Nine teeth received bone grafting with autogenous crushed bone, RegenerOss Allograft Putty (BIOMET 3i, LLC, Palm Beach Gardens, FL), Bio-Oss Collagen (Geistlich, Wolhusen, Switzerland), PAD™ Demineralized and Allowash XG® Sterilized Bio-Implants (Stryker CMF, Kalamazoo, MI), Novabone Dental Putty (NovaBone Products, Jacksonville, FL), CollaPlug (Zimmer Dental, Warsaw, IN) or a combination of these materials. Of the nine grafted cases, one received a Bio-Gide (Geistlich, Wolhusen, Switzerland) membrane. Combined clinical and radiographic data led to 20 designations of *complete healing*, two designations of *reductive healin*g and two *failure* yielding a 91.7% success rate. One failure occurred in a 44 year old ASA II female that did not receive a bone graft and had recall percussion and palpation tenderness, despite a radiographic presentation of complete osseous healing (Fig. 3*M-O*). The second failure occurred in a 25 year old ASA II male who received a PAD™ Demineralized and Allowash XG® Sterilized Bio-Implants (Stryker CMF, Kalamazoo, MI), Novabone Dental Putty (NovaBone Products, Jacksonville, FL), and autogenous bone on the distal root, had recall percussion and palpation tenderness and was also classified a radiographic failure (Fig. 4*J-L*). When considered independent of clinical findings, radiographic criteria for *complete healing* were met by 20 cases, *reductive healing* by 3 cases, with 1 "radiographic" *failure*. Thirteen teeth did not have the minimum twelve-month recall. Of these one (tooth #15) was extracted despite early signs of surgical success because it could not be integrated into a new implant-retained removal prosthetic treatment plan (Fig. 2*G-H*).

Raters reached consensus for radiographic assessment in all cases. The intra-rater Cohen's kappa coefficients were 0.43 (95% CI: 0.19 – 0.69; p = 0.006) for both raters, 0.77 (95% CI: 0.50 – 1.00; p < 0.0001) for Rater 1, and 0.21 (95% CI: -0.05 – 0.46; p = 0.50) for Rater 2. Rater 1 and the combined ratings had a significant intra-rater agreement.

DISCUSSION

This retrospective outcomes assessment is a preliminary indication that TEMS guided trephine bur root end resection leads to successful outcomes at rates similar to those established for freehand EMS carbide and diamond bur resections (8-10). Further, all but four cases showed complete healing on periapical radiograph 12-28 months after surgery, which is in keeping with prior evidence that osteotomies restricted to 5 mm (all TEMS osteotomies were 5 mm or less) exhibit enhanced healing (5). We further speculate that healing after TEMS may partially be due to time savings during osteotomy and resection with overall reduced surgical time. However, TEMS intraoperative efficiency gains have only been documented in surgical simulations and clinical investigation is required to substantiate this speculation (4). Finally, all thirteen cases that were not included in this cohort due to lack of a 12 month recall, but that had a recall four to eleven months after treatment, had a radiographic appearance indicative of *complete* or *reductive healing* with normal clinical findings.

Of note, 70.8% of cases in this cohort presented with anatomic complexities that may have precluded treatment without a surgical guide: palatal approaches to the palatal roots of maxillary first and second molars (Fig. 1*D-O;* Fig. 2*A-F*), facial roots of maxillary second molars (Fig. 1*A-C, G-L*), maxillary first and second molar re-surgery (Fig. 1*A-C*), distal roots of mandibular first molars (Fig. 3*G-L;* Fig. 4*A-O*), mesial and distal roots of mandibular second molars (Fig. 3*A-F*). Such complexities did not result in decreased success for teeth that may have otherwise required extraction. Indeed, many of these difficult surgeries were performed by novice residents, highlighting the enabling characteristics of TEMS.

