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Review Article

Indexes for periapical health evaluation: A review

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Abstract

Assessment of periapical health is important for the diagnosis, treatment planning, and evaluation of endodontic treatment outcomes. Radiographic evaluation of the status of the teeth is the most common modality used for assessing the periapical condition. Therefore, different radiographic indexes have been developed, which are used widely in clinical and epidemiological studies. With the advances in imaging, three-dimensional imaging techniques using cone-beam computed tomography (CBCT) are very popular now. Indexes based on CBCT, which analyses the condition of tooth in different planes, have been found to give a more accurate assessment of periapical conditions compared to conventional radiography. This review aims to summarize different indexes developed for assessing periapical health.

Keywords: CBCT, periapical index, dental radiograph, two-dimensional imaging, three-dimensional imaging

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Introduction

Prevention and elimination of apical periodontitis is the most favorable outcome following an endodontic treatment. Therefore, the assessment of periapical health using radiographs has been one of the prime diagnostic modalities employed for evaluating the periapical status, monitoring the disease condition, as well as dictating the treatment outcome. Different radiographic indexes have been developed that can be used for assessing periapical health status and were used widely during clinical practice, clinical trials, and epidemiological studies. These indexes based on two-dimensional imaging are mostly qualitative in nature, and the most popular among them is Orstavik's periapical index (1). However, two-dimensional assessment has its demerits as the initial appearance of pathology is not readily seen in radiographs, difficulty in locating cracks in tooth structure, superimposition of anatomic structures, problems with image distortion, high chances of inter and intra-observer variations in reporting the index score (2, 3).

With the progress in imaging modality, cone-beam computed tomography (CBCT) has been found to possess several benefits over radiographic imaging in diagnosing periapical pathology. CBCT gives three-dimensional analysis and exhibits images in coronal, sagittal, and axial planes giving an accurate evaluation of periapical health (4). It has been found that CBCT helps in revealing 38% more periapical lesions compared to conventional radiographs (5). The sensitivity of periapical radiography was found to be 0.55; however, CBCT has a sensitivity and specificity of 1.0, thus helps in the accurate assessment of periapical pathology (6).

Estrela et al. introduced a periapical index based on CBCT, giving a quantitative evaluation of periapical pathology (7). Different modifications and new indexes based on CBCT have been developed in subsequent years, which helps in raising the sensitivity, specificity, as well as reproducibility of the index (2, 8–10).

This review discusses on the existing and newly introduced indexes for periapical health assessment.

Indexes based on two-dimensional imaging

1. Strindberg index

According to Strindberg, the treatment outcome is depicted as "success" when the tooth has no symptoms or apical periodontitis is absent. "Failure" is denoted when the tooth is symptomatic / presence of apical periodontitis and "uncertain" when the condition of the tooth is unclear (11). These conditions can be applied only when the pretreatment and posttreatment situation of the teeth is known or else "presence" or "absence" of apical periodontitis is suggested (3). These criteria are applicable based on the patient's given history of symptoms during clinical examination and radiographic signs, as shown in Table 1 (12).

The Strindberg's criteria are:
1. Healthy/success
2. Doubtful
3. Diseased/failure

Table 1. Strindberg's criteria (11)

Outcome	Clinical evaluation	Radiographic evaluation
Success	Absence of symptoms	• *Normal periodontal ligament (PDL) anatomy.* • *Widening of PDL seen especially around excess filling.* • *Intact Lamina dura*
Failure	Presence of symptoms	• Minor or no reduction in periapical lesion. • Reduction in periapical lesion size but has not receded completely. • Development of a new lesion or an increase in the size of the initial lesion. • Poorly defined or break in the appearance of lamina dura.
Uncertain		• *Radiographs that are vague or unsatisfactory that could not be interpreted properly.* • *Periapical rarefaction ≤1 mm.* • *Extraction of tooth before recall because of reasons not related to outcome of endodontic treatment.*

2. Probability index

Introduced by Reit and Grondahl, this index gives a probability analysis of the presence or absence of apical periodontitis (13). This index is used for research purposes and has negligible use in clinical practice (3).

