ORIGINAL RESEARCH

Digital Orthopantomography vs Cone Beam Computed Tomography—Part 1: Detection of Periapical Lesions

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Abstract

Aim: Digital orthopantomography (OPT) is usually the first examination step in supervising an incoming patient. Cone beam computed tomography (CBCT) is the most refined and affordable method to search for different dental lesions. The aim of this paper is to evaluate the effectiveness of OPT and CBCT in detecting periapical lesions in different dental groups.

Materials and methods: An OPT and a CBCT scan of the dental arches of 45 patients were examined. The presence of AP was pointed out for OPT and CBCT. Sensitivity, specificity, predictive values, and accuracy were calculated for OPT, using CBCT as the reference standard.

Results: OPT showed low sensitivity (40.0), positive predictive value (90.4), negative predictive value (90.0), accuracy (90.0), and high specificity (99.2). It was found to have higher sensitivity in the lower front and premolar areas, while the lowest was found in the upper molar area.

Conclusions: OPT can be used for endodontic diagnosis in the lower central and premolar sections, but CBCT plays a decisive role in the evaluation of molar areas and in the endodontic treatment planning, when a close relationship between apex and important anatomical structures exists.

Clinical significance: CBCT exposes the patient to higher doses of radiations when compared with OPT, but CBCT, with its more selective sensitivity and the possibility to offer a three-dimensional (3D) rendering of dental and periodontal structures, is an elective choice for uncertain cases and for specific dental areas.

Keywords: CBCT, Cohort study, Digital orthopantomography, Periapical lesions, Radiographic assessment.

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Introduction

Cone beam computed tomography (CBCT) was introduced a decade ago to create three-dimensional (3D) images of dentition, surrounding soft and hard tissues.[1]

It can be a powerful method in endodontics, by-passing the disturbances created by surrounding tissues and offering the opportunity to see in detail current pathologies affecting the apexes and improvement after treatments. CBCT demonstrates high reliability for endodontic studies and a technical evolution and refinement, the micro-CT, is used as a complimentary diagnostic tool for many endodontic researches in animal experiment or laboratory investigations.[2–7]

The outcome of previous root canal treatment is a measurement of success of a treatment within an established time frame and, at the same time, the knowledge of 3D anatomy and conditions of a root canal system allows clinicians to explain to patients about possible treatment alternatives.

Furthermore, also in the case of previous root canal therapy, CBCT can confirm the presence and extension of an apical lesion. It could be useful in predicting a prognosis and compare it with alternative treatments such as implant-supported crown, denture, or tooth replacement with a bridge. The patient may, therefore, be aware of his unique endodontic problem and able to take a more informed decision about his treatment plan.[8]

The outcome in endodontics should be assessed by clinical and radiographic follow-up as both steps were considered necessary as chronic apical periodontitis may even exist without clear clinical signs and symptoms.[5]

Clinical studies comparing the presence of periapical lesions in root-filled teeth with CBCT and periapical radiographs all show that CBCT identifies at least 20% of more lesions than periapical radiographs.[9–12]

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As periapical radiographs fail to detect an important number of untreated lesions, their effectiveness in assessing the outcome of root canal therapies is questionable. Nevertheless, CBCT is currently not recommended for routine assessment of the outcome of root canal treatment, but its use is justified in research to provide a more objective indication of the outcome.[1]

We must consider that CBCT imaging of the endodontic spaces should not only offer 3D assessment of the region of interest but also create images with an adequate spatial resolution to allow detailed assessment of the tooth and the surrounding alveolar anatomy. As periapical radiographs often fail to detect many apical pathologies, their effectiveness in assessing the outcome of root canal treatments is questionable.

Furthermore, today one of the most frequent radiographic assessments to routinely identify tooth decays or apical hidden (asymptomatic) lesions is orthopantomography (OPT).

If CBCT is currently not suggested as routine assessment to evaluate the outcome of root canal treatment,[1] its use, on the contrary, could be surely be justified as a second-level examination to provide a more objective and sound information.

This is especially relevant when children, who are more susceptible to the potential effects of ionizing radiation, are under examination.[13] When a radiographic procedure is prescribed, it should be carried out with a dose as low as reasonably achievable (ALARA), as patient exposure to ionizing radiation such as X-rays must never be considered as routine.[14,15] Nevertheless, to ensure patient safety as an effective way to reduce the patient dose, personnel who use a CBCT scanner must have appropriate training and knowledge of patient's radiation doses related to the specific CBCT scanner they are using. Field of view (FOV) in endodontic practice should be limited to the region of interest that is the FOV encompassing the teeth under investigation and their surrounding structures.

