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Use of CBCT to Determine Morphological Differences of Mandibular Incisor Root Canal Anatomy: A Modified Classification System

Matthew B. Kinstler

INTRODUCTION:

Successful endodontic treatment is a multi-factorial process reliant on proper diagnosis, knowledge of morphology, access design, cleaning, shaping, adequate obturation and host response. The focus of this paper will be the knowledge and intricacies of morphology and access of mandibular incisors. Not knowing what to expect, or look for, when accessing a tooth can lead to missed canals, uninstrumented canal space, and inadequate obturation. On average, at least 35% of the canal surface area remains untouched with Ni-Ti preparations (1). This number becomes even higher when the canal was oval or flattened. Paque et al observed 60 to 80% untouched dentinal walls when the canal is oval shaped (2). Other studies have shown that uninstrumented canal surfaces will not be cleaned and disinfected as expected by conventional irrigation methods with Sodium Hypochlorite (3, 4, 5, 6). This is problematic, considering that persistent intraradicular infection is the most common cause of post-treatment apical periodontitis (7). In addition, uninstrumented areas of oval canals have been found more difficult to obturate, leading to a higher incidence of voids (8). With an association between unfilled volume in a canal and periapical lesion size, quality of obturation should be considered an important factor in endodontic outcomes (9).

Studies from 1965 to 2019, involving either clearing and staining or CBCT imaging, report the following percentages of one and two canals present in mandibular central and lateral incisors (10):

Mandibular central 1 canal: 32.5% - 96.2%
Mandibular central 2 canals: 3.8% - 67.5%
Mandibular lateral 1 canal: 36.8% - 89.4%
Mandibular lateral 2 canals: 10.6% - 63.2%

In 2017, a study of over 1000 Israeli patient CBCT scans found long oval shaped canals in 36.8% and 48.9% of mandibular central and lateral incisors, respectively (11). A majority of the CBCT studies on mandibular incisor morphology utilize the Vertucci classification system (13). Type 1, 2 and 3 Vertucci classes are often the most common configuration found in mandibular incisors (10, 11, 12). Type 1 is typically the most prevalent and the most likely to have an oval shaped canal (11). This wide variation in morphology and cross-sectional shape indicates the need for careful treatment planning using CBCT, modified access location and creation of a modified or novel classification system for mandibular incisors.

Straight line access has been a concept recommended and taught with molars and premolars for years but has not become the norm for anterior teeth. Traditional lingual access at or just above the cingulum for maxillary and mandibular incisors is still being taught at most dental schools despite the ability of newer restorative materials to esthetically restore access cavities. By completing traditional access on mandibular anterior incisors, not only is straight line access typically impossible, removal of important pericervical dentin and an increased likelihood for missing lingual canals/anatomy takes place (14, 15,16). Mauger et al found that in mandibular incisors straight line access is achieved 72% of the time through the incisal edge and facial to the incisal edge 28% of the time (14). A more facial/incisal access has been shown to improve obturation quality and preserve more structurally important coronal tooth structure compared to a traditional lingual access (16). Pericervical dentin is the dentin 4 mm coronal and 6 mm apical to the crestal bone and it helps transfer occlusal forces to the root. By removing this dentin there is an increased likelihood for catastrophic or snap off failure of an anterior tooth (14,15,16,17). This study will document the most ideal access location (facial/incisal/lingual) in order to achieve straight line access to the apical 1/3 through CBCT imaging.

The aim of this study was to evaluate mandibular incisors, using CBCT images, in order to 1) assess morphology (canal width, shape, incidence of missed canals and Vertucci classification), 2) identify ideal straight line access location (facial/incisal/lingual), and 3) present a modified Vertucci classification system to help guide initial access location.

MATERIALS AND METHODS:

This study was approved by the Institutional Review Board of Womack Army Medical Center, Fort Bragg, North Carolina. The principal investigator reviewed all images in a database of 100 CBCT images acquired on patients referred to Rohde Dental Clinic, the endodontic specialty clinic at Fort Bragg in North Carolina, a United States Army facility. All images were acquired between January 1, 2016, and June 30, 2022, following recommendations provided in the joint American Association of Endodontist/American Academy of Oral and Maxillofacial Radiology position statement on the use of CBCT imaging in endodontics.

