Original Article

Volumetric correlation of periapical lesion with Orstavik's periapical index: A retrospective cone-beam computed tomographic study

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Abstract

Aim: To assess the correlation among cone-beam computed tomographic periapical volume index (CBCTPAVI) and periapical lesion volume with Orstavik's periapical index (PAI).

Methodology: Seventy-six cone-beam computed tomographic (CBCT) and periapical radiographic images of single-rooted teeth presenting with apical periodontitis from 42 patients were obtained from a period of March 2023 to April 2024. Two observers evaluated the periapical radiographs and assigned PAI scores. CBCTPAVI was allocated based on the volume of the lesion, which was computed using ITK-SNAP software. Spearman's correlation coefficient was employed to evaluate the association between CBCTPAVI and lesion volume with PAI.

Results: A significant and moderate positive relationship between PAI and lesion volume ($\rho = 0.553$, $P < 0.001$) as well as between PAI and CBCTPAVI ($\rho = 0.506$; $P < 0.001$) was observed.

Conclusion: The risk of under/overestimation of results on two-dimensional periapical radiographs exists, despite a favorable connection with volumetric assessment of CBCT images.

Keywords: Apical periodontitis; cone-beam computed tomography; cone-beam computed tomographic periapical volume index; semiautomatic segmentation

INTRODUCTION

Healing and prevention of apical periodontitis (AP) are the primary goals of endodontic treatment. It has been established that AP is primarily a biofilm-mediated disease, and many prognostic factors play an important role in its healing success.[1] It has a high prevalence rate of about 52% in the adult population worldwide.[2] The main variables affecting the prognosis of endodontic therapy include the occurrence and extent of periapical lesion, the degree of canal preparation, obturation to the apical end, technical quality of the obturation, and the coronal seal. A complex apical canal system and an entrenched microbial biofilm have been shown to circumvent the debridement and disinfection processes, making the healing of periapical lesions sometimes unpredictable.[3]

Histopathological tissue examination is the gold standard method for assessing periapical healing.[4-7] Since the use of this method is not ethical, surrogate assessments such as radiographic examination and clinical signs and symptoms are used to evaluate periapical healing. The primary

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method for detecting AP is radiographic observation. To identify and measure periapical lesions, various indices based on cone-beam computed tomography (CBCT) and two-dimensional intraoral periapical radiography (IOPAR) have been introduced.[8-12] Among them, the Orstavik's periapical index (PAI) is the most frequently used and is based on two-dimensional radiographic evaluation. It is a five-point grading system, ranging from 1 to 5, depending on how the lesion appears on the X-ray.[8] However, image distortions, anatomical noise, and limited spatial determination are some of the disadvantages of radiographic assessment.[13,14] Compared to two-dimensional radiography, CBCT, a three-dimensional imaging modality, has higher sensitivity, specificity, and reliability in detecting periapical lesions and eliminates many of the associated disadvantages.[15]

Several studies have confirmed the importance of volumetric evaluation in determining the true nature of periapical lesions, but it is not widely used in practice.[16-19] Boubaris *et al*. introduced a new volumetric index for lesion assessment based on CBCT in 2021 that assigns scores based on the total volume of the lesion calculated using segmentation software.[12] Its importance has not yet been the subject of further published research. Therefore, the fundamental objective of this study is to correlate CBCTPAVI and lesion volume with PAI based on two-dimensional radiography.

METHODOLOGY

This study's reporting criteria were based on Preferred Reporting Items for Observational Studies in Endodontics.[20]

Ethical approval

The study's ethical approval was received from the Institutional Ethics Committee of Narasinhbhai Patel Dental College and Hospital, Visnagar, Gujarat, India (NPDCH/IEC/2023/127). Due to the study's retrospective design, informed consent was waived.

Sample size calculation

Size of the sample was estimated by employing the following formula:

$$n = \frac{\left(Z\,\alpha/2 + Z_{1-\beta}\right)^2}{\frac{1}{4}\left[\log\left((1+r)/(1-r)\right)\right]} + 4$$

r = correlation between PAI and lesion volume from previous study done by Filho *et al*. in 2018.[16]

$Z_{\alpha/2}$ = 1.96 for alpha 0.05

$Z_{1-\beta}$ = 0.84 for power 0.80

Assigning the values to the formula;

$$n = \frac{(1.96+0.84)^2}{\frac{1}{4}\left[\log\left((1+0.596)/(1-0.596)\right)\right]} + 4$$

; gives a minimum sample size of 57. In our study, we took a total sample of 76.

