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Diagnostic value of computed tomography in re-treatment of root fillings in maxillary molars

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Abstract

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Aim To compare the diagnostic information and radiation dose between intraoral radiography and computed tomography (CT) in re-treatment decision making concerning root fillings in maxillary molars.

Methodology Thirty-nine root-filled maxillary molars with suspected apical periodontitis were examined with two intraoral periapical radiographs and CT. Presence of periapical lesion/s per tooth and root were analysed for both techniques. In addition, in the CT images, the number of root canals, erosion, or perforation of cortical bone plates, and the distance between palatal root and cortical bone plates were evaluated. Radiation dose for CT was registered and calculated; and that of periapical radiographs used as reported previously (Ekestubbe *et al.* 2004).

Results Periapical radiographs revealed periapical lesions in 33 teeth compared with 38 on CT images. A lesion of any root was detected more often with CT. The mesiobuccal root had two root canals in 30 teeth of which 27 of the MB2 canals were not filled, and 22 roots with an unfilled canal were associated a periapical lesion. Distances to palatal root, from the buccal and palatal cortex were measured in CT and varied between 5.0–12.0 mm and 0–4.0 mm, respectively. Based on the radiographic information, a variety of treatment alternatives were suggested. Mean effective dose of periapical radiographs was 0.02 mSv and that of CT 0.055 mSv.

Conclusions Computed tomography may give important information in re-treatment decision when considering root fillings in maxillary molars. The radiation dose should be considered individually.

Keywords: computed tomography, endodontically treated, maxillary molars, periapical radiography.

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Introduction

Root-filled teeth are frequently associated with periapical inflammatory lesions (Eriksen *et al.* 2002). When root-filled teeth are associated with post-treatment disease, several factors may influence the decision whether to retreat or not (Kvist 2001, Friedman 2002). If re-treatment is considered, the clinician can choose between a surgical or nonsurgical approach. The introduction of the surgical microscope and micro-instruments has made surgical re-treatment a standard option to nonsurgical re-treatment of maxillary molars. However, periapical surgery of the palatal root of maxillary molars is usually considered difficult (Rigolone *et al.* 2003). Consequently, a key factor in the decision process is whether the palatal root has a periapical lesion or not. If there is a lesion, detailed data are required of its extent, and of the anatomy of the root system and the alveolar process. Such information is not only crucial for the decision whether to treat or not. Should apical surgery be considered the treatment of choice, the information has an influence on whether to choose a buccal or a palatal access, or a combination

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thereof. The information may also result in a decision in favour of other surgical treatment options, such as tooth hemi-sectioning or extraction, or of a nonsurgical management.

Periapical radiography is routinely used for diagnosis, treatment and monitoring of the healing process of periapical lesions. With this technique, three-dimensional anatomic structures become compressed into a two-dimensional image, resulting in superimpositioning of anatomic structures onto the features of diagnostic interest, sometimes to the extent that the latter become concealed. It is well known that under certain conditions periapical lesions may not be seen in intraoral radiographs (Bender & Selzer 1961a,b, Schwartz & Foster 1971). In addition, the actual extent of lesions and their relation to other structures in the direction of the X ray beam is not shown. These limitations become particularly evident in the maxillary molar region with its complex anatomy. It is possible to overcome some of these limitations by using at least two radiographs obtained from different, usually horizontal, directions (Brynolf 1970).

In dentistry, computed tomography (CT) is widely used in preoperative implant treatment planning. It is also used for examinations of temporo-mandibular joint, large jawbone cysts and tumours as well as facial trauma. Overall, the use of CT has increased dramatically over the past two decades.

Computed tomography provides three-dimensional visualization of pathological lesions and their spatial relation to the important anatomical structures, such as the maxillary sinus and the mandibular canal (Velvart *et al.* 2001, Rigolone *et al.* 2003). Data from a single examination consisting of multiple, contiguous scans can be reconstructed and viewed as images also in the coronal and sagittal planes, depending on the diagnostic task. The high radiation dose and relative lack of availability of CT compared with other radiographic methods have limited its use for dental applications. Exposure parameters, however, can be adjusted depending on the diagnostic task resulting in lower radiation doses (Ekestubbe 1999).

It can be hypothesized that CT imaging may produce important information for the re-treatment of root-filled maxillary molars with periapical lesions. The purpose of this study was to compare information available from intraoral periapical radiographs with that of axial CT scanning in the diagnosis and treatment planning of root-filled maxillary first and second molars with signs of periapical inflammatory lesions. In addition, the radiation dose was compared between the two techniques.

