Root canal assessment of mandibular incisors in an Indian population using cone beam CT

Aim: To assess the variation in root canal anatomy of mandibular incisors in an Indian population, using cone beam CT (CBCT).

Material and methods: A retrospective study of 130 Indian patients who underwent a CBCT (Orthophos XG-3D, Sirona, Germany) scan for implants were selected for assessment of variation in the root canal anatomy in the mandibular incisors. The canal configurations were categorised according to Vertucci’s classification. Two endodontists and an oral radiologist assessed the images, and the findings were recorded with respect to variation in anatomy, sex of the patient, side of the jaw, and type of incisor.

Results: Vertucci type I and type III configurations were more prevalent in both mandibular central and lateral incisors. A percentage of 53.1% males and 46.9% females were included in this study. Males showed a 56.5% incidence of single root canal and 12.5% of double root canal. Females showed a 52.25% incidence of a single root canal and 8.75% showed a double root canal. The right side incisors showed an 83.85% likelihood of cases with single root canal and double root canal in 16.15% cases. The left side incisors showed an 83.45% likelihood of cases with single root canal, and double root canal in 16.55% of cases. On average 54.6%, 6.9%, and 38.45% of central incisors showed type I, II and III respectively. With respect to the lateral incisors, an average of 52.3%, 5.8%, 49.5% showed type I, II and III respectively.

Conclusion: The CBCT scanner was able to detect these complex variations. This suggests that CBCT has potential as an auxiliary tool in the evaluation of mandibular incisors with complex canal morphology to improve the quality of root canal therapy.

Introduction

The success of root canal treatment depends on the accurate knowledge of the anatomy of root canal systems. Studies on the internal and external anatomy of teeth have shown that anatomic variations can occur in all groups of teeth and can be extremely complex. This applies to mandibular incisor teeth as well, as many dentists fail to recognise the presence of a second canal. Thus, failure in the root canal preparation of mandibular incisors happens mostly because dentists miss the presence of second and/or lateral canals. Several researchers have examined the root canal systems of mandibular incisors. Vertucci studied the root canal morphology of 300 extracted mandibular incisors and showed that two canals were present in 30% of mandibular central incisors. Pecora et al assessed the prevalence of mandibular
anterior teeth with two canals. This situation was encountered in 29.7% of 300 mandibular central incisors. Mauger et al. assessed the canal anatomy at different root levels in 100 mandibular incisors and reported that 98–100% of the teeth had one canal in the area situated 1–3 mm above the apex.

Knowledge of the anatomy of root canal systems is an essential prerequisite for performing endodontic treatment. Current knowledge of pulp space anatomy is based on research findings and individual case reports. Many studies have examined the root canal systems of mandibular incisors, but there is a lack of consistency in the reported prevalence of second canals in mandibular incisors. The differences may be related to study design (in vivo versus ex vivo), technique of canal identification (radiographic examination, sectioning and clearing) or to racial divergence.

It is important to be familiar with variations in tooth anatomy and characteristic features in various racial groups, since such knowledge can aid location and negotiation of canals, as well as their subsequent management. Additionally, a number of studies have shown different trends in the shape and number of roots and canals among the different races. These variations appear to be genetically determined and are important in tracing the racial origins of populations.

Cone beam computed tomography (CBCT) is one of the revolutionary diagnostic modalities introduced in the dental field. Three-dimensional anatomy can be perfectly visualised on CBCT images with a relatively low radiation dose. Hence this study was undertaken to assess the root canal morphology of mandibular incisors in an Indian population using CBCT.

The aim of the study was to assess the variation in the root canal anatomy of mandibular incisors in an Indian population by using CBCT, with the following objectives:

1. Variation in mandibular incisors anatomy according to Vertucci classification
2. Variation in anatomy in relation to sex of the patient
3. Variation in anatomy in relation to side of jaw
4. Variation in anatomy in relation to central or lateral incisors
5. To determine the prevalence rate of varying anatomy of canals.

