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Prevalence of C-shaped Canals and Three-rooted Mandibular Molars Using CBCT in a Selected Thai Population

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ABSTRACT

Introduction: C-shaped canals and three rooted mandibular molars are challenging to treat. These anatomies are commonly found in mandibular molars, especially in the Mongoloid population. However, there is no report on these anatomies using cone-beam computed tomography on all three mandibular molars in Thais. The objectives of this study were to determine the prevalence of C-shaped canals and three-rooted mandibular molars in Thais and investigate whether there is a relationship between these morphology and gender. **Methods and Materials:** Three pre-calibrated observers independently determined the presence of each anatomy using a specific protocol in 753 molars from cone-beam computed tomographic images. The three observers randomly re-evaluated 20% of the samples to determine inter- and intra-observer agreement using Cohen's Kappa statistic. The relationship of these root canal anatomy with sex was analysed by the Chi-square test. **Results:** The prevalence of C-shaped canals and three-rooted molars was 0.39% and 12.1%, 42.4% and 3.9%, and 16.6% and 9.1% in first, second, and third mandibular molars respectively. The inter-/intra-observer reliability of the results was extremely high. **Conclusion:** This cross-sectional study showed the prevalence of C-shaped canals in mandibular second molars was relatively high and should be considered normal root canal anatomy in Thais. The prevalence of three-rooted molars was highest in first molars and frequently found in third molars. Cone-beam computed tomography was a reliable technique to determine root canal anatomy.

Keywords: Cone-beam Computed Tomography; Molar; Prevalence; Root Canal Therapy; Tooth Root

Introduction

Non-surgical root canal treatment is typically successful [1]. The procedures eliminate the microorganism that are the main cause of pulp and periapical diseases [2]. Undetected canals and canals that are not fully cleaned due to their complex anatomy play an important role in root canal treatment failure [3]. To provide a successful treatment outcome, clinicians must thoroughly understand the complexity and variations in the root canal morphologies of the treated tooth.

A C-shaped root canal presents anatomical challenges, such as difficulty in locating the canal, because its orifice is below the cemento-enamel junction [4], different types of pulp chamber floors [5], and complicated root canal systems (fin, slit, and web) [6]. The apical anatomy of a C-shaped canal is remarkably complex with many anatomical variations [7]; thus, using an electronic apex locator is mandatory for precise working length determination [8]. C-shaped root canal cleaning and shaping procedures need to be carefully performed. Preparation in thinner dentin areas should be limited without compromising root canal system disinfection. Additional irrigation protocols and specific obturation techniques are required with these canals [9].

Three-rooted molar (radix entomolaris, where an additional root is present distolingually, and radix paramolaris, which is

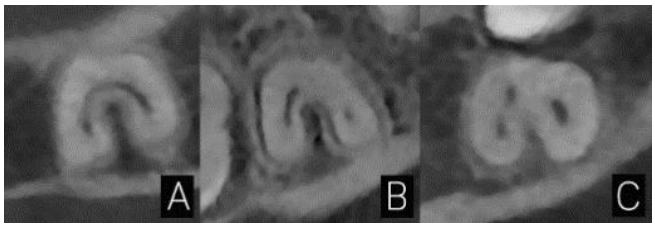

Figure 1. Axial view of a representative CBCT image of mandibular molars with a fused root with a C-shaped canal; *A*) C1: a continuous C with no separation or division; *B*) C2: the interrupted C resulted in semicolon; *C*) C3: three separated canals

located mesiobucally) [10] treatment often results in untreated canals because some canals present as a very small extra root that may not be observed in routine periapical radiographs. The distolingual canal orifice is located disto-to mesio-lingually from the main distal canal [11], which does not correspond to the law of symmetry [12]. Furthermore, root canal preparation in a distolingual root is technically challenging due to severe canal curvature and curving in more than one dimension [13] .

Identifying the presence of these variations could decrease the number of unidentified canals and allow clinicians to select suitable treatment techniques for these complicated root canal morphologies. This could result in improved endodontic treatment outcomes.

Conventional radiographs provide two-dimensional images, thus, visualization is limited to a specific view. In contrast, cone-beam computed tomography (CBCT) generates three-dimensional images that can be observed in multi-views. Furthermore, the superimposition effect on conventional radiographs is eliminated. Root canal anatomic studies using CBCT technology in mandibular molars have been performed in different geographic locations including Europe [14-16], America [16, 17], and Asia [16, 18-25]. Due to methodological advancements, a higher prevalence of C-shaped canals was found [21, 22]. C-shaped canals were mostly found in East Asians (Chinese [16, 18, 22] and Koreans [19]) ranging from 38.6-44%.

