Visibility of lamina dura and periodontal space on periapical radiographs and its comparison with cone beam computed tomography

Nimish Prakash, Freny R. Karjodkar, Kaustubh Sansare, Heena V. Sonawane, Neha Bansal, Reena Arwade

Abstract

Objectives: To retrospectively evaluate the subjective quality of images of cone beam computed tomography and compare with periapical radiographs (PR) to determine whether lamina dura (LD) and periodontal ligament (PDL) space can be detected and reported. **Study Design:** Sixty scans for anterior and posterior teeth with PR were included and scored on four point subjective scale. Scores assessed using Wilcoxon Signed rank test with the level of statistical significance $P < 0.05$. **Results:** Maximum number of ties for LD in anteriors was seen in coronal section (16) and in posteriors with sagittal section (17). Assessing PDL space in anteriors, high number of ties was seen with coronal section (25) and sagittal section (21), while for posteriors showed a high number of ties in all sections. **Conclusions:** LD could be observed and reported in coronal section for anteriors and in sagittal section for posteriors and PDL space in all the sections for both anteriors and posteriors.

Keywords: Cone beam computed tomography, lamina dura, periapical radiographs, periodontal ligament space

Introduction

Lamina dura (LD) is a radiographic landmark viewed largely on periapical radiographs (PR). The terminology LD (or alveolus) is applied to the thin layer of dense cortical bone, which lines the roots of sound teeth. Presence of LD is an indication of the health of the teeth. Radiographically it is seen as a thin radiopaque line running around the length of the roots. Adjacent to the LD, on the tooth side, a thin dark shadow represents the space occupied by the periodontal membrane, known as periodontal space.[1] PR has mainly been used to assess both periodontal ligament (PDL) space and LD. The presence or absence of LD and PDL space on radiographs may also be affected by any variations in the angulation of the X-ray beam. The convexity or concavity of proximal tooth surfaces, the curvature of the roots, the level of the cemento-enamel junction and the thickness of the alveolar bone may also cause variations in the thickness and clarity of the LD.

Department of Oral Medicine and Radiology, Nair Hospital Dental College, Mumbai, Maharashtra, India

Correspondence: Dr. Nimish Prakash,
Department of Oral Medicine and Radiology, Ground Floor,
Dr. A.L. Nair Road, Nair Hospital Dental College, Mumbai,
Maharashtra, India.
E-mail: nimishprakash@gmail.com

Access this article online	
Quick Response Code:	Website: www.contempclindent.org
	DOI: 10.4103/0976-237X.149286

Digital two-dimensional intraoral and panoramic radiography have been widely adopted by dentists in the last few decades. To overcome some of the limitations of two-dimensional analyses, various three-dimensional imaging modality techniques have been proposed. The development of computed tomography (CT) enabled three-dimensional assessment of craniofacial structures. CT has become a widely available means for maxillofacial diagnosis.[2,3] and various surgical procedures' outcomes. CT may not be an optimal diagnostic task in dental applications, such as impacted teeth or apical lesions mainly because of its excessive radiation exposure, increased cost and limited availability. These factors also impede the routine use of this technology for dental applications.

Cone-beam computed tomography (CBCT) is the most recent modality in the imaging armamentarium for advanced diagnosis of various dentomaxillofacial pathologies[4] possessing benefits regarding radiation dose, cost effectiveness, scanning time and better spatial resolution in evaluating the periodontal bone structure in a clinically objective and quantitative way.

Recently, subjective quality of the image obtained by CBCT has been explored in many *in vitro* studies. Hashimoto *et al*.[5] clarified subjective evaluation of image of three-dimensional X as being superior to CT. Loubele *et al*.[6] concluded subjective image quality of the CBCT was significantly better than for the CT about visualization and delineation of the LD and PDL space. Since previous studies on the evaluation of subjective quality of CBCT[5-8] were all performed *in vitro* under "ideal" or well-controlled experimental settings, they are compounded with limitations. Therefore, the findings from *in vitro* models need to be tested in clinical settings before any recommendations for reporting on CBCT examinations in patients can be forwarded.

The aim of this study was to evaluate the subjective quality of images of CBCT in multiplanar sections and compare with PR as the reference method in order to determine whether LD and periodontal space can be detected clearly and should be reported when a CBCT examination is available.