A total of 200 mandibular lateral incisors and 200 mandibular central incisors were evaluated from 100 patients CBCT scans. CBCT images were acquired with a 3D Accuitomo 170 CBCT scanner (J Morita, Kyoto, Japan). All of the CBCT scans were standard resolution scans with a 40 × 40 mm LFOV volume at 90 kV and 7.0 mA. The approximate voxel size for these scans was 0.08 mm.

CBCT images were studied on i-Dixel 3D imaging software (J Morita; Kyoto; Japan) on a 23.8 in computer monitor with a resolution of 1920 x 1200 pixels (Dell Trinitron, Round Rock TX) under standard conditions (semi-dark room with constant light intensity) to view the images in the axial, sagittal, and coronal planes. All measurement were captured from the axial plane. Each measurement was taken three times and the average recorded.

The following information was recorded on an excel spreadsheet and analyzed:

1. The number of root canals
2. The type of canals using Vertucci classification for each mandibular central and lateral incisor
3. The width of the canals orifices at the CEJ

4. The width of the canal buccal-lingually at its widest point
5. Straight line access location (Facial, Incisal, Lingual)
6. Canal shape (the smallest diameter of the canal was measured for this purpose but not analyzed)
7. Missed anatomy on endodontically treated incisors

A strict method for case selection was applied with the following exclusion criteria:

- **1.** Teeth with previous endodontic treatment
- **2.** Teeth with crowns or restorative material blocking canal anatomy
- **3.** Teeth with pulpal canal obliteration
- **3.** Teeth with internal or external root resorption that modified canal morphology
- **4.** Teeth with poor CBCT image quality due to scatter, artifact or motion

RESULTS:

A total of 396 incisors were examined for this study from 100 patients' limited field of view CBCT scans. Overall, four mandibular incisors were missing from the patients' scans when they were analyzed which explains why 396 teeth were evaluated. Any previously treated incisors were used only for missed canal data, and not for canal width measurements or Vertucci classification. 17 teeth were excluded from the analysis due to heavy calcification.

Canal Width:
CEJ widths were submitted to a two-way ANOVA with two levels of tooth type (lateral incisor, central incisor). The main effect of tooth type was significant ($P = 0.01$) indicating the mean CEJ width for lateral incisors was larger than that of central incisors. Similarly, measurements of the widest canal widths were submitted to a two-way ANOVA with two levels of tooth type (lateral incisor, central incisor). The main effect of tooth type was significant ($P < 0.001$) suggesting the mean widest canal width for lateral incisors was larger than that of central incisors. The mean CEJ width in tooth #23, 24, 25, and 26 was 1.48 mm, 1.39 mm, 1.35 mm, and 1.48 mm, respectively. The mean canal width at its widest point in tooth #23, 24, 25, and 26 was 2.31mm, 1.84mm, 1.82mm, and 2.28mm, respectively. The largest long oval canal in this study was 3.6 mm wide, facio-lingually.

Table 1- The average CEJ width for #23/#26 and #24/#25

Tooth	N	Mean	Standard Dev.
23	79	1.48	0.38
26	87	1.48	0.35
24	69	1.39	0.37
25	67	1.35	0.38

Table 2- The average widest width for #23/#26 and #24/#25

Tooth	N	Mean	Standard Dev.
23	79	2.31	0.73
26	87	2.28	0.66
24	69	1.84	0.59
25	67	1.82	0.56

Canal Shape:
Canal shape incidence rates were as follows: circular 17.9%, oval 31.8%, and long oval 50.3%.

Vertucci Classification:
Vertucci classifications included Type 1: 48.6% (n=147), Type 2: 0.06% (n=2), Type 3: 45.4% (n=137), Type 5: 5% (n=15), and Type 7: 0.03% (n=1).

Missed Anatomy:
There were a total of 75 previously treated teeth in the study. Of these teeth, 55% (n=41) presented with missed canals (40 missed lingual canals and 1 missed facial canal).