Study design and setting

This was a retrospective observational study that included CBCT and IOPAR images of 76 single-rooted teeth with pulp necrosis and AP from 42 patients from Malappuram, Kerala. Radiographs of the patients sent to the departments of conservative dentistry and endodontics and oral and maxillofacial surgery between March 2023 and April 2024 were obtained from the archives of the department of oral and maxillofacial radiology.

Inclusion criteria

- Patients aged 12 years and older
- Single-rooted teeth with deep caries, crown fracture, history of trauma, and discoloration
- Teeth with associated gingival swelling or draining sinus tract
- Endodontically treated/previously initiated treatment with radiographically visible AP.

Exclusion criteria

- Multirooted teeth
- Large periapical lesion involving adjacent teeth
- Teeth with periodontal abscess
- Lesions extending to the alveolar crest.

Image acquisition parameters

Limited field-of-view scans (4 cm × 4 cm, 5 cm × 5 cm, 5 cm × 8 cm, and 8 cm × 5 cm) were taken with Carestream CS 9600 (Carestream Dental, USA) at 120 kV, 4–6.3 mA, 75 µm voxel size. Images in DICOM format were exported from the CS 3D Imaging Software (Carestream Dental, USA) for volumetric evaluation in the ITK-SNAP 4.0.1 software (PICSL, University of Pennsylvania, United States).

Intraoral radiographs were taken using bisecting angle technique with a Carestream 5200 radiovisiography sensor using a Carestream 2100X-ray machine operating at 60 kV, 7 mA. The resultant images were viewed in CS Imaging version 8 software (Carestream Dental, USA).

Intraoral periapical image analysis

Two experienced observers (an endodontist and oral radiologist with 5 years' expertise), who were mutually blinded, assessed the digital radiographs using the Orstavik's PAI using CS Imaging version 8 software. The evaluators were trained on 40 radiographic images prior to the study. The analysis was carried out under identical viewing conditions on a 15-inch flat-panel monitor with 1920 × 1080 resolution (HP Victus Palo Alto, CA, USA).

Image enhancement features were not performed during the evaluation. In cases of disagreement, scoring was done after consensus was reached between the two observers [Figures 1a and 2a].

The Orstavik's periapical evaluation criteria are as follows: Score 1, normal periapical region; Score 2, small changes in periapical region; Score 3, changes in the periapical region with some degree of mineral loss; Score 4, periapical lesion with clearly defined radiolucency; and Score 5, severe AP with features of exacerbation.[8]

Volumetric assessment of the periapical lesion

CBCT images in DICOM format were transferred to ITK-SNAP for lesion volume assessment. The periapical lesion was segmented using a semiautomatic segmentation method with the active contour segmentation mode using threshold as the primary pre-segmentation setting. However, in cases of cortical plate erosion where the segmentation mask exceeded the cortical plate boundary, minor adjustments to the mask were made using paint brush mode. The segmented lesion volume was automatically calculated by the software once segmentation was complete [Figures 1b and 2b]. The CBCT periapical volume index (CBCTPAVI) was assigned based on the lesion volume obtained.

The CBCTPAVI scores are as follows: Score 0, intact periapical structure; Score 1, 0.01–0.20 mm3; Score 2, 0.21–0.70 mm3; Score 3, 0.71–8.00 mm3; Score 4, 8.01–70.00 mm3; Score 5, 70.01–100.00 mm3; Score 6, 100.01 + mm3.[12]

Statistical analysis

The data were examined using IBM SPSS (v29.0.2.0; IBM Corp, Armonk, New York, USA). A descriptive analysis was conducted, and percentages were used to express the number of teeth, age, and sex of the patients. Spearman's correlation coefficient was utilized to assess the degree of correlation between PAI with corresponding lesion volume and CBCTPAVI. Cohen's kappa statistics was employed to evaluate the degree of interobserver agreement. Statistical significance was assessed by applying a probability level of 0.05.

RESULTS

Out of all the teeth that were examined, there were 50 maxillary incisors (65.7%), 7 maxillary canines (9.2%), 9 mandibular incisors (11.8%), 4 mandibular canines (5.2%), and 6 mandibular premolars (7.8%). The average age of the patients was 36 ± 13.15 years; among them, 16 patients were male (61.9%) and 26 were female (38.1%).