Looking more closely at the two failures, the first, a mandibular molar, had pain to percussion and palpation and expanded lesion size fourteen months after surgery (Fig. 4*J-L*). Sixteen months after surgery the second failure, an otherwise asymptomatic tooth #28 was painful to percussion and palpation despite radiographic evidence indicating complete osseous healing (Fig. 3*M-O*). Cognitive dissonance in PA-radiograph-based outcomes assessment could arise in part due to the inability to appreciate what is occurring in three dimensions (15, 16). PA-based outcomes assessments have up to a 35% false negative rate and a 16.5% false positive rate for detection of osseous lesions as compared to CBCT-based assessments (14). Thus, the lack of recall CBCT images for this cohort represents an important limitation of these data. Further, radiographic outcomes assessments are complicated when bone grafting materials are placed into the osseous crypt, potentially masking radiographic signs of apical periodontitis at recall. However, in the absence of a radiolucency, signs or symptoms at recall, an outcomes designation of *failure* would be difficult for bone-grafted cases.

Outcomes assessment after endodontic surgery is inherently complex for several reasons: potential bias of evaluators, inability to objectively quantify subjective experience, inconsistency in radiographic and CBCT interpretation and inherent conceptual ambiguity (Is it biologically expected for *healed* cases to possibly have altered or aberrant sensation after a surgical intervention? What is tenderness? What is sensitivity? What is "just feels different?"). The surrogate measures of healing currently utilized provide a *reasonable* understanding of what is *likely* occurring in *most* cases. Histologic correlations are subject to potential incongruity as is seen in studies which attempt to relate symptoms to histologic findings and in the cyst vs. granuloma literature (17-22). Therefore, it is important to recognize that limitations of outcomes assessments in assessment of *biologic* and *subjective* reality, that strict binary categories of "success" and "failure" though helpful, might best be supplanted by understanding of healing upon a continuum, taking into account all of the factors that determine if a treated tooth contributes to the patient's present well-being, and if it is likely to continue to do so into the future.

The three-category outcomes assessment model we utilized allowed balanced consideration of clinical and radiographic findings. *Complete healing* and *reductive healing* cases were deemed *successful*, by definition lacking signs or symptoms with radiographic complete osseous fill or reduction in lesion size. This approach might potentially privilege normal signs and symptoms over radiographic appearance in cases where lesion resolution is incomplete. Conversely, a case with apparent complete radiographic healing and reestablishment of a PDL space, could also be deemed a failure if signs or symptoms were present, a scenario that occurred in this study (Fig. 3*M-O*). Periapical lesions that have reduced in size without complete resolution can be best understood, for outcomes purposes, through histologic evaluation but specimens cannot be harvested at recall exam. Interestingly, TEMS provides a viable way of assessing apical tissues of failed-root-canal-treatment or retreatment with core samples containing bone, root end and periapical lesion with associated biofilms (1). TEMS tissue cores might prove useful in further refining outcomes assessment models for classification of teeth with lesions that have reduced in sized without complete osseous fill.

CONCLUSION

This limited retrospective outcomes assessment is an early indication that TEMS guided trephine bur root end resection leads to successful outcomes at rates similar to those established for freehand carbide and diamond bur resections. Controlled clinical trials with long-term follow-up are warranted.

AUTHORS

Maj Arianne Galino Buniag, DDS, Resident, Air Force Postgraduate Dental School and Uniformed Services of the Health Sciences Postgraduate Dental College.

Lt Col Allen M. Pratt, DMD, Endodontics Residency Training Officer, Air Force Postgraduate Dental School and Uniformed Services of the Health Sciences Postgraduate Dental College.

Lt Col Jarom J. Ray, DDS, Endodontics Residency Program Director, Air Force Postgraduate Dental School and Uniformed Services of the Health Sciences Postgraduate Dental College.

The opinions or assertions contained herein are the private ones of the author(s) and are not to be construed as official or reflecting the view of the DoD or the USUHS.

