CLINICAL AND RADIOGRAPHIC PERIODONTAL PARAMETERS: COMPARISON WITH SOFTWARE GENERATED CBCT MEASUREMENTS

Rachid Sreih* | Nabil Ghosn** | Carole Chakar*** | Nadim Mokbel**** | Nada Bou Abboud Naaman*****

Abstract
Periodontal diagnosis relies mainly on clinical assessment and radiographic images. The increasing accuracy of CBCT images and the corresponding advancement in computer software for data extraction can be of great help in periodontal diagnosis for bone loss and furcation defects. Thus, the aim of this study was to compare direct surgical measurements to data extracted from periapical radiographs and CBCT by means of software (coPeriodontix™ and Blue Sky Plan®) in order to assess the accuracy delivered by these software. Ten patients were included in the study, the number of teeth selected for measurements ranged from one to 10 per patient. Overall: i- 251 measures were included for comparison of linear measurements between surgical and CBCT, ii- 69 measures were compared between surgical and periapical radiographs, iii- 20 furcation defects were recorded peroperatively for comparison with CBCT and periapical radiographs data. All CBCT scans and X-rays were acquired within a maximum period of 1 month prior to surgery. Clinical linear measurements were performed at 6 sites for each tooth, from the cemento-enamel junction to the marginal bone level at the buccal, buccal-mesial, buccal-distal, lingual, lingual-mesial, and lingual-distal side. Furcation defects were recorded according to the classification of Hamp in 1975. Differences between data acquired from these 3 modalities were analyzed. Intra-surgical measurements were considered as “gold standard”. Statistical significance was found between the three modalities concerning linear measurements. CBCT showed less bone loss while intra-surgical measurements showed more bone loss. Furcation defects were similar between CBCT and intra-surgical measurements (p =1). Intra-oral radiographs showed 38.88% accuracy for furcation defects. The coPeriodontix™ tended to underestimate the real bone loss. The Blue Sky Plan® accurately depicted the true furcation defect.

Keywords: Diagnostic – periodontitis - dental radiography - cone beam computed tomography - coPeriodontix™ software.

Résumé


* DDS, Resident, Masters in periodontology, Department of Periodontology
Faculty of Dental Medicine, Saint-Joseph University, Beirut
rachidsreih@gmail.com

** DDS, MScD, Instructor, Department of Oral and Maxillo-facial Radiology
Faculty of Dental Medicine, Saint-Joseph University, Beirut

*** DDS, MSc, PhD, Head of Department of Periodontology
Faculty of Dental Medicine, Saint-Joseph University, Beirut

**** DDS, DUSCP, PhD, Honorary Dean, Professor at the Department of Periodontology
Faculty of Dental Medicine, Saint-Joseph University, Beirut

***** DDS, DUSCP, PhD, Honorary Dean, Professor at the Department of Periodontology
Faculty of Dental Medicine, Saint-Joseph University, Beirut
Introduction

Diagnosis in periodontology relies on clinical and radiographic assessments. Clinical assessment of the periodontium includes probing pocket depth (PPD), bleeding on probing (BOP), clinical attachment loss (CAL), tooth mobility and furcation involvement while radiographic examination relies on panoramic (OPT) and full mouth intra-oral X-rays. These conventional examination methods have some disadvantages. The periodontal probe is unable to assess bone position without an open flap [1]. Nabers probe has a limited access to the furcation area and an estimated clinical probing accuracy of 56% [2]. The image produced by a conventional periapical radiograph is a 2D representation of a 3D area of interest and inherent limitation of superimposition makes diagnosis of missing buccal or lingual plates impossible [3] and while the diagnosis of intra-bony defects is detectable in only 67% of the cases [4], only 38.7% of furcation defects are accurately diagnosed [5]. OPT hinders the same limitations as intra-oral radiographs in addition to the distortion of images and blurring of anatomical structures [6].