Almost two decades ago, the Southeast Asia population was redefined as Southeast Asian rather than Australo-Melanesian with an intermixture of Mongoloid people who migrated from the northern area [26]. C-shaped root canals and three-rooted molars are commonly found in mandibular molars, especially in the Mongoloid population [6]. Currently, there are 3 studies that investigated C-shaped and/or three-rooted molars either one or both in extracted mandibular molars in a Thai subpopulation [27-29]. Forty years after the original study, the increased Mongoloid traits in Thais and the development of CBCT may increase the prevalence of these anatomies in Thais.

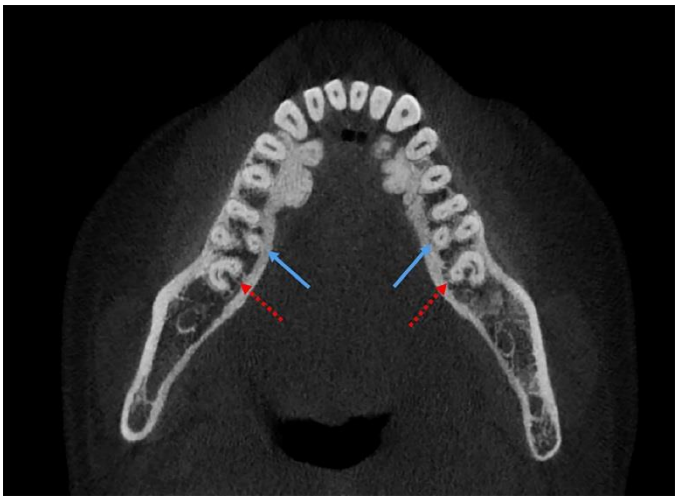

Figure 2. Axial view of a representative CBCT image of mandibular molars with a fused root with a C-shaped canal (dotted red arrows) and the additional root of a three-rooted molar (blue arrows). Bilateral three-rooted first molars and C-shaped canals were seen in the second molars

Furthermore, there is no report of these anatomies in Thai mandibular molars using CBCT in non-extracted teeth. The only study that used CBCT to investigate the anatomic variations in a Thai population was limited to maxillary molars [30]. Therefore, the objectives of this study were to determine the prevalence of C-shaped canals and three-rooted molars and investigate the correlation of these anatomies with sex in Thais using CBCT.

Materials and Method

Sample collection

The study protocol was approved by the Human Research Ethics Committee, Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2017-043). The CBCT images were from patients who required CBCT as a part of their dental diagnosis and/or treatment. The CBCT images were taken by an oral and maxillofacial radiologist (RA) at the Department of Radiology, Faculty of Dentistry, Chulalongkorn University between January 2014 and December 2016. The sample inclusion criteria were being a Thai patient (recorded in the dental chart), with at least one mandibular molar, and good quality CBCT images without artefacts. The exclusion criteria were teeth with open apices, root resorption, calcification, or root canal treatment. A 3D Accuitomo CBCT machine (J. Morita Manufacturing Corp, Kyoto, Japan) was used in this study. The radiographic parameters were adjusted according to the patients' size and treatment (90 kVp, 5-8 mA, 17.5–30.8 sec exposure time, field of view 4×4 and 17×12 cm and voxel size (0.08-0.25 mm^3).

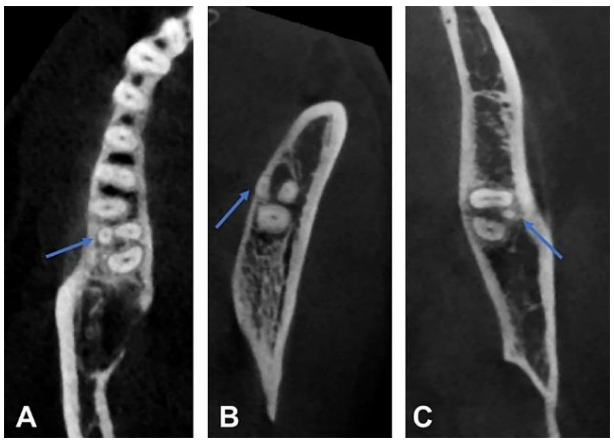

Figure 3. Axial view of a representative CBCT image of mandibular molars with an additional mesio-buccal root of a three-rooted molar (blue arrows); the additional roots are seen as fully developed roots (A, B) or a small appendix (C)