### Materials and methods

A retrospective study was conducted to evaluate the root canals of mandibular anterior teeth by CBCT. Some 130 CBCT images were selected from the 3D Facial Imaging Center at Nashik, Maharashtra, India, between January 2012 and July 2012. All images were taken using Orthophos XG3D CBCT machines (Sirona, Bensheim, Germany) with image capture parameters set at 80 kV and 5.0 mA, and an exposure time of 14 s. The voxel size was 0.125 mm and the slice thickness was 1.0 mm, with a field of view of 5 × 5 cm. The field of view refers to the selected area of interest, which would be scanned by the machine. Samples of fully erupted permanent mandibular incisors were included.

The selected mandibular incisors each demonstrated fully developed apices and lacked root canal fillings, posts and crown restorations. The CBCT images of 130 mandibular incisors from 300 patients of Indian descent were analysed with in-built software (Gallelios viewer) using a Dell Precision T5400 workstation (Dell, Round Rock, USA). Axial, coronal, and sagittal two-dimensional sectional images were displayed on a 32-inch Dell LCD screen with a resolution of 1280 × 1024 pixels in a dark room. Two independent endodontists assessed the number of roots and canals, the position where canal bifurcation occurred and the canal configuration, to reach a consensus in the interpretation of radiographic findings. In cases where consensus was not reached, a third professional oral radiologist was asked to perform a decisive evaluation. The level of significance used was 5% and it was evaluated by Chi-square test.

The canal configurations were categorised according to Vertucci’s classification, as follows:

- **Type I**: a single canal extends from the pulp chamber to the apex
- **Type II**: two separate canals leave the pulp chamber and join short of the apex to form one canal
- **Type III**: one canal leaves the pulp chamber and divides into two within the root; the two then merge to exit as one canal
- **Type IV**: two separate, distinct canals extend from the pulp chamber to the apex
- **Type V**: one canal leaves the pulp chamber and divides short of the apex into two separate, distinct canals with separate apical foramina
Table 1  Mandibular central incisors frequency and percentage of root canal and Vertucci classification on the right and left sides.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Right side frequency</th>
<th>%</th>
<th>Sex</th>
<th>Left side frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Female</td>
<td></td>
<td>Male</td>
<td>Female</td>
<td></td>
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<tr>
<td>Single root canal</td>
<td>56</td>
<td>52</td>
<td>108</td>
<td>108</td>
<td>56</td>
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<tr>
<td>Double root canal</td>
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<td>9</td>
<td>22</td>
<td>22</td>
<td>13</td>
</tr>
<tr>
<td>Vertucci I</td>
<td>45</td>
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<td>74</td>
<td>74</td>
<td>39</td>
</tr>
<tr>
<td>Vertucci II</td>
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<td>4</td>
<td>12</td>
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<td>2</td>
</tr>
<tr>
<td>Vertucci III</td>
<td>16</td>
<td>28</td>
<td>44</td>
<td>44</td>
<td>28</td>
</tr>
</tbody>
</table>

Table 2  Mandibular lateral incisors frequency and percentage of root canal and Vertucci classification on right and left side.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Right side frequency</th>
<th>%</th>
<th>Sex</th>
<th>Left side frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Female</td>
<td></td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>Single root canal</td>
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<td>53</td>
<td>110</td>
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<tr>
<td>Double root canal</td>
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<td>12</td>
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<tr>
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<td>27</td>
<td>69</td>
<td>69</td>
<td>41</td>
</tr>
<tr>
<td>Vertucci II</td>
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<td>2</td>
<td>8</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Vertucci III</td>
<td>21</td>
<td>32</td>
<td>53</td>
<td>53</td>
<td>27</td>
</tr>
</tbody>
</table>

- Type VI: two separate canals leave the pulp chamber, merge in the body of the root, and redivide short of the apex to exit as two distinct canals
- Type VII: one canal leaves the pulp chamber, divides and then rejoins in the body of the root, and finally redivides into two distinct canals short of the apex
- Type VIII: three separate, distinct, canals extend from the pulp chamber to the apex

Results

A retrospective study on 130 CBCT images was conducted. A selection of 69 (53.1%) males and 61 (46.9%) females was included in this study (Tables 1 and 2).

