Cone Beam Computed Tomography in Mandibular Molars Referred for Apical Surgery

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Summary *Introduction:* The purpose of the present study was to compare conventional intraoral periapical radiographs (PA) with limited cone beam computed tomography (CBCT) for evaluation of mandibular molars prior to apical surgery. The apical extent and homogeneity of the root canal fillings (RCF) as well as the number of root canals were examined.
Methods: 38 molars with 75 roots were included in the study. The apical extent and homogeneity of the RCFs as well as the presence of root canal posts or screws were examined on sagittal CBCT slices and on the PAs. The number of root canals was determined on sagittal CBCT slices and the PAs. The mesial and the distal roots were examined separately.
Results: Considerably more root canals were found on the CBCT slices compared to the PAs. The homogeneity and the extent of the RCFs as well as the presence of root canal posts or screws seem subjectively easier to determine on the PAs.
Conclusion: In mandibular molars, because of the better discrimination of root canal anatomy we recommend a CBCT scan prior to apical surgery.

Introduction

The most common cause of periapical inflammatory changes in the alveolar bone is an advanced carious lesion in a non-vital tooth. The therapy of choice is root canal treatment. In this way the cause of the periapical lesion can be removed to allow the affected area of bone to heal. However, if the root canal filling is insufficient or not all canal spaces have been filled, periapical pathology can persist or may even worsen (Friedman et al. 2003). In most cases, intraoral periapical radiography is the accepted method to evaluate root canal fillings in root canal treated teeth.

However, three-dimensional structures represented on a two-dimensional radiograph pose certain problems. Indeed, because of overlapping, complex root canal anatomy, diagnosis is limited or not even possible. Roots of molar teeth are often intertwined with adjacent structures such as the maxillary sinus or the mandibular canal creating superimposed images and making assessment even more difficult (Goldman et al. 1972, Gröhndahl & Huumonen 2004).

Even when clinical symptoms are present, intraoral periapical radiography will not always detect pathological changes (Lofthag-Hansen et al. 2007). In order that a periapical lesion is visible radiographically, a certain degree of bone demineralization must have occurred (Bender & Seltzer 1961). In addition to an intraoral radiograph, an eccentric projection is advised to determine the three-dimensional location of a lesion (Gröhndahl & Hummonen 2004). Using this periapical tube shift technique, images of superimposed structures within the beam path are weakened. Three-dimensional imaging solves this problem because the tissue can be represented in three planes. There are various techniques to generate three-dimensional images in dentistry:

Conventional tomography depicts a defined layer of the body; structures outside of this layer appear out of focus (Lund & Manson-Hing 1975).

Computer tomography (CT scan) represents layers in the axial, coronal or sagittal plane and can provide information about the topographical location of various structures to one another. The CT scanner works using a rotating radiation source and high tube voltages. X-rays are emitted in a fan-shaped beam to stationary detectors placed 360° around the patient. Each rotation of the tube records an axial slice of the volume being examined. The 3-D domain is axially moved and each new section recorded. The coronal and sagittal slices are computed from the axial data (Houndsfield 1973).

Arai et al. 1999 first described the application of *cone beam computed tomography* (CBCT). In contrast to computer tomography the Arai group introduced an Ortho-CT using a conical beam of radiation. The radiation source and the detector rotate around the patient. From a single 360° rotation the complete volume under investigation is recorded. The cone beam computed tomography can capture a cylindrical volume of variable size. Currently, the size of the cylinder varies between 30×40 mm and 300×300 mm.

Within these volumes, layers can be displayed in any desired orientation (Gröhndahl & Huumonen 2004, Künzel & Becker 2009). All methods of three-dimensional imaging are associated with an increased radiation exposure to the patient (Mah et al. 2003).

Recently, great efforts have been made to reduce the radiation exposure from computer tomography. Even so, computer tomography at the moment still produces radiation exposure many times higher than small volume cone beam computed tomography (CBCT) (Dula et al. 1996, Schulze 2009). CBCT results in radiation exposure which on average is 10 times less than that of conventional computer tomography (Tsiklakis et al. 2005, Okano et al. 2009). In particular when information is required to advise apical surgery, fine anatomical structures are not sufficiently well displayed to reach decisions concerning therapy. Queries concerning the number of canals, canal morphology, quality of the existing root canal filling, position of intracanal posts or any perforations as well as the location and extent of existing periapical lesions remain unanswered (Lofthag-Hansen et al. 2007, Low et al. 2008).