ACKNOWLEDGEMENTS

Authors acknowledge Dr. Julie Anderson, Dr. Michelle Giacomino, Dr. Tyler Hawkins, Dr. James Wealleans and Dr. David Weyh who in addition to Dr. Jarom Ray, conducted the surgeries in the cohort.

The views expressed are those of the authors and do not reflect the official views or policy of the United States Department of Defense or its components or the Uniformed Services University of the Health Sciences. The views of the stated manufacturers are not necessarily the official views of, or endorsed by, the U.S. Government, the Department of Defense or the Department of the Air Force. No Federal endorsement of the stated manufacturers is intended. Drs Ray and Wealleans are inventors listed on U.S. Application No. 16/396,185, filed April 26, 2019, and entitled GUIDED ENDODONTIC MICROSURGERY (EMS) WITH TREPHINE BURS, which claims priority to and benefit of U.S. Provisional Application No. 62/662,966, filed April 26, 2018. All rights, title, and interest have been assigned to the Government of the United States as represented by the Secretary of the Air Force. One or more embodiments of the inventions described in these patent applications are described in this manuscript.

REFERENCES

1. Giacomino CM, Ray JJ, Wealleans JA. Targeted endodontic microsurgery: a novel approach to anatomically challenging scenarios using 3-dimensional-printed guides and trephine burs – a report of 3 cases. J Endod 2018;44:671-7.

2. Kim S, Kratchman S. Modern endodontic surgery concepts and practice: a review. J Endod 2006;32:601-23.

3. Ray JJ, Giacamino CM, Wealleans JA. Targeted endodontic microsurgery: digital workflow options. J Endod 2020;46:863-71.

4. Hawkins TK, Wealleans JA, Pratt AM, Ray JJ. Targeted endodontic microsurgery and endodontic microsurgery: a surgical simulation comparison. Int Endod J 2020;53:715-22.

5. von Arx T, Peñarrocha M, Jensen S. Prognostic factors in apical surgery with root-end filling: a meta-analysis. J Endod 2010;36:957-73.

6. Rud J, Andreasen JO, Moller Jensen JE. Radiographic criteria for the assessment of healing after endodontic surgery. Int J Oral Surg 1972;1:195-214.

7. Molven O, Halse A, Grung B. Observer strategy and the radiographic classification of healing after endodontic surgery. Int J Oral Maxillofac Surg 1987;16:432-9.

8. Setzer FC, Shah SB, Kohli MR, et al. Outcome of endodontic surgery: a meta-analysis of the literature—part 1: comparison of traditional root-end surgery and endodontic microsurgery. J Endod 2010;36:1757–65.

9. Tsesis I, Rosen E, Taschieri S, Strauss YT, Ceresoli V, Del Fabbro M. Outcomes of surgical endodontic treatment performed by a modern technique: An updated meta-analysis of the literature. J Endod 2013;39:332-8.

10. Song M, Nam T, Shin S, Kim E. Comparison of clinical outcomes of endodontic microsurgery: 1 year versus long-term follow-up. J Endod 2014;40:490-4.

11. Shinbori N, Grama AM, Patel Y, Woodmansey K, He J. Clinical outcome of endodontic microsurgery that uses EndoSequence BC root repair material as the root-end filling material. J Endod 2015;41:607-12.

12. Wang ZH, Zhang MM, Wang J, Jiang L, Liang YH. Outcomes of endodontic microsurgery using a microscope and mineral trioxide aggregate: A prospective cohort study. J Endod 2017;43:694-98.

13. Kim D, Kim S, Song M, Kang DR, Kohli MR, Kim E. Outcome of endodontic micro-resurgery: A retrospective study based on propensity score-matched survival analysis. J Endod 2018;44:1632-40.

14. Curtis DM, VanderWeele RA, Ray JJ, Wealleans JA. Clinician-centered outcomes assessment of retreatment and endodontic microsurgery using cone-beam computed tomographic volumetric analysis. J Endod 2018;44:1251-6.