Today, Cone Beam Computed Tomography (CBCT) is widely used in many fields of dentistry due to scan time reduction, less radiation exposure, reduced cost for the patient, and a high image quality when compared to Dentascan [7]. The fields of use of CBCT in dentistry include: extraction of impacted mandibular third molars in close proximity to the inferior alveolar canal, orthodontic traction of an impacted canine into normal occlusion, orthodontic/surgical management of complex skeletal abnormalities, endodontic treatment of multi-rooted teeth when root canal anatomy is not adequately shown on conventional intra-oral x-rays, maxillofacial and dental trauma, implant placement and fabrication of surgical stents, use of dynamic surgical navigation technology, jaw bone invasion of oral carcinoma, and the study of temporomandibular joint diseases [8].

Since the establishment of CBCT imaging modality, many studies have been conducted to assess its reliability in measuring periodontal bone breakdown, intra-bony defect width, height and length, and furcation defects [9-13].

Mol et al. [9] stated that the evaluation of alveolar bone height in relation to the CEJ is the primary benefit of radiologic examination in periodontal diagnosis as it shows the severity of bone loss and whether it is localized or generalized. This linear measurement has many advantages in case it is accurately provided by CBCT: First it prevents surgical reentries for measuring defect fill and defect resolution after regenerative procedures [1]. Second it has the benefit, in contrast to PA, of showing the interproximal buccal and lingual bone levels, as well as buccal and lingual bony levels. That is essential because the number of walls remaining determines the potential of regenerative procedures [14]. This measurement might also be used as a parameter for periodontal disease evaluation like clinical attachment level, pocket depth and recession [15] and this knowledge of bone level could be an important way of assessment for the disease condition in periodontally compromised patients [9]. In addition, it can be a mean of quantification for
Parodontologie / Periodontics

disease progression or improvement after periodontal therapy.

From that perspective, we conducted a study with a primary objective of comparing linear measurements and furcation defects on CBCT delivered by dedicated software (coPeriodontix™, Dental Wings and Blue Sky Plan®, Blue Sky Bio, LLC, Grayslake, IL, USA) to those obtained clinically as direct surgical measurements. The secondary objective was to evaluate the accuracy of periapical radiographs to assess bone loss, compared to CBCT and surgical measurements.

Materials and methods

Study design

Patients from the department of Periodontology, Faculty of Dental Medicine at St-Joseph University, Beirut, were recruited for the study between March and November 2016. This observational study was conducted without the need for additional surgeries neither further radiographic exposures since the patients selected for this study had planned surgical treatments and CBCT scans were taken only when indicated for implant placement, bone regeneration procedures or open flap debridement. Informed consent was signed by the patients upon entry to the dental care center; patients were informed about the rationale of the study.

Inclusion criteria

Patients who presented a previous or history of periodontitis with horizontal and vertical bone loss, a recent CBCT (taken in less than 4 weeks prior to intervention) and a treatment plan including an open flap debridement or implant placement adjacent to the investigated teeth.

Exclusion criteria

Compromised patients CBCT (artefacts, blurred images...) were excluded, as well as the images with an inability to locate the CEJ or a fixed reference point because of carious lesions, filling material at the CEJ, metallic crowns, and amalgam fillings near the alveolar crest.
Initial X-ray examination

Peri-apical radiographs (PA) of the studied teeth were taken prior to surgery using digital radiography (Dürr dental image plates, size 2: 3 x 4 cm) using the long cone parallel technique.

The CBCT scans were taken with the Newtom VGI scanner, with an effective dose of radiation of 99 µSv for a full field of view (FOV), with a scan time of 18 seconds (±2.6s), x-ray emission time of 3.6 seconds (±5.4s) and a voxel size of 300µ. CBCT data were saved in DICOM format in order to transfer it to the coPeriodontix™ (Institute Straumann AG, Basel, Switzerland) and Blue Sky Plan software (Blue Sky Bio, LLC, Grayslake, IL, USA).