Apical surgery should only be carried out when the respective tooth has been root canal treated and the root canal treatment displays good quality both in length and homogeneity. Another indication for apical surgery is when secondary endodontic treatment ("re-treatment") is associated with risks or unclear prognosis for the tooth in question.

The objective of this study was to compare intraoral periapical radiography with cone beam computed tomography (CBCT) when mandibular molar teeth were assessed for apical surgery. The evaluation recorded the length and homogeneity of the root canal filling as well as the number of existing canals.

Materials and methods

Patients

Radiographs of 40 patients were consecutively enrolled in the study.

All patients were referred to the Department of Oral Surgery and Stomatology of the University of Bern to assess performing apical surgery in their mandibular molars. The examinations took place between June 2007 and February 2008. Only first or second molars which had been root canal treated were investigated. A total of 41 teeth in 40 patients (21 women, 19 men) showing clinical and/or radiographic signs of apical periodontitis were examined using both intraoral periapical radiography (PA) and cone beam computed tomography (CBCT). The average patient age was 49.5 years (range 30 to 77 years).

Tab. I Distribution of teeth, n=38

Tooth	47	46	36	37
Number	2	15	19	2

Two patients were excluded from the study because the molars in question had been previously treated with apical surgery. One patient presented with two problem molars with periapical lesions in the third and fourth quadrants. In this case one data set was chosen from the other by random allocation. The remaining 38 molars provided a total of 75 roots. Of these, one molar possessed a conical root. This was assigned to the mesial root group. In the end the study examined 38 mesial and 37 distal roots (Tab. I).

Radiographic techniques

Three-dimensional images were taken with a 3 DX Accuitomo (Morita, Tokyo, Japan). Each scan cycle lasted 17 seconds. The equipment was set at 80 kV and 5 mA. A window size of 40×40 mm was chosen. The evaluation of the images was performed on a Dell Precision 380 workstation (Dell SA, Geneva, Switzerland). The computer was equipped with a Pentium 4 processor. The images were evaluated on an Eizo FlexScan L768 monitor. The resolution was 1280×1024 pixels (Eizo Nano AG, Wädenswil, Switzerland).

The linear measurements were taken using the length-measuring function contained in the iDixel software (i-Dixel Version 1.8, Morita, Tokyo).

All intraoral periapical radiographs were made with F-speed dental film (Kodak Insight, Eastman Kodak, Rochester, NY, USA) and using the Rinn film holder (Rinn SCP, Dentsply, Elgin, IL, USA). The radiographs were taken with a dental X-ray machine set at 7 mA and 65 kV with an exposure time of 0.15 s (HDX, Dental EZ, Lancaster, PA, USA). The development took place in a developing machine (XR 24Pro, Dürr Dental, Bietigheim-Bissingen, Deutschland). Measurements were carried out using an X-ray viewer with light-shield, callipers and magnifying (2.5×) loupes (SwissLoupes-SandyGrendel, Aarburg, Schweiz).

Evaluation of images

One examiner (R.L.) measured all radiographs. The order in which the images of patients were examined was randomly allocated. First intraoral periapical radiographs (PA) were assessed, then afterwards cone beam computed tomography (CBCT) images were examined.

The cone beam computed tomography displays images in three planes that are similar to the computer tomography references of "axial" (CBCTa),"sagittal" (CBCTs) and "coronal" (CBCTc).

The mesial and distal roots of mandibular molars were examined separately.

The number of canals and the number of existing posts or screws were determined on intraoral periapical radiographs and sagittal CBCT layers.

The length of the root canal filling in relation to the apex and the homogeneity of the root canal filling were assessed on the intraoral periapical radiograph and the sagittal CBCT section (Fig. 1). The criteria for a homogeneous root-canal filling were continuous contact of the root-canal filling material to the root canal wall and no visible discontinuities within the root-canal filling itself.