15. Seltzer S, Bender IB. Cognitive dissonance in endodontics. Oral Surg Oral Med Oral Pathol 1965;20:505-16.

16. Schloss T, Sonntag D, Kohli MR, Setzer FC. A comparison of 2- and 3-dimensional healing assessment after endodontic surgery using cone-beam computed tomographic volumes or periapical radiographs. J Endod 2017;43:1072–9.

17. Brynolf I. A histological and roentgenological study of the periapical region of human upper incisors. Odontol Revy 1967;18:1-176 (Supplement 11).

18. Langeland K, Block RM, Grossman LI. A histopathologic and histobacteriologic study of 35 periapical endodontic surgical specimens. J Endod 1977;3:8-23.

19. Green TL, Walton RE, Taylor JK, Merrell P. Radiograhic and histologic periapical findings of root canal treated teeth in cadaver. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;83:707-11.

20. Ricucci D, Loghin S, Siquiera JF. Correlation between clinical and histologic pulp diagnoses. J Endod 2014;40:1932-9.

21. Lalonde ER, Luebke RG. The frequency and distribution of periapical cysts and granulomas. An evaluation of 800 specimens. Oral Surg Oral Med Oral Pathol 1968;25:861-8.

22. Nair PNR, Pajarola G, Schroeder HE (1996). Types and incidence of human periapical lesions obtained with extracted teeth. Oral Surg Oral Med Oral Pathol 1996;81:93-102.

