International Endodontic Journal

doi:10.1111/j.1365-2591.2011.01923.x

Diagnostic yield of conventional radiographic and cone-beam computed tomographic images in patients with atypical odontalgia

M. Pigg[1], T. List[2], K. Petersson[1], C. Lindh[3] & A. Petersson[3]

[1]Department of Endodontics; [2]Department of Stomatognathic Physiology; and [3]Department of Oral and Maxillofacial Radiology, Faculty of Odontology, Malmö University, Malmö, Sweden

Abstract

Pigg M, List T, Petersson K, Lindh C, Petersson A. Diagnostic yield of conventional radiographic and cone-beam computed tomographic images in patients with atypical odontalgia. *International Endodontic Journal*, **44**, 1092–1101, 2011.

Aim To investigate whether the additional diagnostic yield of a cone-beam computed tomography (CBCT) examination over conventional radiographs in patients primarily suspected of having atypical odontalgia (AO) improves differentiation between AO and symptomatic apical periodontitis (SAP) in patients with severe chronic intraoral pain.

Methodology In this clinical study, 25 patients (mean age 54 ± 11 years, range 34–72) participated; 20 were diagnosed with AO and 5 with SAP. All patients were recruited from the clinics of the Faculty of Odontology, Malmö University. AO inclusion criteria were chronic pain (>6 months) in a region where a tooth had been endodontically or surgically treated, with no pathological cause detectable in clinical or radiologic examinations. SAP inclusion criteria were recurrent pain from a tooth diagnosed with apical periodontitis in clinical and radiographic examinations. Assessments comprised a self-report questionnaire on pain characteristics, a comprehensive clinical examination and a radiographic examination including panoramic and intraoral radiographs and CBCT images. The main outcome measure was periapical bone destruction.

Results Sixty per cent of patients with AO had no periapical bone destructions detectable with any radiographic method. Overall, CBCT rendered 17% more periapical bone destructions than conventional radiography. Average pain intensity in patients with AO was 5.6 (±1.8) on a 0–10 numerical rating scale, and average pain duration was 4.3 (±5.2) years.

Conclusion Cone-beam computed tomography improves identification of patients without periapical bone destruction, which may facilitate differentiation between AO and SAP.

Keywords: atypical odontalgia, chronic intraoral pain, cone-beam computed tomography, neuropathic pain, orofacial pain, radiography.

Received 10 February 2011; accepted 27 June 2011

Introduction

Persistent intraoral pain is a challenge to the dental practitioner, particularly when it occurs in the absence of pathological findings explaining the pain. Atypical odontalgia (AO) is a severe pain condition, also known as chronic continuous dentoalveolar pain disorder (CCDAP; Ohrbach *et al.* 2010) and classified by the International Headache Society (IHS) as 'persistent idiopathic facial pain of intraoral dentoalveolar subset' (Headache Classification Subcommittee of the International Headache Society 2004). AO has been defined as tooth-related pain or pain at a site where a tooth was extracted, in absence of clinical and radiographic evidence of tooth pathology or other relevant orofacial hard or soft tissue pathology (Melis *et al.* 2003, Woda *et al.* 2005).

Correspondence: Maria Pigg, Department of Endodontics, Faculty of Odontology, Malmö University, Carl Gustafs väg 34, SE-20506 Malmö, Sweden (Tel.: +46 40 665 8498; fax: +46 40 665 8577; e-mail: maria.pigg@mah.se).

Clinically, patients often report pain onset to have occurred after dental treatment (List *et al.* 2007), usually endodontic or surgical treatment. Two recent systematic reviews examined the prevalence of persistent pain (≥6 months) in patients after nonsurgical or surgical endodontic treatment. Meta-analysis revealed tooth pain prevalence to be 5.3% (Nixdorf *et al.* 2010a); when cases judged as related to local inflammation were excluded, the prevalence was 3.4% (Nixdorf *et al.* 2010b). A previous study found that, compared to healthy controls, patients with AO have an affected psychosocial well-being, daily functioning and quality of life (List *et al.* 2007).

The mechanisms responsible for the development of this pain condition are largely unknown but hypothesized to involve deafferentation of peripheral sensory neurons in the trigeminal system occurring in predisposed patients. The origin of AO is suggested to be neuropathic (Marbach 1993, Melis *et al.* 2003, Baad-Hansen 2008). In the endodontic literature, the condition is generally poorly described.

