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Use of CBCT in Periodontology

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ABSTRACT

Periodontium consist of soft tissue including gingiva, periodontal ligament and hard tissues including alveolar bone and cementum. Periodontal disease are caused by various conditions that affect this soft and hard tissues. Periodontitis is one of the most common periodontal disease which results in loss of attachment and reduction in alveolar bone. Clinical signs and symptom helps in the diagnosis of periodontal diseases. Although, if there is destruction of alveolar bone, clinical sings or symptom will not provide us with proper diagnosis in such cases radiographic evaluation must be done.

Key words: Alveolar bone, Cementum, Periodontitis, Gingiva

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INTRODUCTION

To know the level of alveolar bone present mostly panoramic and periapical radiographs are used as diagnostic measures but these radiographic methods can cause distortion and magnification of the X-ray created which makes it difficult for us to get precise diagnosis. The radiographic evaluation of alveolar bone level, lamina dura and bone craters is limited due to super-position of adjacent anatomical structure and projection geometry which is done by panoramic and periapical radiographic technique. Limitation of conventional technique is that it produces 2D radiographs images is that, roots of teeth are superimposed on the alveolar bone due to which bone changes such as involvement of furcation, bone defects on buccal and lingual sides goes unseen [1]. Thus to eliminate this limitation, 2D radiographic techniques are replaced by 3D (three-dimensional) imaging techniques like Computed Tomography (CT). Since many years the 3D imaging like computed tomography is being used in the medical field, however in dentistry the use of CT is new and limited for the diagnosis of head and neck diseases. The usage of CT in dental field is limited as it is expensive and exposes patient to excessive radiation. Recently a new technology known as Cone Beam CT (CBCT) is used for 3D images of oral structures, this technique is cost effective, more compatible and produces low radiation as compared to other radiographic techniques due to which they are present in most of the dental hospital and clinics. CBCT delivers fast volumetric image engaged at various points at a time that are same in geometry and contrast, thus making it possible to assess differences occurring in the fourth dimension time. There are various uses of CBCT in dentistry such as accurate image of teeth and jaws are produced with excellent resolution, which are re-structured three dimensionally, thus making it is possible to view this images from various angle. The most important feature of CBCT is that, radiation dose to which the patient is exposed is five times less than CT. Currently, CBCT is one of the most valued imaging technique in periodontology and implantology. CBCT is used for finding of minutest bony defects, it can show the image in 3D by eliminating the anatomical structures causing distress and making it likely to assess each root and adjoining bone. For implant placement, suitable size and site can be selected before placing an implant and osseointegration can be deliberate over a time period. An engineer named Sir Godfrey N. Hounsfield developed first ever CT in the year 1967. There are five generations of CT technology [2].

LITERATURE REVIEW

Principles and evolution of CBCT

CBCT was first developed at Mayo in 1982 mainly for angiography purpose and for other tasks. After that, CBCT CTA *i.e.,* computed tomography angiography was developed by Fahrig et al., Wiesent et al., SaintFelix et al., Ning et al., Schueler et al., and Kawata et al for angiographic imaging. CBCT was developed for radiographic uses by Jaffray and Siewerdsen and Cho. Now a days CBCT-based imaging systems is being used for mammography.

The two-dimensional detector is used in CBCT scanners, due to which a single revolution of the framework is used to create a scan of the interested area, as which is better than conventional CT scanners which scan multiple slices to get a whole image. When compared with conventional fan-beam or spiral-scan geometries, cone-beam geometry has high efficacy in X-ray use, acquisition of volumetric data is faster and has ability to reduce the cost of CT [3].

The cone beam technique needs only one scan to capture the complete object called as field of view referring to the anatomical area that is captured with X-rays cone. Hence, the time needed to capture both the single cone-beam projection is equal as that for single fan-beam projection.

Four technical and application specific features have made CBCT less costly and small enough to be used in clinics.

- CBCT has compact and high-quality flat-panel.
- Computer power required for cone-beam image reconstruction is easily accessible and is relatively low-cost.
- X-ray tubes required for cone-beam scanning are orders-of-magnitude that are cheap when compared with conventional CT.
- Concentrating only on head and neck scanning, this exclude the essential for sub-second gantry rotation speeds that are required for cardiac and thoracic imaging. Thus reducing the difficulty and price of the gantry.

CBCT image production

CBCT is able to scan patients while they are standing, sitting or in supine position. In spite of patient position inside the principles, the tools required for image production stays the same [4-7].

