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Abstract:

The aim of this deliverable was to assess diagnostic accuracy for bone lesion identification in an animal model. This aim was dealt with by 2 main studies.

The variables assessed in the first study were lesion size, tooth type, field of view (FOV) and cone beam CT. All lesions were assessed by seven observers. FOV did not seem to have an influence on the accuracy. Lesion size was the clearest determinant of sensitivity. Accuracy was much higher in permanent teeth than in deciduous teeth.

In the second study, linear measurements of lesions of different size in different locations were assessed. Measurements were compared to microscopic measurements on the samples. Furthermore, CBCT images were compared to MSCT images. CBCT images were suitable for detection of sub-millimetre defects, while MSCT images were not. Linear measurements gave less measurement errors for CBCT images than for MSCT images, when compared to stereomicroscopy.

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Study 1: Accuracy of CBCT in the assessment of artificially induced periapical bone lesions for deciduous and permanent teeth

Introduction

Currently, periapical imaging is most frequently used in endodontics to establish a diagnosis and therapeutical planning, as well as for the intraoperative control and for the monitoring of bone healing (1). Radiology has rather limited value in diagnosing cases with apical radiolucency, as some radio-opaque or radiolucent anatomic structures will overlap the image (zygomatic bone in the area of the superior molars is radio-opaque, the incisive canal and the maxillary sinuses are radiolucent etc). In some other situations the increased density of the cortical bone may prove an extra challenge in setting the right diagnosis and may produce underestimation of the size of periapical lesions (2).

Bohay (3) reported, after a retrospective study based on 140 cases, that the periapical radiograph has a 70.2% accuracy, 65% sensitivity and 78% specificity in the identification of periapical inflammatory disease. Molander et al. (4) showed that the combined use of panoramic and retro-alveolar radiographs results in a 80-96% sensitivity with 95% specificity for periapical lesion detection but also in an increase of the patient dose.

Another inconvenience of the two-dimensional radiology in endodontic diagnosis is the fact that it is impossible to give the relation of periapical, inflammatory lesions with the neighbouring anatomical structures. Apical periodontitis in the immediate vicinity of the cortical sinuses may lead to the extension of the inflammation processes to the maxillary sinus. The correct assessment of the spatial relationship of the roots and their surrounding anatomical structure is a key factor not only for the appropriate treatment of the periapical lesions but also for avoiding surgical incidents during interventions performed for the treatment of these conditions.

The advent and the wide-spread use of cone beam computed tomography (CBCT) equipment in the last few years offers a new perspective in the endodontic management as it gives more complex spatial information and much more details about the bone structure (5). Several studies reveal that the spatial resolution of the CBCT is clearly superior to the one of the medical CT (6, 7), and that makes this type of tomography a highly useful technique in the assessment of bone healing and endodontic treatment. For the comparison of the results over a certain amount of time given by the endodontic treatments it is important that the radiology readings are reproducible in time, with respect to the same radiation geometry, density and contrast of radiological images. The standardisation of the images facilitates the detection of any changes in the periapical tissues and this can be more easily obtained with the CBCT than with any other conventional radiology methods (8). Due to the low effective dose of CBCT, in the same order of magnitude as conventional dental radiographs (9), this radiological technique may offer improved diagnosis of periapical disease, but there are still very few scientific reports on this subject.

The aim of this study was to assess the accuracy of CBCT for the diagnosis of simulated periapical lesions in an animal model.

Materials and Methods

Six pig mandibles (three with mixed dentition and three with permanent teeth) were obtained with ethical approval and prepared by formalin fixation and with soft tissue simulation (fig. 1).

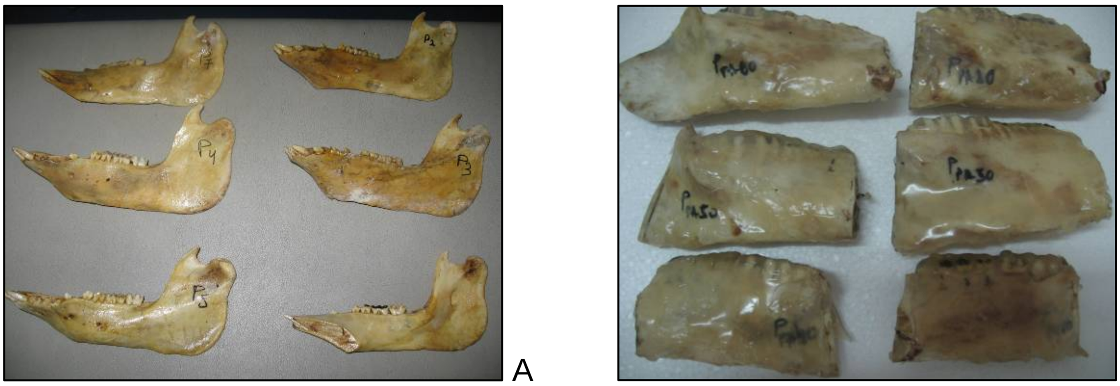

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Figure 1: Six pig mandibles (A) Three mandibles with mixed dentition, (B) Three mandibles with permanent teeth

Standardized periapical bone defects of 1x1mm; 2x2mm and 3x3mm were made in the premolar and molar regions after tooth extraction and root length measurement (fig. 2).