The diagnosis of AO is based on case history and a comprehensive examination assessing clinical and radiographic findings. As the current definition of AO indicates, diagnosis rests heavily on the absence of radiographic evidence of pathosis. The nociceptive pain conditions symptomatic pulpitis and symptomatic apical periodontitis (SAP) are probably the most difficult to distinguish from AO. This study is focused on differential diagnosis between AO and SAP, although further studies are also needed to explore methods for differentiating pain of pulpal origin from neuropathic pain. In apical periodontitis, symptoms overlap to a great extent with those of AO, including continuous or recurrent spontaneous pain and increased pain on stimulation (chewing, thermal stimulation, palpation of gingival tissues/alveolar process, tooth percussion etc; Woda & Pionchon 1999, Melis *et al.* 2003, Ørstavik & Pitt Ford 2008). Patients with AO have often had not only multiple endodontic treatments in the painful area but also other invasive dental treatments such as explorative surgery, apicectomies and extractions (Remick *et al.* 1983, Mock *et al.* 1985), which potentially increase diagnostic difficulty because consequences such as scar tissue formation and permanent loss of labial cortical bone plate may give rise to periapical radiolucency.

Clinical and laboratory studies report that the sensitivity of conventional radiography is low for detecting apical periodontitis – especially for small periapical bone destructions – whereas reports on specificity vary according to study design (Estrela *et al.* 2008, Patel *et al.* 2009, Sogur *et al.* 2009). Few studies have investigated cone-beam computed tomography (CBCT) in this respect, but some laboratory studies indicate higher sensitivity and specificity than in conventional radiography (Patel *et al.* 2009, Sogur *et al.* 2009). A particular advantage of 3-dimensional (3D) over 2-dimensional (2D) radiographic image assessment is the ability to differentiate between a bone tissue defect located around the root tip and a residual surgical defect located in the cortical bone plate. Furthermore, the slice technique eliminates structural noise (Patel *et al.* 2007), and this is particularly helpful in the maxillary molar region where roots and surrounding radiolucent areas can be difficult to identify. Three-dimensional imaging in high resolution also has the potential to detect sources of remaining infection and endodontic treatment failure such as untreated root canals, additional roots, root perforations and root fractures (Lofthag-Hansen *et al.* 2007), which may indicate periapical inflammation as the cause of pain. Several studies thus report that CBCT has great ability to give detailed anatomical information of value for diagnosis and treatment planning (Cotton *et al.* 2007, Lofthag-Hansen *et al.* 2007, Patel *et al.* 2007, Patel 2009, Bornstein *et al.* 2011, Yoshioka *et al.* 2011).

No studies have investigated the use of CBCT as an adjunct in pain investigations. If neuropathic pain could be differentiated from nociceptive pain with greater accuracy, patient benefit would be considerable. Additional, inappropriate dental treatment could be avoided in favour of targeted neuropathic pain treatment. As SAP resembles AO in several aspects, unidentified cases of apical periodontitis may occur amongst patients diagnosed with AO. It was hypothesized that the additional information on anatomical structures in the pain area provided by CBCT examination – compared with conventional intraoral periapical and panoramic radiographs – improves the possibilities to identify AO.

The focus of this clinical study was to improve the diagnostic certainty in chronic intraoral pain assessments; the aim was to determine whether the additional diagnostic yield of a CBCT examination over conventional intraoral periapical and panoramic radiographs in patients suspected of having AO improves the identification of patients with AO.

Materials and methods

Participants and study design

Twenty consecutive patients (18 women and 2 men) diagnosed with AO were recruited from the Department of Stomatognathic Physiology (Faculty of Odontology, Malmö University, Malmö, Sweden) between December 2005 and June 2007. An experienced TMD/orofacial pain specialist examined all patients prior to study participation, ruling out other pain causes with reasonable certainty. The inclusion criterion for the AO group was continuous or recurrent pain persisting for more than 6 months that (i) was located in a region where a tooth had been endodontically or surgically treated or extracted and (ii) had no pathological cause detectable in clinical or intraoral radiographic examinations. The diagnosis of AO is not tooth-specific, and 11 patients had one tooth each, eight patients had two teeth each and one patient had three teeth (n = 30) indicated in the referral as being painful.

As the differential diagnosis of apical periodontitis is generally considered to be characterized by periapical bone destruction, it was thought appropriate to examine some teeth with this diagnosis to ascertain that the methods employed could indeed depict such destructions. Thus, five teeth with symptomatic apical periodontitis (SAP), from five patients (3 women and 2 men) recruited from the Department of Endodontics and the emergency clinic, were used as positive controls for the radiographic assessments. The inclusion criterion for this group was continuous or recurrent pain from a tooth that was diagnosed with apical periodontitis after clinical and intraoral radiographic examinations.

Exclusion criteria for both groups were trigeminal neuralgia, herpes zoster, maxillary sinusitis, cluster headache and paroxysmal hemicrania. Data were collected through self-report measures in a questionnaire and clinical and radiographic examinations.

The study was performed according to the 1964 Declaration of Helsinki (2008 revision, http://www.wma.net) and approved by the Regional Ethics Review Board at Lund University (Lund, Sweden). The patients were asked to sign an informed consent form and received no monetary compensation for their participation.

Assessments

Questionnaire

All patients completed a questionnaire that comprised self-report measures on pain characteristics including average pain intensity (graded on a 0–10 numerical rating scale), pain duration (years) and frequency of pain (continuous, recurrent or occasional).