Materials and Methods

This retrospective study had Ethical approval from the institutional review board of the Nair Hospital Dental College, Mumbai, India (Approval number: 012/EC/2012). Ethical approval was given on the basis that this was a retrospective study and did not involve additional patient exposure to radiation.

Scan selection

A total of 410 CBCT scans from January 2012 to January 2013 were retrospectively reviewed from archives' of the oral radiology unit. Scans only with a small field of view (FOV) 5 × 3.7 cm and with an isotropic voxel size of 0.076 mm were chosen. Scans done for implant site assessment were included. Only those scans whose PR was available were included in the study. All the scans with periapical/periodontal pathology or with implants or any restorations were excluded. Scans of patients with a history of trauma were also excluded.

From the database, a total of 60 scans whose PR were available were finally included in the study consisting of 30 scans for the anterior teeth and 30 for the posterior teeth.

Periapical examination

Periapical radiographs [Figure 1] were recorded on size 1 film (Ektaspeed Plus, Eastman Kodak, Rochester, USA) using Uni Bite holder (Dentsply India,). A Sirona dental unit (Heliodent Plus, Sirona Dental, Wasserfeldstraße 30, A-5020 Salzburg, Austria) operated at 65 kVp, 7.5 mA and 0.21 s, was used to exposing the films. The unit had a 0.7 mm focal spot and a 2 mm aluminum filter. The exposed films were processed in an automatic processing machine at 27°C with a 4.5 min processing cycle. The radiographs were viewed using a ×2 magnification with a constant light intensity.

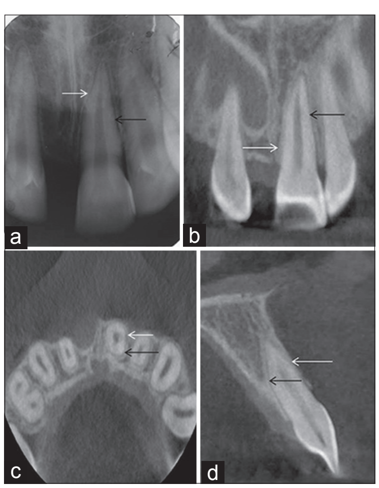

Figure 1: Lamina dura (white arrow) and PDL space (black arrow) observed in the anterior teeth as on the (a) periapicals and on the sections of cone beam computed tomography (b) coronal, (c) axial and (d) sagittal

Cone beam computed tomography examination

Cone beam CT examination was performed using a KODAK 9000 three-dimensional unit (Carestream Health Inc., 150 Veronal Street, Rochester, NY 14608, USA) operated at 80 kVp, 5 mA, 5 × 3.7 cm FOV, voxel size 0.07 mm and an image acquisition time of 10.8 s. One quadrant image rotation was used. The equivalent dose was less than up to 38 μSv/quadrant. The acquired data were reconstructed with a 0.2 mm section interval and thickness. Observers used the Digital Image Communication in Medicine (DICOM) software to evaluate the reconstructed image sections in three planes, that is, coronal, sagittal and axial.

Radiographers who were not a part of the study performed the PR and CBCT radiographic examinations.

Radiographic assessment

Three observers (all experienced radiologists) with at least 5 years of experience in reading PR and CBCT images individually assessed the images from both modalities at different times. All observers assessed the PR first followed by the CBCT in a random fashion. The observers were provided with a training session until the time they were comfortable with the assessment. The observers were not aware of the aim of the study. All CBCT images were obtained in a DICOM format and transferred to a separate workstation. All observations were done in a quiet windowless room with dimmed lighting. CBCT images were viewed on HP Compaq LE 1911, 19" VGA LCD display (Hewlett Packard Company, 3000 Hanover Street, 94304-1185, USA) at a 1280 × 800 resolution using the Kodak dental imaging software (version 6,12,10,0 copyright Carestream Health Inc., 150 Veronal Street, Rochester, NY 14608, USA). Observers were allowed to use two-fold magnification and modify screen brightness. For the CBCT images, the observers could scroll and view all sections in sagittal, coronal, and axial planes. Both PR and CBCT were scored for the presence of LD and PDL space on a four point subjective scale [Table 1].

