

# Cone Beam Computed Tomography – Assisted Morphological Analysis of Mandibular Second Molar's Root Canals of Thai Subpopulation

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## Abstract

The aim of this study was to determine root canal morphology of mandibular second molars of Thai subpopulation in northeastern Thailand by using Cone Beam Computed Tomography (CBCT). A total of 215 extracted mandibular second molars were scanned by using CBCT. After three-dimensional reconstruction of the teeth, all studied teeth were subsequently analyzed by WhiteFox Imaging 3.0 computer software. Root canal morphology was categorized by using Fan's classification and a cross-sectional radiography of canal configurations were investigated at 4 levels of the root canals. Nineteen of 215 mandibular second molars (8.83%) were identified as C-shaped molars as determined by Fan's classification. Among C-shaped molars, C1-C5 configurations were detected along root length, despite the highest incidence of C1 (55.50%) at the orifice level. An apical root canal configurational change was found in 6 of 19 teeth (31.57%). Half of non C-shaped molars exhibited two root canals in mesial root with varying number of root canal openings, while the majority of distal roots displayed one root canal with one opening at the apex. In conclusion, we reported a relatively low incidence of finding C-shaped molars in Thai population, despite a high incidence among Asians. Normal anatomy and variations of root canal morphology should necessarily be taken into an account when performing an endodontic treatment in multi-rooted tooth. CBCT is a useful diagnostic tool that might help identify root canal configuration and facilitates clinical procedures.

**Keywords:** Mandibular second molar/ Cone Beam Computed Tomography/ C-shaped canal/ Root canal morphology

## Introduction

The ability to thoroughly clean a complex root canal system is a key to success of root canal treatment. In addition, the use of irrigating solutions in combination with mechanical instrumentation of the root canals help eliminate resident microbes.<sup>1</sup> Root canal configuration is thus a crucial factor that endodontists should be aware of during the entire treatment procedure.

Previous study has first reported a variation of root canal system in mandibular second molars so called C-shaped canal<sup>2</sup>, in which the fusion failure between buccal or lingual Her twig's epithelial root sheath results in the fused root canals.<sup>3</sup> The prevalence of C-shaped

canals in mandibular second molars ranges between 2.7% to 7.6% in Caucasians.<sup>2,4</sup> This prevalence increases in Mongoloid and Middle Eastern population i.e. among Saudi Arabian and Lebanese population, C-shaped canals were reported in 10.6 and 19.14 % in mandibular second molars, respectively.<sup>5,6</sup> Interestingly, the reported prevalence has shown that, among Eastern Asian population, C-shaped canals were found at 31.5 and 32.7% in Chinese and South Korean indigenous population, respectively.<sup>7,8</sup> It is therefore likely that the existence of C-shaped canals in lower second molars might show an increasing trend in Southeastern

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population. However, a previous study in Thai population living in the capital city has found that 10 and 11% of mandibular second molars and third molars displayed C-shaped root canal configurations, respectively.<sup>9</sup>

Numbers of studies have extensively shown the variable incidence of having C-shaped canal configurations in lower molars among different ethnicities.<sup>2,4-17</sup> Notably, the findings of C-shaped canals derived from several studies in the culturally-matched population have revealed varying prevalence of C-shaped mandibular second molars.<sup>7,11,13,14,17</sup> The resultant discrepancy between studies is likely contributed by the different methods used in experimental execution and number of examined teeth. Since cone-beam computed tomography (CBCT) has been introduced to the dental field, it has been used quite extensively due to its superiority to two-dimensional radiographs. CBCT technology has allowed a three-dimensional imaging of maxillofacial skeletons virtually possible, and a subsequent data analysis by means of multiplanar reconstruction has rendered the use of CBCT in dentistry clinically beneficial.<sup>18</sup> Comparing with a conventional periapical radiography, computerized tomography has demonstrated a precision and geometric accuracy with less amount of distortion, suggesting its potential use as a diagnostic aid.<sup>19</sup> The application of CBCT in endodontics also includes its feasibility of being used in both *in vivo* and *ex vivo* identification of additional canals in maxillary molars in numbers of reports.<sup>20-23</sup>

Remarkably, CBCT scan has revealed significantly more prevalence of C-shaped canals in mandibular second molars in Chinese<sup>13,14</sup>, relative to that of an earlier study using a tooth clearing technique.<sup>7</sup> CBCT might hence offer a better sensitivity, as well as accuracy, for detecting variations of root canal morphology particularly in mandibular second molars.