In CBCT procedure, a cone-beam of X-ray moves round the head of the patient and gathers basic images which helps to build 3D volumetric data from multi-planar *i.e.,* axial, sagittal, coronal and cross-sectional renewals can be made.

Advantages of CBCT

- It is faster in scanning when compared other radiography techniques.
- We can get whole 3D reconstruction and display from several angle.
- Due to presence of beam collimation, the X-ray radiation are limited to interested area.
- Accuracy of the images is with sub-millimeter isotropic voxel resolution extending in a range of 0.4 mm (highest) to 0.076 mm (lowest).
- Radiation exposure of patient is reduced to 29 μSv-477 μSv dose when matched with conventional CT which is approx. 2000 μSv. Thus exposing the patient to radiation is lowered five times than conventional CT, along with it the exposure time is approx 18 seconds, which is one-seventh when compared with the conventional CT.
- With the help of CBCT the projection data can be re-construct in axial, sagittal and coronal planes.
- Multi-planar re-organisation is possible by segmenting volumetric data-sets non-orthogonally.
- Thickening of image which is multi-planar can be done by adding the adjacent voxels involved in the display, known as ray sum.
- Direct and indirect technique makes 3D volume rendering possible.
- Positioning of patient is easy with the help of three positioning beams. Scout images allow even further accurate positioning.
- Artifacts in the image are reduced due to projection geometry of CBCT, along with reduced acquisition time, consequences in a reducing metal artifact in primary and secondary reconstructions.

Limitations of CBCTs

- Image resolution of high contrast is not obtained by CBCT and it does not evaluate soft tissues, hence use of CBCT is limited to hard tissues diagnosis in the dento-maxillofacial complex.
- CBCT is costly and effective radiation dose when related to 2D imaging but CBCT has less resolution power and deficiency of availability.
- The scattering of radiation is high in CBCT due to the of X-ray beam shape, than with fan-beam tomography.
- CBCT can cause metal artifacts, due to silver-amalgam and metalic restorations and can also be caused by implants and filling material used during root-canal treatment. Such defect comprise lines around materials like dark zones that disturb the image quality.
- Beam hardening artifacts, which looks like black bands next to the structures of high-density, can be wrongly diagnosed as disease.

Indications of CBCT

Assessing the bones of jaw which comprises the following:

- Pathology
- Bone defects-furcation defect, infra bony defect
- Periodontal ligament space
- Periodontal evaluation
- Resorption of alveolar ridge
- Identify maxillofacial fractures and structural deformities
- Location of the inferior alveolar nerve before surgery
- TMJ *i.e.,* Temporomandibular Joint evaluation and placement of implant and assessment

Regenerative periodontal therapy and bone graft whenever there is need for 3D reconstructions.

Radiological evaluation of periodontal tissues

CBCT shows two-dimensional and three-dimensional images which are important to give diagnosis and proper treatment plan of defects in bone such as intra-bony defects, involvement of furcation and destructions of bone in buccal/lingual side 4,7,25 but periapical radiographs have superior quality of image, better contrast resolution and clarity when compared to CBCT

[5-9]. However Mol et al in his study concluded that the images of CBCT gives us more precise information on level of bone present in three-dimensions when compared to images stimulated by phosphor plates. In a another research, it was seen that CBCT was superior in description of morphology of periodontal bone defects, but images given by charged coupled device sensor also gave us good bone details. Furthermore, it was stated that both CBCT as well as periapical radiographs measured difference in the height of alveolar bone level but no significant difference was seen with width and depth of defects in bone. Mengel et al concluded that images produced by CBCT gave a better idea of bony defects when compared with CT and periapical radiographs. Similarly, Noujeim et al stated that CBCT technique gives us more correct diagnosis than periapical films in the diagnosis of inter-radicular bony defects [10-14].

DISCUSSION

Furcation involvement

One of the most challenging tasks, for a periodontist, is to evaluate the furcation involvement in multi-rooted tooth. Assessment of the quality of radicular bone is a decisive step in treating furcation involvement. Diagnosis of furcation, in generally, dependent upon factors such as probing pocket depth, attachment loss, probing of the entrance in furcation and periapical radiographs. Detection of the extent of this periodontal pathology becomes strenuous due to limited physical accessibility, morphological variation, and measurements. Early diagnosis of furcation involvement can potentially improve the prognosis [15-17]. The drawbacks of the conventional 2D radiographic technique have forced dentist to evaluate these defects using superlative technologies, thus indirectly emphasizing the need for 3D imaging modalities. CBCT gives us the capability to gather data at greater resolutions and create 3D data at both low price and lesser absorbed doses than conventional CT. 3D CBCT images also reveal details regarding the surrounding bony support of each of the roots of the molar, presence of fused roots, and proximity of the roots of the tooth. Hence, the obtained images may form a reliable basis for planning the treatment and also predicting the treatment outcome [18-21].