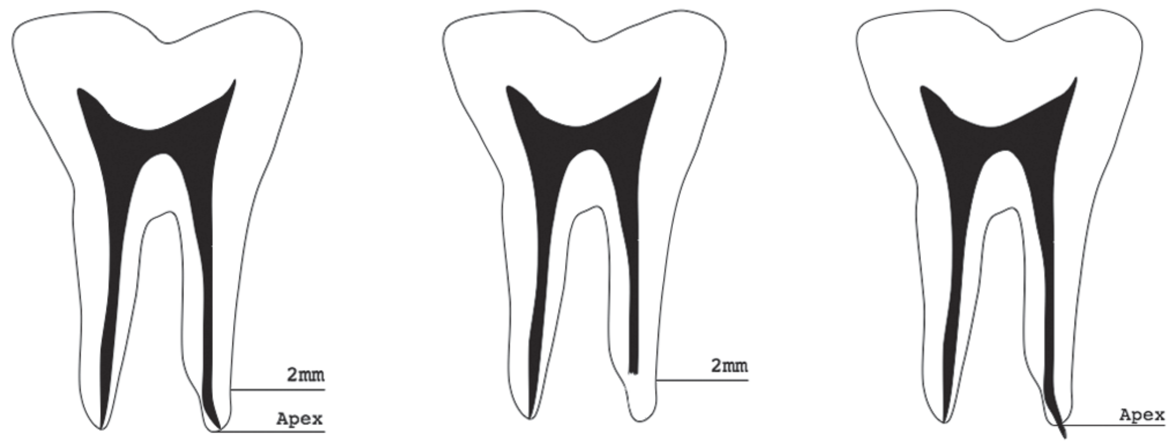


Fig. 1 Apical extent of root canal fillings

Results

From the 38 teeth sample, CBCT slices revealed a total of 121 canals, while intraoral periapical radiographs identified 105 canals (Tab. II). In addition, the mesial and distal roots were assessed separately. Also here in both the mesial root group and distal root group more canals were revealed with the digital volume tomography than using intraoral periapical radiography: 9 additional canals were seen in the mesial root group and 7 additional canals in the distal root group (Tab. III). Furthermore, root canals were checked for the presence of posts or screws. Sagittal CBCT slices were compared with intraoral periapical radiographs. In the CBCT slices, no posts or screws could be detected in 18 teeth; however, in 20 teeth, either posts or screws were found. In the intraoral periapical radiographs, no posts or screws could be detected in 22 teeth, whereas in 16 teeth either posts or screws were found. The majority of posts or screws were found in distal roots (Tab. IV).

When assessing the length of the root canal filling, only small differences were shown.

In particular, the intraoral periapical radiograph described 4 roots that had short root canal fillings in both the mesial and distal aspects (Tab. V). On evaluation of the intraoral periapical radiographs, 7 root canal fillings were seen to be more nonhomogeneous than on the equivalent CBCT image. However,

Tab. IV Presence and location of posts or screws, n=38

	CBCT	PA
No posts or screws	18	22
In the mesial root	2	2
In the distal root	17	14
In mesial and distal roots	1	0
Total	38	38

Tab. II Distribution of canals, n=38

	CBCT		PA	
	Teeth	Canals	Teeth	Canals
1 Canal	1	1	1	1
2 Canals	0	0	10	20
3 Canals	28	84	24	72
4 Canals	9	36	3	12
Total	38	121	38	105

Tab. III Frequency of canals in the mesial and distal roots

	Mesial Root, n=38				Distal Root, n=37			
	CBCT		PA		CBCT		PA	
	Teeth	Canals	Teeth	Canals	Teeth	Canals	Teeth	Canals
1 Canal	2	2	11	11	27	27	34	34
2 Canals	36	72	27	54	10	20	3	6
Total	38	74	38	65	37	47	37	40

Tab. V Apical extent of root canal fillings

	Mesial root, n=38		Distal root, n=37	
	CBCT	PA	CBCT	PA
0–2 mm	23	18	36	25
Overfilled	3	5	3	3
>2 mm	11	15	5	9
Unfilled	1	0	3	0
Total	38	38	37	37

Tab. VI Homogeneity of root canal fillings, n=38

	CBCT	PA
Homogeneous	35	28
Inhomogeneous	3	10
Total	38	38

CBCT slices described 7 additional homogeneous root canal fillings (Tab. VI) than the corresponding intraoral periapical radiograph.