The objective of this study was to determine the prevalence of C-shaped canals in mandibular second molars of population inhabiting in the northeastern region of Thailand by using a CBCT, as well as to examine root morphology of non C-shaped canals in mandibular second molars. Despite the reported prevalence of mandibular second molars with C-shaped canals in a specific group of Thai<sup>9</sup>, whether the prevalence remains constant throughout the population needs to be elucidated. With the aid of CBCT technology, our data might provide critical information of root canal morphology and support the notion of variability of root canal configuration in lower second molars with distinct prevalence among heterogenous, studied population.

## Materials and Methods

This cross-sectional study was conducted by using CBCT to evaluate 215 extracted mandibular second molars for detecting whether each tooth displayed C-shaped canal configurations. All tooth specimens were randomly collected, without restrictions of donor's age and gender, from 20 hospitals located in the Northeastern Thailand. The teeth were specifically collected from patients whose nationality is Thai. The study was reviewed and approved by the Khon Kaen University Ethics Committee for human research based on the declaration of Helsinki and the dismissal of the consent was also approved by the Khon Kaen University Ethics Committee. All teeth must exhibit all of the following inclusion criteria:

1. Mandibular second molars extracted owing to orthodontic purposes or excessive loss of tooth structure.
2. Complete root formation without the presence of fractured root
3. No history of root canal treatment and/or restoring with root-reinforced materials i.e. dental post
4. Pulpal exposure was acceptable but the integrity of pulpal floor must be remained.

Teeth were stored immediately in 10% formalin solution after extraction and soaked in 5.25% sodium hypochlorite to disinfect the specimens upon arrival to the research facility. Gross cleaning was performed by using surgical blade no. 15 in combination with an ultrasonic scaler and rinsed with normal saline solution prior to mounting on a polyethylene foam sheet in which the teeth were pooled and stabilized for the ease of CBCT scanning.

Ten collected mandibular second molars were embedded on a 10 x 12 cm<sup>2</sup> foam sheet in an upright position. Radiographic scanning was performed using CBCT machine (White Fox, de Gotzen® S.r.l., Italy) with specific setting parameters: dental arch size of 120 x 80 mm<sup>2</sup>, voxel size of 500 micrometers, and 9-second exposure time. The CBCT images were then transferred to WhiteFox Imaging 3.0 Software for the analysis of root canal morphology to determine 1) number of root canal and its configuration by using methods classified by Fan et al. for C-shaped canal<sup>24</sup> and by Vertucci for non C-shaped canals<sup>25</sup> and 2) prevalence of finding C-shaped canals in mandibular second molars and 3) percentage of configuration change in root canals of mandibular second molars with C-shaped canals. Canal evaluation was performed at 4 different anatomical levels: 1) canal orifice, 2) coronal 1/3 of the root, 3) middle 1/3 of the root, and 4) apical 1/3 of the root. Briefly, Fan et al. classified C-shaped root canal depending on its shape into 5 categories<sup>24</sup> as demonstrated in Fig. 1 C1, uninterrupted “C” with no separation or division; C2, semi-colon; C3, two to three separate canals; C4, one round-shaped canal in the middle of the root; and C5, no observed root canal. In addition, Vertucci also classified the configuration of human tooth roots into 8 groups as follows:

1. Type I – one single root canal.
2. Type II – two separate canals coronally that fuse to one canal apically.
3. Type III – one canal that branches to 2 canals limited in the middle root level.

4. Type IV – two canals present in the root.

5. Type V – one canal that bifurcates at the middle or apical region.

6. Type VI – Two separate canals with two apical openings but fused to one canal in the middle of the root.

7. Type VII – one single root canal that bifurcates at the middle and apical region with the presence of 2 canal openings.

8. Type VIII – Three root canals present in the tooth root.

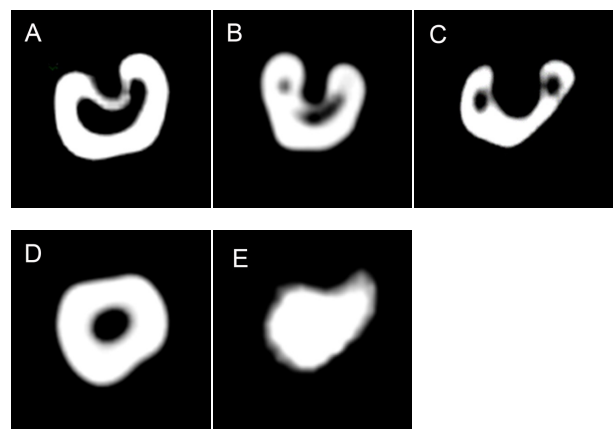


**Figure 1** CBCT images of mandibular second molars categorized by Fan's classification. A,C1. B,C2. C,C3. D,C4. E,C5 configuration.