Material and methods

Patients

The study protocol was approved by the ethics committee at the Sahlgrenska Academy, Göteborg University, Göteborg, Sweden. All subjects gave consent to participate.

Patients referred to the University Clinic of Endodontology, Public Dental Health Service, Göteborg, Sweden with a preliminary diagnosis of apical periodontitis in conjunction with a root-filled maxillary molar were consecutively included in the study. After a preliminary clinical examination by an endodontist and informed consent to participate, the patients were examined at the University Clinic of Oral and Maxillofacial Radiology. A total of 34 patients (19 females and 15 males) with a mean age of 51 years (range: 19–84 years) were included in the study. In five patients, two teeth at the same side of the jaw were analyzed. Hence, 39 maxillary molars (31 first and 8 second molars) were studied.

Radiographic examination

Two intraoral periapical radiographs were taken with a 10° horizontal angle difference using a paralleling technique. Exposures (0.5–1.0 s) were made with a dental X-ray unit (Oralix DC, Gendex Corporation, Milwaukee, WI, USA) operating at 65 kV and 7.5 mA. The films, Kodak Insight film (Eastman Kodak, Rochester, NY, USA), were processed according to the instructions of the manufacturer. Because of difficulties in tolerating intraorally placed films, one patient was examined with dental scanograms (Scanora®, Soredex, Helsinki, Finland). Thereafter, axial CT scans (12–24 of width 1.25 mm) were taken from the marginal bone crest up to the hard palate using a 4-channel multislice LightSpeed QX/i CT (GE Medical System, Milwaukee, WI, USA) operating at 120 kV, 50 mA and an exposure time of 1.0 s per rotation. In case of thick metallic posts, some scans were placed further apically to decrease the influence of metallic artefacts. The reconstruction algorithm used was 'Bone' (edge enhancement).

For each patient, the mean value of the radiation dose in the scanned volume, $CTDI_{vol}$ (Computed Tomography Dose Index in examined volume) was recorded together with the Dose Length Product (DLP), which is a measure of the total radiation used. Both of these factors can be read on CT monitor immediately after each examination. The unit for $CTDI_{vol}$ is mGy and for DLP it is mGy cm^{-1}. The effective dose (E) was determined using the relationship $E = DLP{\cdot}E_{DLP}$. The E_{DLP} (mSv mGy^{-1} cm^{-1}) depends on the examined part of the body. For the skull a factor $E_{DLP} = 0.0023$ mSv mGy^{-1} cm^{-1} as recommended in 'The European Guidelines on Quality Criteria for Computed Tomography' (European Commission 1998) was used. The weighted factor for skull was considered to be the most suitable amongst factors for the whole body. In this factor, salivary glands are not included.

Analysis of radiographs

Two specialists in oral and maxillofacial radiology analyzed all the images. Periapical radiographs and axial CT scans were analyzed separately. In case of disagreement, the case was discussed until consensus was reached. The periapical radiographs were mounted in transparent frames, placed on a light box and analyzed with the aid of a viewer providing a 2× magnification. CT scans were interpreted on an IDS5 workstation (Sectra, Linköping, Sweden) using two RadiForce G21 monocrome LCD monitors (Eizo Nanao Corp., Ishikwa, Japan). The resolution of the monitors was 1600 × 1200 pixels.

For both techniques, the following parameters were analyzed: presence of periapical lesion/s per tooth and root, apical-marginal communication (widened periodontal ligament space from marginal bone crest up to apex or periapical lesion) classified into three groups: not present, probably present and definitively present, lesion location relative to apex and maxillary sinus (Table 1).

Table 1 Parameters scored on radiographs

	Periapicals	Computed tomography (CT)
Presence of periapical lesion	X	X
Location of sinus in relation to apex	X	X
Apical-marginal communication	X	X
Number of root canals		X
Distance between:		
Palatal root and buccal cortex (BC)		X
Palatal root and palatal cortex (PC)		X
Palatal root apex and mesiobuccal root apex		X
Palatal root apex and distobuccal root apex		X
Erosion or perforation of BC or PC		X

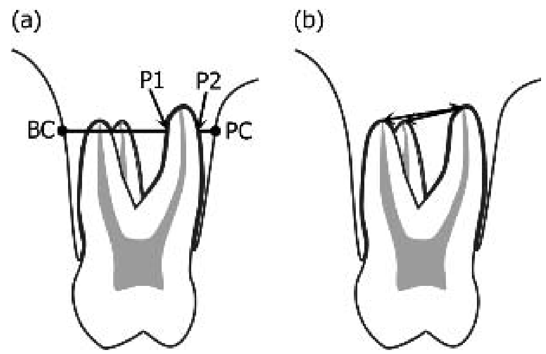

Figure 1 (a) Schematic presentation of the sites of measurements done in computed tomography (CT) images. Distances from buccal cortex (BC) to buccal side of palatal root (P1), and distance from palatal cortex (PC) to palatal side of palatal root (P2). (b) Distance between apices of buccal and palatal root. Reference points at the level of root canal.