They proposed that observer variations in the course of radiographic assessment can be limited by instructing the observers to only register a periapical destruction when certain.

The index scores are as follows:

- Definite periapical bone destruction not present.
- Periapical bone destruction likely not present.
- Doubtful.
- Periapical bone destruction likely to be present.
- Definite periapical bone destruction present.

Index has been dichotomized into “success” for scores 1 and 2 and “failure” for scores 3-5.

3. Periapical index (PAI)

Periapical index was developed by Orstavik et al. and considered as the most popular and significant index for the evaluation of periapical health and was used in epidemiological studies, clinical trials, during clinical practice for assessing endodontic outcomes (1).

This index consists of 5 categories (Fig. 1):

1-Normal periapical anatomy.

2-Mild changes in bone pattern.

3-Changes in bone pattern with diffuse loss of mineral.

4-Apical Periodontitis with definite radiolucency in the periapical area.

5-Severe periodontitis with features of exacerbation.

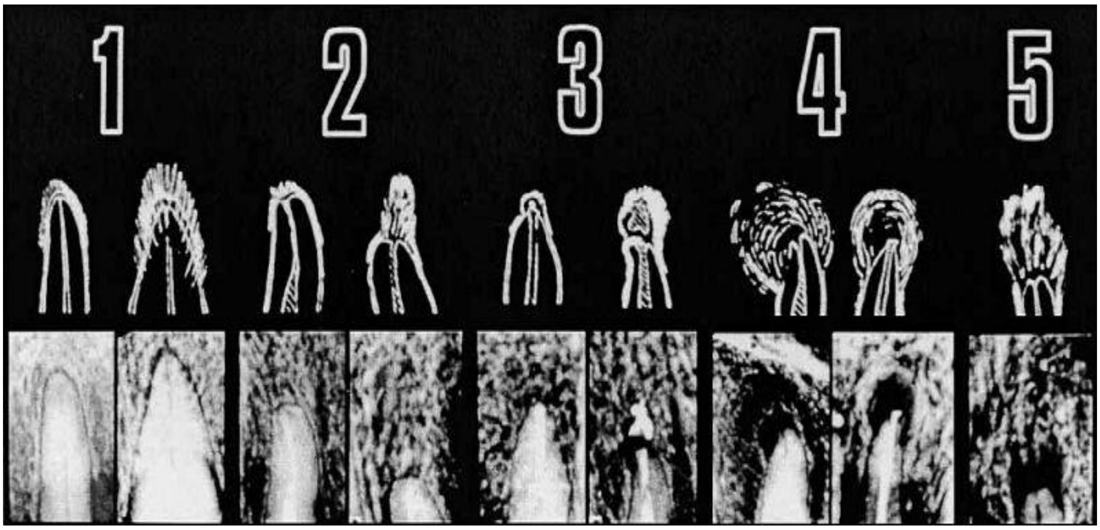

Figure 1. Periapical index scoring criteria (1).

Index has been dichotomized as “success/healthy” for scores 1 and 2 and “diseased/failure” for scores ranging from 3-5 (14, 15).

This index was developed by collating radiographs of the teeth to the reference radiographs of human maxillary incisors with an established histological diagnosis from Brynolf’s study, and given the following instructions while scoring (1):

1. Periapical index score of the reference radiograph, which approximately resembles the periapical area of the tooth studying should be assigned.
2. In case of uncertainty, higher score should be assigned.
3. Highest score must be given for individual roots in case of multirooted teeth.
4. A score must be assigned for all teeth.

This index was developed based on the study performed on upper anterior teeth, and the interpretation could differ in multirooted teeth, teeth with differing morphology, superimposed anatomical structure as well as the degree of bone density (16).

