A Comparison of 2- and 3-dimensional Healing Assessment after Endodontic Surgery Using Cone-beam Computed Tomographic Volumes or Periapical Radiographs

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Abstract

Introduction: The aim of this study was to compare the assessment of healing after endodontic microsurgery using 2-dimensional (2D) periapical films versus 3-dimensional (3D) cone-beam computed tomographic (CBCT) imaging. **Methods:** The healing of 51 teeth from 44 patients was evaluated using Molven's criteria (2D) and modified PENN 3D criteria. The absolute area (2D) and volume (3D) changes of apical lesions preoperatively and at follow-up were calculated by segmentation using OsiriX software (Pixmeo, Bernex, Switzerland) and ITK-Snap (free software). **Results:** There was a significant difference between the mean preoperative lesion volumes of 95.34 mm^3 (n = 51, standard deviation [SD] ±196.28 mm^3) versus 6.48 mm^3 (n = 51, SD ±17.70 mm^3) at follow-up ($P < .05$). The mean volume reduction was 83.7%. Preoperatively, mean lesion areas on periapical films were 13.55 mm^2 (n = 51, SD ±18.80 mm^2) and 1.83 mm^2 (n = 51, SD ±.68 mm^2) at follow-up ($P < .05$). According to Molven's criteria, 40 teeth were classified as complete healing, 7 as incomplete healing, and 4 as uncertain healing. Based on the modified PENN 3D criteria, 33 teeth were classified as complete healing, 14 as limited healing, 1 as uncertain healing, and 3 as unsatisfactory healing. The variation in the distribution of the 2D and 3D healing classifications was significantly different ($P < .05$). Periapical healing statuses incomplete healing or uncertain healing according to Molven's criteria could be clearly classified using 3D criteria. **Conclusions:** CBCT analysis allowed a more precise evaluation of periapical lesions and healing of endodontic microsurgery than periapical films. Significant differences existed between the 2 methods. Over the observation period, the mean periapical lesion sizes significantly decreased in volume. Given the correct indications, the use of CBCT imaging may be a valuable tool for the evaluation of healing of endodontic surgery. *(J Endod 2017;43:1072–1079)*

Key Words

Apicoectomy, cone-beam computed tomography, endodontic, healing, microsurgery, outcome, root-end surgery, success

Significance

CBCT evaluation allowed for a precise volumetric analysis of preoperative periapical lesions and the assessment of healing after endodontic microsurgery. Healing classification in 3D (CBCT) analysis was significantly different from 2D (periapical radiography) analysis.

Endodontic microsurgery uses high-magnification, ultrasonic root-end preparation and biocompatible root-end filling materials. Success rates in the range of 90% have been reported for endodontic lesions (1, 2). Most original studies used Molven's criteria for the assessment of healing after endodontic surgery, including potential clinical symptoms and radiographic healing based on periapical radiographs.

Cone-beam computed tomographic (CBCT) imaging is a widely accepted tool for diagnostic evaluation in dentistry. However, its main limitation is radiation exposure. Indications in endodontics include the detection of periapical lesions, fractures, or perforations; the evaluation of complex root anatomy, existing root fillings, and the location of separated instruments; surgical treatment planning; and the diagnosis of traumatic injuries to teeth or the alveolar bone (3, 4). In surgical treatment planning, CBCT imaging is helpful to assess the extent and location of apical periodontitis; the bone thickness over pathologic defects; and the proximity to anatomic structures such as the mental nerve, sinus cavity, or adjacent teeth.

Studies have shown that CBCT imaging is superior for the detection of apical periodontitis when compared with periapical radiographs (5–7). The risk-benefit ratio in terms of radiation exposure outweighs the use of CBCT imaging for regular follow-ups after endodontic procedures unless the stage of healing is difficult to discern. Few studies compared 2-dimensional (2D) and 3-dimensional (3D) healing for primary endodontic treatment (8, 9) or endodontic surgery (10–12). No investigation compared the outcome assessment for endodontic microsurgery

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derived from either 2D or 3D imaging taking into account planar as well as volumetric changes with or without the use of predefined 3D healing criteria.

The aim of the present study was to compare the assessment of healing after endodontic microsurgery using periapical films (2D) and CBCT (3D) imaging. The evaluation was based on cases in which both a periapical radiograph and a CBCT volume were available after at least 1 year of follow-up. The study investigated 2 hypotheses. The first hypothesis suggested that there would be no differences in outcome classifications derived from the assessment of 2D periapical films and 3D CBCT images after at least 1 year of follow-up. The second hypothesis stated that if a healing assessment was inconclusive by means of periapical radiography, it would also be inconclusive using CBCT imaging.

Materials and Methods

All cases subjected to the 2D versus 3D analysis comparison were from a subpopulation of patients who had received endodontic microsurgery by a single operator (T.S.) between 2011 and 2013. CBCT scans had been taken preoperatively and at least 1 year after surgery. Because CBCT imaging is subject to the "as low as reasonably achievable" principle, only selected patients had received a 3D scan at follow-up. Briefly, these indications included the clarification of healing patterns at follow-up and the diagnostic evaluation of symptoms to determine odontogenic versus nonodontogenic causes.