In the CT images, additional evaluations were made: the number of root canals (unfilled and filled), erosion, or perforation of cortical bone plates and the distance between palatal root and cortical bone plates. The latter measurements were taken between a point at the root surface 2 mm below the apex of the palatal root at the root surface and one at the border of the buccal or palatal cortical bone (Fig. 1a), modified from Rigolone *et al.* (2003). Also, the distance between palatal apex at the level of the root canal and buccal apices was measured (Fig. 1b).

Clinical decisions

Having received the results of the radiographic examination, the patient was scheduled for information and complementary clinical examination. Following this procedure, a suggestion of clinical management was presented to the patient.

Results

In the intraoral radiographs, periapical lesions were found on 33 (85%) of the teeth compared with 38 (97%) in the CT images. When lesions were related to individual roots, 85 lesions were found in CT images versus 78 in periapical radiographs (Table 2).

The alveolar recess of the maxillary sinus was found between the buccal and palatal roots of 20 teeth in the periapical radiographs and of 24 in the CT images. In the periapical images, 18 lesions, and in the CT images 20 lesions, were seen to expand into the maxillary

Table 2 The number of roots (Mb = mesiobuccal, Db = distobuccal and P = palatal) with a periapical lesion present (+) or absent (−) as diagnosed on periapical radiographs and CT images

	Periapical radiographs						
CT	Mb+	Mb−	Db+	Db−	P+	P−	Σ
Mb+	25	4					29
Mb−	1	9					10
Db+			19	5			24
Db−			4	11			15
P+					27	5	32
P−					2	5	7
Σ	26	13	23	16	29	10	117

sinus. Apical-marginal communication was definitely present in four teeth and probably present in another five teeth when intraoral radiographs were evaluated. In CT, such communications were judged as definitely present in nine teeth. In four teeth, communications were seen only in CT images, in five teeth they were also identified by the intraoral technique.

The CT examination showed the fusion of the palatal and distobuccal roots in four first molars. Amongst the 39 teeth being examined, the mesiobuccal root was found to have two root canals in 30 teeth. In 27 (mb2), no traces of root filling material could be seen in the palatally situated canal. In 22 of these cases, periapical lesions were seen.

The distances between the palatal and buccal roots, and that of the palatal root and cortical bone plates are shown in Table 3. The mean value of the distance between buccal cortex (BC) and the buccal side of the palatal root was 9.6 mm (SD 2.0 mm, range: 5.0–12.0 mm), whilst the corresponding distance between the palatal side of the root and palatal cortex (PC) was, as a mean, 1.2 mm (SD 1.0, range: 0–4.0 mm). The mean distance of fused palatal and distobuccal roots from the palatal root to the PC was 3.8 mm (range: 3.0–4.0 mm). Lesions of 23 teeth were connected with erosion or perforation of the PC and/or BC as evaluated in CT images.

Table 3 Distances in millimetre from palatal root at the level of 2-mm inferior of apex to different anatomical structures using the CT images as shown in Fig. 1

	Mean	SD	Median	Range
PC	1.2	1.0	1.0	0–4.0
BC	9.6	2.0	10.0	5.0–12.0
Apex of mesiobuccal root	9.8	1.4	10.0	7.0–12.0
Apex of distobuccal root	9.0	2.5	10.0	3.0–12.0

Table 4 Clinical decisions for examined teeth

Selected management	*n*
A. No treatment	6
B. Nonsurgical retreatment	8
C. Surgical retreatment	
1. Only buccal roots	3
2. All roots – buccal entry	1
3. Palatal root only – palatal entry	6
4. Buccal and palatal roots – buccal and palatal entries	4
D. Hemisection	1
E. Combinations	
B + C 3	1
B + D	1
C 2 + D	1
F. Extraction	6
G. Surgical removal of root filling surplus	1
Total	39

The radiation dose in the scanned volume, $CTDI_{vol}$ (Computed Tomography Dose Index in examined volume) was 11.8 mGy. As the height of the scanned volume differed between patients, the DLP-value varied between 17.6 and 35.3 mGy cm^{-1} with a mean value of 23.8 mGy cm^{-1}. The mean value of the effective dose for CT was 0.055 mSv, a value that has to be compared with the effective dose of two intraoral periapical radiographs of 0.02 mSv in maxillary molar regions according to Ekestubbe *et al.* (2004).