A revised version of the PAI guide with the interpretation of PAI scores was assessed by Zanini et al. to corroborate its dependability and reproducibility among undergraduates. The modified practical guide included Orstavik’s drawings and a new set of original radiographs (Fig. 2). The reliability of their judgment was evaluated by equating the student’s assessment to that of three teachers. Average success rates of 61-65% were noted for the student’s group and study phase. Hence, the reliability of the PAI assessment for the undergraduates was considered excellent (17).

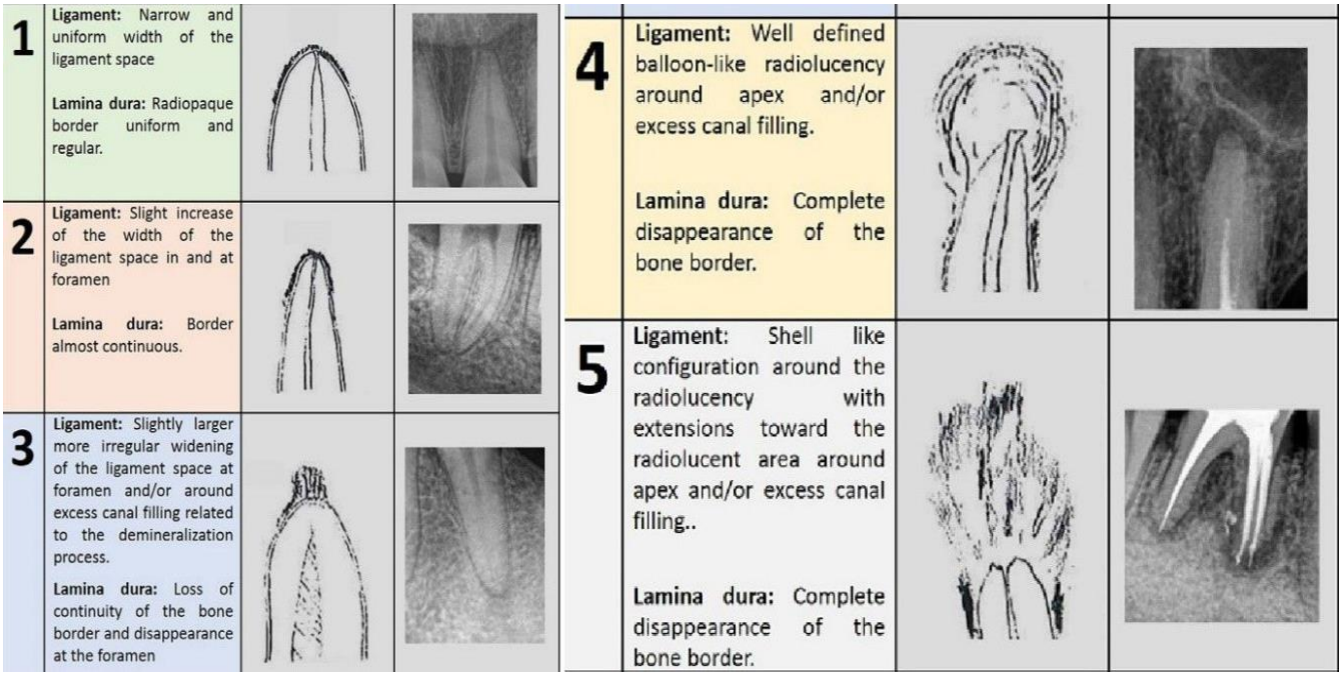

Figure 2. Modified version of periapical index guide (17).

Indexes based on three-dimensional imaging

1. Cone-beam computed tomography – Periapical index (CBCT-PAI)

This is the first index developed by Estrela et al. based on CBCT technology (7). They developed this index based on measuring the periapical lesion size in 1014 images in CBCT and periapical radiographs. Measurements were taken in three planes (buccopalatal, mesiodistal, and diagonal) by using CBCT software (Fig. 3). This index gives a quantitative estimation of variation in periapical lesion size by measuring the largest extension of the lesion in 3 planes and also considers the expansion and destruction of cortical plates which can be included along with the scores if present.

Figure 3. Axial, sagittal, and coronal CBCT slices for evaluation of CBCT-PAI (7).