Root canal treatment and retreatment studies show variable success rates of 28–97.7%.[16,17]

Many studies have limitations like low recall rates or the employment of inexperienced operators.[18–20] All these studies assessed the radiographic outcome using periapical radiographs as the current accepted reference standard for the detection of apical pathosis is the periapical radiograph.[1] However, a single radiograph is limited in its diagnostic ability essentially by the fact that is two dimensional (2D).[21,22] Other factors influencing the effective dose are scanners themselves, the region of the jaw being scanned, exposure settings of the CBCT scanner, exposure time (s), the size of the FOV, and the energy/potential (kV).[23,24]

The effective dose is also dependent on the region of the oral cavity being scanned.[25–27]

The aim of this research is to perform a retrospective standardized study to compare the effectiveness of digital OPT and CBCT in evaluating the presence of periapical lesions in an ample tooth sample (1,060 teeth).

Materials and Methods

Forty-five patients, 20 males and 25 females, aged in between 19 and 54 years were randomly selected from our archives between January 2013 and January 2018. Every selected patient had previously received two radiographic examinations (a digital OPT and a CBCT scan of the dental arches) for clinical reasons not related with our study. The maximum time interval that was accepted between the two examinations was 2 months. Patients wearing an orthodontic appliance, teeth with an immature apex, impacted teeth, and residual roots were excluded from the sample.

From a theoretical pool of 1,440 teeth (from the 45 patients examined), only 1,060 teeth were present, while the other 380 teeth had previously been extracted or lost.

Panoramic radiographs and CBCT scans were acquired with a Sirona Orthophos XG 3D hybrid imaging device (Sirona Dental), with an 8 × 8-cm FOV, at the operating conditions of 85 kV and 7 mA. The high definition mode used for these radiographs provided for a 360° rotation of the X-ray source and a scan time of 14.4 seconds with a continuous exposure. This allowed to acquire 500 individual images and to reduce the resolution from 160 to 100 µm, thus obtaining detailed, high-resolution volumes for the evaluation of the most minute structures. The X-ray dose for the 8 × 8 cm FOV was 136–191 µSv. A periapical lesion was defined as a radiolucent area, which was at least twice the width of the periodontal ligament space, in connection with the dental apex.

Risk factors that can cause apical bone lesions have also been analyzed.

The prosthetic rehabilitation of the tooth has been analyzed in terms of the presence of posts and/or prosthetic crowns; the crowns have been classified into single crowns and bridges. The presence of caries, fillings, and endodontic treatment was noted. The quality of the canal treatment was evaluated by CBCT: in addition to identifying the presence of any untreated canals, the distance between the apical end of the root canal filling and the radiological apex was measured for each canal, and if this distance was more than 2 mm, the filling was considered inadequate. Finally, the presence of the Schneiderian membrane and the presence of the inferior alveolar canal at less than 2 mm from the dental apices were annotated.

Results of the radiographic evaluation have been reported in frequency tables for the presence of apical lesions.

The indexes of sensitivity, specificity, predictive values, and accuracy of the panoramic radiograph were calculated, considering the CBCT scans as a reference standard.

Results

The prevalence of periapical lesions was found to be 15.6%, as 165 periapical lesions were identified in a total of 1,060 teeth included in the study.

When a periapical lesion was present, verified by CBCT, OPT gave a positive result only in 40.0% of cases. Table 1 summarizes the results of radiographic evaluation for the presence of apical lesions identified by OPT considering both teeth in general and each group of teeth individually (anterior teeth, premolars, and molars).

The percentage of lesions identified by OPT was also calculated for each of the maxillary posterior teeth (premolars and molars), since we wanted to refine and specify the assessment in these areas, which were the ones with the lowest sensitivity values (Table 2).