A precise diagnosis about the amount of bone loss plays an important role to decide proper treatment options which include apical positioned flaps with or without preparation of tunnel, removal of root, root hemi-section or separation. The conventional 2D radiographs can mislead us in knowing the amount of inter radicular bone present and periodontal tissue evaluation due to emplacement of adjacent anatomic structures. Nevertheless, 3D images gives us in depth data about regions of multiple rooted teeth. CBCT images provides detailed information about the furcation involvement of maxillary molars so that we can give a proper diagnosis and treatment plan for the same [22-26]. Measurement of furcation involved taken during surgery were compared with CBCT image and it was concluded that CBCT image was proven to give higher accuracy rate in measuring the periodontal tissue loss and categorising the grade of furcation involved in maxillary molars. Authors measured CBCT images of furcation which was artificially produced in the second mandibular molars of pig, the accuracy rate of CBCT image of furcation was found to be around 78% to 88%. A comparative study was done between dental radiographs and HR-CT *i.e.,* high resolution CT in identifying and classifying of artificially created furcation in jaw of cadavers. The accuracy in rate of diagnostic of dental radiographs was 21% while it was 100% for HR-CT. Rees et al. had concluded that CBCT imaging gives us an accurate diagnosis of furcation defects involving facial and lingual surfaces and osseous defects on proximal surfaces of multi-rooted teeth [27-30]. Conversely, defects on the facial and lingual root surfaces are very difficult to identify radiographically. They had also said that it is challenging to diagnose the furcation involvement of first left mandibular molar on an IOPA. Thus CBCT can be useful in such cases.

Infra bony defect

The alveolar process is a part of the maxilla and mandible and is one of the most important components of the periodontium. Among the hallmark events of periodontitis, namely gingival inflammation and alveolar bone loss deemed as a foremost factor of tooth loss. Apart from alveolar bone loss, irregularities in the contour of the bone, such as dehiscence and fenestration may also exist [31-33]. Fenestrations are isolated, denuded regions over the root surface covered only by periosteum and the overlying gingiva leaving the marginal bone intact. Dehiscence is isolated, denuded areas over the root surface, covered only by periosteum and overlying gingiva, and extends to the marginal bone. Diagnosis and assessment of these bony defects play a crucial role in detecting and preventing the onset and progression of the disease, respectively. Therefore, the investigations carried out must provide precise and adequate information regarding the same. The use of conventional radiographic techniques such as IOPAs and OPGs has been proved to be insufficient as the changes in the architecture of the spongy bone as they are obstructed by the cortical plate. Hence, the use of 3D imaging such as CBCT is being advocated.

Alveolar bone defect radiograph should be precise in order to assess the bony defect. Two dimensional radiographs can lack recognition of intrabony defects due to the impediment of sponges bone alterations by cortical plate. In a study where the authors associated the image quality of CBCT with conventional CT they had concluded with the result that the CBCT scanner providing enhanced quantitative and diagnostic data on bone levels in three-dimensions than conventional CT [34-36]. However, it was seen that in both the techniques the accuracy was limited in the anterior part of the jaws. In a study done by B Vandenberghe et al, he evaluated that the periodontal bone loss with the help of digital intraoral and cone beam computed tomography image he had found that there was no significant difference between the two methods. Misch and colleagues proved that CBCT was as exact as measurement taken directly by the use of periodontal probe and as dependable as interproximal areas radiographs itself. In their 2005 study, Mengel et al examined the use of CBCT in the analysis of bony defects. It was seen that intra-bony defects could be measured by CBCT in all three planes with higher accuracy true to scale. Similar results were found by Noujeimand et al when CBCT was used to detect inter-radicular lesions of variable depth when compared with intraoral radiography.