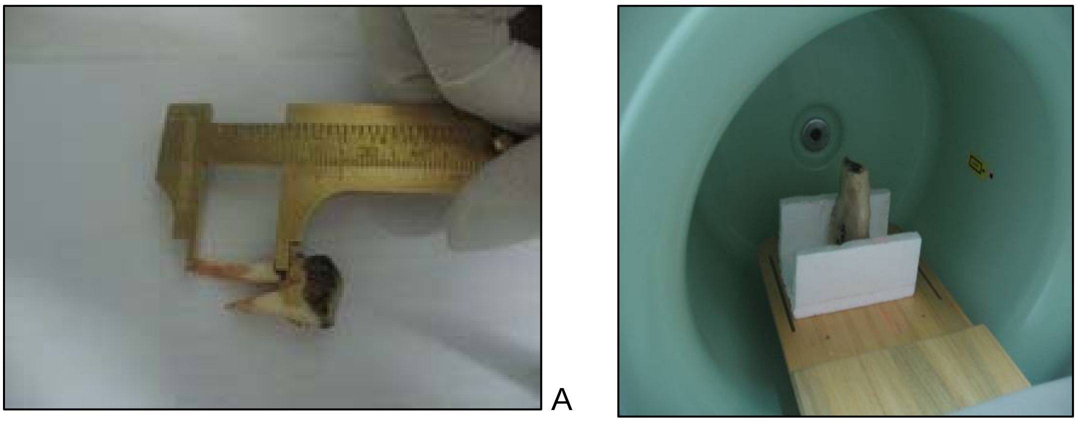

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Figure 2: (A) root measurement after tooth extraction; (B) CBCT scanning after creating periapical bone defects and repositioning the teeth

All mandibles were scanned with one CBCT machine: NewTom 3G (QR Verona, Italy) using the follow scanning protocol:

- Acquisition parameters:
    - NewTom 3G (QR, Italy) , 110kV, 4mA
    - 3 different field of views (FOV) (6, 9 and 12 inches)

- Volumetric data - high resolution - primary reconstruction 0.4mm slices
- Secondary reconstruction – panoramic and cross-section setup at 1x1mm

The roots of the pre-molars and molars were identified and numbered on the axial slices. A total number of 133 roots were found: 39 roots of temporary teeth; 24 roots of young molars and 70 roots of fully grown teeth (fig.3).

Seven examiners assessed the presence of apical periodontitis using a 5-point probability scale: 0 – definitely absent; 1 – probably absent; 2 – uncertain diagnosis; 3 – probably present; 4 – definitely present.

Inter-observers agreement for periapical lesion on the permanent teeth for all FOV was tested (Kendall method; SPSS 14).

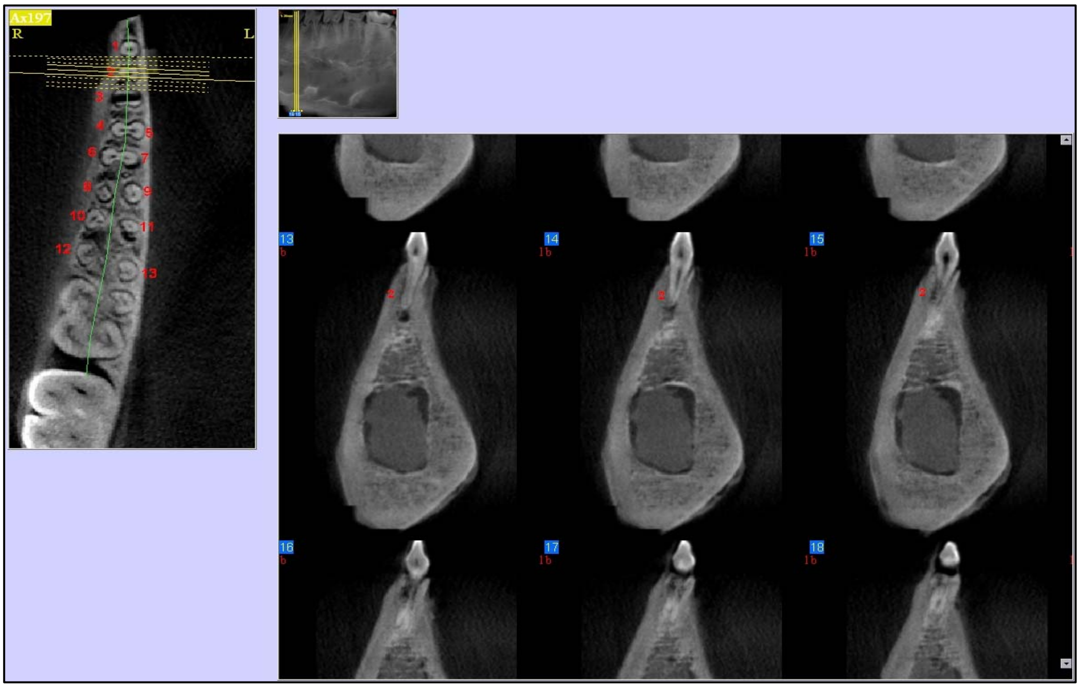
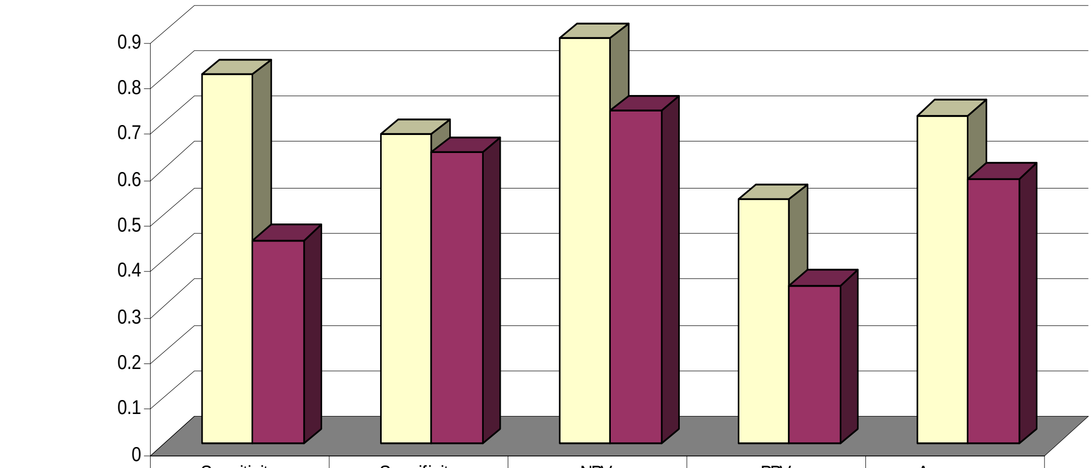