Surgical procedure and clinical measurements

After administration of local anesthesia, flaps were reflected allowing identification of the cemento-enamel junction and good access to the marginal bone, then bony defects were thoroughly debrided, and all direct surgical measurements were made.

The following measurements were performed by a single operator:

- Hard tissue measurements were recorded by a periodontal probe CP 15 UNC (HU-Friedy®, Chicago, IL, USA) accurate to the nearest 0.5mm, placed parallel to the long axis of the tooth. Six measurements of the linear distance between the cemento-enamel junction (CEJ), or the margin of an existing restoration, and the base of the defect (BD) (Fig. 1) were taken at the following locations:
  - V (buccal),
  - VD (buccal-distal),
  - OD (lingual-distal),
  - O (lingual),
  - OM (lingual-mesial),
  - VM (buccal-mesial).
- Furcation defects (FD) were assessed using a curved Nabers probe (PO2N, HU-Friedy®) according to Hamp classification (1975): At three locations for the investigated maxillary molars (buccal, mesio-palatal and disto-palatal) and at 2 locations for...
the mandibular molars (buccal and lingual).

Once measurements were recorded, periodontal and/or implant surgeries were finalized as planned.

Peri-apical radiograph measurements

The linear distance from the CEJ and BD (Fig. 2) were measured mesially and distally on each tooth on PA, and assessment of furcation involvement were done on the investigated molars.

CBCT measurements of periodontal bone loss using the coPeriodontix™ software

DICOM images were imported into the coPeriodontix™ software. The three-dimensional position of the tooth in x-, y-, and z- coordinate within the dental arch was determined by fixation of the central point of the examined tooth.

A reconstruction process of the 3D anatomy of the dental arch (teeth and surrounding bone) was performed. First, a panoramic curve was defined at the level of the CEJ (Fig. 3). In order to have an accurate positioning, the CEJ was referred to in both sagittal and coronal planes. The axis of each tooth was manually oriented in a defined centered position in the 3 spatial planes: transversal (Fig. 4a), sagittal (Fig. 4b) and axial (Fig. 4c).

The distance between the CEJ and the marginal bone position was measured at 6 locations on each tooth:
1. V (buccal),
2. VD (buccal-distal),
3. OD (lingual-distal)
4. O (lingual),
5. OM (lingual-mesial),
6. VM (buccal-mesial).

For each molar, the presence or absence of furcation involvement defect was noted without stating the degree of that involvement.

The coPeriodontix™ software delivered the results in a table and a graphic image showing the value of the distance from the CEJ to the marginal bone at the six previously indicated positions for each tooth, and the linear measurements for furcation involvement.

CBCT measurements of furcation involvement using the Blue Sky Plan

Since the results delivered by the coPeriodontix™ software concerning the furcation involvement gives the horizontal width of the furcation area and not the furcation involvement according to the classification of Hamp 1975, we added the results by direct visual observation of the different slices on the Blue Sky Plan® software (Figs. 7a, 7b).

After incorporating the DICOM data of the patient’s CBCT in the Blue Sky Plan® software, custom mesio-distal slices were obtained from the vestibular to the lingual part of the lower molars in order to assess FD, and sections from the buccal to the interproximal sides to assess trifurcation defects of the upper molars. Furcation defects were classified as follow:
• Degree 0 FD: when no radiolucency was observed under any roof of the furcation slices.
• Degree I FD: when 1 or 2 slices showed a radiolucency under the roof of the furcation.
• Degree II FD: when 3 or more slices showed a radiolucency under the roof of the furcation at the condition that at a certain level, no more radiolucency under the roof of the furcation was observed.
• Degree III FD: when all slices showed a radiolucency under the roof.
of the furcation from one side of the tooth to the other.