This index consists of five categories and two additional variables.

0 - Intact periapical structure
1 –Periapical radiolucency diameter >0.5—1 mm
2 - Periapical radiolucency diameter >1—2 mm
3 - Periapical radiolucency diameter 2—4 mm
4 - Periapical radiolucency diameter > 4—8 mm
5 - Periapical radiolucency diameter > 8 mm
E – Periapical cortical bone expansion
D – Periapical cortical bone destruction

2. Modification in CBCT-PAI index

Esposito et al. modified the analysis of CBCT-PAI to obtain reproducible results. According to them, the limitations of the CBCT-PAI where the measurements of the lesions were obtained by positioning the three planes arbitrarily, which does not produce consistent results. Therefore, they did a dimensional analysis in three fixed and reproducible dimensions: mesiodistal, buccolingual and coronoapical (Fig. 4) (2).

Figure 4. Coronal, sagittal and axial slices evaluating the diameter of the lesion by Esposito et al. (2).

Their method of assessment was as follows:

1. The lesion was analyzed in three-dimension so that the intersection between sagittal and coronal plane coincides with the longitudinal axis of the tooth.
2. The positioning of the three planes was done with “drag and drop” on each two-dimensional

plane to align the corresponding tooth with the colored orientation lines.

3. Size of the lesion was measured by recording its largest diameter in each plane. The coronoapical dimension was used instead of the diagonal dimension described by Estrela et al. By orienting the planes in fixed and repeatable dimensions, it was possible to go back to the previous images without losing the orientation.

3. Periapical and Endodontic Status Scale (PESS) index

Venskutonis et al. introduced a complex index called Periapical and Endodontic Status Scale (PESS) which analyses both periapical pathology and quality of endodontically treated teeth using CBCT and can be applied in epidemiological studies and clinical practice (10). The diagnostic parameter of the PESS was obtained from radiographic indexes introduced by Orstavik, Eckerbom, and Estrela (1,7,18). PESS comprises of two indexes: Complex Periapical Index (COPI), which is designed for radiological evaluation of periapical region using CBCT, and Endodontically Treated Tooth Index (ETTI), which is designed for radiographic analysis of endodontic treatment quality.

COPI is composed of three parameters, and each parameter (S, R, and D) is classified into three different treatment risks: mild (green color), moderate (yellow color), and high (red color) (Fig. 5).

S (Size of the radiolucent lesion)	
S0	Widening of the periodontal ligament not exceeding two times the width of the lateral periodontal ligament
S1	Diameter of small well-defined radiolucency up to 3 mm
S2	Diameter of medium well-defined radiolucency 3-5 mm
S3	Diameter of large well-defined radiolucency >5 mm
R (Relationship between root and radiolucent lesion)	
R0	No radiolucency, when widening of the periodontal ligament is not exceeding two times the width of the lateral periodontal ligament
R1	Radiolucent lesion appears on one root
R2	Radiolucent lesion appears on more than one root
R3	Radiolucent lesion with involvement of furcation
D (Location of bone destruction)	
D0	No radiolucency, when widening of the periodontal ligament is not exceeding two times the width of the lateral periodontal ligament
D1	Radiolucency around the root
D2	Radiolucency is in contact with important anatomical structures
D3	Destruction of cortical bone

Figure 5. Complex periapical index (10).

4. Endodontic Radiolucency Index (ERI)

This index was developed by Torabinejad et al. by modifying the CBCT-PAI developed by Estrela et al. CBCT-PAI index is based on the measurement of the largest extension of the lesion; however, it was not clear whether the measurement was taken from the root surface or the widest/longest linear dimension of the radiolucency. This lack of clarity makes it difficult to produce a reliable and consistent results in studies (8).

Their method of evaluation was as follows:

1. The long axis of the teeth parallel to the sagittal and coronal plane was evaluated in all planes until the widest radiolucency adjacent to the root apex was identified.
2. The widest radiolucent area perpendicular to the root surface was measured and assigned a score (Fig. 6).
3. This index has included smaller measuring ranges, which helps in categorizing whether the periapical disease is early in its progression or healing.