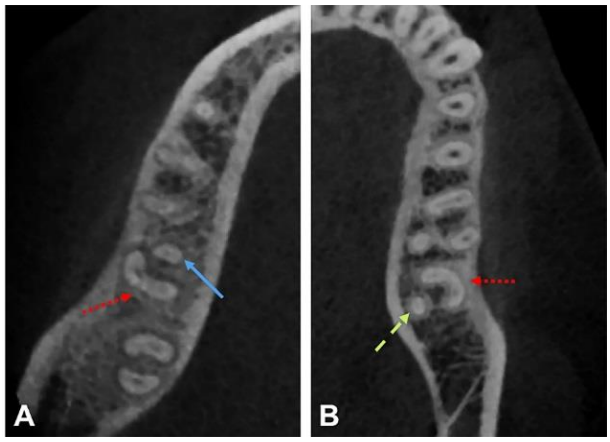

Figure 4. *A*) A mandibular right second molar with a fused-root canal system (red dotted arrow) and an additional mesio-lingual root (blue arrow); *B*) A mandibular left second molar with a fused-root canal system (red dotted arrow) and an additional disto-lingual root (green dashed arrow)

Root canal anatomy identification protocol

Three observers (Endodontist [EN], RA, and an undergraduate dental student) were calibrated for software management by the RA and image determination by the EN before image evaluation. The following protocol was used to identify the root and root canal anatomy: multi-planar reconstructed images were displayed on a diagnostic monitor screen (JVCKenwood Co., Yokohama, Japan) using Infinitt® PACS software (Infinitt Healthcare Co., Seoul, South Korea). The density and contrast of the images were adjusted using the image processing tools in the software to maximize image clarity. The tooth to be evaluated was set in an up-right position in corrected sagittal and coronal views. The axial plane was then set at the root canal orifice level. The axial images were consecutively observed to the root apex. Any tooth with a cross-sectional fused-root root canal anatomy was classified as C1 (uninterrupted C), C2 (semicolon) or C3 (two or three separated canals) as described by Fan *et al.* [4] was considered a C-shaped canal (Figure 1). Whereas, any tooth evaluated along the occluso-cervical direction from the CEJ to the root apex in axial sections with an additional root to the mesial and/or distal roots was considered a three-rooted molar. A representative image of a three-rooted molar and C-shaped canal is seen in Figure 2. If a definite identification could not be made based on the axial sections, other planes were used to identify the fused-root area or additional roots to confirm the lack of these structures in the axial view. The three observers independently evaluated the CBCT images. The presence or absence of C-shaped canals and three-rooted molars was judged by the majority among the three investigators. Two weeks after the evaluation, the three observers randomly re-evaluated 20% of the samples to determine inter and intra-observer agreement.

Statistical analysis

The relationship of these anatomies with sex was analysed by the Chi-square test. Cohen's Kappa statistic was used to determine the intra-examiner and inter-examiner reliability.

Results

Two hundred and eighty-five CBCT series were obtained, however; only 248 cases met the inclusion criteria. These cases comprised 111 males and 137 females, aged 15-79 years old, with a mean age of 45 years old. The evaluated teeth comprised 256 first molars, 311 second molars, and 186 third molars. The Kappa scores for the intra- and inter-examiner agreement ranged from 0.937-0.973 and 0.972-0.983, respectively. The prevalence of each anatomy classified by sex is shown in Table 1. Three-

Table 1. The prevalence of C-shaped canals and three-rooted molars classified by sex

	N	First Molar [N=256 (100%)]		Second Molar [N=311 (100%)]		Third Molar [N=186 (100%)]	
		C-shaped canal	Three-rooted	C-shaped canal	Three-rooted	C-shaped canal	Three-rooted
Females	137	1 (0.39%)	18 (7%)	91 (29.3%)*	7 (2.3%)	24 (12.9%)*	7 (3.8%)
Males	111	0 (0%)	13 (5.1%)	41 (13.2%)	5 (1.6%)	7 (3.8%)	10 (5.4%)
Total	248	1 (0.39%)	31 (12.1%)	132 (42.4%)	12 (3.9%)	31 (16.7%)	17 (9.1%)
***P*-value**		0.32	0.288	<0.0001	0.873	0.007	0.217

**Indicates a significant relation between C-shaped canal prevalence and females*

rooted molars were most prevalent in the mandibular first molar (12.1%), while C-shaped root canals were most commonly found in mandibular second molars (42.4%). Among the three- rooted molars evaluated, 57 teeth had an additional distolingual root and 3 teeth had an additional mesio-buccal root (Figure 3). Only 2 teeth exhibited a fused-root canal system and additional root, both of which were second molars (Figure 4). The Chi-square test demonstrated a relation between C-shaped root canals and second and third mandibular molars in females ($P<0.01$).