The clinical management of the investigated cases following the radiographic examination and treatment planning is shown in Table 4, one case is shown in Fig. 2.

Discussion

In this study, the radiographic examinations were carried out on patients with a preliminary diagnosis of periapical inflammatory lesions of maxillary molars. Hence, no great difference in the presence of periapical lesions was expected for the two techniques. From a treatment point of view, an important finding was that lesions were diagnosed in 38 of the 39 teeth in CT scans but only 33 in the periapical radiographs. The same magnitude of difference was seen when comparing the number of roots involved (85 vs. 78).

It is well known that periapical radiographs do not always accurately reflect the existence of normal or pathologic tissues, and that it is possible to have periapical lesions without radiographic evidence. Bender & Selzer (1961a,b) and Schwartz & Foster (1971) have described the difficulties in detecting lesions in the trabecular bone and noted that periapical lesions are

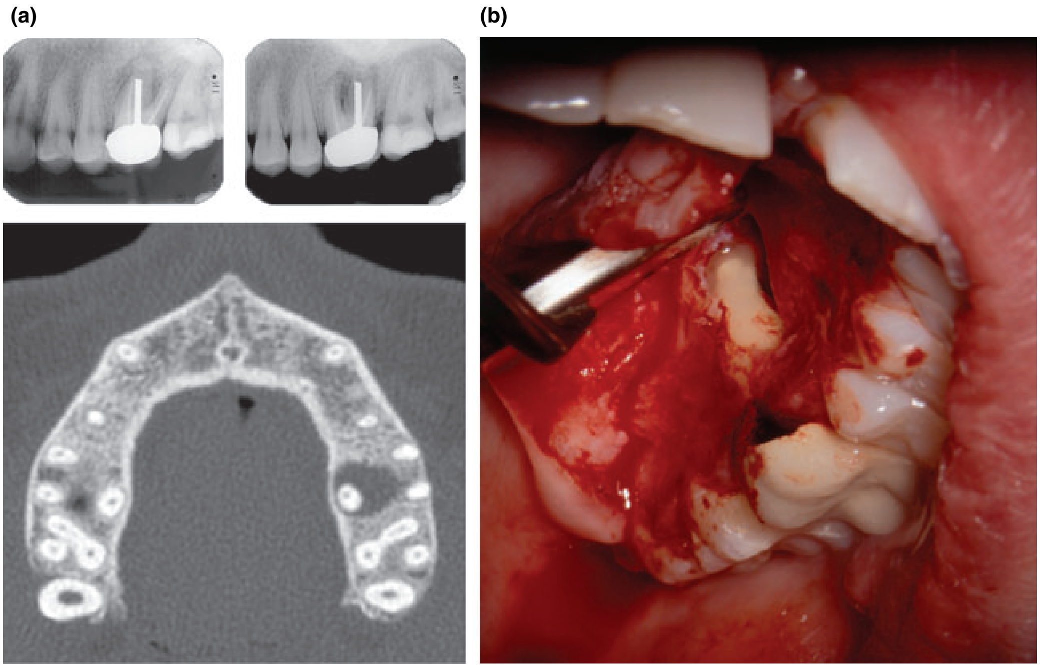

Figure 2 (a) Intraoral radiographs of first maxillary molar showed unclear extent of periapical lesion. Axial CT-scan revealed that only the palatal root was involved. (b) The pathological process was approached surgically by a palatal entry.

not often detected until the lesion has eroded the corticomedullary junction. Fortunately, most root apices are close to the cortical bone, which is then quickly affected by an inflammatory lesion. In the present study, an attempt was made to achieve the best possible prerequisite for accurate diagnoses with an intraoral technique, namely by using the so-called paralleling technique for the two radiographs obtained with different horizontal directions.

