### 4. TITLE AND SUBTITLE
Patient Centered Outcomes Assessment of Retreatment and Endodontic Microsurgery Using CBCT Volumetric Analysis

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### 14. ABSTRACT
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Authors: Darrell M. Curtis, DDS, MS, Jarom J. Ray, DDS, Richard A. VanderWeele, DMD James A. Wealleans, DMD.  
Introduction: Outcomes assessment of retreatment and endodontic microsurgery (EMS) are traditionally based on clinical findings and radiographs. The purpose of this study was to incorporate cone beam computed tomography (CBCT)-based periapical radiolucency (PARL) volumetric change analysis into outcomes assessment.  
Methods: For 68 retreatments and 57 EMS, pre-operative and recall clinical data, periapical radiographs (PA) and CBCT were retrospectively obtained. Specialized software was used by 2 board certified endodontists for PARL volumetric analysis. For EMS and retreatment, clinical outcomes were determined by combining clinical data with CBCT-generated volumetric analysis (PA was not used). Additionally, percent volume r

### 15. SUBJECT TERMS

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Authors: Darrell M. Curtis, DDS, MS, Jaron J. Ray, DDS, Richard A. VanderWoude, DDS

Abstract: Outcomes assessment of retreatment and endodontic microsurgery (EMS) are traditionally based on clinical findings and radiographic exams. The purpose of this study was to incorporate cone beam computed tomography (CBCT)-based periradicular radiolucidity (PARL) volumetric analysis to outcomes analysis approach.

Methods: For 68 retreatments and 57 EMS, pre-operative and recall clinical data, periradicular radiographs (PA) and CBCT were retrospectively obtained. Specialized software was used by 2 board-certified endodontists for PARL volumetric analysis. For EMS and retreatment, clinical outcomes were determined by combining clinical data with CBCT generated volumetric analysis (PA was not used). Additionally, percent volume reduction comparisons for EMS and retreatment were performed. Paired and 2 sample t-test were used to compare means.

Results: In their study of which 65 PA did not detect a PARL, PA time was not statistically significant in 33 (65.5%) PA false positive rate. Of the 79 recall studies in which CBCT did not detect a PARL, PA did not detect PARL in 1 in 16.5% PA false positive rate.

Conclusions: In this study 2-Dimensional PARL is more sensitive and specific than 2-D PARL in assessing PARL and has demonstrable utility in outcomes assessment.

Materials and Methods: Pre-operative and recall clinical data was entered into a secure database containing all patients who were at least 18 years of age and who had received retreatment or EMS at Wilford Hall Ambulatory Surgery Center Endodontics Residency between 1 July 2011 and 31 July 2015. Patients whose treatment included pre-treatment PA and CBCT imaging, and who returned for a recall examination (range of 12-53 months) with PA and CBCT imaging were included in the study. Criteria were met by 125 teeth of 97 patients: 68 retreatments and 57 EMS treatments. The mean patient age was 47.7 years with a range of 19-86 with 54 men and 43 women. A retrospective treatment outcomes assessment was conducted based upon clinical and CBCT findings. The 59th Medical Wing Institutional Review Board approved the protocol.

Treatment Protocol

Treatments were completed by endodontists residing under the supervision of board-certified Endodontists. Retreatment and EMS were completed using a dental operating microscope (Zeiss OPMI PR0 ergo) and contemporary materials and techniques. Retreatment protocol involved use of a rubber dam, 6-12% NaOCl, 17% EDTA, 2% Chlorhexidine, Ca(OH)₂ inter-appointment dressing for a minimum 7 days as deemed necessary by the provider, gutta-percha and Roth’s Sealer, and bonded onlay barriers. Apical surgery involved full thickness mucoperiosteal flap reflection, osteotomy preparation and root-end resection, ultrasonic preparation and root-end fillings with grey or white ProFile MTA (Dentsply, Tulsa, OK) or EndoSequenCe BC Root Repair Material (Braunler USA, Savannah, GA). Nineteen ostetomy sites were grafted with Calcium Sulfate and OraGraft DF05A and one site was grafted with Geistlich Bio-Oss Collogen®. No membranes were used.

A 3D Acutomo 170 (I. Munita USA, Irvine, CA) generated CBCT scans with 60x60mm or 40x40mm fields of view at 90 kVp and 5.9 mA. All pre-operative and post-operative periradicular images were taken utilizing a paralleling technique and external cone positioning device (XCP) using size 2 digital sensors (Kodak RVG 6000). A desktop x-ray machine (Planmeca Intra, Helsinki, Finland) was used to expose the sensors with adjustable kVp, mA, and time settings dependent upon patient size and location in the oral cavity.