Periodontal ligament space

The initial indication of periodontitis which are noticed on a radiograph is by observing the continuity of the lamina dura. Whenever the continuity is absent, more changes where observed in the space of periodontal ligament. Ozmeric et al. did an evaluation in order to associate between CBCT and conventional radiographs produced a phantasm model with artificial periodontal ligament space and had found that the periapical radiographs were higher to CBCT for the measuring of periodontal ligament space [37,38]. But conflicting results were reported by the authors of another *in-vitro* study that proved that CBCT to be superior then conventional radiography for evaluating the periodontal ligament space.

Role of CBCT in regenerative periodontal therapy

Apart from controlling the inflammation and infection of the periodontium, regeneration of the supporting structures is one the aims of modern periodontal therapy. The objective of regenerative periodontal therapy includes reduction in probing depth, attachment gain, treating the osseous defects and regeneration of bone, cementum and periodontal ligament. Grafting of bone is initiated in cases where sinus lift is indicated or in case where intrabony defects are present [39]. Grading the bone loss forms the basis for regeneration; the use of conventional radiographic methods for the same proves to be inadequate due to superimposition of the images. Pre-operative measurement of the bone defect with the help of CBCT could aid in determining the amount of grafting material necessary to adequately fill the defect, thereby directly or indirectly aiding to fulfill the objective of regenerative periodontal therapy. Various studies have implied that CBCT was more accurate than digital intraoral radiographs when measured during surgery and serves as the gold standard for the assessment of intrabony defects and its treatment outcome for regenerative procedure. The use of CBCT may substitute surgical re-entry as it provides 3D images and precise measurement of the affected site which is nearly equivalent to direct surgical measurement [40].

Radiographic examination of healing bone after bone graft is difficult as there is overlap of losing and gaining parts within the graft. Recent technology like CBCT, helps to look within the bone and locate and measure masses in minor localized areas such as an intra-bony defect, or an alveolar bone graft. This accuracy of CBCT makes it possible for us to enumerate the remodelled bone after the bone grafting. CBCT is considered to be more precise than digital intraoral radiographs.

In a study done by Grimard et al. related clinical, radiograph, and CBCT measurement techniques for evaluating changes in bone level after regenerative periodontal therapy in thirty-five intra-bony defects. Author concluded that CBCT was suggestively more accurate and precise than periapical radiographs and stated that CBCT may obviate surgical re-entry as a technique for assessing regenerative therapy outcomes. Ito et al., in his study uses CBCT imaging to assess the result of regenerative therapy. The CBCT images permits imaging the bony defect in three dimensions; only the axial dimension was used to make the template of GTR membrane. Due to the use of template membrane it was observed that the membrane could be easily modified and adapted to the surface of root on either the mandibular or maxillary arch [41]. On the other hand it was observed that without the CBCT, the membrane was a bigger interproximally, and smaller in mesial buccal area. The modification of membrane took less time with the help of CBCT. CBCT gives exact measuring the volume of alveolar bone defect and grafting of bone in cleft patients. By doing preoperative CBCT imaging we can calculate the amount of bone needed to seal the bone defect, and postoperative scans give correct follow-up evaluation post surgery.

CBCT in implant planning

For proper placement of implant, radiographic evaluation is important, each radiographic technique has its own benefits and drawbacks. Selection of proper radiographic technique is important as it offer the maximum diagnostic data which help us to reduce complications and give best outcomes while providing as low as reasonably achievable radiation dose to the patient.

Dentist have being treatment planning, diagnosing, restoring and placing modern dental implants with the help of panoramic and periapical radiograph to evaluate anatomy bone for many years [42]. Two-dimensional have few drawbacks because of innate distortion factors and the non-interactive nature of film gives very little data regarding density of bone, width of bone or spatial proximity of vital structures. Several factors affect the choice of radiographic techniques for a specific case which include price, accessibility, exposure of radiation.

Cross-sectional imaging modalities that include conventional x-ray tomography, computed tomography and CBCT are valuable imaging modalities. Among all of them, CBCT imaging is the most effective, beneficial and valued imaging technique for 3-D and cross-sectional assessment of the implant patient. The advantages and disadvantages are same as CT scanning. The most important dissimilarity is that CBCT causes less exposure of radiation.

Site is the utmost essential factor while insertion an implant. From 3D preparation to CT-directed placement, to take the benefit of available bone and evade anatomic structures, the science of implantology has been transformed by 3D imaging. It has not only added protection and accurateness, it has also reduced use for supportive procedures like bone and tissue grafting in many situations.