Figure 3: CBCT multiplanar view – root identification on axial, panoramic and cross-sectional view

Results

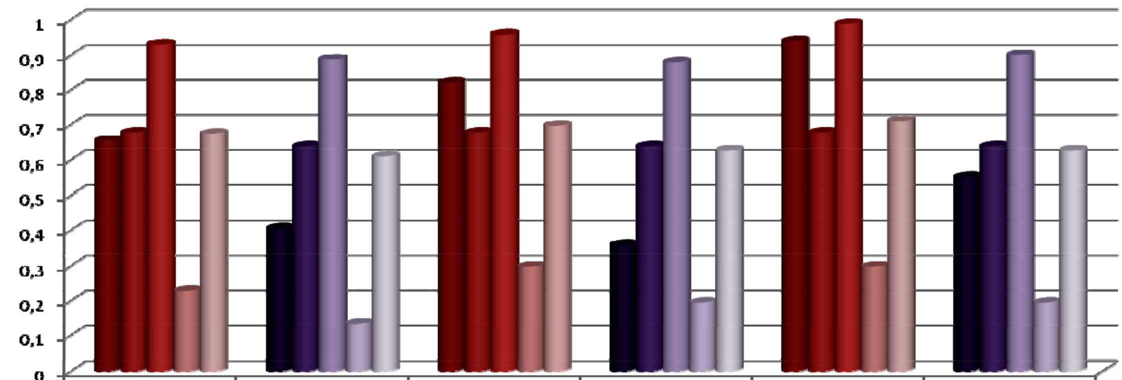
The accuracy for periapical diagnosis was lower for deciduous teeth (57,8% accuracy) than for permanent teeth (71,6% accuracy) (Graph 1).



	Sensitivity	Specificity	NPV	PPV	Accuracy
Permanent teeth	0.8052	0.6756	0.8833	0.5322	0.7163
Mixed teeth	0.4436	0.6364	0.7259	0.345	0.5782

Graph 1: CBCT Accuracy for periapical bone defects on permanent teeth vs. mixed teeth

Sensitivity of CBCT for periapical lesion detection increased with lesion size for permanent teeth (65.3% for 1mm ø defect, 82.1% for 2 mm and 93.9% for 3mm) but remained much lower for deciduous teeth (40.5% for 1mm ø defect, 35.7% for 2mm and 55.1% for 3mm) (Graph 2). There was a statistically significant difference of sensitivity of CBCT for periapical lesion detection between permanent and temporary teeth (p<0.001).



	1mm		2mm		3mm	
	Permanent teeth	Mixed teeth	Permanent teeth	Mixed teeth	Permanent teeth	Mixed teeth
sensitivity	0,6531	0,4048	0,8214	0,3571	0,9388	0,551
specificity	0,6756	0,6364	0,6756	0,6364	0,6756	0,6364
NPV	0,9303	0,8869	0,9578	0,8789	0,987	0,8991
PPV	0,227	0,1318	0,2968	0,1942	0,2968	0,1942
accuracy	0,6727	0,6086	0,6964	0,6246	0,7091	0,6246

Graph 2: CBCT Accuracy for different lesions size of periapical defects on permanent and mixed teeth

The CBCT analysis using different FOV demonstrated that there were no statistically significant differences in the detection of periapical lesions of 1-3mm diameter for permanent teeth (p=0.5880 for FOV6 inch vs.FOV12inch) (table 1).

Table 1: CBCT accuracy for periapical bone defects on permanent teeth for different FOV (field of view)

Accuracy parameters [95%CI]	**FOV 6 inches**	**FOV 9 inches**	**FOV 12 inches**
Sensitivity	**0.8052** [0.7369-0.8614]	**0.7727** [0.7016-0.8332]	**0.7727** [0.7016-0.8332]
Specificity	**0.6756** [0.6242-0.7239]	**0.6190** [0.5663-0.6698]	**0.6429** [0.5906-0.6927]
NPV	**0.8833** [0.8392-0.9177]	**0.8560** [0.8073-0.8954]	**0.8606** [0.8132-0.8988]
PPV	**0.5322** [0.4681-0.5955]	**0.4818** [0.4200-0.5440]	**0.4979** [0.4349-0.5610]
Accuracy	**0.7163** [0.6752 0.7548]	**0.6673** [0.6247-0.7080]	**0.6837** [0.6415-0.7236]

Discussion

The potential applications of volumetric tomography in endodontic diagnosis were discussed by several authors who showed the benefits of three dimensional imaging on assessing the root canal anatomy, the proximity of adjacent anatomical structures or the size of periapical lesions (10, 11, 12).

The results of our study revealed that CBCT should enable to detect the periapical lesions on permanent teeth, with lower accuracy for mixed dentition in pig jaws. Similar results were found by Stavropoulos and Wenzel (13) in their *in vitro* study, performed also on pig mandibles with spherical periapical lesions with a diameter of 1 and 2mm.

Higher values of CBCT sensitivity and specificity had been reported by Patel et al (14) after a study on 10 molars on a human mandible with periapical bone lesions of 2 and 4 mm diameter. For the small lesions and for the bigger ones as well, the sensitivity and the specificity of the CBCT was 100%, the authors even consider the use of the tomography scan as a gold standard examination in the evaluation of the presence of apical periodontitis.