Clinical examination

The clinical examination included assessment of pain location and pain on percussion or apical palpation, assessment of periodontal pocket depth, selective loading with a FracFinder (Denbur Inc., Oak Brook, IL, USA), transillumination of natural teeth with an optical fibre (when possible), sensibility testing of non-root filled teeth and a qualitative somatosensory examination assessing sensory function in the pain area. The masticatory system was examined according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD; Dworkin & LeResche 1992). A specialist in stomatognathic physiology with extensive experience in orofacial pain investigations (TL) examined all patients clinically, carefully assessing all findings to, as far as possible, exclude other pain reasons such as periodontal disease, cracks, root fractures and referred pain from the masticatory system or head and neck.

Radiographic examination

The radiographic examination of the pain area comprised panoramic, intraoral periapical and CBCT images. Panoramic and intraoral periapical radiographs of the pain area were taken in conjunction with the clinical examination. Radiographs taken by the referring dentist were used if image quality was adequate. Panoramic radiographs were taken of all patients except two with AO, and all patients were examined with CBCT. Hereafter, 'conventional images (or radiographs)' will be used to refer to the panoramic and intraoral periapical radiographs studied together.

All intraoral radiographs not taken by the referring dentist were taken at the Department of Oral and Maxillofacial Radiology (Faculty of Odontology, Malmö University) or the Department of Radiology (Malmö University Hospital, Malmö, Sweden). All panoramic radiographs and all CBCT images were taken at the latter department. Intraoral radiographs were analogue (n = 14) or digital (n = 11). All panoramic radiographs (Promax; Planmeca, Helsinki, Finland) were taken with imaging plates using a computerized radiologic system (Agfa CR; Agfa Gevaert, Mortsel, Belgium). The CBCT machine was 3D Accuitomo (J Morita Corp, Kyoto, Japan). The image area was 3 × 4 cm, and contiguous tomographic slices of 1 mm were reformatted in three perpendicular planes (axial, coronal and sagittal). The sagittal slices were placed parallel to the alveolar process in the area of interest.

Two specialists in oral radiology with extensive experience of digital radiography and CBCT assessed all radiographs. Observer 1 (AP) first assessed conventional images only and then conventional and CBCT images together on the same occasion. For calculation of intraobserver agreement, observer 1 repeated his assessments 3 months later. For calculation of interobserver agreement, observer 2 (CL) assessed only conventional images on the first occasion, which were compared with observer 1's assessments on the first occasion. Three months later, observer 2 assessed conventional and CBCT images together, which were then compared with observer 1's assessments on occasion 2 (Table 1). All image assessments were made in a room with low ambient light. Digital images were viewed on a 19-inch monochromatic monitor (Barco; MFGD 1318, Kortrijk, Belgium). Film radiographs were assessed on a viewbox with fixed light intensity and with the aid of a magnifying viewer. The radiologists were not calibrated prior to assessing the images of this study, but the criteria for assessment were discussed and agreed on beforehand. The observers had no information on whether the diagnoses were AO or SAP, but the pain region was known.

All radiographic images were assessed as follows: The tooth was the studied unit. The pain location was described as in the maxilla or mandible. The assessed teeth were described as anterior (13–23 or 33–43) or posterior (14–18, 24–28, 34–38 or 44–48). Periapical bone destruction, defined as resorption of the periapical bone tissue resulting in a radiolucent area, was rated on a 3-point scale: 0 = not detectable, 1 = uncertain and 2 = detectable.

Other findings in the pain area were noted as detectable/not detectable on the image assessment protocol. These findings were unfilled root canals (present in root filled teeth), root fractures/perforations, excess root filling material and mucosal swellings in the maxillary sinus. Other findings of interest and artefacts (findings not related to existing conditions in the area of interest, such as metal artefacts) were also noted.

Observer disagreement on periapical bone destruction was resolved by reassessing and then discussing the radiographs in a joint session until consensus was reached. These findings were then used in all comparisons of radiographic method. Findings other than bone destruction were rated as present if noted by at least one observer.

Statistical analysis

Mean values and SDs were calculated for all continuous variables. The independent samples *t*-test was used for between-group comparisons of age, pain duration and pain intensity as well as comparisons between pain locations. Cohen's kappa assessed inter- and intraobserver agreement (Landis & Koch 1977). Kappa values ≤ 0.2 were considered poor agreement; 0.21–0.40 fair; 0.41–0.60 moderate; 0.61–0.80 good and 0.81–1.00 very good (Altman 1991). The percentage of total agreement was also calculated.

Statistical tests were performed two-tailed and at the 5% significance level. All calculations were made using Predictive Analytics Software (PASW) Statistics 18 (Ver. 18.0 for Windows; SPSS Inc., Chicago, IL, USA).