In the planning of root canal re-treatment, especially prior to apical surgery in the maxillary molar regions, knowledge of the extent of the periapical lesion should be known as well as its relation to buccal and palatal cortical bone. Further, the location of the maxillary sinus is of importance. The axial views obtained with CT provide possibilities for interpretations of bucco-palatal details of both anatomy and pathology. The maxillary sinus was found to be interposed more often in CT scans than in intraoral radiographs, 62% vs. 51%. Regardless of technique, the values recorded were larger than those found by Rigolone *et al.* (2003), who found the maxillary sinus to be located between the buccal and palatal roots of first molars in 25% using the cone beam CT. They also measured the distance between BC and the buccal side of the palatal root of the maxillary first molar and arrived at similar results as reported in the present study. They concluded that cone beam CT provides support for a buccal entry towards the palatal root of first molars and is particularly useful when selecting the direction and length of surgical instruments. The information derived from CT was found to be essential for the clinical decision making, although a variety of treatment alternatives was suggested. When surgical re-treatment involved the palatal root, a palatal entry was chosen in 11 out of 13 cases (Table 4, Fig. 2).

Failure of the intraoral technique to diagnose periapical lesions does not justify a routine use of CT examinations in endodontic therapy, but the technique can be used in situations when more information is needed for the clinical management of periapical lesions. If only intraoral radiography is available, decisions often have to be made during the surgical procedure, and this runs the risk of being unpredictable.

In the field of endodontics, few reports have dealt with the use of CT. Velvart *et al.* (2001) claimed that the relation between periapical lesions and the mandibular canal, as studied before endodontic surgery, could be reliably assessed by means of CT. Also, Cotti *et al.* (1999) found CT useful for obtaining the detailed information of the size of a lesion and its spatial relationship to anatomical landmarks. CT can even show the morphology of the root canal system provided it does not contain metallic posts (Robinson *et al.* 2002).

Drawbacks with CT include the high radiation dose, the presence of artefacts and the financial costs. The CT technique is a popular technique in dental implant planning and hence, dentists are used to refer patients to hospital radiology departments. In this matter, it is important to inform the personnel at the hospitals about the purpose of the CT examination to make it easier to reduce the radiation dose as far as possible. When metallic objects are present in the tooth of interest or an adjacent one, artefacts can make evaluations difficult. The problem can, to a certain extent, be handled by reducing the scanned volume. By reduction of the scanned volume, the radiation dose will decrease. In this study, a relatively large variation in scanned volume amongst the cases was observed, 12–24 axial scans were taken with a slice thickness of 1.25 mm. The number of scans was smaller in some cases to avoid the artefacts from metallic posts as scans were expected to have low diagnostic information from these areas. Another possibility to reduce radiation dose is to use as low exposure parameters as possible. The image quality was not significantly altered when exposure parameters were reduced from 80 to 40 mAs for mandibular implant planning purposes (Ekestubbe *et al.* 1999). The difference in mean effective dose between periapical radiographs and CT examinations, when applying a low-dose protocol, was of a factor 3, with CT yielding the highest radiation dose.

Three-dimensional information of teeth and surrounding jawbone can also be obtained with a so-called cone beam CT, a technique that has lately been developed for the dental market. Several machines are now available of which one (3D Accuitomo; J Morita MFG. Corp, Kyoto, Japan) is made to display small parts of the jawbone (a height of 30 mm and diameter of 40 mm). The technique has been found to be useful in the diagnosis of periapical lesions (Lofthag-Hansen *et al.* 2006). The effective dose has been shown to be about 0.01 mSv (Iwai *et al.* 2000), which is lower than the dose of the low-dose protocol for CT used in this study, and even lower than that of the intraoral examination. In cone beam CT artefacts from metallic objects, and to some extent even root fillings, can be disturbing (Gröndahl & Huumonen 2005). The cone beam CT technology is also used in X-ray machines that collect data from a larger volume (Ziegler *et al.* 2002), and has been shown to be useful in the planning of endodontic surgery (Rigolone *et al.* 2003). A comparable effective dose to our low-dose CT has been found (Mah *et al.* 2003).

An advantage with conventional CT is that the scanned volume also includes the opposite side of the jawbone, a fact that in some of cases made it easier to distinguish between a normal bone pattern with irregular and large trabecular spaces and a lesion.

Conclusions

In this study, the diagnostic performance of CT was compared with that of intraoral radiography for the detection of periapical lesions. The study gave support for the hypothesis that CT gives important adjunct information in re-treatment decision of root-filled maxillary molars. The costs, both monetary and in the form of radiation dose, emphasizes, however, that CT should be used in selected cases and after a thorough clinical examination and deliberation. It is clear that three-dimensional imaging, using conventional CT or other techniques, provides potentially significant clinical information.

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