Data analysis

Surgical measurements were done by one operator (RS) and were considered as the reference values. The CBCT measurements were conducted by the same operator and monitored by an experienced periodontist (NG) in both 3D imaging and CBCT usage. Statistical analyses were performed using a software program (SPSS for Windows, Version 22.0, Chicago, IL). The level of significance was set at \( \alpha = 0.05 \). The normality distribution of continuous variables were assessed using the Shapiro-Wilk tests. Since measurements were not normally distributed, non-parametric tests were carried out. Wilcoxon tests were used to compare the measurements between PA measurements and surgical values.

CoPeriodontix™ software measurements and surgical values.

Comparison of the linear measurements

The linear measurements on each surface were performed using three different techniques: (1) the direct surgical values considered as the reference, (2) the PA radiographs, and (3) CBCT measurements using the coPeriodontix™ software.

CoPeriodontix™ and surgical measurements

Statistical analysis showed that the mean value of linear measurements using the coPeriodontix™ software was significantly lower compared to the surgical method (4.32 and 5.53 respectively with \( p<0.001 \)).

There was a medium positive correlation between the two techniques as the high coPeriodontix™ value was associated with higher surgical value (Spearman correlation coefficient \( r=+0.496; p<0.001; N=251 \)).

Periapical and surgical measurements

Statistical analysis showed that the mean linear value for PA measurements was significantly lower compared to the surgical method value \( (p<0.001) \).

There was a strong positive correlation between these two techniques with high PA value associated with higher surgical value (Spearman correlation coefficient \( r=+0.839; p<0.001; N=68 \)).

Periapical and coPeriodontix™ software

The mean linear measurements for PA measurements was significantly higher than the coPeriodontix™ mean value \( (p=0.005) \) and a strong positive correlation between the two techniques with high periapical value associated with higher surgical value (Spearman correlation coefficient \( r=+0.764; p<0.001; N=69 \)).

Assessment of furcation involvement

Six patients were examined for furcation defects. A total of 20 furcations for 9 molars (2 upper and 7 lower) were assessed using three techniques: the clinical PA radiographs, CBCT images (Blue Sky Plan®) and the surgical assessment which was considered as the reference source.

Statistical analysis showed that the diagnosis of each type of furcation involvement was significantly different between PA radiographs and surgical assessment \( (p=0.01) \), in contrast CBCT and surgical evaluations were similar \( (p=1.000) \).

Compared to surgical assessment, furcation involvements on PA radiographs were underestimated for 11.11%, overestimated for 50% and truly determined for 38.88%, while two furcation involvements were not detected.

Discussion

The primary objective of this study was to compare linear measurements and furcation defects on CBCTs to those obtained clinically by direct surgical measurements. The first in vitro study to address the accuracy of linear measurements in CBCTs was conducted on cadavers in 2006 [4]. In contrast to our present study, the results showed no statistically significant difference for this modality when compared to direct measurements. However, the findings of that study should be interpreted with caution because the CEJ was replaced by gutta percha markings, the bony defects were artificially made by burs which do not reproduce the exact morphology and demineralization of bone in periodontal diseases, and since measurements were obtained from skulls, there was absence of motion when taking radiographs in contrast to patients.

Another in vitro study by Vandenberghe et al. [3] showed more accurate results, with no statistical difference between CBCT (90% accuracy) and PA radiographs (82% accuracy) where 1 mm discrepancy for direct measurements was allowed. However, this ex vivo study had inherent factors that differ from clinical situations: standardized repositioning and stabilization provided by a rigid occlusal key during exposure ensured a complete absence of motion for the image intakes for both modalities. Gutta-
percha was positioned at the level of the faded JEC. There was no interference of soft tissues (cheeks, gingiva, tongue, lips and alveolar mucosa) when measurements were performed on the dry skull. However, such accurate probe positioning and fabrication of waxed bite blocks for PA radiographs cannot be reproduced on patients.

