African J. Biol. Sci., 21 (2): 103-113 (2025)
ISSN 1687-4870 **e- ISSN 2314-5501 (online)**
www.ajbs.journals.ekb.eg **E-mail: aasdjournal@yahoo.com**

Low dose cone beam computed tomography versus high dose cone beam computed tomography in measuring furcation involvements: (diagnostic accuracy study)

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Received: October 21, 2025; Accepted: November 5, 2025; Available online: November 5, 2025

ABSTRACT

Accurate diagnosis of furcation defect is essential in periodontal therapy planning. Cone beam computed tomography (CBCT) provides three-dimensional visualization, but higher radiation doses remain a concern. This study aims to assess and compare the diagnostic accuracy of low-dose CBCT (LD-CBCT) and high-dose CBCT (HD-CBCT) in detecting and measuring furcation defect using a pig mandible. Detection and accurate assessment of periodontal disease is important to determine the tooth prognosis and treatment. Radiographic assessment provides information about the pattern and extent of the furcation defect. CBCT provides unique 3D images used for diagnosis and treatment plans, but its use in periodontology not well-reviewed as there is few numbers of studies searched about the role of CBCT in periodontology. Fifteen molars from nine pig mandibles with naturally occurring and simulated furcation involvements were scanned using both LD-CBCT and HD-CBCT protocols. Real measurements obtained with periodontal probes and digital calipers served as the gold standard. Furcation defect were recorded and compared across the both doses (LD-CBCT & HD- CBCT). Inter- and intra-observer reliability were assessed. The results indicated that the mean furcation measurements were highest in the gold standard group (8.61 ± 1.90 mm), followed by HD-CBCT (7.22 ± 2.27 mm) and LD-CBCT (6.99 ± 2.15 mm). Differences between HD-CBCT and gold standard were not statistically significant ($p = 0.062$), whereas LD-CBCT showed a significant difference from the gold standard ($p = 0.008$). However, diagnostic agreement between HD and LD protocols was high, with acceptable variability. In conclusion it was found that LD-CBCT demonstrates acceptable diagnostic accuracy for measuring furcation defect, suggesting that reduced-dose protocols may be viable in clinical settings to limit radiation exposure without compromising diagnostic outcomes.

Keywords: Low-dose CBCT, High-dose CBCT, Furcation involvement, Periodontal diagnosis, Diagnostic accuracy, Radiation dose reduction.

INTRODUCTION

Furcation involvement is one of the major problems in the treatment of periodontal disease and is directly associated with tooth loss. Therefore, furcation lesions must be detected with accuracy at an early stage of the disease (Walter et.al. 2011). The exact structure of a furcation defect helps with prognostic optimization and periodontal therapy planning. Furcation defects have been found with the Nabers probe, unfortunately the complex of the anatomy form and stiffness alters the probe's and decreasing its usefulness in identifying the anatomy (Walter *et al*., 2020). Now, CBCT is thought to be the best diagnostic technology available for periodontology applications. When evaluating periodontal structures, CBCT scanning was found to be more successful than other 2D imaging modalities. Comparing CBCT to periapical radiographs, the latter demonstrated a lower capacity for identifying periodontal bone abnormalities in all orientations. Furthermore, intraoral radiographs did not distinguish buccal and lingual abnormalities from one another in interproximal locations (Misch *et al*., 2006 and Aljehani, 2014).Consequently, CBCT has the potential to become non-invasive diagnostic instrument for various dental applications in which furcation defect characterization, localization and volume measurements are important (Pinsky, 2006).Nevertheless, compared to traditional two-dimensional methods (panoramic and intraoral radiographs), CBCT exposes the patient to higher radiation doses (Ludlo, 2015 and Qiang *et al*., 2019). By employing pulsed radiation, cutting the scan duration, and lowering the radiation dose, for example, more recent CBCT machines can reduce the radiation dose. These low dose (LD)-CBCT procedures, which vary depending on the manufacturer, can lower the dose-area product (DAP) by up to 90% when compared to HD-CBCT protocols from the same device. These DAPs resemble those of a panoramic radiograph and, in certain situations, are even less radioactive than a full mouth status examination (Hingst & Weber, 2020). Research has demonstrated that buccal and oral bone lamellae, among other delicate structures, can be seen with LD-CBCT (Ruetters *et al*., 2022). In this study, it was compared between HD-CBCT and LD-CBCT protocol in assessment the furcation defect and if the image quality using LD-CBCT is accepted compared with that by HD-CBCT.