Data analysis

Statistical analyses were performed by transferring all the data on Microsoft Excel 2003 software (Microsoft Corporation) and

Table 1: Subjective image quality determining visibility of LD and periodontal space using a 4 point rating scale

Definitely absent
Probably absent
Probably present
Definitely present

LD: Lamina dura

the Statistical Package for the Social Sciences software (SPSS Inc. Released 2007. SPSS for Windows, Version 16.0. Chicago, SPSS Inc.) was used. The scores were compared with assess the subjective image quality by applying Wilcoxon Signed rank test[9] for each observer and for both anterior and posterior teeth since the measurements were done on different imaging modalities. Positive rank, negative rank, and ties were assigned to assess visibility of LD and PDL space in each section where positive rank showed better visibility, negative rank suggested poorer visibility and ties were indicative of similar visibility. When the score improved from periapical to CBCT it was considered a positive rank, and when it worsened it was negative rank. A tie indicated no change in the scores. The level of statistical significance was $P < 0.05$. CBCT imaging quality was poorer then PR if $P < 0.05$.

Results

Lamina dura

Anteriors: The positive scores for all three observers ranged from 2 to 5 in multiplanar reconstruction (MPR) sections, with score of 4 when observed overall. The ties ranged from 3 to 16 with an overall score of 13 and the negative scores ranged from 9 to 24 with an overall score of 13 [Table 2].

Posteriors: The positive scores for all three observers ranged from 0 to 2 (overall; 2) the ties ranged from 1 to 18 in MPR sections with overall score of 18 and the negative scores ranged from 10 to 29 with overall score of 12 [Table 2].

Periodontal ligament space

Anteriors: The positive scores for all three observers ranged from 2 to 3 in MPR sections with overall score of 3, the ties ranged from 19 to 26 with overall score of 23 and the negative scores ranged from 2 to 9 with overall score of 4 [Table 3].

Posteriors: The positive scores for all three observers ranged from 0 to 2 in coronal and 2 in both axial and sagittal, (overall; 2) the ties ranged from 18 to 26 with overall score of 27 and the negative scores ranged from 2 to 11 overall score of 1 [Table 3].

Discussion

The objective of this study was to assess whether LD and PDL space could be detected on CBCT. Guidelines on reporting CBCT scan are not available, this study, therefore, assessed if LD and PDL space could be reported on a CBCT. The working hypothesis of this study was that cross-sectional imaging would provide a better image quality image than PR for detecting LD and PDL space.

The high number of positive ties means that the periapicals and the CBCT were equally capable of demonstrating LD. This suggests that there has been a marginal improvement in the visibility of LD. Combining the ties and positive scores would suggest that there was either a similar or improved visibility on the CBCT. Maximum number of ties for visualizing LD in anterior teeth was seen with coronal sections and minimum number of ties seen with sagittal sections of CBCT as compared with PR indicating visibility of LD better in coronal section and poor in sagittal section for anterior teeth. This could be plausible because the coronal CBCT is the corresponding section in which a PR is viewed. This also could be because of the thin buccal cortical bone as seen in the sagittal section. The clinicians are therefore advised to view LD for anterior teeth on the coronal sections. It should also be noted that the radiologists could report LD preferably on a coronal section.

Observing LD for posterior teeth maximum number of ties seen with sagittal section and minimum number of ties seen with coronal section as compared with PR indicates visibility

Table 2: Positive and negative ranks for LD as seen on CBCT and periapicals (PR) of both anterior and the posterior teeth for all three observers

	Observer 1				Observer 2				Observer 3			
	Positive rank	Negative rank	Ties	*P*	Positive rank	Negative rank	Ties	*P*	Positive rank	Negative rank	Ties	*P*
LD for anterior teeth												
Coronal-PR	5	9	16	0.378	3	14	13	0.008	4	10	16	0.092
Sagittal-PR	4	18	8	0.012	4	16	10	0.006	4	17	9	0.006
Axial-PR	3	23	4	0.000	2	24	4	0.000	3	24	3	0.000
Overall-PR	5	12	13	0.122	4	16	10	0.007	4	13	13	0.038
LD for posterior teeth												
Coronal-PR	0	29	1	0.000	0	29	1	0.000	0	29	1	0.000
Sagittal-PR	2	11	17	0.013	2	12	16	0.007	2	11	17	0.001
Axial-PR	2	12	16	0.020	1	13	16	0.002	2	12	16	0.005
Overall-PR	2	12	16	0.020	1	13	16	0.002	2	12	16	0.005