The scores are as follows:

1- Broadest diameter of PDL: ≤ 0.5 mm
2- Broadest diameter of PDL: 0.5 mm < x ≤ 1.0 mm
3- Broadest diameter of PDL: 1.0 mm < x ≤ 1.5 mm
4- Broadest diameter of PDL: 1.5 mm < x ≤ 2.0 mm
5- Broadest diameter of PDL: 2.0 mm < x ≤ 2.5 mm
6- Broadest diameter of PDL: > 2.5 mm

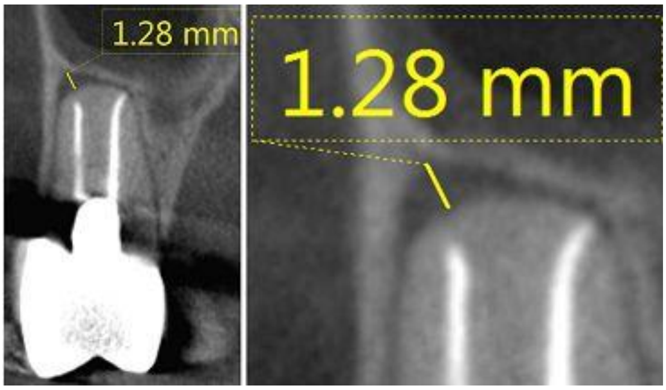

Figure 6. Evaluation of lesion diameter for ERI (8).

5. Cone-beam computed tomographic periapical volume index (CBCT-PAVI)

This index was developed by Boubaris et al. (9). According to them, CBCT-PAI does not consider the three-dimensional volume of the lesion, which plays an important role in assessing the overall status and progress of the lesion. Their study assessed volume of the lesion using the semiautomatic segmentation process, and index was developed using partition classification analysis. Scores for this index are given in Table 2. Several studies previously have assessed the volumetric changes in periapical lesion using CBCT. However, Boubaris et al. were the first to develop periapical index for the volumetric changes in periapical lesion.

This index considers the expansion (E) and destruction (D) of cortical plates, which can be included along with the scores if present.

Their method of assessment was as follows:

1. Grayscale thresholds for each lesion were estimated to create a mask which segments out the lesion slice by slice (Fig. 7). Manual adjustments for addition or subtraction of any unrelated areas of the segment were done to produce an accurate border for the lesion.
2. If lesion has perforated, the cortex adjustment was done by extending the border of the mask.
3. The segmented mask of the periapical lesion was then removed from the remainder of the CBCT data and converted into a stereolithography file.
4. The volume was determined using CBCT software, and partition classification analysis was used to create new CBCT-PAI based on volume.

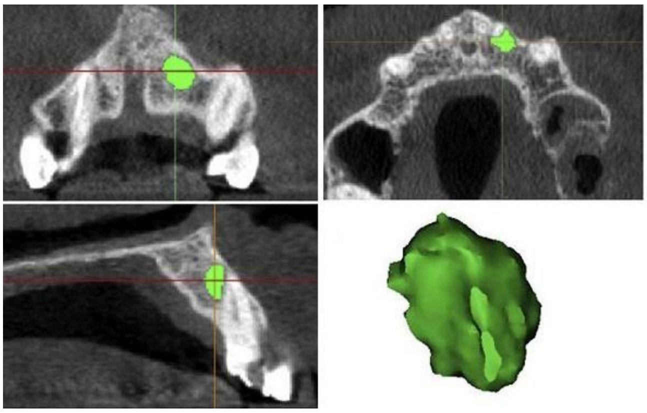

Figure 7. Axial, coronal, sagittal slices and stereolithography format for assessing the volume of periapical lesion (9).

Table 2. CBCT-PAVI scores (9).