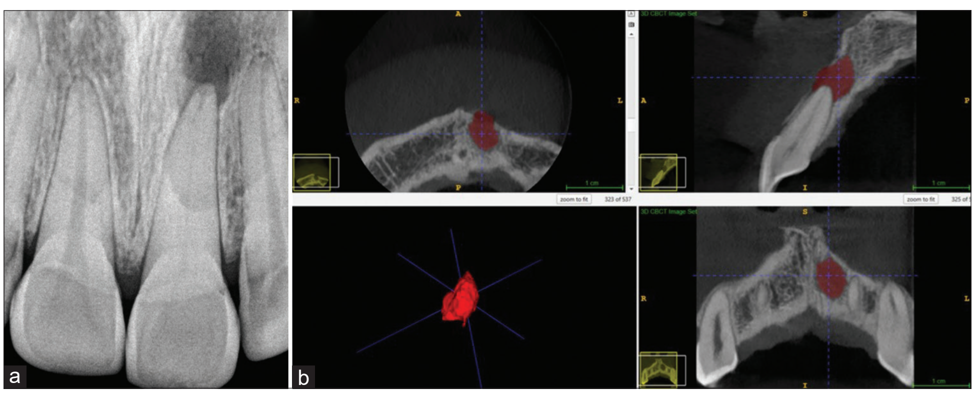


Figure 1: (a) Periapical radiographs of 21 showing periapical lesion; (b) axial, sagittal, coronal, and three-dimensional view of periapical lesion as segmented area in red color associated with 21 in ITK-SNAP software

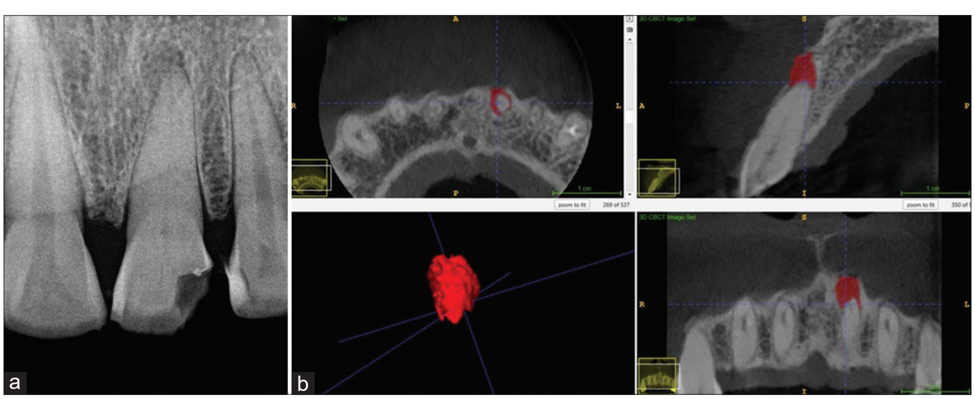


Figure 2: (a) Periapical image of 21 with lesion at the periapex; (b) segmented lesion in red color seen in axial, sagittal, coronal sections and as three-dimensional representation in the software

Spearman's "Rho" correlation indicated that there existed a significant and moderate positive relationship between PAI and lesion volume ($\rho = 0.553$, $P < 0.001$) as well as between PAI and CBCTPAVI ($\rho = 0.506$; $P < 0.001$) [Graphs 1 and 2]. Cohen's kappa statistics revealed a substantial agreement (0.72) among observers in periapical image analysis.

DISCUSSION

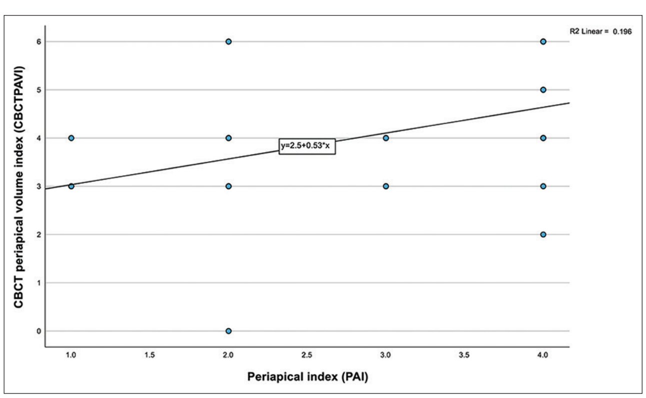
Several indices based on periapical radiographs and CBCT have been developed, and the Orstavik's PAI is the most commonly used in clinical and research contexts. Many indices have been created based on CBCT because of its increasing popularity and its capacity to provide three-dimensional views of anatomical structures.[8-12] All CBCT indices took into account the linear measurement of lesion size in each of the three planes; in 2021, Boubaris *et al*. presented a novel CBCT index based on lesion volume by partition classification analysis, and they reported improved sensitivity, specificity, and precision.[12] To date, no research has been done to determine the new CBCTPAVI's clinical applicability. In our study, we took CBCT images of patients from Malappuram, Kerala, and associated the lesion volume and CBCTPAVI of the teeth with the Orstavik's PAI. The results revealed a moderate positive correlation between PAI and lesion volume as well as with CBCTPAVI.