The inclusion criteria were

1. A history of primary endodontic microsurgery (no resurgeries)
2. Radiologically and clinically intact restoration at follow-up (exclusion of reinfection by coronal microleakage)
3. Compliance of CBCT scans with as low as reasonably achievable principles and indications following local guidelines for appropriate CBCT use (4) as described previously

The exclusion criteria were as follows:

1. Patients with a history of systemic disease, such as anemia, diabetes mellitus, metabolic disease, arteriosclerosis, or liver or kidney disease; a compromised immune response; a history of radiation in the head/neck area; a history of cancer treatment; a history of heavy smoking (World Health Organization); or a history of medication with bisphosphonates, steroids, or cytostatics
2. Teeth with an earlier history of endodontic surgery (apicoectomy, root-end surgery, root amputations, or bi- or trisections)
3. Teeth with root fractures or iatrogenic perforations
4. Teeth with apicomarginal defects, periodontal probing depths >4 mm, and/or increased mobility (II/III) (classes D–F according to Kim and Kratchman (13) [impaired volume analysis])
5. Endodontic surgery with the use of bone grafting or barrier materials (impaired volume analysis)

Endodontic Microsurgery

Treatment Planning. All patients had a consultation appointment for the collection of diagnostic information (including acquisition of a preoperative CBCT volume) as well as a thorough review of the surgical protocol, potential complications, and postoperative and follow-up procedures.

Surgical Procedures. The surgery was performed using modern microsurgical techniques in a consistent manner in all patients, including high-magnification, ultrasonic root-end preparation and root-end fillings with mineral trioxide aggregate.

Radiography

Acquisition and Clinical Evaluation. All periapical films were obtained with the parallel technique using a film holder (Dentsply Rinn, Elgin, IL) and an x-ray tube (Sirona Dental GmbH, Walls bei Salzburg, Austria) at 60 kV and 7 mA and intervals ranging from 0.08 to 0.18 seconds depending on the area and regional bone density using a XIOS PLUS sensor (Sirona Dental GmbH) and SIDEXIS XG software (Sirona Dental GmbH). CBCT images were obtained using the Veraviewepocs 3De CBCT machine (J Morita Mfg Corp, Kyoto, Japan) using a limited field of view (40×40 mm) at a 9.4-second duration for a 180° rotation at 80 kV and 5.0–8.0 mA and a voxel size of 0.125 mm. All CBCT volumes were analyzed using i-Dixel 2.0 software (J Morita Mfg Corp) and reconstructed at a slice thickness and intervals of 0.125 mm.

Healing Evaluation. Molven's criteria were used for the 2D assessment for the purposes of this study (14–16). All preoperative and follow-up radiographs were evaluated independently from the CBCT volumes and blinded and randomized by 2 faculty members of an American Dental Association–accredited endodontic specialty program with long-term experience in the evaluation of surgical healing in endodontics (F.S. and M.K.). Both evaluators were calibrated and reviewed the radiographs under standardized conditions. Magnification tools could be used if necessary. After evaluation, scores were reviewed, a kappa value for agreement was calculated, and situations with differing opinions were resolved by discussion until an agreement was reached. Outcomes were classified as complete healing and incomplete healing (dichotomized as success) or uncertain healing and unsatisfactory healing (dichotomized as failure) following Molven's criteria.

Modified PENN 3D criteria were used for the evaluation of surgical endodontic healing by CBCT imaging (Fig. 1) (17). Similar to the assessment of 2D healing as outlined earlier, 3D healing was assessed by 2 examiners (T.S. and F.S.), and any disagreement was resolved by discussion until a final agreement was reached. Outcomes were classified as complete healing and limited healing (dichotomized as success) or uncertain healing and unsatisfactory healing (dichotomized as failure).

Lesion Area and Volume Calculation. Both 2D and 3D lesion calculation was performed using ITK-SNAP (free software under the GNU General Public License developed by the National Institutes of Health, the US National Institute of Biomedical Imaging and BioEngineering, the US National Library of Medicine, the Universities of Pennsylvania and North Carolina, and an independent developer group). For 2D images, the software allowed for a straightforward assessment of the periapical defect size preoperatively and at follow-up using a grayscale color identification module. The area of the defect was then expressed as a percentage of the total area of the digital image, a standard size for all periapical images taken with the XIOS PLUS sensor. After calculation of the proportional relationship of the defect size compared with the total area of the digital image, the defect size area was expressed as the number of pixels and converted to mm^2 (Fig. 2). If a multirooted tooth had more than 1 periapical lesion, the individual defect areas were calculated and then added together to get a total defect area.

The 3D volumes preoperatively and at follow-up were similarly calculated using ITK-SNAP (Figs. 3–5). However, the complexity of a 3D defect around the root tips required additional steps of rendering, manual correction, and translation. Defect area segmentation and volume calculation were performed using the volumes at highest resolution (slice thickness and intervals = 0.125 mm) in a Digital Imaging and Communication in Medicine 3 Format exported from i-Dixel 2.0. The Digital Imaging and Communication in Medicine images were then converted into the Neuroimaging Informatics Technology Initiative format, processed anonymously, and