The anatomical relationships between apices and the maxillary sinus or the mandibular nerve have been studied. These relationships can influence the visibility of the periapical lesion, when present, or simulate its presence, if the lesion is absent (Figs 1 and 2). In fact, 49 periapical lesions (84.5%) in the maxillary arch

Table 1: Periapical lesions revealed in different tooth positions by OPT and CBCT

	All	*Maxillary arch*	*Anterior teeth*	*Premolars*	*Molars*	*Mandibular arch*	*Anterior teeth*	*Premolars*	*Molars*
OPT	66	24	8	10	6	42	7	13	22
CBCT	165	92	15	37	40	73	11	18	44
Percentage	40%	26%	53%	27%	15%	58%	64%	72%	50%

Table 2: Apical lesions detected by OPT and CBCT scans, divided by tooth type in the upper premolar and molar areas

	First upper premolar	*Second upper premolar*	*First upper molar*	*Second upper molar*	*Third upper molar*
OPT	3	7	4	2	0
CBCT	18	19	22	16	2
Percentage	16.7%	36.8%	18.2%	12.5%	–

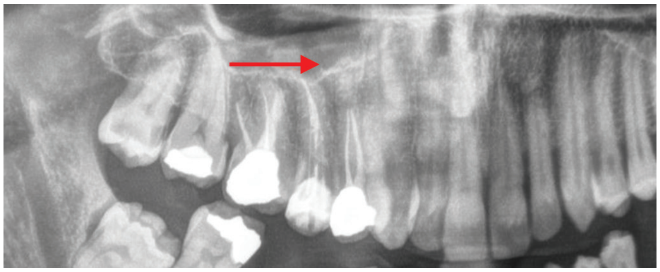


Fig. 1: Example of periapical lesion (first upper right premolar) that was invisible on the OPT because of the superimposition of the maxillary sinus

were invisible on the OPT and, similarly, 7 periapical lesions (64.6%) were not identified in the mandibular arch (Table 3).

Results of true positives, false positives, false negatives, and true positives are reported in Table 4. They were used to calculate sensitivity (40.0%), specificity (99.2%), positive predictive value (90.4%), negative predictive value (90.0%), and diagnostic accuracy of the OPT (90.0%) (Table 5).

Table 3: Number of periapical lesions in close relationship with anatomical structures (maxillary sinus and inferior alveolar nerve) detected by CBCT and simultaneously invisible on OPT. In the last row the percentage of these periapical lesions was reported on the total of periapical lesions close to the same anatomical structures

	Maxillary sinus	*Inferior alveolar nerve*
CBCT	49	7
Total	58	11
Percentage	84.5%	63.6%

Table 4: True positives, false positives, false negatives and true negatives and totals of OPT exams, using CBCT as the gold standard

	Presence of apical lesion	*Absence of apical lesion*	*Total*
Positives	66	7	73
Negatives	99	888	987
Total	165	895	1,060

Table 5: Summary table of sensitivity, specificity, positive and negative predictive values and diagnostic accuracy of the panoramic radiograph

Sensitivity	*Specifity*	*Ppv*	*Npv*	*Accuracy*
40.0%	99.2%	90.4%	90.0%	90.0%

Discussion

Choice of Radiographic Examinations

In addition to the countless studies in literature that compare CBCT to periapical intraoral radiography, only Estrela et al.,[10] and, recently, in 2017, Nardi et al.,[28] considered OPT for their studies. Even though intraoral radiography is superior in sensitivity and it is, therefore, the most suitable radiographic device for endodontic diagnosis, OPT represents the first and fundamental diagnostic tool for the initial examination of the patient and it is, therefore, essential to provide as much information as possible. The quality improvement of the panoramic radiographs obtained with the most recent devices could also reduce the need to use second level radiographic investigations to confirm the diagnostic hypothesis. For all these reasons, OPT, not periapical radiography, was compared with CBCT.

Use of CBCT as the Gold Standard

Authors of previous *in vivo* human studies pointed out that the possibility of obtaining false positives and false negatives in CBCT images cannot theoretically be eliminated, leading to an inevitable error, if CBCT is used as the gold standard.[21,26,27]

However, if we take into consideration the results of these studies, it is possible to deduce that CBCT provided few false negatives or do not generate false negatives at all.

Since the false positives and false negatives of CBCT are absent or rare in clinical studies,[21,26,27] the use of the cone beam CT as a gold standard is actually possible without incurring statistically significant errors.

Recently, Nardi et al.,[28] also used CBCT as the gold standard for their study. They argued that histological analysis is a practice difficult to introduce in clinical everyday life and that, at present, cone beam images represent the most accurate tool for the identification of bone lesions due to apical periodontitis.[28]

Validity of the Diagnostic Test

OPT showed higher sensitivity (40.0%), negative predictive value (90.0%), and diagnostic accuracy (90.0%) for the diagnosis of periapical lesions compared to previous similar studies; it also showed similar specificity (99.2%) and positive predictive value (90.4%).

In contrast, previous studies[10,28] found a lower sensitivity, negative predictive value and accuracy, and similar specificity and positive predictive value.