Recently, more *in vivo* studies revealed the increased sensitivity of the CBCT in detecting apical periodontitis, demonstrating the superiority of the CBCT compared to periapical radiographs in the identification of small periapical lesions (15).

Loftang-Hansen et al. (16) compared the results of CBCT examinations with periapical radiology in periodontitis. The authors identified 38% more lesions using CBCT than with conventional radiology.

Similar results were obtained also by Esterela (17) who found a sensitivity of 1.0 for CBCT in lesion detection on CBCT compared to a much lower sensitivity of the panoramic or periapical radiograph (respectively 0.28 and 0.55).

In our study, the sensitivity in case of apical periodontitis of the permanent teeth with bone lesions larger than 2 mm was only 82.14% with a specificity of 67.56%. This difference in results compared to the ones published in literature based on *in vivo* or *in vitro* studies, on human mandibles are to be considered as generated first of all by the morphologic differences of the teeth and mandibular bone in humans and pigs. The immediate vicinity of the molar and premolar apex on pig mandibles with the mandibular canal that is of much larger dimensions than in the human mandible, represented one of the causes of errors in the detection of perapical defects in the animal model study.

The results obtained in our study reflect the analysis of a large number of roots (70 roots compared to only 20 roots in Patel's study). The 7 examiners analyzed the apical spaces of every single dental root both temporary and permanent ones, studying the arches without any clues considering the number or location of the bone lesions.

Our study can be concluded with the statement that the sensitivity of CBCT in detecting apical periodontitis largely depends on the dimension of the lesion. If the diameter of the lesion is about 3 mm, the sensitivity was 93.88% whereas it was only 65.31% in case of small defects, of just 1 mm in the case of permanent teeth. In case of temporary teeth, even though there was a variability of the CBCT sensitivity depending on the dimensions of the defect, it was not significantly different.

There was a significant statistically difference between the sensitivity of CBCT for permanent and primary teeth. The reduced sensitivity in detecting periapical periodontitis in the case of mixed dentition was caused by the presence of follicles of the permanent teeth and by their vicinity to the apex of the temporary teeth. This overlapping influenced the accuracy of bone defect identification, leading to a significant decrease in the CBCT sensitivity, quite unaffected by the periapical radio-transparency.

In literature, there are few data concerning the diagnostic accuracy based on radiology for detecting apical periodontitis in case of temporary teeth. Nevertheless, conventional radiographic examinations are considered to assess inflammation of the pulpal tissue and its extention into the root canals as well as the involvement of the periapical and bifurcation area. They are also considered suitable for long-term monitoring of the results of endodontic treatments (18, 19). Due to the higher doses of radiation compared to the conventional radiography, CBCT cannot be considered as a first choice method in the assessment of periodontitis in the case of temporary teeth. It can be useful though, in the diagnosis of inflammatory lesions or the evaluation of apical resorption in patients who had a CBCT scan in order to establish an orthodontic treatment (20).

Diagnostic accuracy achieved by a radiologic method is highly influenced by the resolution of the imaging system and by the quality of the obtained image. These parameters determine also the intra- or inter-examiner variability that gives the reliability of the particular radiologic method. In this moment there is a large number of different CBCT systems used in practice, some of them with limited volume scan and small volumes of data that can include just two or three individual teeth (3D Accuitomo, J. Morita, Japan) and other CBCT devices with variable size of the field of view (FOV) that can capture the entire maxillofacial skeleton. (e.g. NewTom 3G, QR, Verona Italy or I-CAT, Imaging Sciences International, Hartfield, PA, USA, Scanora, Soredex).

Heiter Neto et al (21) compared the diagnostic accuracy for caries detection of two different cone beam CT systems (NewTom 3G with three FOVs: 6, 9 and 12 inches and 3DX Accuitomo) with two intraoral receptors. The results showed that NewTom 3G 12 inch and 9 inch images had a significant lower diagnostic accuracy for detection of caries lesions than intraoral modalities and the 3DX Accuitomo CBCT and NewTom 9 inch and 6 inch had significantly lower specificities than intraoral receptors.

Comparative analysis of diagnostic accuracy for periapical lesion detection with NewTom 3G CBCT using three FOVs demonstrated that sensitivity, as well as specificity of the CBCT is increased when using a small FOV (6 inch) compared with medium and large FOVs (9 and 12 inches).

Even though the results of an *in vitro* study using an animal model cannot be considered a perfect reference for clinical, *in vivo* situations, this research allowed us to analyze a large number of periapical spaces and assess the accuracy parameters of the CBCT system in a comparative manner, as a tool in the detection of apical periodontitis lesions in mixed and permanent teeth. The use of an animal model also enabled us to compare and interpret the accuracy of different CBCT systems and their various FOV.

Study 2: Accuracy of CBCT in the detection and measurement of bone defects. A comparative study with stereomicroscopy

Introduction

To evaluate the bony structure of the maxilla and to assess the radiologic techniques in the detection of minor changes that appear in the structure of the trabecular or cortical bone represent the subject of study for a high number of researchers (22, 23). The continuous improvement of the methods used in radiology offers the possibility to identify micro-structural changes of the alveolar bone and the increase in the resolution of the images leads to an increase of the reliability and reproducibility of these imaging methods (24).

Currently there are several methods for the quantitative assessment of bone structure. Conventional radiographs, computed tomography (CT) and dual X ray absorptiometry (DXA) are useful for macrostructure assesment whereas for assessing microstructure of trabecular bone the high resolution peripheral quantitative CT (HR-pQCT), microcomputed tomography (micro-CT), high-resolution magnetic resonance (HR -MRI), and micromagnetic resonance (micro-MR) can be used (25). Some of these methods can only be used *in vitro*, others are helpful also in the study of the bony structure *in vivo*. Computed tomography is the method of choice to assess oral and maxillofacial bone lesions because it provides a good accuracy in maxillofacial lesions detection with an excellent anatomic resolution.