Results

Self-report measures and clinical findings

Table 2 describes patient and pain characteristics in each group. There was no significant difference in age between men and women for the 25 patients ($P = 0.964$).

Table 3 describes the pain distribution in both groups. There were no significant differences in average pain intensity between maxilla and mandible ($P = 0.413$) or between anterior and posterior teeth ($P = 0.446$).

Radiographic findings

A total of 35 teeth in 25 patients were assessed. In the AO group, only the teeth or regions indicated as being

Table 1 Intra- and interobserver analysis of conventional radiographic (intraoral periapical and panoramic) assessment and of conventional + cone-beam computed tomographic (CBCT) image assessment

	Assessment I	Assessment II
Observer 1	Conventional[a,b]	Conventional[a]
	Conventional and CBCT[c]	Conventional and CBCT[c,d]
Observer 2	Conventional[b]	Conventional and CBCT[d]

[a]Assessment used for intraobserver agreement analysis of conventional radiographs.
[b]Assessment used for interobserver agreement analysis of conventional radiographs.
[c]Assessment used for intraobserver agreement analysis of conventional and CBCT images.
[d]Assessment used for interobserver agreement analysis of conventional and CBCT images.

Table 2 Patient and pain characteristics of atypical odontalgia (AO) and symptomatic apical periodontitis (SAP)

	AO (n = 25)	SAP (n = 5)
Age (mean years [SD])	52 (10)	62 (11)
Gender (n)		
Women	18 (90%)	3 (60%)
Men	2 (10%)	2 (40%)
Pain duration (mean years [SD])	4.3 (5.2)	4.5 (4.2)
Average pain intensity (mean NRS [SD])	5.6 (1.8)	5.6 (2.5)
Pain frequency (n)		
Continuous pain	19 (95%)	2 (40%)
Recurrent pain	1 (5%)	3 (60%)

Table 3 Pain distribution in atypical odontalgia (AO) and symptomatic apical periodontitis (SAP)

	AO group	SAP group
Patients, n	20	5
Teeth, n	30	5
Pain location (number of patients/teeth)		
Posterior region	13/16[a]	4/4
Anterior region	8/12[a]	1/1
Maxilla	12/18	3/3
Mandible	8/12	2/2

[a]One patient had pain located in both the anterior and posterior regions (2 teeth).

painful (1–3 teeth per subject) in the referral were assessed radiographically; in the SAP group, only the teeth diagnosed with SAP were assessed. Agreement (kappa value) between assessment of conventional images alone and assessment of conventional images with CBCT was 0.63 for periapical destructions (80% total agreement). No artefact was noted in any image.

In the SAP group, each patient (n = 5) had one tooth diagnosed with SAP. Two of these teeth had been endodontically treated. Periapical bone destruction was observed in all five teeth with all methods. These patients served as positive controls, to ascertain whether conventional radiography and CBCT scanning could depict periapical bone destruction. No other findings in the SAP group were analysed.

Tables 4 and 5 present the radiographic findings in patients with AO. In the 20 patients with AO, 30 teeth were assessed radiographically. Twenty-one of these teeth had been endodontically treated: 2 teeth were undergoing primary endodontic treatment and 2 retreatment, 12 teeth were root filled, and 5 teeth were root filled and had undergone apical surgery. Six teeth in the pain regions had not undergone invasive treatment but were assessed radiographically to determine whether they could be responsible for the pain.

Table 5 Other radiographic findings than periapical bone destruction in patients with atypical odontalgia (AO): conventional (intraoral periapical and panoramic) radiographs alone and in combination with cone-beam computed tomography (CBCT; n = 30 teeth)

	Conventional	Conventional and CBCT
Listed on protocol		
Canal not root filled canal (in root filled tooth)	0	0
Root fracture	0	0
Root perforation	0	0
Excess root filling material	1	3
Mucosal swelling in sinus	1	1
Artefacts	0	0
Not listed on protocol		
Short root[a]	5	7
Retrograde filling	1	2
Short root filling	1	2
Buccal bone loss[b]	0	4
Marginal bone defect[c]	1	2
Other[d]	2	1

[a]Described by observer as: apical resorption, apicectomied or short root.
[b]Described by observer as thin buccal bone or buccal bone defect.
[c]Described by observer as vertical bone defect, marginal bone defect or furcation defect.
[d]Instrument fragment in canal, widened periodontal ligament.

Table 4 Radiographic findings of periapical bone destruction in the atypical odontalgia (AO, n = 30 teeth) and symptomatic apical periodontitis (SAP, n = 5 teeth) groups on conventional (intraoral periapical and panoramic) radiographs alone and in combination with cone-beam computed tomography (CBCT). Results are consensus assessments

	Teeth with periapical bone destruction, n (%)			
	Conventional		Conventional + CBCT	
	Detectable	Uncertain	Detectable	Uncertain
AO	4 (13)	3 (10)	9 (30)	2 (6)
SAP	5 (100)	–	5 (100)	–

Three teeth had been extracted in the pain regions. All patients with AO had at least 1 tooth (and often more) in the pain region that had been endodontically treated or extracted.