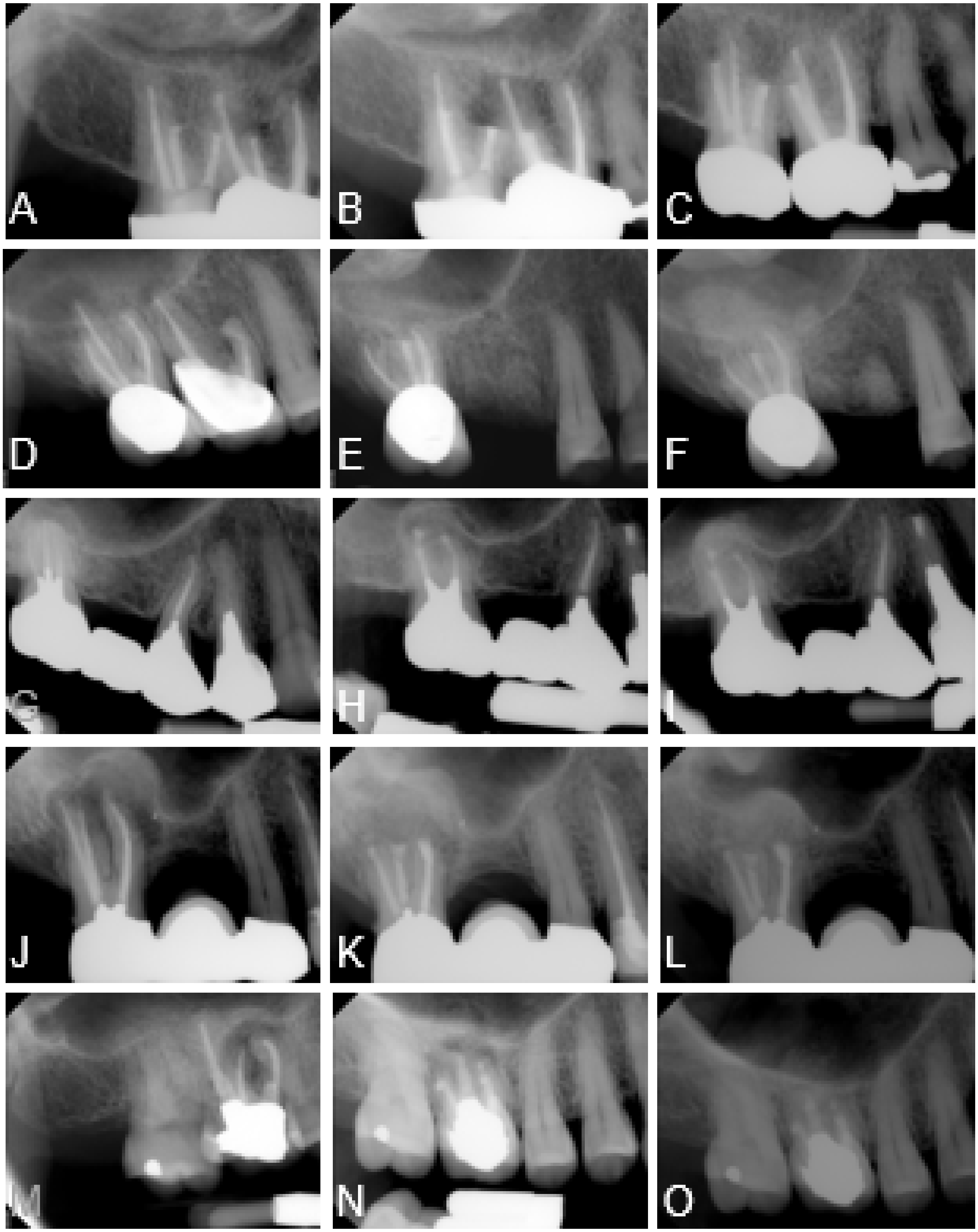

Figure 1. Representative periapical radiographs of right maxillary posterior TEMS cases: Presurgical (*A, D, G, J,* and *M*), immediate postsurgical (*B, E, H, K,* and *N*) and follow-up (*C, F, I, L,* and *O*). Tooth #2 MF and tooth #3 DF roots (*A-C*). Tooth #2 palatal root (*D-F*). Tooth #2 MF, DF, and palatal roots with bone graft (*G-I*). Tooth #2 MF, DF, and palatal roots with bone graft (*J-L*). Tooth #3 MF, DF, and palatal roots with bone graft (*M-O*).