CBCT represents an increasingly used technical solution in imagery for identifying the structural changes in the maxillofacial bone system or for measurements carried out on the level of the alveolar structures.

Several studies concluded that the image quality of CBCT scans is superior to multi-detectors CT (MDCT) for assessing the dental and bone structure (26, 27, 28, 29) and has a high reproducibility (30). For the subjective image quality, the CBCT offered better visualization of details of the small bony structures.

Due to its high spatial resolution characteristics, CBCT may prove a useful tool for quantification of the bone structure of the maxillofacial area. Ballrick JW et al. (31) found the worst spatial resolution was 0.86 mm for I-CAT CBCT machine, and this was lower at faster scan times and larger voxel size but a high resolution (0.32 mm) could be obtained by using a new flat-panel detector type (32).

Dougherty G et al (33) measured the fractal analysis and lacunarity of trabecular bone on clinical CT images and they showed that CT slice thickness of 1 mm or less is necessary for keeping essential architectural information from getting lost. Using high resolution medical CT for bone changes detection or bone density assessment leads to higher radiation. CBCT systems have a low effective dose in reaching the same order of magnitude as conventional dental radiographs, so enabling the medical staff to use CBCT to detect and monitor over a longer period the evolution of small changes in the bone structure of the maxillofacial area.

The aim of this study was to assess the sensitivity of different CBCT machines and an 8 row multi-detector medical CT (MSCT) for identification and linear measurement of small cortico-trabecular bone defects using stereomicroscopy as the gold standard.

Materials and Methods

Five pig hemi-mandibles prepared using formalin fixation and soft tissue simulation were selected to simulate spherical bone defects on the lingual cortex. Another 5 pig hemi-mandibles were sectioned at the premolar/molar level, obtaining 20 bone blocs, designated for the creation of standardized cortico-trabecular bone defects (diameters 0.5; 0.8; 1; 1.2 and 1.5 mm) (fig.1A, B).

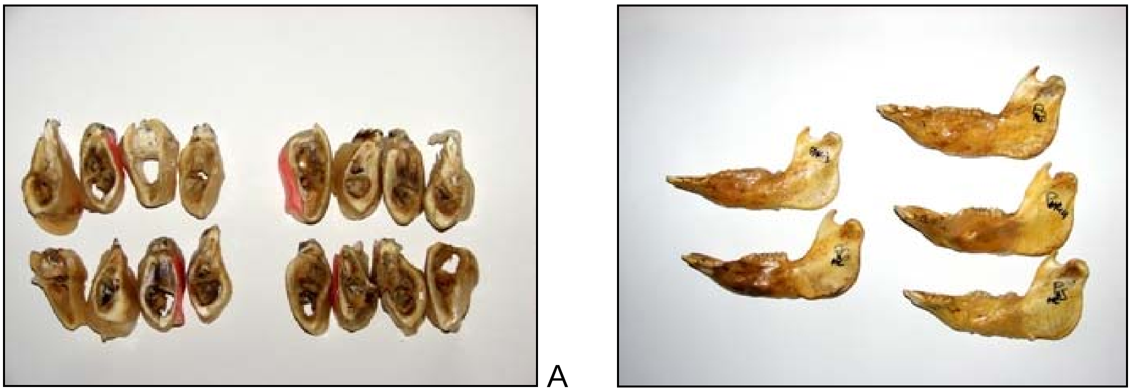


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Figure 4: Five pig mandibles prepared for the creation of standardized (A) trabeccular and (B) cortical bone defects

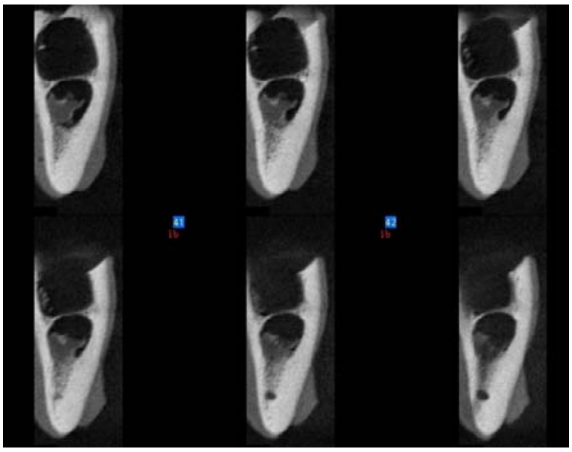
CBCT scans and MSCT scans (Bright Speed 8, GE) of all specimens were performed (fig.2).

The protocol for CBCT scans (NewTom 3G, Italy)

- o 3 different FOV: 6, 9, 12 inches
- o Resolution: 0,2 mm

MSCT 8 slices (Bright Speed 8, GE)

- o 140kV and 187 mA
- o Resolution: 1,3 mm for axial scan
- o Dental CT reformatted images



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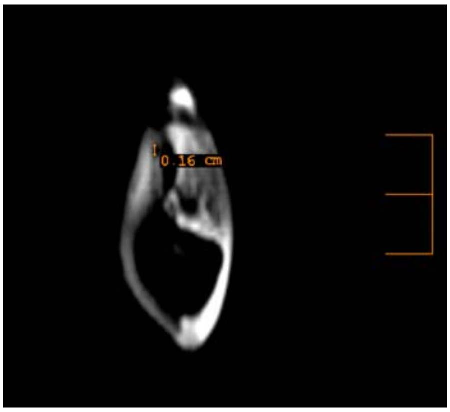