Twenty-one teeth (70%, $n = 30$) in 12 of the patients with AO (60%, $n = 20$) had no periapical bone destruction detectable with any method. In the other nine teeth ($n = 8$ patients), periapical bone destruction was (i) not detected on conventional images but detected with CBCT ($n = 4$ teeth), (ii) suspected on conventional images but not seen in the CBCT image ($n = 1$ tooth) and (iii) detected with certainty in conventional images and in the CBCT image ($n = 4$ teeth, Table 4). All teeth with detected or suspected periapical bone destruction, regardless of radiographic method, had been endodontically treated.

Table 5 lists findings besides periapical bone destruction. All findings in conventional radiographs without the adjunct of CBCT were made around teeth that had been endodontically treated.

Observer agreement

Table 6 presents inter- and intraobserver agreement. Interobserver agreement was poor to fair and intraobserver agreement moderate to good.

Discussion

The most important observation of this study was that the majority of the patients diagnosed with AO had no detectable periapical bone destruction when CBCT was added, thus increasing the certainty that the patients suffered from AO. Also, the use of CBCT as an adjunct to conventional radiographic techniques increased the number of observed periapical bone destructions compared with the use of conventional radiography alone. This finding emphasizes the difficulties in identifying the condition AO, and it cannot be excluded that in some patients diagnosed with AO based on periapical or panoramic radiography, the pain is caused by SAP.

Because the AO condition is relatively rare, the patient group was small and a descriptive approach was adopted in this study, so as not to draw conclusions based on statistical analyses of a comparatively small and heterogeneous material.

Patient characteristics

The age and gender distributions of the patients with AO in this material agree well with previous reports. List *et al.* (2007) described 46 patients with AO where 85% were women with a mean age of 56 years; others have reported similar distributions (Graff-Radford & Solberg 1992, Schnurr & Brooke 1992, Vickers *et al.* 1998, List *et al.* 2007). Average pain intensity in the study by List *et al.* (2007) was similar to the present findings, although mean pain duration was longer (7.7 years). The patients with AO in the present study frequently reported continuous pain; 87% of the patients with AO in the List *et al.* (2007) study experienced pain daily or several times a week. The patients were therefore considered to be representative of a clinical AO population.

The differences in pain characteristics between the two patient groups were not analysed statistically, because the SAP group was small and was included to serve only as a positive control for radiographic assessments. Nevertheless, similarities were observed between SAP and AO in reports of pain frequency, intensity and duration (Table 2). Further studies examining the pain characteristics of AO and SAP are needed to elucidate whether these parameters are important for differentiating between these pain entities.

Observer agreement

The interobserver (0.19–0.40) and intraobserver (0.52–0.65) agreements for periapical bone destruction

Table 6 Inter- and intraobserver agreement in image assessment of periapical bone destruction. Kappa values and percentage of total agreement between assessments

	Kappa value (% of total agreement)
Interobserver	
Conventional	0.19 (57)
Conventional and cone-beam computed tomography	0.40 (66)
Intraobserver	
Conventional	0.65 (83)
Conventional and cone-beam computed tomography	0.52 (74)

Kappa values ≤0.2 were considered poor agreement; 0.21–0.40 fair; 0.41–0.60 moderate; 0.61–0.80 good and 0.81–1.00 very good agreement.

assessment ranged from poor to good; the addition of CBCT improved the kappa value substantially only for interobserver agreement. Another study reported similar kappa values (Sogur *et al.* 2009), whilst others have found greater agreement (Estrela *et al.* 2008, Patel *et al.* 2009). There is disagreement on whether kappa is an appropriate method for quantifying the level of agreement between raters. Kappa is used to correct for the possibility that raters agree by chance. The problem is that sample size and trait prevalence (distribution of ratings within categories) affect the stability of kappa, and use of other measures to supplement kappa is often recommended (Feinstein & Cicchetti 1990, Byrt *et al.* 1993, Lantz & Nebenzahl 1996).

Percentage total agreement was calculated to further analyse agreement. This analysis showed that the proportions of total inter- and intraobserver agreement were reasonable (57–83%) regardless of which radiographic method was used, reflecting that for a majority of the patients, no radiographic findings were reported by any of the observers.

The relatively low interobserver agreement may reflect the difficulties to identify the AO condition amongst long-lasting tooth-related pain conditions. This material was heterogeneous in both that different tooth groups were included and that different interventions had been applied. Repeated invasive treatment had sometimes been performed in the imaged region, which apart from being difficult to blind, also made assessment a challenge.