Variation in mandibular incisors anatomy according to Vertucci classification

As depicted in Tables 1 and 2, Vertucci classifications I and III were more prevalent in both central and lateral incisors on both sides. Results showed that on average 53.45% of samples showed Vertucci type I, 6.35% of samples showed Vertucci type II and 40.2% showed Vertucci type III (Figs 1 to 3).
Variation in anatomy in relation to sex of the patient

A selection of 69 (53.1%) males and 61 (46.9%) females were included in this study. As depicted in Tables 1 and 2, a single root canal was seen commonly in both sexes, while a double root canal was more commonly seen in males compared with females in both incisors. Males showed a percentage of 56.5% with a single root canal and 12.5% of cases showed a double root canal. Similarly females showed a percentage of 52.25% with a single root canal and 8.75% cases showed a double root canal. There was no significant correlation found between two sexes with respect to variation in anatomy.

Variation in anatomy in relation to side of the jaw

With respect to number of root canals, the right side incisors showed a single root canal in an average 83.85% of cases, and a double root canal in 16.15% of cases. The left side incisors showed a single root canal in an average 83.45% of cases, and double root canal in 16.55% of cases. With respect to Vertucci classification, the right side incisors showed on average 55% type I, 7.7% type II and 37.3% type III. The left side incisors showed on average 51.9% type I, 5% type II and 43.1% type III.

There was no significant correlation found between the two sides with respect to variation in anatomy.

Variation in anatomy in relation to type of incisor

Tables 1 and 2 describe a variation in anatomy in relation to the central and lateral incisors. On average, 83.85% and 16.15% of cases showed single and double root canals respectively in the central incisors. On average 54.6%, 6.9% and 38.45% of cases showed type I, type II and type III classifications respectively in the central incisors (Fig 4).

In case of the lateral incisors, on average 83.45% and 16.55% of cases showed single and double root canals respectively in the lateral incisors. On average 52.3%, 5.8% and 41.95% of cases showed type I, type II and type III classifications respectively in the lateral incisors.
Discussion

Root canal anatomy is studied by both \textit{in vitro} and \textit{in vivo} methods. \textit{In vivo} methods include the clinical treatment of a tooth followed by radiographic evaluation of the root canal anatomy\textsuperscript{10-13}.

\textit{In vitro} methods include:
- direct observation
- microscopic observation
- macroscopic sectioning
- microscopic sectioning
- dyes
- filling and decalcification
- micro CT
- radiography
- contrasting media (Hypaque)
- cone beam computed tomography (CBCT).

It is generally accepted that many mandibular incisors have two canals, which may merge into one canal before reaching the apex\textsuperscript{14-16}. In rare cases, separate foramina may form. In a radiographic study of 364 specimens, Benjamin and Dowson\textsuperscript{16} reported that 41.4\% of the mandibular incisors they studied had two separate canals; of these, only 1.3\% had two separate foramina. In a study of 1085 specimens, Miyashita and others\textsuperscript{15} reported that only 3.1\% of the samples had separate canals and foramina. In a study of mandibular incisors in which a sections of the root were cut at 1, 2, and 3 mm from the apex, simulating a 20-degree beveled surgical resection, Mauger et al demonstrated that, at the apical 1, 2 and 3 mm levels in the mandibular incisor, the canal is only rarely separated by the hard tooth structure, and that only 2\% of the teeth they studied had two canals at the 1 mm resection level\textsuperscript{4}.

Cone beam CT is proving to be the third eye in the dental arena. With tooth anatomy being accessed in all dimensions, endodontic treatment has been simplified a lot. A retrospective study was conducted on 130 CBCT images, which included 69 males and 61 female patients. The results showed that in 53.45\% of cases, a single orifice was present in mandibular incisors, while in the remaining cases two canals were present. The results of the present study are similar to the study conducted by Madeira and Ernesto\textsuperscript{17}. In their study, 65.6\% of the mandibular incisors presented a single canal, whilst the rest contained two canals in different configurations. The results from this study present a higher frequency in occurrence of a second canal than that reported by previous studies\textsuperscript{13,17,18}.