Score	Volume V (mm³)
1	0.01 -0.20
2	0.21 -0.70
3	0.71 -8.00
4	8.01 -70.00
5	70.01 -100.00
6	100.01 +

In literature, various studies have compared the reproducibility, reliability, and intra/inter-observer variations among different radiographic indexes. A comparative study between PAI and probability index was done by Orstavik et al., assessing the reliability, reproducibility, accuracy, and discriminatory ability in which PAI showed better results (1). Rasbech et al. studied the observer variation when periapical evaluation was assessed using Strindberg system and the PAI. According to their study, Strindberg system showed better interobserver agreement compared to PAI, whereas better agreement was obtained when the PAI was dichotomized (19).

Tarcin et al. evaluated observer variation and reproducibility in the periapical interpretation using Strindberg system, periapical index, and the probability index. The report stated that lower intraobserver variation was noted for Strindberg system, whereas PAI showed lower interobserver variation compared to the other two indexes. Higher intra and interobserver agreements were obtained when PAI and probability index were dichotomized (3).

Eliminating the observer variation present while assessing two-dimensional periapical radiographs is nearly impossible. Certain factors like taking multiple angled radiographs, observer calibration, skill and experience of the observer, improving the viewing condition, xeroradiography, and utilizing digital radiography, which consists of additional features that help in adjusting the sharpness, contrast, brightness, density of radiographic image has to be considered to improve the reliability and reproducibility of the index (3).

According to the study by Souza Nunes et al., they evaluated the relevance of PESS index in determining the association of endodontically treated teeth with maxillary sinus abnormalities by CBCT, and PESS index was found to be helpful in those evaluations (20). A two-year endodontic treatment follow-up was assessed by Gudac et al.; they reported that the sensitivity and specificity of PESS index was over 80% in all risk groups, the exception being for the high-risk group because of less number of cases (21).

A comparative study was conducted by Sisli et al., assessing intra and inter-observer agreement of CBCT-PAI, ERI, and COPI of the PESS index. The highest self-agreement and interobserver reliability were observed for COPI, whereas ERI showed the highest intra-observer variation and CBCT-PAI showed the highest inter-observer variation (22).

Most of the indexes so far have measured the periapical lesion size using CBCT linearly, and very few studies support the use of volumetric assessment for periapical bone changes. Ahlowalia et al. determined the accuracy of CBCT for volumetric measurement of intraosseous cavities within the bovine bone and compared it with two methods of physically measuring the cavities and with microcomputed tomography. Results showed that both CBCT and micro-CT showed good agreement when compared to the two methods of physical measurement of the cavities (23). Liang et al., first volumetrically analyzed the periapical radiolucency on the CBCT images in clinical research (24). Filho et al. correlated the Periapical Index with volume of periapical lesion obtained by CBCT, and they found that the radiographic evaluation of the periapical lesion does not reflect the lesion's volumetric characteristics (25). A summary of periapical index is given in table 3 regarding the method of assessment, its benefits, and disadvantages.

Table 3. Summary of periapical indexes

Sl no	Periapical Index	Assessment Method	Pros	Cons
1.	Strindberg index	Based on clinical and two-dimensional radiographic assessment according to the Strindberg criteria.	First criteria developed for outcome assessment which includes patient's symptoms, clinical and radiographic assessment.	Rigid and strict criteria. Standardization is difficult. Radiographic evaluation is subjective and prone for observer bias. Chances of false negative report in two-dimensional radiographic evaluation because of image distortion, density of bone, superimposition of anatomical structures. Number of roots/lesion and their relation to surrounding anatomical structures are not considered.