Radiographic issues and clinical implications

The radiographic methods used to set the AO diagnosis were not standardized in this study. Some patients were examined with analogue techniques and others with digital; a few patients had no panoramic images taken. This lack of standardization is partly explained by a change in equipment during the data collection period and partly by the good quality of the recent images that accompanied several referrals, for whom no new periapical images were judged necessary. Previous studies have shown that digital and analogue radiographic techniques have similar diagnostic reliability (Kullendorff *et al.* 1996, Barbat & Messer 1998, Holtzmann *et al.* 1998, Sogur *et al.* 2009), so this difference in methods was considered to have no importance. Whilst considered less useful for periapical assessment, panoramic images are often taken in patients with persistent intraoral pain to exclude other pain causes, such as osteomyelitis and malignant processes. When panoramic radiographs were available, they were assessed alongside the periapical images and the findings were not separated in the analyses, which is also how it is performed clinically. This clinical perspective was considered to be a strength of the study, as the aim was to examine the benefits to diagnostic yield of CBCT as an adjunct in the clinic.

Overall, 17% more periapical bone destructions (14% if the 'uncertain' findings made with both methods were included) were observed in patients with AO when CBCT and conventional images were assessed together compared to when only conventional radiographs were assessed. Thus, 21 of 30 teeth (70%) in 12 of 20 patients still had no definite signs of periapical bone destruction, which increases the likelihood that the pain in these patients was not caused by inflammation.

Overall, agreement between assessments was moderate, but all destructions found with conventional imaging techniques were also found with CBCT. All observed periapical destructions were located around root filled teeth. Such radiolucencies were interpreted as healing apical periodontitis (if previous images are available and bone destruction has diminished) or as a defect as a result of apical surgery (if recently performed).

The diagnosis of AO requires that at least one tooth in the pain area has undergone invasive treatment, and in this study, 21 of the 30 teeth in the AO group were endodontically treated. In the endodontically treated tooth, a small radiolucent zone around the root tip, in the absence of clinical symptoms and further signs of disease, is not always a reason to diagnose disease and recommend endodontic retreatment. Such radiolucent zones are many times interpreted as ongoing healing or scar tissue. In the patient with persistent pain, however, limited periapical bone destruction could indicate an inflammatory feature in the pain condition and instigate further dental treatment. This is indeed the crucial point of differential diagnosis. In neuropathic pain conditions, it is strongly recommended that invasive treatment be avoided because it puts further strain on the dysfunctional nervous system and has been reported to increase the pain (Mock *et al.* 1985, Schnurr & Brooke 1992, Marbach 1993). Thus, distinguishing nociceptive pain from neuropathic pain is essential, because treatment regimes differ radically; the treatment for nociceptive pain will include measures to eliminate infection, whereas the treatment for neuropathic pain is usually pharmacologic. The use of

CBCT in this study revealed no signs of periapical bone destruction in a majority of the teeth and patients, thus increasing the likelihood that the pain condition in these patients was neuropathic in character.

The greater number of radiolucent findings made with CBCT does not necessarily imply that periapical disease is present in all such cases; however, it cannot be ruled out. The proper interpretation of small root-tip-orientated radiolucencies is still unclear; some of them could be associated with the healing process, which may be slower than previously thought. Christiansen and co-workers used intraoral radiography and CBCT to assess periapical bone defects 12 months after endodontic surgery and detected 28% more remaining defects with CBCT (coronal sections) than with conventional techniques (Christiansen *et al.* 2009). To adequately interpret such findings, the time span between treatment and imaging should be known, even though the time required for complete bone healing is unknown. Average observer agreement between periapical and CBCT images was 67% in Christiansen's study, which compares favourably with 63% in the present study.

Other findings than periapical bone destructions were relatively scarce in this material, but overall, such findings were more numerous with the adjunct of CBCT compared with conventional radiography alone. No untreated root canals in root filled teeth or root perforations were detected. Excess root filling material was more often detectable with CBCT.

Cone-beam computed tomography artefacts can be problematic, but the observers were experienced radiologists and aware that root filling material and metal in restorations could cause artefacts. Although the assessment protocol included space for noting artefacts, none were recorded.

Amongst the additional findings not listed on the examination protocol were some that were possibly related to previous invasive treatment (signs of apicectomy, a root end filling and buccal bone loss). Others were possibly indicative of endodontic treatment failure, periodontal pathology or root fracture as the cause of pain (apical resorption, short root filling, marginal defect and buccal bone loss). In particular, information on buccal bone loss, marginal defects and excess root filling material may be relevant for pinpointing the cause of pain. Others have made similar observations when comparing conventional techniques to CBCT; for example, one study reported 10% more root canals and 31% more periapical bone destructions on CBCT images than on periapical radiographs (Lofthag-Hansen *et al.* 2007). In the present study, some findings in conventional radiographs (other than periapical bone destruction) were supported in the CBCT examination and others were not.