Discussion

Before a therapeutic decision for or against apical surgery can be made, various clinical and radiographic aspects need to be examined. The prognosis of apical surgery is dependent upon the periodontal condition of the tooth, the clinical symptoms of the patient, the quality of the restoration and the quality of the root canal filling (Rahbaran et al. 2001).

The periodontium of the tooth designated for apical surgery should not be inflamed and provide sufficient attachment to the underlying bone. An apico-marginal bone defect is associated with an especially poor prognosis after apical surgery. This type of osseous deficiency can be detected clinically with a probe or radiographically with CBCT imaging. The intraoral periapical radiograph is not at all suited to identify such bony breakdowns because only mesial and distal aspects of the periodontium are visible.

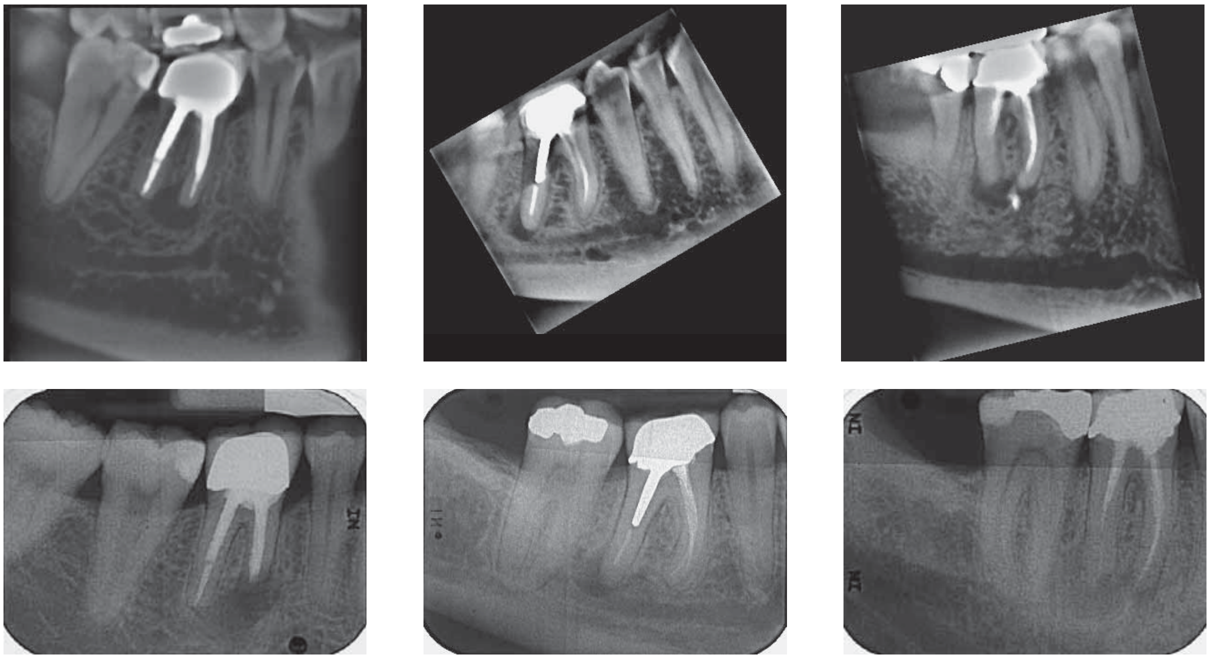
In addition, a tooth being considered for apical surgery with clinical signs and symptoms of disease also has a negative influence on the prognosis (von Arx et al. 2010).

The quality of the restoration or the ability to restore a tooth is important.

