Comparison of cone-beam computed tomography and osteometric examination in preoperative assessment of the proximity of the mandibular canal to the apices of the teeth

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Abstract

The risk of postoperative neurosensory impairment after extraction of a third molar will be greater if the inferior alveolar nerve is in close proximity to the apices of the root. Precise preoperative evaluation of the relative positions of the nerve and the mandibular apices is important to protect the nerve from mechanical irritation. The aim of this study was to assess the accuracy of cone-beam computed tomography (CT) in the identification of the positional relations of the mandibular third molar and the inferior alveolar canal using Rood’s criteria.

Panoramic images of 10 dry hemimandibles were obtained, and 20 teeth each with one of Rood’s criteria indicating close relations to the mandibular canal were selected. Cone-beam CT images of the selected points were obtained. The closest distance between the apex of the root and the inferior alveolar canal was measured on cross-sectional cone-beam CT images. The same measurements were made on the corresponding osteometric sections with digital callipers. The intra-class correlation coefficient (ICC) was used to measure the consistency between the two measurements as the reference method, and showed that there was a high level of inter-rater agreement (r > 0.90). The mean (SD) deviation of cone-beam CT measurements from the gold standard osteometric measurements was small at 0.30 (0.24). There were almost perfect matches between cone-beam CT and gold standard measurements. Cone-beam CT is an accurate technique to measure the proximity of the mandibular apices to the alveolar nerve.

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Keywords: Cone beam computed tomography; inferior alveolar nerve; tooth root

Introduction

The inferior alveolar nerve (IAN) is one of the largest branches of the mandibular division of the trigeminal nerve, which originates from the mandibular foramen and passes through the body of the mandible in an anteroposterior direction in close proximity to the apices of the roots.1 A detailed knowledge of the anatomical relations between the tips of the mandibular roots and the IAN is crucial, because of its susceptibility to injury with subsequent neurosensory impairment, paraesthesia, or neuropathic pain during dental procedures such as root canal treatment, extraction of third molars, placement of dental implants, orthognathic surgery, and invasive procedures. The incidence of injury to the nerve during extraction of third molars has been reported to be 0.4% to 13.4%, and it has been suggested that the shorter the distance of the apex of the teeth from the nerve canal, the greater the prevalence of neurosensory disturbances.2 The distance between the nerve canal and apices of the roots is so small that it needs accurate measurement with an error of less than 1 mm.3
During recent decades various radiographic techniques have been proposed to help us further understand the anatomical proximity of the IAN and the apices of the roots.\textsuperscript{5,6} Cone-beam computed tomography (CT) allows 3-dimensional reconstructions of the maxillofacial structures with high resolution and no magnification, superimposition, or distortion.\textsuperscript{6,7} According to the European Commission guidelines, cone-beam CT should be used when a conventional radiograph suggests that there are close relations between the nerve and the apices, and 2-dimensional images provide inadequate information for planning treatment. Numerous studies have compared the diagnostic value of different conventional radiographic methods and cone-beam CT images for the relative position of the apices and the IAN.\textsuperscript{8–14} These have considered cone-beam CT images as the gold standard, and shown that they give a better idea of the position of the nerve canal than conventional radiographs. Despite this, some studies have reported that cone-beam CT is relatively inaccurate at predicting exposure of the neurovascular bundle in those highly selected exposures that shown close relations between the nerve canal and apices of the roots.\textsuperscript{15–18}

To the best of our knowledge there is little published information about the evaluation of the accuracy of cone-beam CT images in the assessment of the topographic relations between the nerve canal and the mandibular molars.\textsuperscript{4,5} The aim of the present study, therefore, was to compare the radiographic measurements with osteometric information for the assessment of the proximity of the interior alveolar canal to the mandibular molar apices.

**Material and methods**

**Sample selection**

The protocol for this pilot study was approved by the university’s ethics committee, and 10 dried dentulous hemimandibles fixed in formalin were used. Panoramic images in which close relations between the tooth and the mandibular canal were suspected were obtained using Planmeca ProMax (Helsinki, Finland) at 63 KV, 14 s, and 7 mA. Twenty points were chosen based on the criteria of Rood and Shehab\textsuperscript{19}: darkening of the root, interruption of the white line, diversion of the IAN canal, narrowing of the root, a dark and bifid root, narrowing of the IAN canal, and deflection of the root. The mandibles were scanned by the same clinician with a NewTom (NNT) VG cone-beam CT machine (QR-SRL, Verona, Italy) with the exposure factor set at 110 KVP, 2.04 mA, exposure time of 3.6 seconds, and a field of view of 8 × 12 cm.