When clinical findings and patient history strongly suggest a diagnosis of AO, nociceptive pain conditions need to be excluded with as great a certainty as possible. If periapical bone destruction is not seen, even on CBCT images, it may be reasonably sure that it is not present; making it less probable that inflammation is the main cause of the pain. But *is* CBCT evidence of periapical bone destruction a clear sign of disease? In root filled teeth, how does one interpret such evidence, which is not detectable in periapical images? At present, it is not known how well evidence of periapical bone radiolucency on CBCT images corresponds with the histology of the tissue in humans. In a recent experimental study in dogs, periapical radiolucencies detected with CBCT in infected and subsequently root filled teeth were found to correspond with inflammatory changes in histological examination of the periapical bone tissue (de Paula-Silva *et al.* 2009). But are all small periapical bone destructions, detected with CBCT and not explained by clinical history, signs of inflammation? More studies are needed to elucidate this issue.

Supplementing conventional radiographic examination with CBCT has disadvantages, mainly the rise in cost and in total radiation dose to the patient, so to justify inclusion of CBCT in the clinical examination, the diagnostic gain must exhibit a clear patient benefit. Such benefit that may be the indication of effective treatment made possible if patients with AO and SAP can be differentiated with higher certainty. No strong recommendations to the patients concerning dental treatment were made, so it is not possible to judge the patient benefit of the supplemental examination.

Overall, CBCT does seem to provide additional information in the investigation of patients with persistent tooth-related pain, and it is recommended to supplement conventional examinations with this technique. However, until further studies have assessed CBCT validity in detecting periapical disease, the method cannot be recommended as the method of choice in tooth-related pain investigations.

Conventional radiography and CBCT both record structural changes in bone tissue. Periapical bone destruction has been reported to have a high degree of correlation with localized inflammation in endodontic disease in human maxillary incisors (Brynolf 1967). The majority of apical periodontitis, however, is chronic in nature and does not cause pain (Ørstavik

& Pitt Ford 2008). Other methods, such as MRI, which is able to detect oedema, may be superior in identifying symptomatic inflammation in the jaws and should be explored in future studies. Still, it is probable that absence of periapical bone destruction may exclude a major proportion of inflammatory reasons for pain and thus facilitate differentiation of neuropathic pain conditions from inflammatory pain because of apical periodontitis.

Conclusions

In patients with persistent dentoalveolar pain, the diagnostic yield was higher when conventional imaging techniques (periapical and panoramic radiographs) were supplemented with CBCT. The additional findings in CBCT images over conventional radiographs are such that CBCT evidence may be relevant in the diagnosis of persistent intraoral pain conditions, above all in the differentiation of AO from SAP by identifying patients with no periapical bone destruction.

Acknowledgements

The Faculty of Odontology at Malmö University supported this study. There were no conflicts of interest.

References

Altman DG (1991) *Practical Statistics for Medical Research*, 1st edn. London, UK: Chapman & Hall.

Baad-Hansen L (2008) Atypical odontalgia – pathophysiology and clinical management. *Journal of Oral Rehabilitation* **35**, 1–11.

Barbat J, Messer HH (1998) Detectability of artificial periapical lesions using direct digital and conventional radiography. *Journal of Endodontics* **24**, 837–42.

Bornstein MM, Lauber R, Sendi P, von Arx T (2011) Comparison of periapical radiography and limited cone-beam computed tomography in mandibular molars for analysis of anatomical landmarks before apical surgery. *Journal of Endodontics* **37**, 151–7.

Brynolf I (1967) *A histological and roentgenological study of the periapical region of human upper incisors* (PhD Thesis). Uppsala, Sweden: University of Lund, Sweden.

Byrt T, Bishop J, Carlin JB (1993) Bias, prevalence and kappa. *Journal of Clinical Epidemiology* **46**, 423–9.

Christiansen R, Kirkevang LL, Gotfredsen E, Wenzel A (2009) Periapical radiography and cone beam computed tomography for assessment of the periapical bone defect 1 week and 12 months after root-end resection. *Dentomaxillofacial Radiology* **38**, 531–6.

Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG (2007) Endodontic applications of cone-beam volumetric tomography. *Journal of Endodontics* **33**, 1121–32.

de Paula-Silva FW, Wu MK, Leonardo MR, da Silva LA, Wesselink PR (2009) Accuracy of periapical radiography and cone-beam computed tomography scans in diagnosing apical periodontitis using histopathological findings as a gold standard. *Journal of Endodontics* **35**, 1009–12.

Dworkin SF, LeResche L (1992) Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. *Journal of Craniomandibular Disorders* **6**, 301–55.

Estrela C, Bueno MR, Leles CR, Azevedo B, Azevedo JR (2008) Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. *Journal of Endodontics* **34**, 273–9.

Feinstein AR, Cicchetti DV (1990) High agreement but low kappa: I. The problems of two paradoxes. *Journal of Clinical Epidemiology* **43**, 543–9.

Graff-Radford SB, Solberg WK (1992) Atypical odontalgia. *Journal of Craniomandibular Disorders* **6**, 260–5.