2.	Probability index	Based on examination of two -dimensional radiographs and assigning the appropriate probability index score.	Introduced in an attempt to minimize the observer variation by registering the periapical destruction only if it is certain.	Limited use in clinical practice. Does not consider the relation of root / lesion to surrounding anatomical structures. Radiographic evaluation is subjective and prone for observer bias. Chances of false negative report because of two-dimensional radiographic assessment.
3.	Orstavik's periapical index	Based on examination of two-dimensional radiograph to be assessed and assigning the appropriate score by comparing it with the reference radiograph with confirmed histologic diagnosis.	More objective criteria for radiographic evaluation of periapical status of teeth. Calibration kit is provided. PAI index allows interpretation on transitional phases in the healing or failing process.	Does not consider the relation of root/periapical lesion to the surrounding anatomical structures. Original study was done based on upper anterior teeth and is not based on clinical outcomes. Radiographic evaluation is prone for observer bias. Cut off for the presence or absence of disease is arbitrary. Chances of false negative report in two-dimensional radiographic evaluation.
4.	CBCT-PAI	Gives a quantitative estimation in the variation in periapical lesion by measuring the largest extension of the lesion in 3 planes. (buccopalatal, mesiodistal, and diagonal).	First index developed based on CBCT and displays images as cross sections in the three planes, which allows the visualization of teeth and their associated pathology in three dimensions. CBCT imaging reduces the incidence of false-negative diagnosis, which occurs during examination of periapical radiographs. Minimizes observer interference and increase the reliability of epidemiologic studies.	The number of roots affected, bone destruction related to anatomic structures and the position of the lesion are not discussed. Does not consider the three-dimensional volume of the lesion.
5.	Modification in CBCT-PAI	Dimensional analysis of the lesion done in three fixed and reproducible dimensions: mesiodistal, buccolingual, and coronoapical.	Helps in assessing the periapical pathology in three dimensions. Analysis done in fixed dimensions which helps in increasing the reliability and reproducibility of the index.	The number of roots affected, bone destruction related to anatomic structures, and the position of the lesion are not discussed. Does not consider the three-dimensional volume of the lesion.
6.	PESS index	Analyses both periapical pathology and endodontic treatment quality using CBCT.	Gives more information about the disease and its possible causes. Considers the number of roots and lesion size as well as its relation to adjacent anatomical structures. Includes the endodontic treatment quality assessment. COPI periapical index has prognostic value because it provides treatment risk degrees.	Does not consider the three-dimensional volume of the lesion.

7.	Endodontic Radiolucency Index	Analyses the periapical pathology and assigns score by measuring the linear width of widest radiolucency perpendicular to root apex.	Assigns smaller measuring intervals which help in categorizing whether its an early periapical lesion or healing. Helps in documenting the detail of small dimensional changes in lesion size.	Observer bias can occur because of small dimensional intervals in lesion size. Does not consider the three-dimensional volume of the lesion. Cortical bone expansion and destruction are not considered. The number of roots affected, bone destruction related to anatomic structures, and the position of the lesion are not discussed.
	CBCT-PAVI	Volume of the lesion in CBCT is calculated using semiautomatic segmentation process and the index was developed using partition classification analysis.	The three-dimensional volume of the lesion is assessed. Helps is assessing the true change in volume of the lesion and thus helps in evaluating treatment outcomes.	Index does not consider the relation of root/lesion with adjacent anatomical structures. Reliability, Sensitivity, and Specificity of the index need to be validated.

Conclusions

Periapical indexes are a valuable tool for diagnosis, treatment planning, and outcome evaluation of teeth. Orstavik's index is the most popular index based on two-dimensional radiography, which is still currently used for periapical evaluation which has better reliability and reproducibility. However, three-dimensional imaging using CBCT gives a more accurate assessment and additional information about the condition of the tooth, which might not be seen in conventional radiographs. The major limitation of using CBCT is its high cost and higher radiation compared to periapical radiographs limiting its routine use in dental practice.

Therefore, intraoral radiographs should be the first choice of assessment, and CBCT has to be suggested only when periapical radiographs do not yield sufficient data or, in case of dealing with complex cases, for epidemiological studies and research purposes. Among the indexes based on CBCT, recently introduced indexes such as PESS and CBCT-PAVI index has more prognostic value compared to other indexes in the literature. PESS index evaluates both the status of periapical tissues and endodontic treatment quality and can be used in clinical practice and epidemiological studies, whereas CBCT-PAVI assesses the accurate three-dimensional volume of the lesion. Therefore, further studies are required to validate its reliability and application.

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