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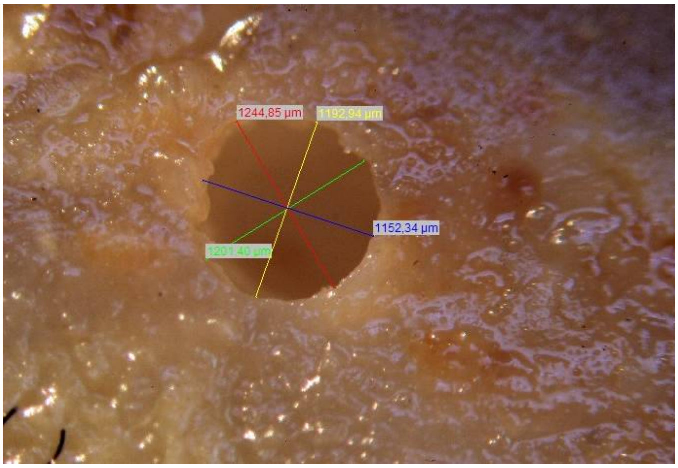
Figure 2 A) CBCT images; B) MSCT image

Seven examiners evaluated these images independently under controlled viewing conditions to identify the presence, number and dimensions of the bone defects. The results were compared to gold standard measurements obtained by stereomicroscopy and dedicated image analysis software.

The results were compared to the gold standard measurements obtained by stereomicroscopy and dedicated image analysis software (stereoscopic Olympus SZ 2 – ILST microscope and special software elaborated for the image analysis called "Cell A®")



Results

The smallest lesion size that could be detected on NewTom 3G CBCT images was 0.8mm in trabecular bone in contrast to MSCT images, on which only trabecular bone defects larger than 1.2mm could be detected (table 1).

Table 2: The CBCT sensitivity for the smallest bone defects detected with NewTom 3G

Smallest bone defects detected	**sensitivity**	**lower CI 95%**	**upper CI 95%**
CBCT 0.8mm trabecular defects	0.5769	0.387	0.7668
CBCT 0.5mm cortical defects	0.3714	0.2133	0.5315
MSCT 1.2mm trabecular defects	0.5	0.369	0.631

The assessment of the sensitivity of CBCT and MSCT in detecting bone damage compared to standard *in vitro* examinations of the mandible pieces demonstrated that there are statistically significant differences between the 2 computer tomography methods (p<0.001). CBCT had a higher sensitivity than MSCT regardless of the scanning volume used (FOV 6, 9 or 12 inch) (table 2).

On the other hand there were no statistically significant differences between the CBCT sensitivity levels in case of different sizes of volume scan (FOV small compared with FOV medium: p=0.4282; FOV small – large: p= 0.4787; FOV medium - large: p= 0.8313).

Table 3: Sensitivity of CBCT with three FOV dimensions and MSCT for trabecular and cortical bone identification

	Location of bone defects	**Sensitivity [CI95%]**	**Ratio of false negative [CI95%]**
CBCT FOV 6 inches (small)	Trabecular	**0.6357** [0.5539-0.7120]	0.3643 [0.2880-0.4461]
	Cortical	**0.8352** [0.7747-0.8839]	0.1648 [0.1161-0.2253]
CBCT FOV 9 inches (medium)	Trabecular	**0.6000** [0.5175-0.6784]	0.4000 [0.3216-0.4825]
	Cortical	**0.8514** [0.7926-0.8977]	0.1486 [0.1023-0.2074]
CBCT FOV 12 inches (large)	Trabecular	**0.6071** [0.5247-0.6852]	0.3929 [0.3148-0.4753]
	Cortical	**0.8229** [0.7608-0.8735]	0.1771 [0.1265-0.2392]
MSCT	Trabecular	**0.4000** [0.3216-0.4825]	0.6000 [0.5175-0.6784]
	Cortical	**0,568182** [0.4914-0,6418]	0.4318 [0.3581 – 0,5085]

The results showed that there was a variability of the CBCT sensitivity depending on the diameter of the bone lesion, both in case of a trabecular bone lesion and the cortical bone lesion (table 3). The sensitivity of the CBCT was reduced in a statistically significant way when infra-millimeter lesions had to be studied, compared to those having a diameter that exceeded 1 mm (p<0.001).

The analysis of the sensitivity variations of the CBCT proved that this depends also on the location of the bone damage. The infra-millimetric lesions that were situated on the cortical bone were detected more easily compared to those on the trabecular bone (p<0.001), unlike the lesions with a diameter larger than 1 mm in case of which there were no statistically relevant differences in the levels of CBCT sensitivity (p=0.2448).

Table 4: CBCT sensitivity for trabecular and cortical bone defects assessment related to the bone defect size

	Trabecular bone defects		**Cortical bone defects**	
	Diameter<1mm	diameter>1mm	diameter<1mm	Diameter>1mm
	Value [CI95%]	Value [CI95%]	Value [CI95%]	Value [CI95%]
CBCT with FOV 6 inch (small)				
sensitivity	**0.4318** [0.3319-0.5361]	**0.9808** [0.9031-0.9962]	**0.7264** [0.6361-0.8041]	**1.0000** [0.9581-1.0000]
Rate of false negative	0.5682 [0.4639-0.6681]	0.0192 [0.0038-0.0969]	0.2736 [0.1959-0.3639]	0.0000 [0.0000-0.0419]
CBCT with FOV 9 inch (medium)				
sensitivity	**0.3647** [0.2683-0.4702]	**0.9636** [0.8811-0.9902]	**0.7524** [0.6634-0.8270]	**1.0000** [0.9581-1.0000]
Rate of false negative	0.6353 [0.5298-0.7317]	0.0364 [0.0098-0.1189]	0.2476 [0.1730-0.3366]	0.0000 [0.0000-0.0419]
CBCT with FOV 12 inch (large)				
sensitivity	**0.3958** [0.2670-0.5369]	**0.7174** [0.6195-0.8014]	**0.7048** [0.6127-0.7854]	**1.0000** [0.9479-1.0000]
Rate of false negative	0.6042 [0.4631-0.7330]	1.0000 [0.8912-1.0000]	0.2952 [0.2146-0.3873]	0.0000 [0.0000-0.0521]

Kendall's correlation coefficient showed that there was a significant correlation between the results the examiners had for trabecular and cortical bone detection using CBCT (table 4).