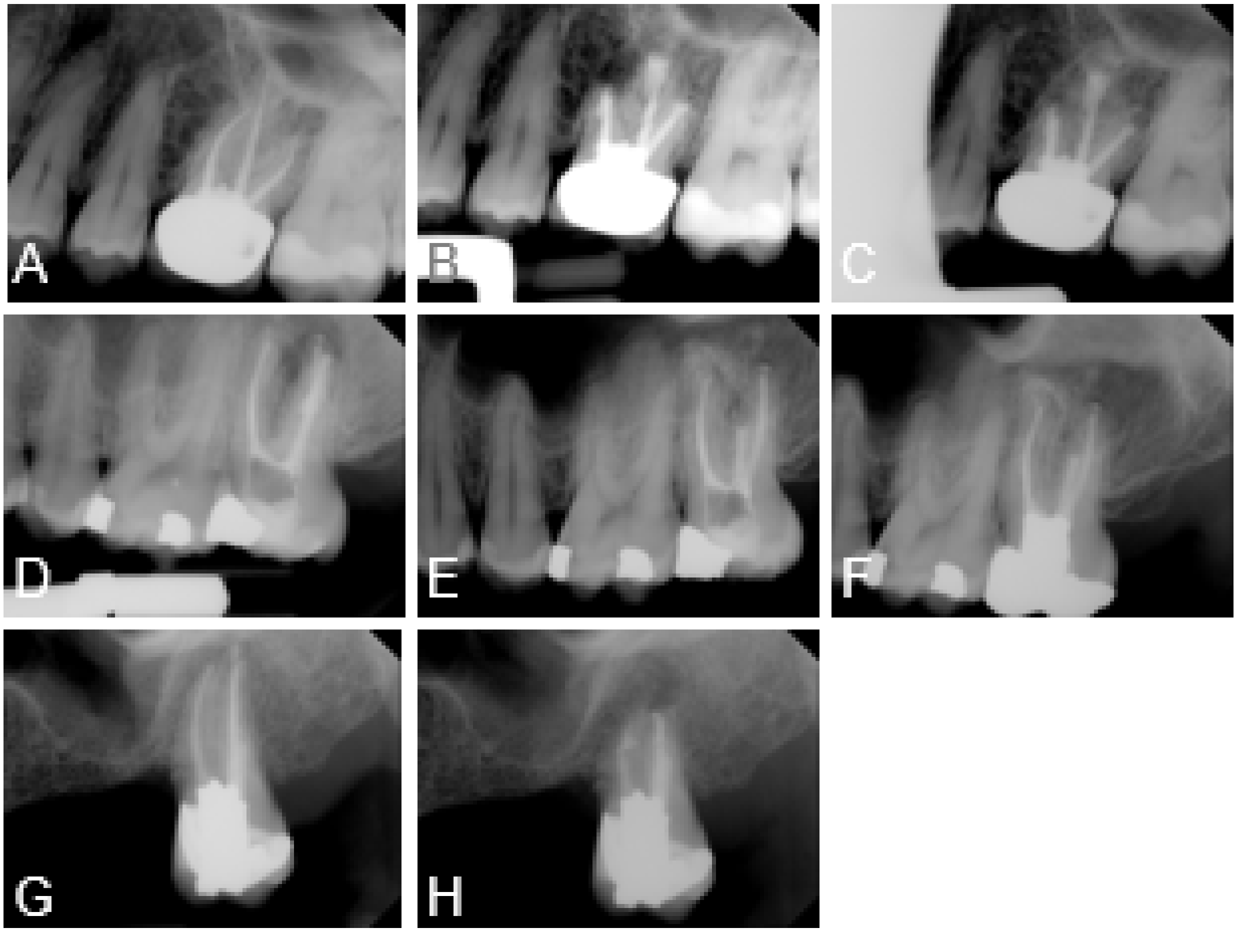

Figure 2. Representative periapical radiographs of left maxillary posterior TEMS cases: Presurgical (*A, D,* and *G*), immediate postsurgical (*B, E,* and *H*), and follow-up (*C* and *F*). Tooth #14 MF, DF, and palatal roots with bone graft (*A*-*C*). Tooth #15 palatal root with bone graft (*D*-*F*). Tooth #15 MF, DF, and palatal roots with bone graft (*G*-*H*); this tooth was extracted due to a change in the restorative treatment plan and no follow-up radiographs were available.