Majority of the samples in our study fall under CBCTPAVI 4 (55.26%) with corresponding PAI showing wide variations in scores ranging from 1 to 4. The following variables may contribute to some of the possible variations in the outcomes that we have seen: (1) underestimation of lesion size on periapical radiograph which resulted in a lower PAI score; however, those lesion after CBCT imaging appears much larger buccolingually /mesiodistally, which resulted in a higher CBCTPAVI score, (2) few samples were found to have no periapical lesion and a lack of labial cortical plate after CBCT imaging, which was misinterpreted as apical rarefaction in periapical radiographs resulting in a higher PAI score,(3) interobserver variations in assigning PAI scores,(4) due to varying directions of spread of lesion observed in CBCT, lesions with similar volumes appears with different PAI scores after digital radiographic examination.

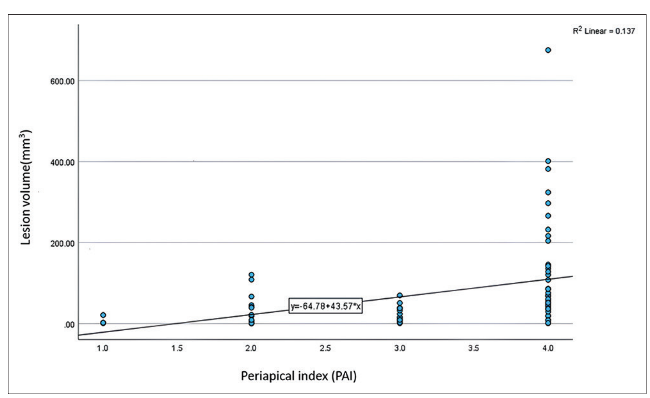
The results are consistent with a study conducted by Maia Filho *et al*. in 2018, in which they found a similar positive correlation with PAI and lesion volume and found that a 35% variation in PAI depends on variation in lesion volume. They concluded that periapical radiographs should be assessed with caution because several factors may influence their accuracy.[16] According to a recent systematic review by Mostafapoor and Hemmatian in 2022, it was reported that periapical radiographs have lower specificity and sensitivity compared to CBCT.[21]

Periapical radiographs are frequently used because they are quick, inexpensive, and have low radiation levels. Previous studies have shown that AP contained in the cancellous bone is challenging to identify on radiographs and requires erosion and involvement of the cortical bone.[22,23] According to a recent study by Chang *et al*. in 2020, however, regardless of location, larger lesions within the cancellous bone are more likely to be detected.[24] Several factors influence the identification of AP, including the type of tooth observed, the direction in which the lesion spreads, the two-dimensional nature of the assessment, the structures overlying the tooth, the limited spatial determination, subjective nature of the evaluation, geometric distortion, and image quality.[25-27]

In this study, lesion volume was calculated using a semiautomatic segmentation method using ITK-SNAP software. It is free, open-source software primarily used for biomedical image segmentation. It is user-friendly and offers manual and semiautomatic segmentation using the active contour method and is frequently employed in the medical field.[28] Few studies have been performed in dentistry using this software, which has been shown to be reliable and accurate.[29-31] It took us an average of 5–20 min for image segmentation, depending on the complexity of the case. There were challenges in determining lesion volume in some cases due to difficulty in understanding the margins of lesion and bony trabecular spaces. Furthermore,



Graph 1: Correlation between cone-beam computed tomographic periapical volume index and periapical index



Graph 2: Correlation between periapical lesion volume and periapical index

there are increased chances for misinterpretation of lesion volume in smaller scores of CBCTPAVI 1 and 2, in cases of widened periodontal ligament space in CBCT. Therefore, some training in the assessment of CBCT image segmentation and CBCTPAVI is needed.

Application of image segmentation and its corresponding CBCTPAVI in practice helps in assessing lesion size, shape, and direction of spread, reduces operator subjectiveness, better communication between clinicians, and assessing lesion healing. In the future, volumetric calculations will be simpler and more precise as artificial intelligence (AI) in dentistry gains traction.[32] In a recent study published in 2024, Boubaris *et al*. used AI to compute lesion volume and CBCTPAVI. They found that AI was faster and more accurate than semiautomatic segmentation, but they still believed that very small lesions needed human assistance.[33] Therefore, more research with a larger sample size and an evaluation of lesion healing outcomes is needed in the future to evaluate the validity of the novel CBCTPAVI and the application of AI in volume calculation.

CONCLUSION

Lesion volume and CBCTPAVI have a statistically significant correlation with Orstavik's PAI, within the constraints of the current study. Periapical readings, however, should be taken with awareness of the potential variations that may arise, and CBCT should be taken into account in treatment planning and volume assessment if necessary.

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Conflicts of interest
There are no conflicts of interest.

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