CONCLUSION

CBCT is an emerging technology in the field of periodontology. Present means of identifying change in level of bone are insufficient. This problem was addressed by the new cost effective CBCT, which is affordable produces less-radiation and higher quality 3-D information. CBCT necessary for analysis of implant design and its placement. CBCT gives us better diagnostic images quality with less radiation exposure to the patient when compared with other radiographic techniques thus maintaining the principles of alara *i.e.,* as low as reasonably achievable. Thus, CBCT with its high 3-D resolution, easily affordable, small in size, low acquisition and easy maintenance have made it suitable for periodontal imaging.

CONFLICT OF INTEREST

No conflict of interest.

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REFERENCES

1. Lang NP, Lindhe J. Clinical periodontology and implant dentistry, 2 volume set. 6th edition, John Wiley and Sons, 2015.
2. Highfield J. Diagnosis and classification of periodontal disease. Aust Dent J 2009; 54:11-26.
3. du Bois AH, Kardachi B, Bartold PM. Is there a role for the use of volumetric cone beam computed tomography in periodontics? Aust Dent J 2012; 57:103-108.
4. Umetsubo OS, Gaia BF, Costa FF, et al. Detection of simulated incipient ifurcation involvement by CBCT: An in vitro study using pig mandibles. Braz Oral Res 2012; 26:341-347.
5. Özmeric N, Kostioutchenko I, Hägler G, et al. Cone-beam computed tomography in assessment of periodontal ligament space: *In vitro* study on artificial tooth model. Clin Oral Investig 2008; 12:233-239.
6. Mohan R, Singh A, Gundappa M. Three-dimensional imaging in periodontal diagnosis-Utilization of cone beam computed tomography. J Indian Soc Periodontol 2011; 15:11.
7. Robb RA. The dynamic spatial reconstructor: An x-ray video-fluoroscopic CT scanner for dynamic volume imaging of moving organs. IEEE Trans Med Imaging 1982; 1:22-33.
8. Fahrig R, Fox AJ, Lownie S, et al. Use of a C-arm system to generate true three-dimensional computed rotational angiograms: Preliminary *in vitro* and *in vivo* results. Am J Neuroradiol 1997; 18:1507-1514.
9. Fahrig R, Nikolov H, Fox AJ, et al. A three-dimensional cerebrovascular flow phantom. Med Phys 1999; 26:1589-1599.
10. Wiesent K, Barth K, Navab N, et al. Enhanced 3-D-reconstruction algorithm for C-arm systems suitable for interventional procedures. IEEE Trans Med Imaging 2000; 19:391-403.
11. Saint-Felix D, Trousset Y, Picard C, et al. *In vivo* evaluation of a new system for 3D computerized angiography. Phys Med Biol 1994; 39:583.
12. Ning R, Chen B, Yu R, et al. Flat panel detector-based cone-beam volume CT angiography imaging: System evaluation. Trans Med Imaging 2000; 19:949-963.
13. Schueler BA, Sen A, Hsiung HH, et al. Three-dimensional vascular reconstruction with a clinical X-ray angiography system. Acad Radiol 1997; 4:693-699.
14. Kawata Y, Niki N, Kumazaki T. Measurement of blood vessel characteristics for disease detection based on cone-beam CT images. IEEE Trans Nuc Sci 1996; 43:3348-3354.
15. Jaffray DA, Siewerdsen JH. Cone-beam computed tomography with a flat-panel imager: Initial performance characterization. Med Phys 2000; 27:1311-1323.
16. Cho PS, Johnson RH, Griffin TW. Cone-beam CT for radiotherapy applications. Phys Med Biol 1995; 40:1863.
17. Chen B, Ning R. Cone-beam volume CT mammographic imaging: Feasibility study. Med Imag Phys Med Imag 2001; 4320:655-664.
18. Shah MA, Shah SS, Dave DH. CBCT-A positive amelioration in periodontics. Nat J Integr Res Med 2013; 4.
19. Agrawal P, Sanikop S, Patil S. New developments in tools for periodontal diagnosis. Int Dent J 2012; 62:57-64.
20. Tyndall DA, Rathore S. Cone-beam CT diagnostic applications: Caries, periodontal bone assessment, and endodontic applications. Dent Clin North Am 2008; 52:825-841.
21. Jervoe-Storm PM, Hagner M, Neugebauer J, et al. Comparison of cone-beam computerized tomography and intraoral radiographs for determination of the periodontal ligament in a variable phantom. Oral Surg Oral Med Oral Pathol Oral Radiol Endodontol 2010; 109:e95-e101.
22. Eshraghi T, Mc Allister N, Mc Allister B. Clinical applications of digital 2-D and 3-D radiography for the periodontist. J Evid Bas Dental Prac 2012; 12:36-45.