Headache Classification Subcommittee of the International Headache Society (2004) The International Classification of Headache Disorders, 2nd edn. *Cephalalgia* **24**, 9–160.

Holtzmann DJ, Johnson WT, Southard TE, Khademi JA, Chang PJ, Rivera EM (1998) Storage-phosphor computed radiography versus film radiography in the detection of pathologic periradicular bone loss in cadavers. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **86**, 90–7.

Kullendorff B, Nilsson M, Rohlin M (1996) Diagnostic accuracy of direct digital dental radiography for the detection of periapical bone lesions: overall comparison between conventional and direct digital radiography. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **82**, 344–50.

Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. *Biometrics* **33**, 159–74.

Lantz CA, Nebenzahl E (1996) Behavior and interpretation of the kappa statistic: resolution of the two paradoxes. *Journal of Clinical Epidemiology* **49**, 431–4.

List T, Leijon G, Helkimo M, Oster A, Dworkin SF, Svensson P (2007) Clinical findings and psychosocial factors in patients with atypical odontalgia: a case-control study. *Journal of Orofacial Pain* **21**, 89–98.

Lofthag-Hansen S, Huumonen S, Grondahl K, Grondahl HG (2007) Limited cone-beam CT and intraoral radiography for the diagnosis of periapical pathology. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **103**, 114–9.

Marbach JJ (1993) Is phantom tooth pain a deafferentation (neuropathic) syndrome? Part I: Evidence derived from pathophysiology and treatment. *Oral Surgery, Oral Medicine and Oral Pathology* **75**, 95–105.

Melis M, Lobo SL, Ceneviz C *et al.* (2003) Atypical odontalgia: a review of the literature. *Headache* **43**, 1060–74.

Mock D, Frydman W, Gordon AS (1985) Atypical facial pain: a retrospective study. *Oral Surgery, Oral Medicine and Oral Pathology* **59**, 472–4.

Nixdorf DR, Moana-Filho EJ, Law AS, McGuire LA, Hodges JS, John MT (2010a) Frequency of persistent tooth pain after root canal therapy: a systematic review and meta-analysis. *Journal of Endodontics* **36**, 224–30.

Nixdorf DR, Moana-Filho EJ, Law AS, McGuire LA, Hodges JS, John MT (2010b) Frequency of nonodontogenic pain after endodontic therapy: a systematic review and meta-analysis. *Journal of Endodontics* **36**, 1494–8.

Ohrbach R, List T, Goulet JP, Svensson P (2010) Recommendations from the International Consensus Workshop: convergence on an orofacial pain taxonomy. *Journal of Oral Rehabilitation* **37**, 807–12.

Ørstavik D, Pitt Ford T (2008) *Essential Endodontology. Prevention and Treatment of Apical Periodontitis*, 2nd edn. Oxford, UK: Blackwell Munksgaard Ltd.

Patel S (2009) New dimensions in endodontic imaging: Part 2. Cone beam computed tomography. *International Endodontic Journal* **42**, 463–75.

Patel S, Dawood A, Ford TP, Whaites E (2007) The potential applications of cone beam computed tomography in the management of endodontic problems. *International Endodontic Journal* **40**, 818–30.

Patel S, Dawood A, Mannocci F, Wilson R, Pitt Ford T (2009) Detection of periapical bone defects in human jaws using cone beam computed tomography and intraoral radiography. *International Endodontic Journal* **42**, 507–15.

Remick RA, Blasberg B, Barton JS, Campos PE, Miles JE (1983) Ineffective dental and surgical treatment associated with atypical facial pain. *Oral Surgery, Oral Medicine and Oral Pathology* **55**, 355–8.

Schnurr RF, Brooke RI (1992) Atypical odontalgia. Update and comment on long-term follow-up. *Oral Surgery, Oral Medicine and Oral Pathology* **73**, 445–8.

Sogur E, Baksi BG, Grondahl HG, Lomcali G, Sen BH (2009) Detectability of chemically induced periapical lesions by limited cone beam computed tomography, intra-oral digital and conventional film radiography. *Dentomaxillofacial Radiology* **38**, 458–64.

Vickers ER, Cousins MJ, Walker S, Chisholm K (1998) Analysis of 50 patients with atypical odontalgia. A preliminary report on pharmacological procedures for diagnosis and treatment. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **85**, 24–32.

Woda A, Pionchon P (1999) A unified concept of idiopathic orofacial pain: clinical features. *Journal of Orofacial Pain* **13**, 172–95.

Woda A, Tubert-Jeannin S, Bouhassira D *et al.* (2005) Towards a new taxonomy of idiopathic orofacial pain. *Pain* **116**, 396–406.

Yoshioka T, Kikuchi I, Adorno CG, Suda H (2011) Periapical bone defects of root filled teeth with persistent lesions evaluated by cone-beam computed tomography. *International Endodontic Journal* **44**, 245–52.