Table 5: Kendall's tau b Correlations for inter-examiner variability

		ex1	ex2	ex3	ex4	ex5	ex6	ex7
ex1	Correlation Coefficient	1.000	.614(*)	.953(**)	.911(**)	.657(**)	.905(**)	.706(**)
	Sig. (2-tailed)	.	1.25E-02	1.52E-04	3.46E-04	7.96E-03	4.82E-04	4.41E-03
	N	12	12	12	12	12	12	12
ex2	Correlation Coefficient	.614(*)	1.000	.638(**)	.487(*)	.342	.569(*)	.435
	Sig. (2-tailed)	1.25E-02	.	8.25E-03	4.61E-02	1.50E-01	2.20E-02	6.79E-02
	N	12	12	12	12	12	12	12
ex3	Correlation Coefficient	.953(**)	.638(**)	1.000	.849(**)	.590(*)	.862(**)	.655(**)
	Sig. (2-tailed)	1.521E-04	8.25E-03	.	6.83E-04	1.52E-02	7.05E-04	7.20E-03
	N	12	12	12	12	12	12	12
ex4	Correlation Coefficient	.911(**)	.487(*)	.849(**)	1.000	.747(**)	.815(**)	.704(**)
	Sig. (2-tailed)	3.46E-04	4.61E-02	6.83E-04	.	2.41E-03	1.55E-03	4.30E-03
	N	12	12	12	12	12	12	12
ex5	Correlation Coefficient	.657(**)	.342	.590(*)	.747(**)	1.000	.614(*)	.842(**)

		ex1	ex2	ex3	ex4	ex5	ex6	ex7
	Sig. (2-tailed)	7.96E-03	1.50E-01	1.52E-02	2.41E-03	.	1.42E-02	4.43E-04
	N	12	12	12	12	12	12	12
ex6	Correlation Coefficient	.905(**)	.569(*)	.862(**)	.815(**)	.614(*)	1.000	.645(*)
	Sig. (2-tailed)	4.821E-04	2.20E-02	7.05E-04	1.55E-03	1.42E-02	.	1.02E-02
	N	12	12	12	12	12	12	12
ex7	Correlation Coefficient	.706(**)	.435	.655(**)	.704(**)	.842(**)	.645(*)	1.000
	Sig. (2-tailed)	4.40E-03	6.79E-02	7.20E-03	4.30E-03	4.4235E-04	1.02E-02	.
	N	12	12	12	12	12	12	12

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Descriptive statistics of the measurements for trabecular and cortical bone defects with CBCT compared with stereomicroscopy as a gold standard is represented in table 5. The mean error and standard deviation, minimum and maximum deviation in millimetre are given for different field scans. Over- and underestimation greater than 0.5 mm was reported as a percentage of the total number of holes.

The linear measurement assessment demonstrated that MSCT tended to overestimate the size of the hole on the trabecular bone, while CBCT tended to underestimate the size compared to stereomicroscopy measurements.

Underestimation of bone lesion dimension was found in 87.5% of the total number of holes on CBCT but that was no greater than 0.5mm.

No statistically significant mean error difference for different CBCT volume scans was found, for trabecular nor cortical bone defects (p value = 0.0798 - 0.7421 respective p value = 0.800- 0.6992).

Comparative analysis of CBCT and MSCT measurements using t-test showed that there was a statistically significant difference of mean errors for linear measurement of bone defects dimensions between these radiological methods (p=0.0042) (table 6). An overestimation of the size was found in 75% of total number of holes on MSCT examination and that was greater than 0.5 mm in 37.5% of total number of holes.

Table 6: Descriptive statistics of the linear measurements of trabecular and cortical bone defects for linear measurements of trabecular and cortical bone defects for CBCT and MSCT

	CBCT linear measurements for trabecular bone defects	**CBCT linear measurements for cortical bone defects**	**MSCT linear measurements for trabecular defects**
mean error ±SD (mm)	**0.208±0.12**	**0.259±0.22**	**0.436±0.22**
min error	0.04	0.017	0.11
max error	0.48	0.784	0.73
%underestimation 0.5 mm	0	16.66	0
%overestimation 0.5 mm	0	0	37.5
% overestimation	12.5	29.16	75
%underestimation	87.5	72	25
Number of holes measured (sample size)	16	25	8

Table 7: Comparative analysis of CBCT and MSCT measurements using t-test results

Group	**CBCT**	**MSCT**
Mean error	0.21	0.44
SD	0.13	0.22
SEM	0.03	0.08
N	16	8

Discussion

A great number of studies prove the accuracy of the CBCT in detecting and measuring bone lesions with a diameter bigger than 1mm (34). Patel S. et al. (35) noted a sensitivity of 100% for the detection of periapical bone defects of 2 and 4 mm diameter on the human mandible. Similar results were found in the 1st study. WP4.2. which evaluated the accuracy of CBCT for artificially induced periapical bone lesions for deciduous and permanent teeth and demonstrated that CBCT has a sensitivity of 65.3% for a 1mm ø, 82.1% for 2 mm and 93.9% for 3mm diameter periapical defect for permanent teeth.

In order to appreciate the accuracy of CBCT for alveolar bone structure quantification it is necessary to know the lowest size limit where these cortical or trabecular bone lesions are still positively detectable and it is necessary to determine the sensitivity and reliability of this radiological method for small, infra-millimetre bone defects. Yet there are few studies that we are aware of to determine the accuracy of CBCT in detecting and measuring the small, infra-millimetre size bone lesions.