LD: Lamina dura; CBCT: Cone beam computed tomography; PR: Periapical radiographs

Table 3: Positive and negative ranks for PDL space as seen on CBCT and periapicals (PR) of both anterior and posterior teeth for all three observers

	Observer 1				Observer 2				Observer 3			
	Positive rank	Negative rank	Ties	*P*	Positive rank	Negative rank	Ties	*P*	Positive rank	Negative rank	Ties	*P*
Periodontal space for anterior teeth												
Coronal-PR	3	2	25	0.655	2	2	26	1.000	3	2	25	0.655
Sagittal-PR	3	6	21	0.248	2	6	22	0.132	3	6	21	0.317
Axial-PR	2	8	20	0.058	2	9	19	0.035	2	9	19	0.033
Overall-PR	3	4	23	0.705	3	4	23	0.705	3	4	23	0.705
Periodontal space for posterior teeth												
Coronal-PR	1	11	18	0.005	0	12	18	0.001	1	11	18	0.005
Sagittal-PR	2	2	26	1.000	2	2	26	1.000	2	2	26	1.000
Axial-PR	2	2	26	1.000	2	2	26	1.000	2	2	26	1.000
Overall-PR	2	1	27	0.564	2	1	27	0.564	2	1	27	0.564

PDL: Periodontal ligament; CBCT: Cone beam computed tomography; PR: Periapical radiographs

of LD is best in sagittal section and poor in coronal section for posterior teeth. This again is because posteriors' periapicals are visualized in the corresponding sagittal section of CBCT. The clinicians are therefore advised to view LD for posterior teeth on the sagittal sections of a CBCT scan. It should also be noted that the radiologists could report LD for the posteriors on the sagittal section.

For assessing PDL space in anteriors, maximum number of ties was seen with coronal sections also with high number of ties seen with sagittal sections of CBCT as compared with PR indicates visibility of PDL space better in all the sections. This could be because the coronal CBCT is the corresponding section in which a PR is viewed. This is because PDL space being a radiolucent structure is better delineated with adjacent radiopaque alveolar bone and tooth structure.

Assessing PDL space in posteriors showed the high number of ties and low number of negative rank means that the periapicals and the CBCT were equally capable of demonstrating PDL space and suggests that there has been a marginal improvement in the visibility of PDL space. This again is because PDL space being radiolucent is better delineated with the radiopaque tooth structure and alveolar bone.

In a study evaluating four CBCT systems for differences in the subjective quality of images on human cadaveric mandible concluded that the Veraviewepocs three-dimensional (FOV: 4 × 4: voxel size: 0.125 mm^3) had the highest quality images for most of the assessed features, including LD and PDL space whereas the Iluma low-resolution (voxel size 0.3 mm^3) scans were rated as the lowest quality images.[7] Interestingly, Gaudino *et al.* suggested detection of PDL space was significantly better in magnetic resonance imaging (MRI) than with CT or CBCT.[8] LD was also best seen in MRI than CT (not detected) and CBCT (inconstantly detected).

In the present study, both PR and CBCT of the same patient were retrieved from the database. This could be significantly different from scans made on dry mandibles/skull as the X-ray beam undergoes attenuation on passing through not only external soft tissue, but also the soft tissue within the bone. The image contrast is more when bone is imaged against air and water, as with a dry skull, than imaging bone against soft tissue, as in the case of patients. Imaging dry skulls may show better quality images because the image contrast is high, which adds to the ease of delineating structures and boundaries of structures. Having soft tissue surrounding the bone not only reduces this contrast but also provides an additional source of scatter radiation, thus altering the image contrast. Other than soft-tissue attenuation, radiographic images may be affected by a reduction in image quality due to metallic artefacts and patient motion.

The inclusion of all multiplanar sections demonstrated capability of three-dimensional imaging to visualize LD in areas where conventional modalities fall short. The difference in the diagnostic accuracy of CBCT between anterior and posterior teeth is likely due to different morphology of the periodontal bone between these areas. Both LD and PDL space were well seen in coronal section of CBCT for the anterior teeth [Figure 1b], whereas it was difficult to comment on the presence of LD in sagittal section, especially on the buccal side, this could be attributed to the fact that buccal cortical plates are thinner in anterior region and the alveolar bone tapered toward the crest of alveolar bone [Figure 1d]. In multirooted teeth, it was difficult to visualize LD due to close an approximation of roots [Figure 2c].