MATERIALS AND METHODS

Nine mandibles of young adult pigs were used. The mandibular molars were intact, and the adjacent cortex was preserved. Before the simulated lesions were created, the pig jaw was assessed clinically and topographically in order to assess whether they had any original bone defect that could be misinterpreted in the ensuing diagnostic imaging. Any pig jaw that had a bone defect was excluded from the study.

Simulating lesions in the furcation region:

-Simulated lesions were created in the furcation region of the molars of each mandible, for a total of 15 possible sites. Two-millimeter cotton pledges soaked in 70% per chloric acid were kept in contact with the bone for 2 hours, after each application, the mandibles were washed for 1 min under tap water According to the methodology used in previous studies assessment of furcation involvement:

- CBCT provides 3D assessments; classification of FI in horizontal bone loss was included (Zhang *et al* 2018)
- According to modified Glickman's classification:

- Class I, incipient or early stage of furcation involvement, bone destruction is less than 2 mm into the furcation
- Class II, horizontal bone destruction extending deeper than 2 mm but less than 6 mm into the furcation
- **Class III**, horizontal bone destructions communicate between furcation of the tooth, and result in a through-and-through tunnel.

The classification was done on CBCT by measuring the depth of FI on axial view where the slice showed the greatest amount of bone loss (Zhang *et al* 2018). On this slice, a line was drawn tangentially to the adjacent root surfaces. The distance from this line to the deepest point of bone loss was designated as the amount of furcation bone loss (Fig. 3).

The mandibles were investigated radiographically by LD CBCT and HD-CBCT using the same CBCT device (Planmeca Promax 3D MID) (Fig. 1). For HD-CBCT, volumetric acquisition was performed under the following conditions: (LD) using (2) mA, (100) Kvp, and effective exposure time 3.22 s, while CBCT (HD) using (8) mA, (100) Kvp, and effective exposure time 3.12 s, Where upper light beam indicated the top of the field of view (FOV), and another lower light beam indicated the bottom of the FOV and reconstructed cross section CBCT images were obtained. Then Romax software was used for analysis and measurements. A panoramic curve was drawn at the crystal end of the bone and parallel to the buccal cortical bone. Cross sectional images were obtained perpendicular to that curve. The scan orientation was prepared to adjust all the scans in the same orientation. To align CBCT section and actual measurement as close as possible, we chose a middle cross section cut. Images were reviewed independently by three dentists with more than 15 years of experience in CBCT diagnostics. Each furcation defect was assessed in all three planes. The measured line was defined on each image to ensure that the researcher measured in the same plane during both HD-CBCT and LD-CBCT (Fig. 2). Each measurement was taken twice for each protocol with an interval of two weeks between the measurements to exclude a memory effect. Furcation defects were also segmented by AI software and then were examined by researcher, and these segmentations were used to calculate the furcation volume in defined contiguous layers with HD-CBCT and LD-CBCT and to assess the volume reproducibility (Fig4).

Fig 1: A CBCT (Planmeca Romax 3D MID) with pig jaw

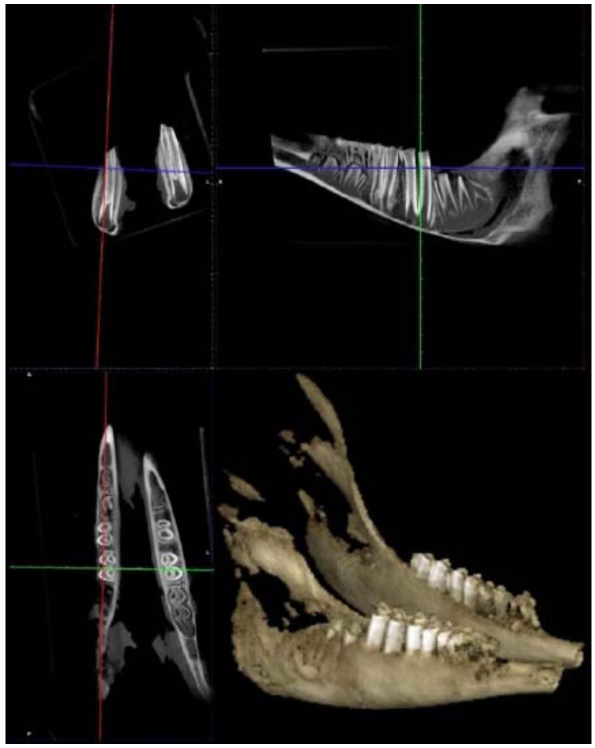

Fig 2: Orientation of the orthogonal planes to be perpendicular on the furcation area to be measured.