Our study showed similar findings to that conducted by Grimard et al. [1] regarding linear measurements from CEJ-BD, as they had statistically different values between surgical measurements and CBCTs and PA radiographs. They found an underestimation of the CBCT values, and to a lesser extent for the PA radiographs. The authors explained that many factors could have accounted for this discrepancy: the thorough debridement of the surgical site prior to the measurements could have removed some of the mineralized bone, observed on the CBCT, resulting in higher surgical values. Another issue could be due to a deeper penetration of the periodontal probe when cancellous bone is located at the marginal bone level, therefore probe angulation plays a major role in the accuracy of surgical values.

These results are in accordance with the study of Li et al. [12] who found CBCT values underestimated the bone position (mean value was 8.14 mm with CBCTs versus 8.9 mm for surgical) while in our study the mean value for CBCTs was 4.31 mm compared to 5.53 mm with surgical measurements. For
those authors, CBCT has no advantages than PA for CEJ-BD measurements.

Feijo et al. [11] performed an in vivo study on 12 teeth, resulting in 72 linear measurements from the CEJ to BD compared to 251 in our present study. They showed a statistically significant difference between surgical and CBCT measurements concerning the buccal and palatal aspects but no difference for interproximal measurements. The authors highlighted the fact that surgical measurements are nearest to 1 mm. However, CBCT measurements are calculated in decimals and lack contrast, in addition bone and lamina dura are not well defined as in the PA radiographs, and this observation was also perceived in our present study.

In a recent study conducted by Guo et al. [7] the authors relied also on the six-site linear measurements but had no statistically significant difference between surgical and CBCT measurements. This study was conducted by trained investigators on CBCT measurements (three investigators were post-graduate students in dental and maxillofacial radiology and one was a post-graduate student in periodontology); measurements were done under strict conditions (calibration of the observers) which is more important than the observers clinical experience [15]. However, the authors concluded that the values delivered by CBCT tend to be lower than the ones measured during surgery suggesting that bone loss is actually greater clinically to what is observed on CBCTs.

Another important factor for CBCT measurement is image quality, it is in fact related to parameters such as milliamperage, kilo-voltage and voxel size [14]; the images acquired in this study were regular computed tomography parameters with a maximum FOV of 15 cm x 15 cm and a maximum voxel size of 0.3 mm, implying that a slightly better resolution of the CBCT slices was obtained compared to other in vitro studies where they had a voxel size of 0.4 mm [3,4] but inferior to some in vivo studies that used a voxel size of 0.2 mm [1,7,11].

Other linear measurements were taken in some of the in vivo studies listed previously, but seem to be scarce in the literature, like the depth of the defect AC-BD, the buccal-lingual depth of the defect [12] and the mesio-distal depth of the defect [1,4,12]. All these linear measurements on CBCT showed accuracy in depicting the measurements surgically. This discrepancy for the lack of accuracy for JEC-BD and AC (alveolar crest)-BD on one hand and a good accuracy for JEC-AC on the other could be due to the fact that the alveolar crest is more cortical in nature, so it is less likely to be removed with thorough debridement. In addition, the apical position of the depth of the defect is more cancellous, so it is more prone to bone removal with bone debridement, leading to a deeper probe insertion while measuring. The accuracy of the linear measurements on CBCT for the depth of the defect in mesio-distal and buccal-lingual directions seems useful for regenerative and healing potential of osseous defects [12].

The secondary objective of our study was to evaluate the accuracy of periapical radiographs where this modality showed a lack of precision when depicting the height from the CEJ to BD, this is in accordance with other in vivo studies [12] were there was a tendency to underestimate surgical measurements (mean 8.9 mm surgical versus 8.09 mm for PA) [1] compared to a mean of 5.35 mm for surgical and 4.45 mm for PA obtained in the present study, and that can be due to the cancellous nature of the apical depth of the defect that is eliminated with thorough debridement and deeper probe insertion in surgeries. A high percentage of correlation was seen in our study between PA and surgical value (83.9%) and a moderate one between surgical and CBCT (49.6%). One factor accounting for this discrepancy is that PA radiographs were manually measured on the screen and noted, in addition CBCT measurements were numerically delivered on a table after inserting the landmarks points. These numerical values seemed anarchical as some values did not match with the measurements performed on the CBCT slices. A lack of technical support for this issue prevented the adjustment of the errors.