**Cone-beam CT measurements**

The measurements were established on the reconstructed cross-sections of the mandible with slices 0.3 mm thick and the interval between slices 0.3 mm. The most apical point of the selected tooth was specified on these sections, and the minimum linear distance from the lowest point of the tooth to the inside edge of the bony boundary of the mandibular canal was measured using NNT viewer software with the accuracy of 0.1 mm (Fig. 1A). The cone-beam CT images were evalu-

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig1.png}
\caption{(A) Cross-sectional cone-beam computed tomographic image. (B) Diagram of a selected tooth. (C) Osteometric images of a selected tooth.}
\end{figure}
ated by two oral and maxillofacial radiologists concurrently, and they reached agreement in selecting the reference points to measure the minimum distance. The cone-beam CT images were measured again by the same observers, with a two-week interval between recording phases, to assess the significance of any errors during measurements.

### Osteometric measurements

After imaging, access cavities were prepared in the occlusal surfaces of the selected teeth. Numbers 10–20 K files were placed in the canals of these teeth to their radiographic apices and cemented to the most apical position with cyanoacrylate adhesive. We ensured that the anatomical and radiographic apices were at the location. The bone between the selected teeth was sectioned with a band saw. The adjacent bone was then ground down on the mesial half in a circular grinder (Rockwell Manufacturing Co, Pittsburg, PA, USA) until the endodontic files could be identified (Fig. 1B). This allowed the accurate sectioning of the roots in the long axis of the tooth to be sure that the same distances were measured using both techniques (Fig. 1C). The closest distance between the apex and the mandibular canal was measured by an observer who was unaware of the cone-beam CT measurements using Mitutoyo Adigimatic sliding callipers (Mitutoyo Ltd, Andover, UK) with an accuracy of 0.01 mm.

### Statistical analysis

The data were analysed with the help of PASW Statistics for Windows (version 18 SPSS Inc, Chicago, IL, USA). The results of the first and second series of measurements were compared using the interclass correlation coefficient (ICC) and the paired samples test to assess the inter-observer reliability of measurements. The ICC was also used to evaluate the consistency between the cone-beam CT and osteometric measurements. The paired t test with the acceptable 0.5 mm mean absolute error was also used to assess the significance of differences between the osteometric and radiographic measurements.

### Results

There were no significant differences between dual measurements (p = 0.56). The ICC showed that there was good intra-rater agreement (r > 0.90), so the mean of the first and second measurements was used in further analysis to minimise the error in the measurement of distances. Table 1 shows the the mean (SD) and range of the cone-beam CT and the osteometric measurements. The distances between the apices of the tooth and the IAN canal in the cone-beam CT and osteometric findings were 1.08 (1.25) and 1.33 (1.22), respectively. The mean absolute difference of the cone-beam CT measurements from the “gold standard” osteometric measurements was small at 0.30 (0.24), which was significantly less than 0.5 mm (p < 0.001).

### Discussion

Accurate preoperative assessment of the anatomical proximity of the roots of the mandibular teeth to the IAN canal is critical to reduce the risk of injury to the IAN. A standard validation method should be used to calculate the diagnostic accuracy of the radiographic techniques. Although some previous studies have used cone-beam CT findings as the reference standard for assessment of the accuracy of conventional radiographs in identifying the relations between the canal and mandibular teeth, other studies have shown controversial findings about the efficacy and diagnostic usefulness of cone-beam CT for this. Guerrero et al suggested that cone-beam CT images should not be used as the standard diagnostic tool for assessment of the relations because of their false positive and false negative findings, and Ghaeminia et al showed that it is no more accurate than panoramic radiography in predicting exposure of the nerve. We therefore planned the present study to compare the cone-beam CT findings with those of osteometric examination, to assess the accuracy of measurement, and to confirm its clinical efficiency and diagnostic value in identifying the position of the IAN canal to the apices of the roots.