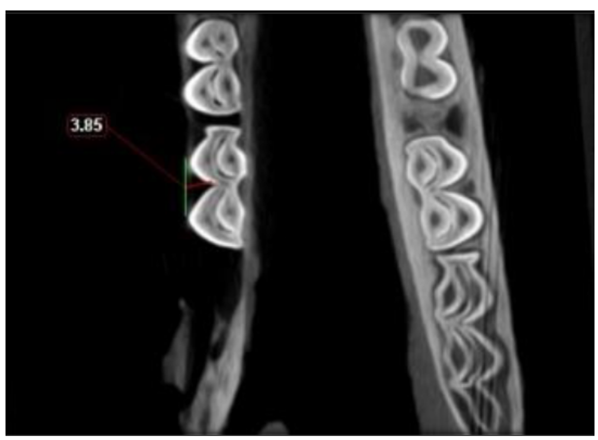

Fig 3: CBCT axial cut showing measurement of furcation bone loss: class II FI (3.85) mm class II horizontal bone destruction extending deeper than 2 mm but less than 6 mm into the furcation area.

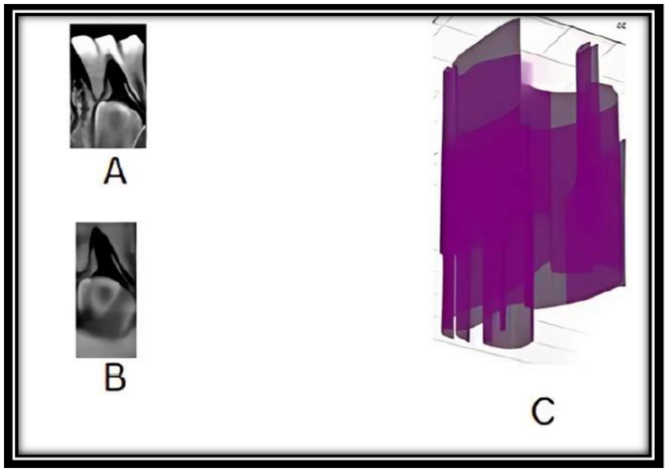

Fig 4: A- Furcation image by High Dose Cone beam computed tomography (HD CBCT)
B- Furcation image by Low Dose Cone beam computed tomography (LD CBCT).
C- overlap volume segmentation of furcation bone defect of the same area exposed twice.

Statistical Analysis:

Data was collected, tabulated and subjected to statistical analysis which was performed by SPSS in general (version 20), while Microsoft office Excel was used for data handling and graphical presentation. Quantitative variables were described by the Mean, Standard Deviation (SD), the Range (Minimum – Maximum), Standard Error (SE), 95% confidence interval of the mean, median and Inter Quartile Range (IQR). Shapiro-Wilk test of normality was used to test normality hypothesis of all quantitative variables for further choice of appropriate parametric and non-parametric tests. As variables are not normally distributed, Mann-and Whitney U test was applied. For accuracy assessment Dahlberg Error, Relative Dahlberg Error, Bland & Altman limits of agreement and Concordance Correlation Coefficients CCC with 95% confidence intervals were reported. Significance level was considered at $P < 0.05$ (S); while for $P < 0.01$ was considered highly significant (HS). Two Tailed tests were assumed throughout the analysis for all statistical tests.

Research Ethics Committee:

This study was approved by the ethics committee of the faculty of dentistry British University in Egypt no. EX.2409. Date:10-09-2024.

RESULTS AND DISCUSSION

a- Low Dose accuracy assessment:

Table 1: Assessment of the accuracy of D method.