Clinical Data Collection & Interpretation

De-identified pre-operative and recall clinical data was entered into a secure digital file. A random sequence generator was used to assign each patient a number such that the clinical data obtained from patient records could be matched with corresponding radiographic images. Pre-operative variables that were analyzed included: presence of pain, percussion and palpation findings, probing depths, presence of a sinus tract and presence of un-instrumented canals. Intraoperative variables analyzed included: grafted materials [when used] and root-end filling and obturation materials. Recall variables analyzed included: presence of pain, percussion and palpation tenderness, probing depths, the presence of a sinus tract. Patients were asked to return for a recall examination within 3-4 months.

Examiner Calibration and Radiography and analysis

De-identified patient CBCT scans (125 pre-op and 125 recall) were imported into specialized imaging software (Amira 5.3.4, Visage Imaging GmbH, Berlin, Germany) for analysis by 2 board-certified Endodontists. During tracing of PARL, borders, examiners constantly discussed and reached consensus on border designations. A minimum of 7 individual circumferential tracings at various fields of view on the borders of the PARL were utilized by specialized imaging software for volume rendering. The 3-D rendering did not intimately conform to the anatomy of the PARL, as in lesions with aberrant borders, additional tracings were conducted until intimate conformity was achieved.

In order to assess variability in volumetric measurements, eighteen CBCT scans (9 Pre-op, 9 recall) of 36 sites were traced 30 days after initial tracing. Variability was calculated for five size groups (two of which overlapped) based on volume, and a two-sided 95% confidence limit (CL) was calculated for each group (Table 3). The CL was applied to all volumetric measurements when determining if post-op volumes changed relative to pre-op volumes. Based on the 95% CL, for measurement in the 0-10mm³ range, a volume measuring less than or equal to 3.6 mm³ was designated as no PARL.

Of the total 250 scans evaluated, 100 determined to have a low density area ≥ 3.6 mm³ (no PARL designation). For the remaining 150 scans PARL volumes from >3.6 mm³ up to 1440.3 mm³. Pre-operative and post-operative PARL volumes, percent change in volume, and mean volume change for both EMS and retreatment were calculated.

Examiners used MIPSAC dental enterprise viewer (LEAD Technologies Inc, Charlotte, NC) to interpret randomized pre-operative and recall digital PA. The presence or absence of a periradicular radiolucency was defined as at least one radiolucidity ≥ 0.2 times the width of the PDL space and was determined by consensus. If disagreement occurred between examiners with regards to the presence or absence of a PARL, the stricter interpretation (radioluency present) was accepted. PA interpretations were not utilized in outcomes assessment. The number of PARL identified with CBCT was compared to the number identified with PA to determine how often agreement existed.

Assessment of Healing

Pre and post-operative clinical findings were matched with CBCT PARL volumetric changes in determining outcomes assessment. Complete healing was defined as absence of pain, absence of percussion and palpation tenderness, no probing indicative of endodontic failure, and pariradicular lesion volume ≤ 3.6 mm³. Reductive healing was defined as absence of pain, absence of percussion and palpation tenderness, no probing indicative of endodontic failure, and a PARL that reduced in volume but was ≥ to the CL volume of 3.6 mm³. Failure was defined as superimposition of several radio-densities of bone and soft tissue at various depths, into one planar image. The clinician is then required to "interpret" this planar summation of radio-densities, factoring in the possibility of geometric distortion, prior to determining an outcomes assessment. Often, this has the effect of inaccurate lesion size interpretations and false negative and less commonly false positive designations (5,6).

Historical studies using 2 dimensional x-ray interpretations show that it may take up to 4 years for healing to occur following root canal treatment. The purpose of this study was to incorporate cone beam computed tomography (CBCT)-based periradicular radiolucidity (PARL) volumetric change into outcomes analysis approach.
presence of pain, percussion or palpation tenderness, probing indicative of endodontic failure, or a periapical lesion volume that remained unchanged or increased in volume.

Results:

The mean follow-up period for retreatment was 22 months (range of 12-33 months) and for EMS cases was 23 months (range of 15-33 months). The combined mean follow-up period for the study was 22.3 months (Fig. 2).

Retreatment volumetric changes

Fifty-nine retreatment teeth had a pre-operative PARL at recall 52/59 or 88.1% of PARL reduced in volume, 2/59 or 3.4% remained unchanged, and 5/59 or 8.5% increased in volume (Fig. 3A). Average volumetric change was calculated by adding all of the percentage volume changes for each tooth then dividing by the total number of teeth. For example, a pre-operative PARL with a volume of 100 mm³ that reduced to a final volume of 50 mm³ at recall (50% reduction), was weighted equally with a PARL that reduced from 10 mm³ to 5 mm³. The average volumetric change was 62.4%. All 9 teeth with no pre-operative PARL did not have a recall PARL (Fig. 3B).

