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Patient Centered Outcomes Assessment of Retreatment and Endodontic Microsurgery Using CBCT Volumetric Analysis

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Maj Curtis, Darrell M

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
59th Clinical Research Division
1100 Willford Hall Loop, Bldg 4430
JBSA-Lackland, TX 78236-9908
210-292-7141

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Abstract:
Title: Patient centered outcomes assessment of retreatment and endodontic microsurgery using CBCT volumetric analysis.
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

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Abstract:

Title: Patient centered outcomes assessment of retreatment and endodontic microsurgery using CBCT volumetric analysis.

Authors: Matt M. Curtis, DDS, MS, Jason J. Ray, DDS, Richard A. VanderWeele, DDS. James A. Winnell, DDS, MMD.

Introduction: Outcomes assessment of retreatment and endodontic microsurgery (EMS) are traditionally based on clinical findings and randomized controlled trials. The purpose of this study was to incorporate cone beam computed tomography (CBCT)-based periapical radiolucency (PARL) volumetric analysis into outcomes assessment.

Methods: For 68 retreatments and 57 EMS, pre-operative and recall clinical, periapical radiographs (PA) and CBCT generated volumetric analysis (PA was not used). Additionally, percent volume reduction comparisons for EMS and retreatment were performed. Recall PA and CBCT periapical status examiner outcomes interpretations were compared.

Results: In teeth with or without a preoperative PARL, EMS resulted in a statistically significant difference in complete healing (94.57% vs 86.0%) versus retreatment (28/68 or 41.2%) with P=0.001. EMS resulted in a statistically significant difference in complete healing and radiographic healing (54.57% vs 49.78%) versus retreatment (56/68 or 82.4%) with P=0.035. Of 46 recalls in which CBCT detected a PARL, PA detected 30 (35% PA false negative rate). Of the 79 recall studies in which CBCT did not detect a PARL, PA did detect PARL in 13 (16.5% PA false positive rate).

Conclusions: In this CBCT and clinical data-based outcomes assessment EMS resulted in greater mean volume 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.

Superimposition of several radio-opacities of bone and soft tissue at various depths, summation of radio-opacities, factoring in the possibility of geometric distortion, take up to 4 years for healing. A four-year observation period following endodontic surgery in cases demonstrating uncertain healing has been proposed (8). Radiographic signs of osseous healing after endodontic surgery have classically been divided into four groups: complete healing, incomplete healing, uncertain healing, and unsatisfactory healing (9). Recall examinations over a four-year period do not always occur. More sensitive and specific three-dimensional imaging measures provide a more clear and timely patient-centered outcomes assessment.

CBCT utilizes x-ray beams to acquire multiple images that render a 3-D representation of the teeth and surrounding tissues. Tissue can be analyzed in axial, coronal, and sagittal views. Recent evidence indicates an enhanced diagnostic ability of CBCT over two-dimensional radiography in the detection of periapical lesions, as seen in Figure 1 (10-16). Moti de Almeida et al, found that treatment plan alterations were attributed to CBCT in 38% of referred endodontically significant in which a pre-operative CBCT was acquired (17). It et al. reported endodontic treatment plan alterations occurred in 62-2% of cases after CBCT imaging, versus PA alone (18). Rodrigues et al concluded: “CBCT imaging has a substantial impact on endodontic decision making among specialists, particularly in high difficulty cases” (19). CBCT images can be imported into specialized imaging software for PARL volume rendering based on detailed tracings. This method might overcome interpretation error inherent with two-dimensional PA alone, specifically the presence or absence of osseous healing trends. Counter arguments suggest that the ultimate benefit of CBCT in endodontics is unclear and its routine use for detecting periapical radio-opacities is not justified (20, 21).

Potential gains in sensitivity and specificity in outcomes assessment, studies incorporating CBCT pre-operatively and at recall are warranted. A gap in knowledge is illustrated by cases where an outcome seems unclear based on PA alone but becomes clear with CBCT. Recent studies have found that post-op CBCT yields a less favorable outcome assessment versus PA alone for initial root canal treatment, retreatment, and EMS (22,23,24). The question is: should CBCT routinely be employed in assessment of post-operative outcomes?

The aim of this study was to retrospectively assess treatment outcomes for retreatment and EMS through clinical assessment, and a CBCT-based calculation of volumetric change. The study also compares examiner CBCT interpretations with examiner CBCT findings in identification of PARL.