	Mean	SD	Dahlberg error DE	Relative Dahlberg Error RDE	Mean of Differences (Reference - measured)	SD of the Difference	Bland & Altman Limits of Agreement (LOA) 95%confidence limits Lower	Upper	Concordance Correlation Coefficient CCC	95%confidence limits Lower	Upper
Jaw	3 .99	1.79	0.30	7.4%	0.1800	0.39	-0.59	0.95	0.969	0.925	0.987
LD	3.81	1.66									

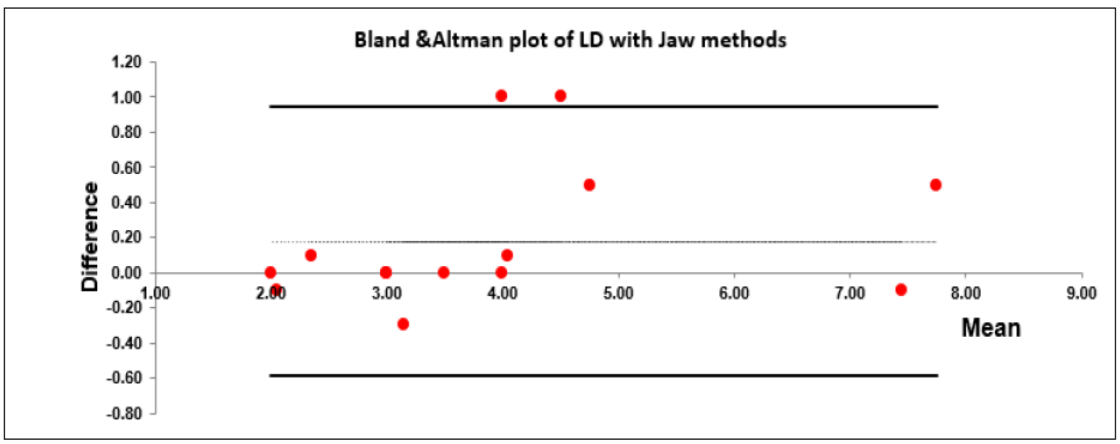

Fig. 5. Bland& Altman plot of Low dose method in comparison with the Gold standard jaw real measurements.

As shown in Table (1) and Figure (5) there was **a s**mall Dahlberg error (less than 0.4) and medium relative Dahlberg Error (less than 8 %). Medium Bland and Altman Rane (-0.59 to 0.95) and high CCC value was more than 0.9. Two values are outside the upper limit. In general LD method shows good accuracy.

b-High-Definition accuracy assessment:

Table (2) and Figure (6) indicated that there was a very small Dahlberg Error (less than 0.1) and relative Dahlberg Error (less than 2%). Also, there was a small Bland and the Altman Range was (-0.19 to 0.21). The value of THE Concordance Correlation Coefficients (CCC) was almost 1 (perfect correlation Only one value outside the lower limit). In general HD method shows excellent accuracy.

Table 2: Assessment of the accuracy of HD method.

							Bland & Altman Limits of Agreement (LOA)		Concordance Correlation Coefficient		
							95%confidence limits			95%confidence limits	
	Mean	SD	Dahlberg error DE	Relative Dahlberg Error RDE	Mean of Differences (Reference - measured)	SD of the Difference	Lower	Upper	CCC	Lower	Upper
Jaw	3 .99	1.79	0.07	1.8%	0.0100	0.10	-0.19	0.21	0.998	0.997	0.999
LD	3.98	1.74									

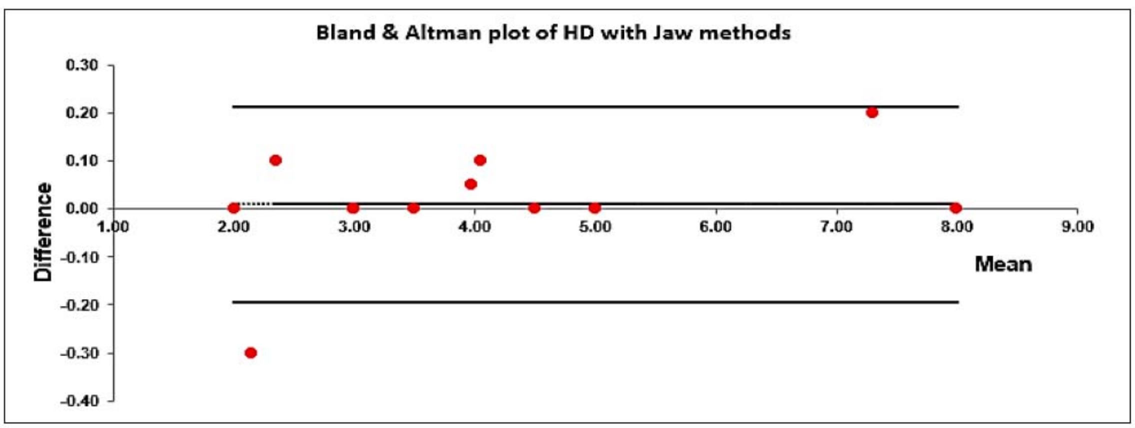

Fig. 6. Bland & Altman plot of High definition method in comparison with the Gold standard jaw real measurements

c- Comparison of the absolute errors of the two methods LD and HD

Although the mean absolute error of the HD method was lower than that of the LD method, the difference did not reach statistical significance (P = 0.07) which indicates that there was no significant difference between Hd and LD methods

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Table 3: Mann Whitney test as P > 0.05 NS.