Discussion

The present study determined the prevalence of C-shaped canals and three-rooted molars and investigated the relationship of these anatomies with sex in Thais using CBCT. The results indicated that the prevalence of C-shaped canals in mandibular second molars was relatively high, especially in females and should be considered normal tooth anatomy in Thais. Moreover, the presence of a third root was detected in all three molars, however, the prevalence in the second molars was quite low.

Mandibular first molar

A three-rooted molar was most commonly found in this tooth, which is comparable to a previous Thai population study (12.7%) [28]. However, our findings were slightly lower than that in another study (19.2%) [27]. According to a previous systematic review, an additional root should be considered a normal anatomic variation in Mongoloids [31].

Our study found only one (0.39%) first molar with a C-shaped root canal. A previous study of Indian extracted teeth evaluated using spiral computed tomography also found one (0.94%) C-shaped root canal among their samples [32]. Furthermore, two other cone-beam compute tomographic studies found 0–1.7% [17, 33]. Thus, a C-shaped canal in a mandibular first molar can also be present in Thais.

Mandibular second molar

A C-shaped root canal system was most commonly found in this tooth, which was four-fold higher compared with a previous Thai subpopulation report (10%) [28]. This prevalence was in the same range as for Chinese (38.6%) [22] and Korean (44.5%) populations [34]. This may be because Thais, Chinese, and Koreans share a common racial background, and Thais have been increasing in Mongoloid traits during the past twenty years. Another study reported the prevalence as 8.83% [29], the difference may be due to the different subpopulation, which was a population inhabiting the Northeastern region of Thailand. There was a relationship between the prevalence of C-shaped root canals in the second and third mandibular molars in females, which is in agreement with a systematic review and meta-analysis that founds lower odds of a male having a C-shaped canal [35].

The prevalence of three-rooted molars in our study was also approximately four-fold higher compared with a previous Thai study (1.2%) [28]. In contrast, this anatomic variation is less common in Korean (0.7%) [13] and Chinese (1.27%) populations [21].

The combination of a fused-root and additional root in the same tooth results from disturbances in Hertwig's epithelial root sheath function that affect both root shape and number. Although this combination is rarely found, it makes the root canal treatment procedure more complicated. These results indicate that clinicians should always search for an extra located either distolingually or mesiobuccally in teeth that exhibit C-shaped canals.

Mandibular third molar

We found that the prevalence of both anatomical variations were higher compared with a previous report in a Thai population (1.15% for three-rooted molars, 10.9% for C-shaped canals) [28]. The different prevalence's of both anatomies in the three teeth between ours and other studies may come from differences in the type and number of samples, ethnicity, methodologies, changes in traits over time.

There are various methodologies for studying root canal anatomy, including clearing [28], sectioning [12], radiographs [36, 37], spiral computed tomography [32], micro-computed tomography [38], and CBCT [14, 21, 22, 39]. Our study used CBCT because it is non-invasive and the images can be seen in multiple planes with acceptable resolution while reducing superimposition effects. Importantly, sample integrity was preserved. An additional root that presents as a small appendix may break during extraction and thus be excluded, resulting in an inaccurate determination of the three-rooted molar prevalence in studies associated with extracted teeth. CBCT provides axial images for identifying these anatomies. Although this data can also be obtained using sectioning and micro-CT, the use of these techniques is limited because they require tooth extraction [12, 38].

The sample size in the present study was twice that used in previous studies in a Thai population and was adequate for this study according to our sample size calculation for an infinite population proportion [40] using the results of Gulabivala *et al.* [28] as an estimate of the prevalence of Thai C-shaped root canals and three-rooted molars. Care should be taken when

providing dental treatment to these teeth. Not detecting an additional root may result in endodontic treatment failure and complications during tooth extraction. Identifying these variations will improve endodontic treatment outcomes. CBCT using a specific identification protocol was an effective and reliable method for studying tooth anatomies either for an experienced endodontist/radiologist or undergraduate dental student. The prevalence of dental anatomies related to traits should be evaluated in every country after an appropriate period of time, especially in populations with a growing racial and ethnic diversity.

Conclusions

This cross-sectional study showed the prevalence of C-shaped canals in mandibular second molars was relatively high, especially in females and should be considered normal tooth anatomy in Thais. Clinicians should be aware that there is a 42.4% chance of having a C-shaped canal in this. However; the presence of a three-rooted molar in the first and third molars cannot be ignored.

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Conflict of Interest: 'None declared'.

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