Materials and Methods:

De-identified 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 two board-certified Endodontists. During tracings of PARL borders, examiners constantly discussed and reached consensus on border specifications. A minimum of 7 individual circumferential tracings at various locations on the borders of the PARL were utilized by specialized imaging software for volume rendering. If the 3-D rendering did not intimately conform to the anatomy of the PARL, as in lesions with absent 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 adjacent sites were traced 30 days after initial tracing. Variability was calculated for five site groups (two of which overlapped) based on volume, and a two-sided 95% confidence limit (CL) was calculated for each group (Table 1). 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 were determined to have a low density area >3.6 mm³ (no PARL designation). For the remaining 150 scans PARL volumes ranged from >3.6 mm³ up to 4,483.13 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 MiPACS dental enterprise viewer (LEAD Technologies Inc, Charlotte, NC) to interpret randomized pre-operative and recall digital PA. The presence or absence of a periapical radiolucency was defined as at least one radiolucency 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 (radiolucency present) was accepted. PA interpretations were not utilized in outcome analysis, 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 periapical 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 >3 to the CL volume of 3.6mm³. Failure was defined as
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 12-53 months) and for EMS cases was 23 months (range of 14-32.3 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 15 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 95.0% (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. 3C). 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 in a statistically significant difference in complete healing of 38/45 or 84.4% versus retreatment 21/59 or 35.5% (P=0.001). Moreover, when combined reductive healing and complete healing was considered, EMS showed 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 12/12 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, 2016) 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 asymptomatic and functional, or teeth with or without radiographic periradicular (apical pathosis) (radiolucency), which are asymptomatic and nonfunctional), 3) "Healing- Teeth with periradicular (apical pathosis) (radiolucency), which are asymptomatic and functional, or teeth with or without radiographic periradicular (apical pathosis) (radiolucency), which are symptomatic and functional (reduction of 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 contain 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.

In this study, periapical radiographs detected a recall PARL in only 30/46 retreatment and EMS cases in which CBCT detected a PARL. Thus, if CBCT had not been utilized, 54.9% of recall PARL would have gone undetected. In a twenty-year analysis of biopsied radiolucent jaw lesions, only 21/56 had a percentage of inflammatory lesions were scar tissue (27). Likewise, a histological evaluation of persistent periradicular lesions associated with nonsurgical endodontic treatment failures yielded a diagnosis of scar tissue in only 2.5% of cases (29). Thus, use the CBCT radiography might support a dubious healing; this could be the case if complete healing has occurred when it has not, making future recall visits less likely to take place.

Combining CBCT with volume rendering capability adds a new dimension to outcomes assessment by providing quantification of PARL volumetric changes. Bender and Seltzer showed that digital radiography detects lesions in cortical bone only when there is perforation of cortical plate, or erosion of the inner or outer surface of the cortex (4). Ostavisk showed that apical healing might take four years following root canal therapy (7). In this study, when examiners disagreed on presence or absence of PARL, the more inclusive "PARL, present" designation was made. Even so, PA exhibited less sensitivity in identifying PARL than did CBCT. Our findings indicate that changing definitions in follow-up PARL could be occurring after treatment, with inadequate detection by PA alone. Post-operative CBCT could influence treatment decisions in such situations. For example, a CBCT scan taken one year after retreatment that shows increased in PARL volume compared to panoramic serials of subclinical bone), was not detected by PA alone. Combining clinical data and CBCT, it was observed in a statistically significant difference in complete healing of 38/45 or 84.4% versus retreatment 21/59 or 35.5% (P=0.001). Moreover, when combined reductive healing and complete healing was considered, EMS showed statistically significant difference of 41/45 or 95.6% versus retreatment; 49/59 or 83.1% (P=0.048).
The authors have no conflicts of interest related to this study.

References:


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

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<tr>
<th>Volume Range (mm³)</th>
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<th># Images retrieved in each volume range</th>
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<tr>
<td>0.1 -10</td>
<td>51</td>
<td>2</td>
<td>± 3.6</td>
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<tr>
<td>0.1 - 25</td>
<td>83</td>
<td>4</td>
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<td>50</td>
<td>3</td>
<td>± 10.8</td>
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<tr>
<td>101 - 500</td>
<td>26</td>
<td>4</td>
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<tr>
<td>201 - 1500</td>
<td>16</td>
<td>7</td>
<td>± 31.6</td>
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Figure 1. At 32 months post-apical surgery, the PA on the left indicates no apical radiolucency associated with tooth #2. In contrast, the CBCT image on the right was taken on the same date and clearly indicates a PARL associated with the MP and DP roots of tooth #2.

Figure 2. Mean Follow-up Period 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 size reduction per tooth. (D) Outcome of teeth with pre-operative PARL based on volumetric changes in PARL and clinical findings.