A similar study conducted with the mandibular incisors of a Jordanian population showed a single
canal (73.8% of teeth possessed a type I canal system). Although 26.2% of the roots possessed two canals, only 8.7% had two separate apical foramina\textsuperscript{13}.

A study conducted by Boruah and Bhuyan\textsuperscript{18} in a north east Indian population concluded that mandibular incisors had a single canal (63.75% of teeth possessed a type I canal system). Although 36.25% of the roots possessed two canals, only 6.25% had two separate apical foramina\textsuperscript{18}. Lack of detection of the second canal usually leads to failure in endodontic treatment, presenting as periapical lesions and combined endodontic-periodontal lesions.

The Vertucci type I followed by type III configuration was the most prevalent among roots with two canals in the present study. Root canal instrumentation and filling are relatively accessible in type I and II morphology canals, because each canal emerges distinctly from the pulp chamber and can be located distinctively with the aid of the operating microscope. The type III group presents different situations, as the canals share the same space in some radicular areas and split in other zones. This requires adjustment and individualisation of root canal preparation and filling, in order to obtain the best results in endodontic treatment.

Scarlatescu et al\textsuperscript{19} recommended that the access cavity should therefore be extended in a cervical direction, in order to expose the lingual canal orifice, and the scouting should be made in both vestibular and lingual directions. They also mentioned that the South Eastern Romanian population had high failure rates with mandibular incisors because of anatomic variation.

Although no significant correlation was found in this study between gender and root canal, male patients had an increased number of double root canals than female patients. Similarly no significant correlation was found between variation in anatomy and side of jaw and type of incisor.

Cone beam computed tomography (CBCT) uses a cone-shaped beam instead of the fan-shaped one used by regular CT scanners. An outstanding review by Taylor et al\textsuperscript{20} reported on the many possible endodontic applications of CBCT. Simon et al\textsuperscript{21} reported that the CBCT might provide more accurate diagnostic information than biopsy and histology when evaluating large periapical lesions\textsuperscript{22}. The most frequent use of CBCT was for diagnosis of pathology, preparation for endodontic treatment or endodontic surgery, and for assistance in the diagnosis of trauma-related injuries in a survey conducted by Dailey et al\textsuperscript{23}.

Smaller scan volumes (small field of view) generally produce higher resolution images, and since endodontics relies on detecting disruptions in the periodontal ligament space measuring approximately 200 μm, optimal resolution is necessary\textsuperscript{24}.

Even in the statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology, the importance of using CBCT in the identification of potential accessory canals in teeth with suspected complex morphology based on conventional imaging and identification of root canal system anomalies and determination of root curvature was mentioned\textsuperscript{25}.

The application of CBCT has been suggested in these cases to provide a 3D confirmatory diagnosis without causing any tooth damage. It offers high resolution and is well suited for endodontic applications as a complement to conventional radiography. When uncertainty exists in the diagnosis of canal variations, or a change of shape/direction in the middle-apical third of the canal is detected, periapical radiography associated with CBCT can be used to determine or confirm the presence and location of canals. According to a study by Matherne et al\textsuperscript{22}, a greater number of root canals can be identified on CBCT images than by evaluations of phosphor-stimulated plates or charge-coupled device images.

**Conclusion**

Mandibular incisors in an Indian population exhibited high variability and complexity in their root canal systems. The management of endodontic problems is reliant on radiographs to assess the tooth anatomy and its surrounding structure. However, conventional radiography has inherent limitations, as the three-dimensional anatomy of the area radiographed is compressed into a two-dimensional image. CBCT scanning is of great value in detecting anomalous canal morphology when diagnosis by conventional radiography is not possible.
Radiography is inconclusive. This suggests that CBCT has the potential to be used as an auxiliary tool in the evaluation of mandibular incisors with complex canal morphology, and to improve the quality of root canal therapy.

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References