The results of the present study were in line with those of some previous studies. Nasel et al compared the accuracy of measurements of length on the CT and magnetic resonance images with that of direct osteometry. Although the mean difference between dental CT scans and direct osteometry was reported to be 0.51 (1.91) mm, the authors found no significant differences in the accuracy for the different methods tested, but they did find a strong correlation among the three methods. In the present study the absolute mean difference between the cone-beam CT measurements and the osteometric measurements was 0.30 (0.24). This margin of error was neither statistically significant nor clinically relevant. In another study, Bou Serhal et al evaluated the accuracy of spiral CT for localisation of the mandibular canal, and concluded that it provided accurate information with sufficient details for operations on the posterior mandible. In an earlier study by Massey et al, in which they assessed the accuracy of linear measurements of micro-CT with higher resolution than we used for assessing the position of IAN, they found good consistency between measurements made with digital callipers and micro-CT, which is in line with our results.
We know of only two studies up to now that have assessed the accuracy of cone-beam CT in the region of the mandibular canal. Like us, Kamburoğlu et al found a high degree of accuracy of cone-beam CT in various measurements of distance around the IAN canal that were comparable with the direct measurements with the digital callipers. These findings were also in line with those of another study that found no significant difference between direct measurements by a Boley gauge and cone-beam CT measurements in calculating the distance between the apices of the posterior teeth to the IAN canal. The results showed that both measurement techniques were highly predictive of, and highly correlated with, each other. The authors therefore concluded that cone-beam CT can be used to measure the distances from the apices of the mandibular roots to the alveolar canal as accurately as direct anatomical dissection.

Several variables such as the accuracy of software measurements, the sensitivity of the mouse, the resolution of the cone-beam CT unit, the accuracy of the operator in the selection of reference points, and the small sample size, may profoundly influence the accuracy of the measurements of the present study, and this may affect extrapolation of these findings for clinical application. Ludlow et al suggested that the experience of the observer and professional status are important factors that influence the accuracy and reproducibility of cone-beam CT measurements. Both observers in the present study were experienced, and trained for interpretation of cone-beam CT images and measurement of distances.

The scanning position of the skull may also affect the accuracy of the cone-beam CT measurements, so all cadaver sections were placed in a phantom to have the Frankfurt plane parallel to the floor and consequently in a position as close as possible to the ideal head position. The need to select adequate spatial resolution also affects the evaluation of distances in cone beam CT images. In this study, minimum spatial resolution (0.3 mm) was chosen and it seems to be enough not to alter the accuracy of measurements. Massey et al recommended placing a marker on the mandible as the reference point in future studies to reduce the inaccuracies during the dissection and measurement stages of the study. We used K files in this study to ensure that the mandible was sectioned at the exact location indicated by the marker and also to ensure that the specimens were sectioned at the same site measured on the cone-beam CT images.

One of the limitations of this in vitro study was the use of dry skulls for measurement as the gold standard. We did this to make it as similar as possible to previous studies for assessment of the accuracy of cone-beam CT findings because there is no accurate, non-invasive method of assessing the proximity of the neurovascular bundles to the apices of the roots apart from cadaveric dissection. An in vivo measurement of the real distances is impossible for ethical reasons. We used the New Tom VGi cone-beam CT machine to evaluate the relative position of the canal and apices of the roots. However, the findings of one cone-beam CT system cannot be generalised to other systems because of the differences in resolution. Further studies using different cone-beam CT units are therefore recommended to confirm or refute our results. We evaluated only the supero-inferior anatomical position of the IAN canal in relation to the apices of the roots. Further investigations are required to provide more information about the accuracy of cone-beam CT in calculating the horizontal position of the apices of the roots relative to the IAN canal.

We conclude that the most important risk factor for damage to the IAN during dental procedures is the proximity of the canal to the apices of the roots. The risk of temporary damage increases when a close relation is obvious radiographically. We think that cone-beam CT is an accurate tool with which to make preoperative linear measurements of the proximity of the alveolar canal to the mandibular teeth.

Conflict of interest

We have no conflict of interest.

Ethics statement/confirmation of patients’ permission

The protocol was approved by the university ethics committee. No permission required.

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