The results of our study show that bone lesions with a diameter smaller than or equal to 1mm were only visible with the help of CBCT, while MSCT could only detect lesions with at least a 1.2mm diameter. Nevertheless, the sensitivity of CBCT for infra-millimetre bone defects was quite low compared to the sensitivity seen in case of lesions with a diameter bigger than 1mm ($p<0.001$).

These results prove that CBCT is absolutely superior to MSCT in detecting small changes of the bone structure, and the lowest limit of lesion size where this method is still trustworthy is 0.5mm in cortical bone and 0.8mm in trabecular bone. These results are conclusive in selecting the proper technique of radiology in order to quantify the bone macro-structure and inframillimetre-structure (e.g. CBCT, medical CT, HRCT or µCT), in best accordance with the spatial resolution of these equipments and the size of the bone changes which need to be interpreted.

The sensitivity of CBCT was significantly higher in identifying bone lesions of the cortical bone of the mandible compared to the ones of the trabecular bone ($p<0.001$). This fact proved that any interruption of the cortical bone continuity is better detected when using CBCT. The study performed by Loubele M. backs up these results showing that the subjective image quality of the CBCT was significantly better than for the MSCT with regard to visualization and delineation of the lamina dura. Gupta R. et al. (36) 2004 showed though that flat-panel CBCT machine is superior to MSCT in defining the fine bone structure of temporal bone.

The assessment of inter-examiner variability of CBCT images interpretation showed a significant level of correlation in detecting the artificially induces bone defects.

There is a great variability of CBCT systems with different technical characteristics. Two essential parameters make the differences between these CBCT machines: the voxel dimension and the quality of detectors. The accuracy of this method applied in quantifying the bone structure, as well as the accuracy of the measurements could also be influenced by the field of view or by different types of CBCT machines and detectors (CCD or FP). Katsumata A. (37) has demonstrated that there is a variability of the sizing up of the bone density depending on the field of view used for CBCT examinations. Smaller CBCT volumes get a better image resolution but highest density variability in contrast with larger-volume CBCT scans.

In the present study, we evaluated the influence of the field of view on sensitivity of CBCT for small bone defects identification. Results proved that there are no statistically relevant differences between the CBCT sensitivities using different field of view (FOV small vs. FOV medium: $p=0.4282$; FOV small vs. large: $p= 0.4787$; FOV medium vs. large: $p= 0.8313$).

These results match the ones found by Liedke GS et al. (38). The authors assessed *in vitro* the diagnostic ability of CBCT scans in the detection of simulated external root resorption and the authors observed that the variation of voxel resolution did not change the sensitivity and specificity values but the better likelihood ratio value was obtain with 0.3mm voxel.

Although there were no significantly different sensitivity levels using various FOV, it is necessary to conduct yet another study to compare the sensitivity of different

CBCT systems, with different type of detectors (CCD and Flat panel) and acquisition volume scan.

The accuracy of the linear measurements done with different CBCT systems was largely debated in literature. The linear measurements of the alveolar bone, performed for implant placement (39) but also the ones done on 3D CBCT with orthodontic (40, 41) purposes were matched with the gold standard measurements.

In literature we found very few studies to determine the accuracy of CBCT in case of small dimension bone lesions, with diameter less than 1.5mm. Loubele M. (42), assessed the accuracy of CBCT (Accuitomo 3D, Morita, Kyoto) and MSCT (4-slice and 16- slice Somatom, Siemens, Germany) and authors concluded that both CBCT and MSCT yield sub-millimetre accuracy for linear measurements on *ex vivo* human maxilla (accuracy was 0.35+/-1.31mm for MSCT and -0,09+/-1,64 mm for Accuitomo CBCT machine).

Our study demonstrated that there was a statistically significant difference of mean errors for linear measurement of bone defects dimensions between CBCT and MSCT (p=0.0042) although both computer tomography methods had a sub-millimetre accuracy. The accuracy of CBCT was -0,208 +/-0.12 mm for trabecular bone defects, -0,259+/-0.22 mm for cortical bone while the accuracy of MSCT was 0,436+/-0.22 mm.

The CBCT tended to underestimate the bone lesion dimension (in 87.5% of total number of holes) but that was no greater than 0.5mm. Compared with CBCT, the MSCT made an overestimation of the size lesion (in 75% of total number of holes) and that was greater than 0.5 mm in 37.5% of total number of holes.

The same differences between CBCT and MSCT for linear measurements were found by different authors (43, 44). In all cases the mean error was less than 1 mm. In contrast with CBCT, conventional radiology proved to have less accuracy for linear measurements especially when small bone defects were assessed. Mengel R (45) evaluated in a comparative study the accuracy of different radiology techniques in the measurement of various periodontal defects that had been artificially produced and obtained an error level of 0.19 mm in case of CBCT and of 0.10 mm in case of CT whereas the panoramic radiology had an error level of 1.7mm and the intra-oral radiography one of 0.33mm.

Conclusions

The conclusion of this study was that the volumetric tomography is a useful method for diagnosis of periapical lesions in permanent teeth. CBCT diagnostic accuracy for periapical lesions was less for deciduous teeth compared with permanent teeth.

Sensitivity was greater on CBCT examinations with a small FOV compared with medium or large FOV.

The assessment of CBCT accuracy related to the bone defect dimension showed a significant statistical difference between the sensitivity for identification of the lesions with 3mm diameter compared to 1mm diameter on permanent teeth.

CBCT could detect smaller bone defects than MSCT.

Remarks

Comparative analysis of different CBCT machines (NewTom3G, Gallileos, Scanora and Accuitomo) is in progress in Cluj and Leuven to complete the study of bone lesion identification and quantification in an animal model (estimated date of delivery – end of June 2009).

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