EMS volumetric changes

Forty-five EMS teeth had a pre-operative PARL at recall 44/45 or 97.8% of PARL reduced in volume and 1/45 or 2.2% remained unchanged (Fig. 3A). The average volumetric reduction among these PARL was 95.6% (Fig. 3C). All 12 teeth with no pre-operative PARL remained unchanged at recall.

Retreatment healing compared to EMS healing

Combining clinical data and CBCT, 21/59 or 35.6% of retreatment teeth with a pre-operative PARL showed complete healing; 28/59 or 47.5% had reductive healing, and 10/59 or 16.9% failed (Fig. 3D). For EMS teeth with a pre-operative PARL, 38/45 or 84.4% showed complete healing; 5/45 or 11.1% had reductive healing, and 2/45 or 4.4% failed (Fig. 3D).

In teeth with a pre-operative PARL, EMS showed a statistically significant difference in complete healing of 38/45 or 84.4% versus retreatment 21/59 or 35.5% (P=0.0001); further, when combined reductive healing and complete healing was considered, EMS showed a statistically significant difference of 41/45 or 95.6% versus retreatment 49/59 or 83.1% (P = 0.048).

In teeth without a pre-operative PARL, 7/9 or 77.8% of retreatment teeth showed complete healing, and 11/12 or 91.7% of EMS teeth had complete healing. Failure was observed in 2/9 or 22.2% of retreatment cases and 1/12 or 8.3% of EMS cases. All of these failures were related to the presence of clinical signs or symptoms at recall; a PARL did not develop in any of these cases.

Under the heading of "outcome" The American Association of Endodontists Glossary of Endodontic Terms (ninth edition, 2014) defines four categories: 1) "Healed" - Functional, asymptomatic teeth with no or minimal radiographic periradicular (apical pathosis), 2) "Nonhealed" - Functional, symptomatic teeth with or without radiographic periradicular (apical pathosis) (radiolucency), which are symptomatic with or without radiographic periradicular (apical pathosis) (radiolucency), which are symptomatic (pain, function is not altered), and 4) "Functional" - A treated tooth or root that is serving its intended purpose in the dentition. Taken together, each of these designations contains provision for a radiolucency at recall, which places the clinician in the position of subjectively categorizing a case by considering if a rarefaction is absent, minimal or otherwise. If CBCT PARL volume rendering gains prominence, greater clarity in our terminology will be possible with quantification of outcomes criteria. Each outcomes designation could then be used to prudent course(s) of action, which is the ultimate utility of diagnostic terminology. Clarity of terminology and course of action are required if trends toward extraction of servicable teeth in favor of implant placement are to be stemmed. We propose that for treated asymptomatic teeth with lesions that have reduced in size, but have not completely resolved, the term “Reductive Healing” be utilized instead of the term “healing.” This will more clearly differentiate cases that have an asymptomatic reduction in PARL from cases where PARL has remained unchanged or increased in size. We suggest that the clinical course of action indicated by an outcome designation of Reductive Healing is a recall interval based on best evidence, clinician experience and patient desires.

Conclusion:

In this CBCT and clinical data-based outcomes assessment EMS resulted in greater mean volumetric reduction and a higher healing rate compared to retreatment. Post-operative CBCT is more sensitive and specific than PA in assessing PARL and has demonstrable utility in outcomes assessment. These findings suggest that in the future, volume rendering can be incorporated into outcomes assessment, and terminology and treatment recommendations can be refined.

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The views expressed are those of the authors and do not reflect the official views or policy of the Department of Defense or its Components or the Uniformed Services University of the Health Sciences.
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The authors have no conflicts of interest related to this study.

References:

Figure 1. At 32 months post-apical surgery, the PA on the left indicates no apical radioluency associated with tooth #2. In contrast, the CBCT image on the right was taken on the same date and clearly indicates a PARIL associated with the MF and DF roots of tooth #2.

![Image](image1.png)

**Table 1.** 95% CL for various PARI volume ranges. Note, PARI measuring 3.6 mm³ or less are counted as 0 mm³ (no PARI).

<table>
<thead>
<tr>
<th>Volume Range (mm³)</th>
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<th># Images retraced in each volume range</th>
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</tr>
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<tr>
<td>0.1 - 10</td>
<td>51</td>
<td>2</td>
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<td>83</td>
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<tr>
<td>50 - 100</td>
<td>26</td>
<td>4</td>
<td>± 15.4</td>
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<tr>
<td>100 - 1500</td>
<td>16</td>
<td>7</td>
<td>± 31.6</td>
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Figure 2. Mean Follow-up for Retreatment and Endodontic Microsurgery Cases.
Figure 3. (A) Percentage of teeth with pre-operative PARL in which a PARL increased in size, decreased in size, or remained unchanged. (B-C) PARL volume reductions per tooth. (D) Outcome of teeth with pre-operative PARL based on volumetric changes in PARL and clinical findings.