23. Loubele M, van Assche N, Carpentier K, et al. Comparative localized linear accuracy of small-field cone-beam CT and multislice CT for alveolar bone measurements. Oral Surg Oral Med Oral Pathol Oral Radiol Endodontol 2008; 105:512-518.
24. Misch KA, Yi ES, Sarment DP. Accuracy of cone beam computed tomography for periodontal defect measurements. J Periodontol 2006; 77:1261-1266.
25. Walter C, Kaner D, Berndt DC, et al. Three-dimensional imaging as a pre-operative tool in decision making for furcation surgery. J Clin Periodontol 2009; 36:250-257.
26. Mol A, Balasundaram A. *In vitro* cone beam computed tomography imaging of periodontal bone. Dentomaxillo Radiol 2008; 37:319-324.
27. Vandenberghe B, Jacobs R, Yang J. Diagnostic validity (or acuity) of 2D CCD versus 3D CBCT-images for assessing periodontal breakdown. Oral Surg Oral Med Oral Pathol Oral Radiol Endodontol 2007; 104:395-401.
28. Mengel R, Candir M, Shiratori K, et al. Digital volume tomography in the diagnosis of periodontal defects: An *in vitro study on native pig and human mandibles*. J Periodontol 2005; 76:665-673.
29. Noujeim M, Prihoda TJ, Langlais R, et al. Evaluation of high-resolution cone beam computed tomography in the detection of simulated interradicular bone lesions. Dentomaxill Radiol 2009; 38:156-162.
30. Mohan R, Mark R, Sing I, et al. Diagnostic accuracy of CBCT for aggressive periodontitis. J Clin Imag Sci 2014;4.
31. Pour DG, Romoozi E, Shayesteh YS. Accuracy of cone beam computed tomography for detection of bone loss. J Dent 2015; 12:513.
32. Walter C, Weiger R, Zitzmann NU. Accuracy of three-dimensional imaging in assessing maxillary molar furcation involvement. J Clin Periodontol 2010; 37:436-441.
33. Fuhrmann RA, Bücker A, Diedrich PR. Furcation involvement: Comparison of dental radiographs and HR-CT-slices in human specimens. J Perio Res 1997; 32:409-418.
34. Rees TD, Biggs NL, Collings CK. Radiographic interpretation of periodontal osseous lesions. Oral Surg Oral Med Oral Pathol 1971; 32:141-153.
35. de Faria Vasconcelos K, Evangelista KM, Rodrigues CD, et al. Detection of periodontal bone loss using cone beam CT and intraoral radiography. Dentomaxill Radiol 2012; 41:64-69.
36. Özmeric N, Kostioutchenko I, Hägler G, et al. Cone-beam computed tomography in assessment of periodontal ligament space: *In vitro study on artificial tooth model*. Clin Oral Investig 2008; 12:233-239.
37. Walter C, Schmidt JC, Dula K, et al. Cone Beam Computed Tomography (CBCT) for diagnosis and treatment planning in periodontology: A systematic review. Quinte Int 2016; 47:25-37.
38. Sutton MW, Fontenot JD, Matthews II KL, et al. Accuracy and precision of cone-beam computed tomography guided intensity modulated radiation therapy. Prac Radia Oncol 2014; 4:e67-e73.
39. Ito K, Yoshinuma N, Yoshinuma E, et al. Clinical application of a new compact computed tomography system for evaluating the outcome of regenerative therapy: A case report. J Periodontol 2001; 72:696-702.
40. Grimard BA, Hoidal MJ, Mills MP, et al. Comparison of clinical, periapical radiograph, and cone-beam volume tomography measurement techniques for assessing bone level changes following regenerative periodontal therapy. J Periodontol 2009; 80:48-55.
41. Takane M, Sato S, Suzuki K, et al. Clinical application of cone beam computed tomography for ideal absorbable membrane placement in interproximal bone defects. J Oral Sci 2010; 52:63-69.
42. Zhou WN, Xu YB, Jiang HB, et al. Accurate evaluation of cone-beam computed tomography to volumetrically assess bone grafting in alveolar cleft patients. J Craniofac Surg 2015; 26:e535-e539.