The discrepancy that has been observed between the data we obtained and those from previous studies can be explained by the high prevalence of periapical lesions in their samples.

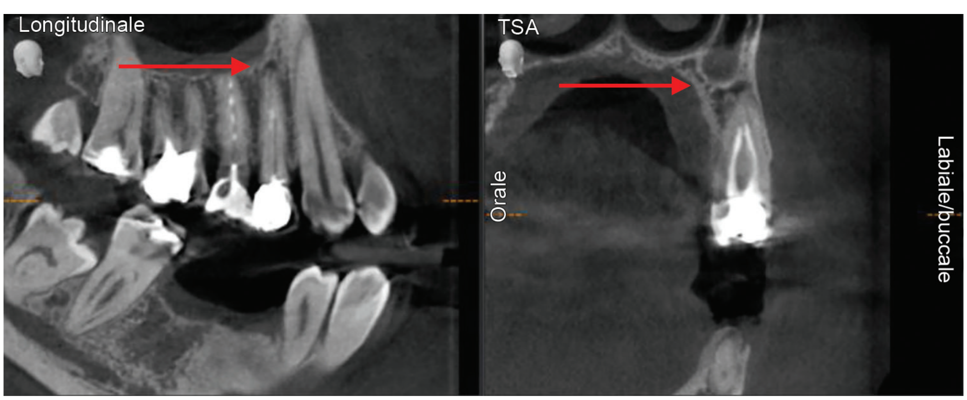


Fig. 2: On the contrary, it was possible to identify the same periapical lesion by evaluating the CBCT scan. Please note the overlap between the periapical lesion and the maxillary sinus in the cross section of the CBCT scan

Identification of Apical Lesions

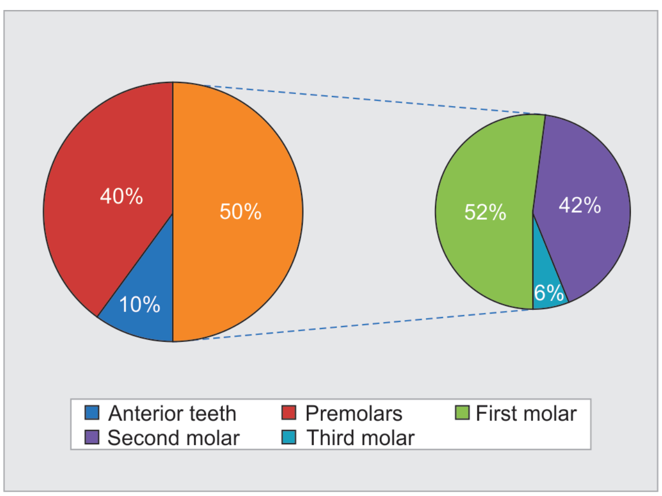
Periapical lesions that are most likely identified by OPT are those located in the mandibular premolar area, while lesions in the maxillary molars and premolars are the most difficult to detect.

In fact, the upper arch presents greater interpretative difficulties than the lower arch for different reasons. Overall, the maxillary arch is more frequently subject to superimposition of extraoral radiopaque structures—such as the zygomatic arch and nasal bones—and anatomical cavities containing air—such as the maxillary sinus and the nasal cavities—which reduce the visibility of the area of interest. Furthermore, the frequent root curvatures and the root convergence or divergence lead the apices to be rarely orthogonal to the incident beam.[28]

The greatest contribution to the reduced sensitivity of OPT in the maxillary arch is given by molars. These data are not in agreement with the studies by Estrela et al.,[10] and by Nardi et al.,[28] according to which the greatest diagnostic difficulty is found in the two incisive groups. In the maxillary molar area, only 15% of periapical lesions were detected by evaluating the OPT. In fact, a thicker cortex and the superimposition of structures complicate the interpretation of the images and often prevent the identification of the radiolucencies. Structures that are superimposed to the molar apices with high frequency rarely reach the premolar area and this explains the relative improvement of sensitivity observed in the premolar area (27%).

In the posterior area of the maxilla, the periapical lesions were also analyzed for individual teeth. It was observed that OPT was able to detect only 16.7% of the lesions of the first premolar, 36.8% of the second premolar, 18.2% of the first molar, and 12.5% of the second molar. The upper third molar, with a sample of only two lesions, was not associated with a statistically reliable value. This fluctuation in the values in the posterior maxillary region may be due to the shape of the parabola made by the X-ray tube and to the direction of incidence of the beam, as well as to the variable thickness of the maxillary bone.