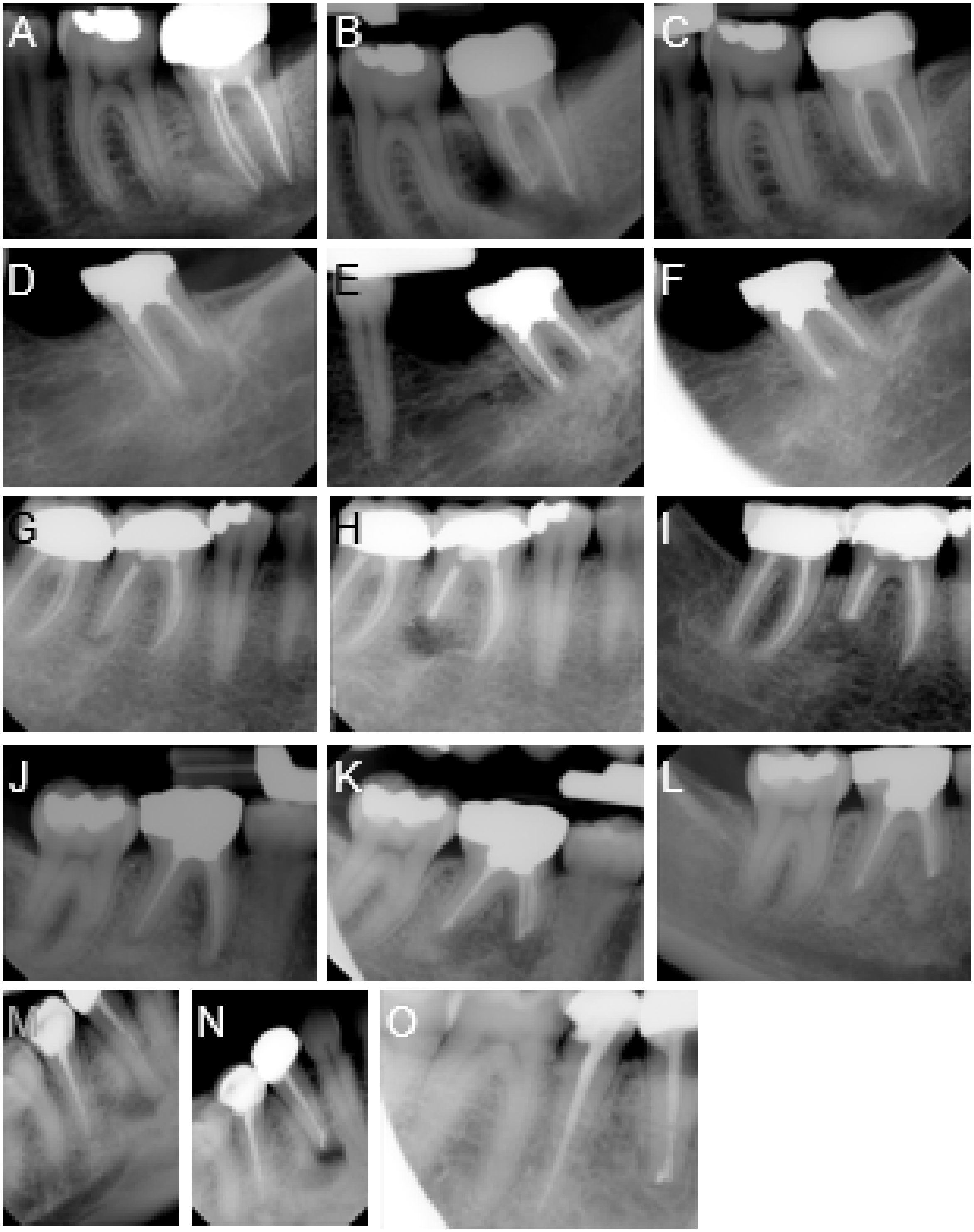

Figure 3. Representative periapical radiographs of left and right mandibular posterior TEMS cases: Presurgical (*A, D, G, J,* and *M*), immediate postsurgical (*B, E, H, K,* and *N*), and follow-up (*C, F, I, L,* and *O*). Tooth #18 M, D roots (*A-C*). Tooth #18 M, D roots with bone graft (*D-F*). Tooth #30 D root (*G-I*). Tooth #30 D root only with bone graft (*J-L*); #30 M root received free-hand osteotomy and resection. Tooth #28 (*M-O*); failed case demonstrating recall percussion and palpation tenderness.