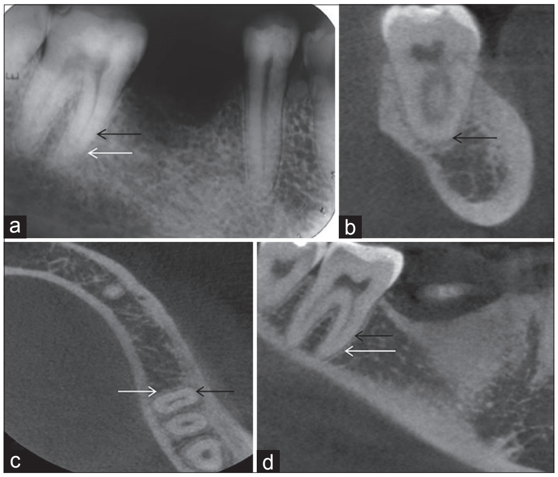

Figure 2: Lamina dura (white arrow) and PDL space (black arrow) observed in the posterior teeth as on the (a) periapicals and on the sections of cone beam computed tomography (b) coronal, (c) axial and (d) sagittal

All previous studies were done determine efficacy of CBCT in displaying LD or PDL space is *in vitro* studies. It's important that *in vitro* studies are followed by clinical studies to obtain a higher level of evidence-challenge-obtain a validation for the radiographic findings. It is important to note that this is the first *in vivo* study to detect the visibility of LD and PDL space on a CBCT scan.

Conclusion

It may be stated that though CBCT is better than PR both in terms of image quality and diagnostic accuracy, when viewed in the prospective section. LD could be observed and reported in coronal section for anterior teeth and in sagittal section for posterior teeth. It is therefore proposed that whenever a CBCT scan is available for any other purpose the LD and PDL space should be reported in its corresponding section. The radiologist should also be cautious in reporting LD and PDL space in scans with metallic artefacts, motion artefacts, regions adjacent to implants, prosthesis metallic restorations and fracture teeth. Future studies could validate this finding with larger sample size and on different CBCT machines (with varying FOV's, sensor types and voxel sizes) to authenticate reporting LD and PDL space in the CBCT scan.

References

1. Worth HM. Principles and Practice of Oral Radiologic Interpretation. Chicago: Year Book Medical Publishers Inc.; 1969.
2. Fuchs T, Kachelriess M, Kalender WA. Technical advances in multi-slice spiral CT. Eur J Radiol 2000;36:69-73.
3. Bou Serhal C, Jacobs R, Flygare L, Quirynen M, van Steenberghe D. Perioperative validation of localisation of the mental foramen. Dentomaxillofac Radiol 2002;31:39-43.
4. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc 2006;72:75-80.
5. Hashimoto K, Kawashima S, Kameoka S, Akiyama Y, Honjoya T, Ejima K, *et al.* Comparison of image validity between cone beam computed tomography for dental use and multidetector row helical computed tomography. Dentomaxillofac Radiol 2007;36:465-71.
6. Loubele M, Guerrero ME, Jacobs R, Suetens P, van Steenberghe D. A comparison of jaw dimension and quality assessments of bone characterisitics with cone beam computed tomography, and multi-slice spiral CT. Int J Oral Maxillofac Implants 2007;22:446-54.
7. Kamburoglu K, Murat S, Kolsuz E, Kurt H, Yüksel S, Paksoy C. Comparative assessment of subjective image quality of cross-sectional cone-beam computed tomography scans. J Oral Sci 2011;53:501-8.
8. Gaudino C, Cosgarea R, Heiland S, Csernus R, Beomonte Zobel B, Pham M, *et al*. MR-Imaging of teeth and periodontal apparatus: An experimental study comparing high-resolution MRI with MDCT and CBCT. Eur Radiol 2011;21:2575-83.
9. Siegel S. Non parametric statistics for the behavioural sciences. McGraw-Hill series in Psychology. New York: McGraw-Hill; 1956.

How to cite this article: Prakash N, Karjodkar FR, Sansare K, Sonawane HV, Bansal N, Arwade R. Visibility of lamina dura and periodontal space on periapical radiographs and its comparison with cone beam computed tomography. Contemp Clin Dent 2015;6:21-5.

Source of Support: Nil. **Conflict of Interest:** None declared.