	N	Mean	SD	Mean Rank	Sum of Ranks	Mann Whitney U	Z	P value
LD	15	0.2467	0.3502	18.17	272.50	72.50	-1.81	0.07030
HD	15	0.0500	0.0906	12.83	192.50			

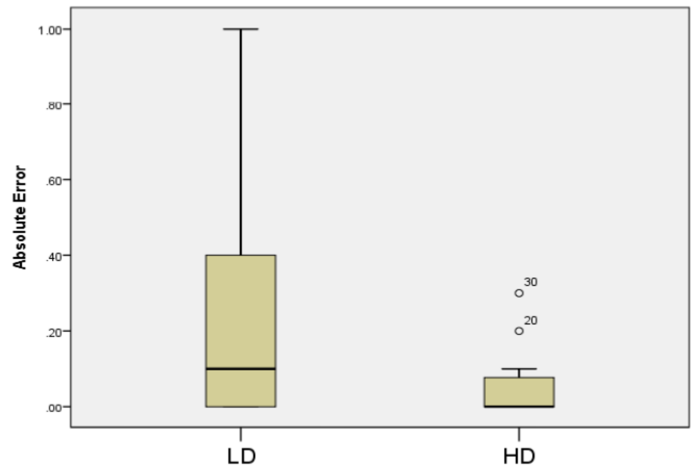

Fig. 7. Descriptive statistics of the Absolute Error of two methods.

In this study, it was hypothesized that LD-CBCT would detect and visualize furcation defects with the same diagnostic quality as HD-CBCT. The current results confirmed this hypothesis in an ex vivo setting. It was observed high intramodality, interrater agreement, indicating that HD-CBCT and LD CBCT are both reliable methods for detecting and measuring furcation defects. This is in line with the findings of other studies testing different CBCT protocols for furcation diagnostics (Bornstein *et al.*, 2014). The stiffness and predetermined curvature of the probe may lead to erroneous measurement of a grade II defect instead of a grade III defect in a maxillary molar. This is in line with the findings of Zappa *et al.*, who reported a 27% underestimation of grade III furcation defects measured intrasurgically using the Nabers probe. This underestimation may be due to the shape and diameter of mandibular molars. The high agreement between HD-CBCT and LD-CBCT in the present study shows that (at least when conducted by an experienced examiner) LD-CBCT is just as effective as HD-CBCT at detecting and measuring furcation defects. Earlier studies have already confirmed that HD-CBCT is an accurate method for describing furcation defects (Sala *et al.*, 2018; Vervaeke *et al.*, 2014). The current investigation indicated that LD-CBCT can also accurately describe furcation defects. The radiation dose used in the current study corresponds to only 7% of that used in the HD-CBCT protocol on the same device (Lau *et al.*, 2016). Slightly higher doses were used in earlier studies. For example, digital panoramic views used a DAP of 28 mGy cm^2, whereas analogue panoramic views use about 88 mGy cm^2, both of which were higher than the dose used in the present LD-CBCT protocol (Tavelli *et al.*, 2021). A full mouth status with digital technology has a DAP of approximately 67 mGy cm^2, which was within the range used in CBCT, but only represents the structures in two dimensions (Tavelli *et al.*, 2021). Benefits of CBCT to periodontology have been shown, but clinical studies are needed to confirm these benefits (Aguilar-Duran *et al.*, 2020; Gupta *et al.*, 2015). In the present study, the volume of furcation defects was measured to define the defect margins as precisely as possible. This allowed to quantify and compare the subjective image quality of HD-CBCT and LD-CBCT. There was a good reproducibility in volume measurements between HD-CBCT and LD-CBCT in the present study, indicating that LD-CBCT can produce furcation images of adequate quality compared to HD-CBCT (Fig. 4), at least in the hands of an experienced investigator. Image quality that is reduced but enough is in line with the guiding principle of radiation safety ALARA (as low as Reasonably achievable) principle. In addition, segmentation data may be used for automated evaluation programs in the future, allowing evaluation algorithms for LD-CBCT to be developed.