Regarding furcation involvement, the coPeriodontix™ software was unable to deliver the degree of furcation involvement according to the classification of Hamp 1975. The original classification of Hamp 1975 is a clinical method of measurement for periodontal breakdown in furcation areas that does not necessarily reveal inter-radicular bone loss, so the term FD should be used when referring to radiologic or intra-surgical findings [16], implying that the term FD is referred to in this study for furcation bone loss.

The incapacity of the coPeriodontix™ to assess FD is due to the lack of parameters requested by the software. It requests the CEJ position along with the bone position on each determined slice. If the tooth is multi-rooted, and in order for the software to be able to determine the degree of FD, it should ask for additional landmarks: the most coronal point of the roof of the furcation and the deepest part of the furcation (or the absence of the latter in case of degree III FD), but the software only delivered a linear measurement for the horizontal length of the roof of the furcation when the operator indicated the presence of a multi-rooted tooth.

Many studies also assessed furcation defects in maxillary molars and found a high accuracy rate between CBCT and intra-surgical measurements [17, 18]. These studies showed that CBCT is a nearly accurate tool for assessment of furcation defects, the difference in terms of accuracy to our study is probably due to methodology, i: the results of the study conducted by Walter et al. [18] assessed only maxillary molars in contrast to our study where only 2 maxillary molars were assessed, ii: it has a far superior number of furcation involvement (75) in contrast to our study where only 20 furcations were assessed because big-
ger pools leads to more challenging or critical situations, iii: the open flap surgeries for intra-surgical furcation assessment were conducted three to six months after the CBCT scans. Most of the cases were underestimated intra-surgical evaluations, probably due to the lapse of time between CBCT and surgery where bone resorption or remodeling occurred. Another probable cause was over-instrumentation; one single case showed a degree class III FD for a degree I intra-surgical, it could be due to demineralization of bone in the furcation area.

PA radiographs showed a low accuracy in depicting the degree of furcation defects, as two furcations were excluded due to the inherent disadvantage of PA to identify vestibular maxillary FD. 11.1% furcation defects were underestimated, 50% were overestimated, and only 38.88% were in accordance with the intra-surgical results. This finding is in line with other studies [5] where the sensitivity of a PA to identify an actual furcation invasion was 38.7%. That means that “furcation arrow” defined by the authors as the small triangular radiolucent shadow sometimes seen across the mesial or distal roots of maxillary molars, showed a small predictive value for the presence of furcation bone loss and that most actual furcation involvement were not associated with this radiolucent shadow. This finding suggests that post anesthesia bone sounding has greater diagnostic value in furcation assessment than pre-anesthetic probing.

Recently, the American Academy of Periodontology underlined the importance of continued research on CBCT, for the widespread and the quick advancement in this field could be a useful tool of diagnosis and treatment planning in patients with compromised periodontium [8]. Keeping in mind the principle ALARA in radiology, CBCT could have advantages in periodontal diagnosis in certain cases of orthodontic treatment including patients with a thin biotype and those with concomitant recession, in advanced periodontitis with concurrent endodontic pathologies, in advanced furcation lesions where bone loss reached critical resorption near gold anatomical structures like the sinus or inferior alveolar or mental nerve, when a suspected root fracture or resorption that could not be identified in clinical and 2D imaging, in refractory localized periodontitis, peri-implantitis, and some selected cases where limited FOV could be used for adding information concerning severe and complex periodontal defects. These statements are expert opinions and do not rely on evidence-based studies for routine periodontal treatment planning.

**Conclusion**

This study showed that linear surgical measurements showed to be less accurately replicated by the coPeri-dontix™ and PA radiographs, where both showed underestimation of the real bone loss with a lesser extent of the later. CBCT measurements (with Blue Sky Plan® software) can accurately reflect the true furcation defect in posterior maxillary and mandibular molars.
References