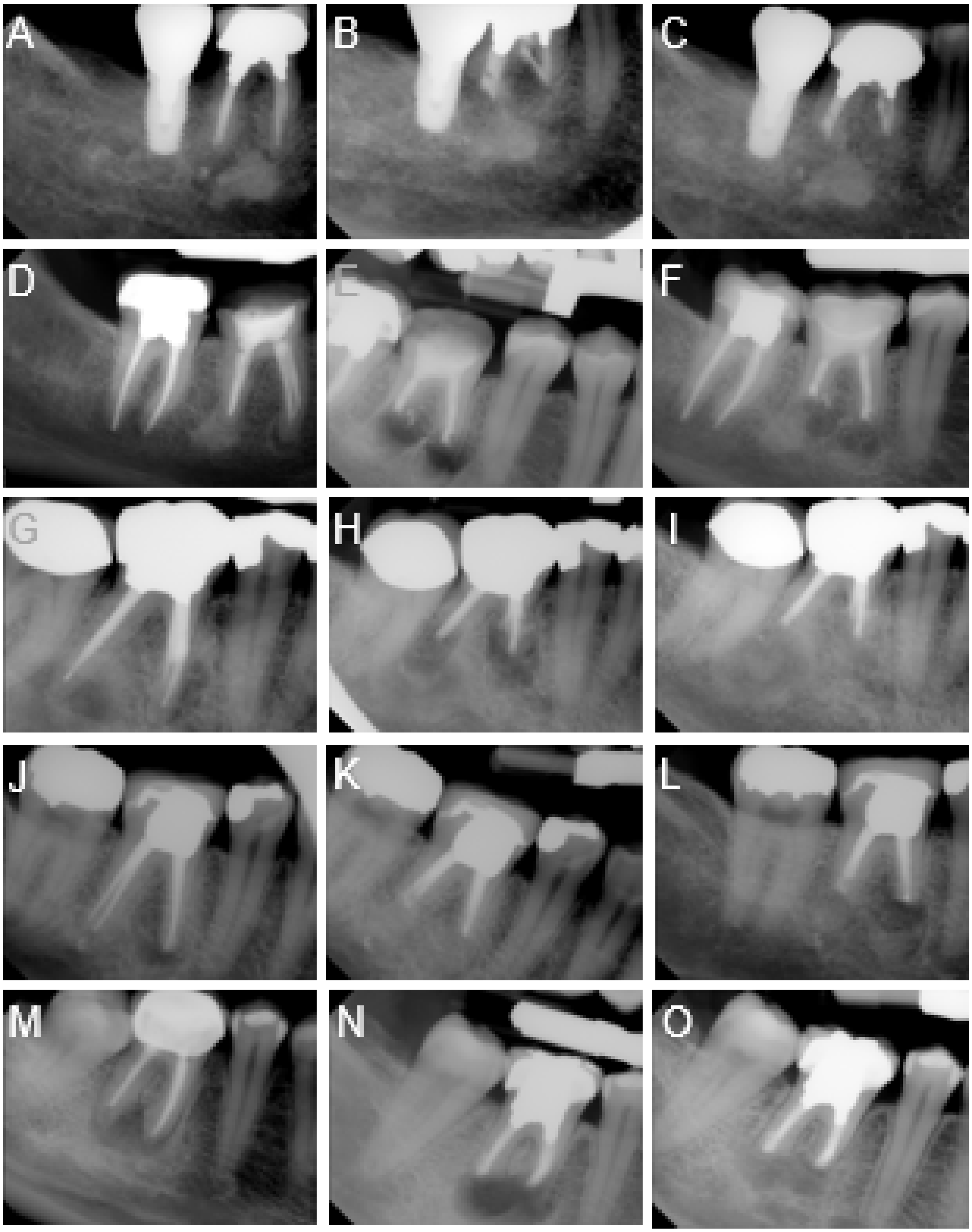

Figure 4. Representative periapical radiographs of right mandibular posterior TEMS cases: Presurgical (*A, D, G, J,* and *M*), immediate postsurgical (*B, E, H, K,* and *N*), and follow-up (*C, F, I, L,* and *O*). Tooth #30 M, D roots with bone graft (*A-C*). Tooth #30 M, D roots (*D-F*). Tooth #30 M, D roots (*G-I*). Tooth #30 M, D roots with bone graft (*J-L*); failed case demonstrating recall percussion and palpation tenderness and was classified as a radiographic failure. Tooth #30 M, D roots (*M-O*).