Although the High-Definition protocol demonstrated slightly greater accuracy (Fig. 3), there was no statistically significant difference between the Low-Dose and High-Definition protocols (Table 3). Taking into consideration the ALARA principle (as Low as Reasonably Achievable) and the importance of ensuring patient safety from X-ray hazards, the Low-Dose protocol holds considerable clinical value. It enables us to minimize patient exposure while still obtaining enough diagnostic information without compromising image quality or diagnostic reliability.

Conclusion

Reduction in radiation dose during CBCT scans may be possible without affecting accuracy of radiographic furcation defect measurements and thus opens the way to a wider utilization of CBCT in dentistry.

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التصوير المقطعي المحوسب ذو الجرعة المنخفضة مقارنةً بالتصوير المقطعي المحوسب ذو الجرعة العالية في قياس تأثرات التفرع السني(:دراسة دقة التشخيص)

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المستخلص

يُعد التشخيص الدقيق لعيب التفرع السني أمرًا أساسيًا في تخطيط علاج اللثة. يوفر التصوير المقطعي المحوسب ذو الجرعة العالية (CBCT) تصويرًا ثلاثي الأبعاد، إلا أن جرعات الإشعاع العالية لا تزال تُشكل مصدر قلق. تهدف هذه الدراسة إلى تقييم ومقارنة دقة التشخيص لـ CBCT بجرعة منخفضة (LD-CBCT) و CBCT بجرعة عالية (HD-CBCT) في الكشف عن عيب التفرع وقياسه باستخدام الفك السفلي للخنزير. إن الكشف عن أمراض اللثة وتقييمها بدقة أمر مهم لتحديد تشخيص الأسنان وعلاجها. يوفر التقييم الشعاعي معلومات حول نمط ومدى عيب التفرع. يوفر CBCT صورًا ثلاثية الأبعاد فريدة تُستخدم في التشخيص وخطط العلاج، ولكن استخدامه في طب اللثة لم تتم مراجعته جيدًا نظرًا لوجود عدد قليل من الدراسات التي تم البحث فيها حول دور CBCT في طب اللثة. تم مسح خمسة عشر ضرسًا من تسعة فكوك خنازير ذات تورطات تفرع طبيعية ومحاكاة باستخدام بروتوكولي LD-CBCT و .HD-CBCT كانت القياسات الحقيقية التي تم الحصول عليها باستخدام مجسات اللثة والفرجار الرقمي بمثابة المعيار الذهبي. تم تسجيل عيب التفرع ومقارنته عبر كلتا الجرعتين(LD-CBCT و HD-CBCT). تم تقييم موثوقية النتائج بين المراقبين وداخلهم. أشارت النتائج إلى أن متوسط قياسات التفرع كان أعلى في مجموعة المعيار لذهبي (8.61 ± 1.90 مم)، يليه التصوير المقطعي المحوسب عالي الكثافة (HD-CBCT) (7.22 ± 2.27 مم) ثم التصوير المقطعي المحوسب منخفض الكثافة (LD-CBCT) (6.99 ± 2.15 مم). لم تكن الفروق بين التصوير المقطعي المحوسب عالي الكثافة والمعيار الذهبي ذات دلالة إحصائية(p = 0.062) ، بينما أظهر التصوير المقطعي المحوسب منخفض الكثافة فرقًا كبيرًا عن المعيار الذهبي .(p = 0.008) ومع ذلك، كان التوافق التشخيصي بين بروتوكولي التصوير المقطعي عالي الكثافة و LDمرتفعًا، مع تباين مقبول. وقد تم التوصل الى أن التصوير المقطعي المحوسب منخفض الكثافة يُظهر دقة تشخيصية مقبولة لقياس عيب التفرع، مما يشير إلى أن بروتوكولات الجرعة المخفضة قد تكون قابلة للتطبيق في البيئات السريرية للحد من التعرض للإشعاع دون المساس بالنتائج التشخيصية.

الكلمات المفتاحية: التصوير المقطعي المحوسب بجرعة منخفضة، التصوير المقطعي المحوسب بجرعة عالية، إصابة التفرع، تشخيص أمراض اللثة، دقة التشخيص، تقليل جرعة الإشعاع.