Half of the invisible lesions of the maxillary arch was located in the molar area and more than half of these are in correspondence with the first molar, which is the most likely to be in proximity of the maxillary sinus, followed a short distance from the second molar, which coherently collects more than 40% of the invisible lesions of the molar area. The remainder of the non-identifiable apical lesions (6%) is distributed on the third molar roots (Graph 1).



Graph 1: Percentage distribution of invisible periapical lesions in the maxillary arch

The present study confirmed that lesions in which the distance from the sinus membrane was less than 1 mm have a greater probability of not being identified with respect to the distant apex.[29] In fact, 84.5% of the lesions that occurred near to the maxillary sinus were invisible on the OPT.

Furthermore, two roots with a proximal or superimposed apex to the maxillary sinus had radiolucencies that could be identified exclusively on the 2D radiographs. In fact, proximity of the sinus air cavity can generate a radiolucent area at the apex, which can mimic the presence of an apical lesion of endodontic origin: this happens because the reduced density of the maxillary sinus induces a minimum attenuation of the X-ray beam.[30] According to Abella et al.,[31] this phenomenon seems to occur mainly at the level of the upper second molar roots particularly close to the maxillary sinus, while in our survey, both roots erroneously identified as affected were the maxillary second premolars' ones.

The incisal areas are generally characterized by reduced visibility on OPT: air cavities, the nasal spine, the mental fossa and the vertebral column, overlapping the anterior teeth, hesitate in irregular and widespread radiotransparent or radiolucent areas without pathological significance. The 65% of false positives were located at the level of the incisors or canines. This agrees with previous studies, according to which the mental fossa and the nasal cavities may simulate the presence of radiolucent areas at the apices, which can be confused for bone lesions due to apical periodontitis.[28]

Nonetheless, the results of the present study showed overall discrete levels of sensitivity in the frontal areas, both in the upper (50%) and lower (57%) arches. These data contrast with those from previous studies[10,28] which observed a limited probability of correct incisal diagnosis (15%). An important factor for the OPT quality obtained with Orthophos XG 3D is the constant radiation produced by the high-frequency generator with an automatic simultaneous adjustment to the density oscillations of the object in the area of the vertebral column. In this area, the kilovoltage is increased so far that the anterior teeth are not obscured by the vertebral column.

The lower molar and premolar apical lesions were more easily identified than the superior ones, despite the greater thickness of the posterior mandibular cortex. In fact, mandibular roots are more frequently straight than the upper ones and, in the multi-rooted teeth, are arranged in a mesiodistal direction. Therefore, the apex generally does not superimpose the root itself or the adjacent roots. The mandible is, moreover, free from interference with other anatomical structures, although the projection of the mental foramen and of the main branches of the lower alveolar nerve can be found in the premolar area, but they are normally easily distinguishable from small apical lesions of endodontic origin. This resulted in a good level of agreement between OPT and CBCT (72%).

Moving backwards along the lower jaw, in the mandibular molar area, the sensitivity of OPT reduced again. The presence of the submandibular fossa reduced the image quality and the probability that the second and third molar apices are in proximity of the mandibular canal is high (15 and 31%, respectively).[32] These reasons explain the discrepancy between the lower premolar and the molar area, that is not supported by previous studies, which show corresponding sensitivity values between premolars and molars[28] or even higher values in the molar area.[10]

Conclusions

OPT appeared useful for the diagnosis of apical lesions in specific dental sectors, thus, it can be used with advantages for endodontic evaluation in the lower central and premolar areas, where it has a sensitivity of 64 and 72%, respectively.

CBCT, with its superior diagnostic accuracy in all dental areas, can play a fundamental role in the diagnosis of periapical lesions of the maxillary arch, especially in the molar area, where the minimum sensitivity was observed for OPT (15%) and in the lower molar area, where sensitivity is not high (50%). CBCT plays an important role in the endodontic treatment planning, surgical and nonsurgical, of the first and second maxillary molars, which, in 50% and 45% of cases, are in a very close relationship with the maxillary sinus, and of the second and third mandibular molars, which, in 15% and 30% of cases, are in close contact with the mandibular nerve.

Clinical Significance

CBCT exposes the patient to higher doses of radiations, when compared with OPT, but CBCT, with its more selective sensitivity and the possibility to offer a 3D rendering of dental and periodontal structures, is an elective choice for uncertain cases. This is true for specific dental areas like the maxillary molar area or any tooth in relation with the maxillary sinus or the mandibular nerve.

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