Straight Line Access Location:
Straight line access locations were facial: 28.5% (n=86), incisal: 69.9% (n=212), and lingual: 1.6% (n=4).

DISCUSSION:

80% of the root canal systems in this study were found to be oval or long oval and 94% of the canal systems were either Vertucci Type 1 or Vertucci Type 3. Over 50% of the incisors had two canals. Although Vertucci Type 1 morphology, by definition, is only one canal, this can be misleading if an oval or long oval shaped canal is present. An oval canal is defined as a canal that has a diameter that is two times greater than the minimum diameter, while a long oval canal has a diameter two to four times greater than its minimum diameter (18). There is a high propensity of Vertucci type 1 mandibular incisors to have oval or long oval canals (11), which was confirmed in this study. Oval and long oval canals should be treated differently than circular canals in order to maximize process centered and patient centered outcomes.

The mean greatest widths of mandibular incisor canals in this study were 1.5-3x larger than the maximum flute diameter of some of the most popular rotary files in use today. The use of pre-bent hand files and straight-line access should be practiced as they can help facilitate cleaning and leave less walls untouched. These canals should be treated as multiple canals or considered to have multiple “points of negotiation”. Not doing so leads to more untouched anatomy, left behind pulpal remnants and bacteria, making quality obturation more difficult (2,3,4,5,6,8,19). The widest widths of these canals almost always occurred in the middle 1/3 of the root, including teeth that were Vertucci type 3 where the canal was the largest right before it split into a buccal and lingual path.

Straight line access should be the goal for mandibular incisor endodontic therapy and ideally taught in dental schools, as well as endodontic residencies. In this study, 98.4% of the time, straight line access was either through the incisal edge or facial to the incisal edge. This finding is in close agreement with Maugers study that showed 100% of the time straight line access was through the incisal edge or facial to it (14). There must be an artful balance of removing just enough tooth structure to complete the endodontic treatment adequately while preserving pericervical dentin to minimize future structural failure. Straight line access on mandibular incisors allows you to navigate that tight rope with the proper balance of tooth removal and access to the canal system.

There is a high propensity to miss lingual canals in mandibular incisors. All 75 of the previously treated teeth had a traditional lingual access that was at or close to the cingulum, and 53% had a missed lingual canal. Straight line access is vital in these teeth to preserve pericervical dentin since these are already relatively small and thin teeth. A traditional lingual access increases the likelihood of iatrogenic mistakes like gouging, perforating or missing canals. With contemporary esthetic restorative materials, it is no longer necessary to "hide" the access on the lingual surface of the tooth. This is not a new concept. Clinicians started recommending a labial or incisal access for mandibular anterior teeth almost 40 years ago to help increase the endodontic success rates in these teeth (20). Neo and Chee in 1990 discussed how missed lingual canals in mandibular incisors are not an uncommon finding and there is a need to have an appropriate access with a proper incisal extension (21, 22).

We are advocating the use of a straight-line access indicator that can be added to the Vertucci classification. The straight-line access indicator would be F (facial), I (Incisal), or L (Lingual). For example: Vertucci type 3^{F}. It is firmly believed that this access indicator can help clinicians better plan and orchestrate successful endodontic treatment on mandibular incisors with less iatrogenic mistakes, missed canal anatomy and improved obturation of canals. This is an appropriate classification system to implement with the use of CBCT imaging.

Some pitfalls of the study include the use of arbitrary locations in the canal where the clinician reading the CBCT had to decide where the largest and smallest widths occurred. The prior probability of a previously treated tooth presenting to an endodontic residency with a problem, like missed anatomy, is higher than would be expected in the general population. There is an opportunity for future studies looking more closely at the incidence rate of missed canals in mandibular incisors. There are plenty of CBCT studies on missed MB2 canals but very few on the incidence of missed lingual canals in mandibular incisors.

In conclusion, an incisal or facial approach is recommended when accessing mandibular incisors due to their oval shape and high probability of possessing two canals. Adding a straight-line access designator to Vertucci's classification system for mandibular incisors may help encourage adequate cleaning, shaping, and obturation of these canal systems. The straight-line designator may also help reduce iatrogenic errors and preserve pericervical dentin.

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