In general, a tooth being considered for apical surgery reveals a long restorative history. A typical tooth history would describe initial treatment for caries, then a few years later the filling shows secondary caries that is also treated. Eventually this pattern results in pulp necrosis leading to root canal treatment. The success of root canal treatment is not only dependent upon correct therapeutic techniques but equally on an adequately sealed restoration of the affected tooth. A leaky filling or crown worsens the prognosis of a root canal filling per se and inevitably affects the prognosis of the ensuing apical surgery due to reinfection of the root canal system (Williams & Williams 2010). The quality of the restoration can be determined in a clinical examination. A fine explorer can detect breakdown of the filling or crown margin. As mentioned before, the intraoral periapical radiograph only shows the mesial or distal aspects of the filling or crown. Only when a certain degree of demineralization has occurred can an intraoral periapical radiograph be used to diagnose secondary caries. CBCT images are not suitable for the evaluation of restorations as all modern restorative materials or crowns are radiopaque. This property causes signal loss and streak artefacts in the immediate vicinity of the restoration (Schulze et al. 2010). Finally, the quality of the root canal filling was assessed. Both the extent and the homogeneity of the root canal filling are important (Fig. 2, 3). Inhomogeneous root canal fillings may indicate an incomplete obturation of the root canal. Incomplete root canal obturation negatively affects the prognosis after apical surgery (von Arx et at. 2010). Although the extent of the root canal filling is not a prognostic factor, the ideal prior to surgical intervention is a homogeneous root canal filling which ends 0–2 mm from the apex. Root filling material extending beyond the apex can only partly be removed with an orthograde revision. Root canal fillings ending more than 2 mm short of the apex allow a quite complicated apical delta to remain effectively untreated (Skidmore et al. 1971). If this area is not filled, infected tissue remains, which could support a periapical infection. The detection of canals on a CBCT section is clearly easier than on an intraoral periapical radiograph (Tab. II, III). The assessment of a root canal filling and the detection of root canal posts or screws appear to be easier to identify on an intraoral periapical radiograph; however, more canal posts or screws were detected on the CBCT section (Tab. IV). This may be due to artefact formation on a CBCT section that mimics a root canal post or screw (Fig. 4). Determining the apex on a intraoral periapical radiograph is not always assured. This is due to the fact that the central beam is not constantly on the orthograde tooth axis. This results in a discrepancy between the anatomical and radiographic apex. Nevertheless, when measuring root canal fillings it appears easier to determine the extent (Tab. V) and, in particular, the homogeneity on the intraoral periapical radiograph compared to the CBCT slices. This is shown in Table VI, where significantly more inhomogeneous root canal fillings were found on intraoral periapical radiograph than on the CBCT slices. Air voids in the root canal are better represented on individual CBCT slices than intraoral periapical radiographs, where overlapping keeps them hidden.

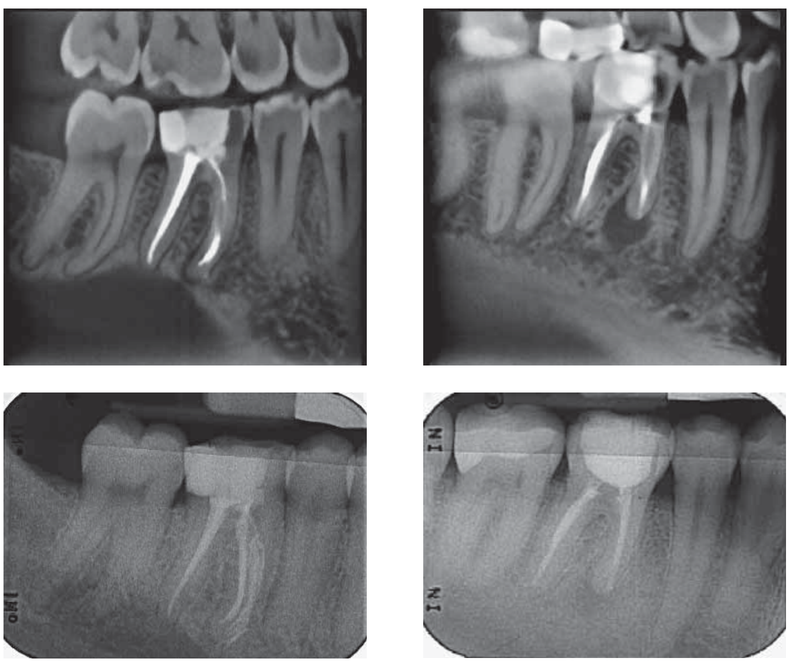
The sometimes tortuous path of root canals was intersected by individual CBCT slices making their interpretation especially difficult.

The use of intraoral periapical radiography to assess complex root canal anatomy is limited. The advantage of cone beam tomography is that it allows a periapical lesion to be better described and exactly localised. The distance of the lesion to the mandibular canal and the cortical alveolar bone surface can be determined accurately (Bornstein et al. 2010). This information is vital not only for the diagnostic planning process but also when undertaking the operative procedure. We recommend, before considering apical surgery in lower molars, to carry out a CBCT scan in order to clarify the root canal anatomy as well as the morphology of any periapical defect.



The root canal filling ends 0 mm–2 mm from the apex | The root canal filling ends more than 2 mm from the apex | The root canal filling extends beyond the apex (mesial root)

Fig. 2 Apical extent of root canal filling. Comparison of sagittal CBCT slices with intraoral periapical radiographs.



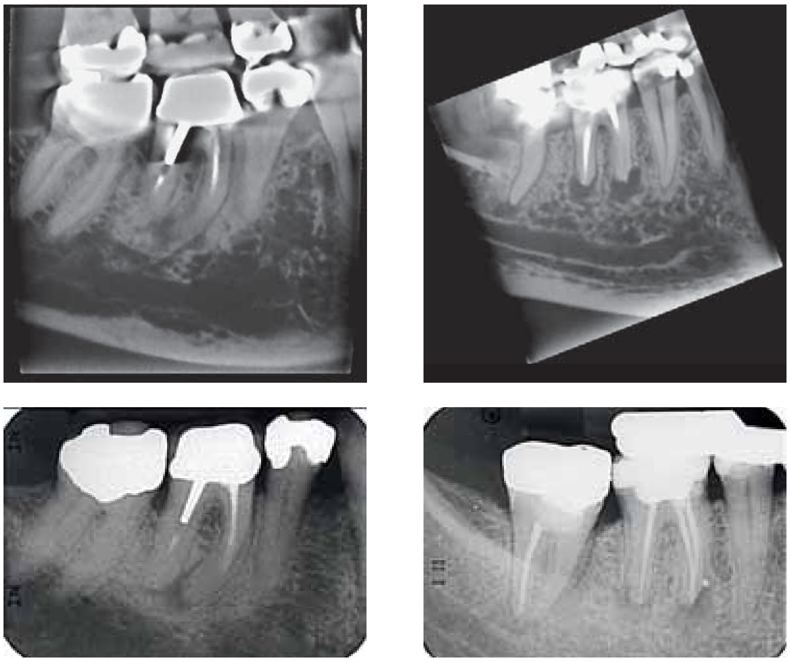
Inhomogeneous (mesial canal) | Homogeneous (distal canal)

Fig. 3 Homogeneity of the root canal filling. Comparison of sagittal CBCT slices with the intraoral periapical radiographs.

Résumé

Introduction: Le but de cette étude était de comparer les radiographies apicales conventionelles avec les tomographies volumétriques à faisceau conique lors de l'examen de molaires inférieures avant une chirurgie apicale. La longueur et l'homogénéité des obturations des canaux radiculaires, ainsi que le nombre de canaux présents ont été analysés.

Matériel et méthode: 38 molaires avec au total 75 racines ont été incluses dans cette étude. La longueur et l'homogénéité des obturations des canaux, ainsi que la présence de tenons ou vis radiculaires ont été étudiés sur les radiographies apicales, ainsi



Canal post or screw present (distal canal) | Canal post or screw not present

Fig. 4 Presence of a root canal post or screw. Comparison of sagittal CBCT slices with the intraoral periapical radiographs.

que sur les coupes sagittales des tomographies volumétriques à faisceau conique. Le nombre de canaux radiculaires a été étudié de manière identique tout en analysant les racines mésiales et distales séparément.

Résultats: Un plus grand nombre de canaux ont été trouvés sur les coupes des tomographies volumétriques à faisceau conique que sur les radiographies apicales. L'examen de la présence ou non d'un tenon ou d'une vis, de la longueur des canaux, ainsi que de l'homogénéité de l'obturation canalaire semblent subjectivement plus faciles à déterminer sur les radiographies apicales que sur les radiographies à tomographies volumétriques à faisceau conique.

Conclusion: Sur la base d'une meilleure vision de l'anatomie des canaux radiculaires, nous recommandons la prise d'une tomographie volumétrique à faisceau conique avant un traitement de chirurgie apicale.

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