## Results

Our results analyzed from 215 extracted mandibular second molars have shown that the prevalence of finding C-shaped canals was 8.84% (19/215) shown in Table 1. However, non C-shaped mandibular second molars which were accounted for 91.17% of studied teeth (196/215) exhibited diverse canal configurations. With respect to the orifice of C-shaped canals, the most prevalent configuration found was C1 morphology as determined by Fan's classification<sup>24</sup>, while the minority of the canal orifices displayed C3 and C4 in Fig. 2 Interestingly, the percentage of C1 configuration at canal orifice decreased toward root ends, indicating an apical change of canal

configuration in mandibular second molars. It is also worth noting that root canal morphology at the apical 1/3 region did not exhibit the C2 configuration. Thus,

physical anatomy of mandibular second molar consists of a complex root canal system, and likely differs at distinct root sites of the root.

**Table 1** Prevalence of C-shaped and Non C-shaped mandibular second molars in Thai subpopulation

| Root canal configuration | Percentage of finding <sup>*</sup> |
|--------------------------|------------------------------------|
| C-shaped                 | 8.84% (19/215)                     |
| Non C-shaped             | 91.16% (196/215)                   |

<sup>\*</sup> Number in parenthesis indicates proportion of interested findings.

**Table 2** Percentage of C-shaped mandibular second molars either with or without a changed canal configurations

|                               | Percentage of teeth with C-shaped canal <sup>†</sup> |
|-------------------------------|------------------------------------------------------|
| Uniformed canal configuration | 68.42% (13/19)                                       |
| Canal configuration changed   | 31.57% (6/19)                                        |
| • Orifice to coronal level    | 26.31% (5/6)                                         |
| • Coronal to middle level     | 21.05% (4/6)                                         |
| • Middle to apical level      | 5.26% (1/6)                                          |

<sup>†</sup> Number in parenthesis indicates proportion of teeth with selected feature of interest.

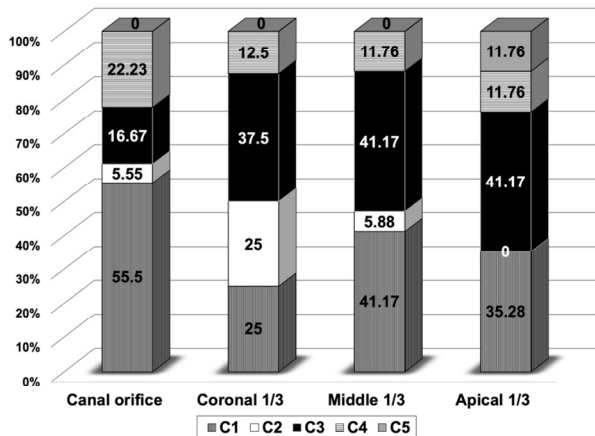


**Figure 2** Percentage of root canal configurations present at different locations of C-shaped root.

Among C-shaped canals of mandibular second molars, 68.42% (13/19) displayed an unchanged morphology from coronal to apical direction and 31.57% (6/19) showed configurational alteration of the root as shown in Fig. 3 CBCT scanning results revealed the alteration of root canals appeared to be most frequent at the coronal level (5/6). A change of root canals was also

detected from coronal to middle (4/6), and from middle to apical levels (1/6) as shown in Table 2.

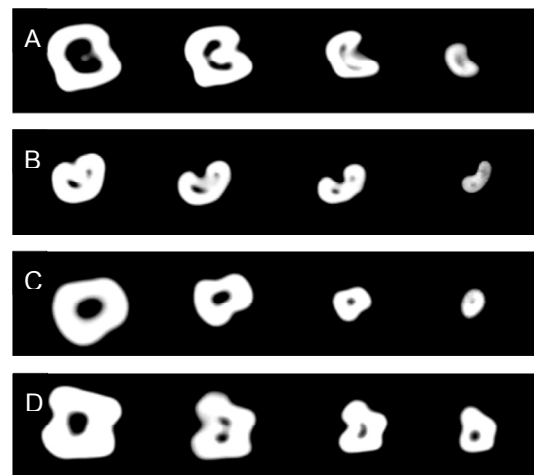


**Figure 3** Representative images of C-shaped canals in which the canal's configurational change was detected by CBCT (from the left to right: orifice→ coronal 1/3→ middle 1/3→ apical 1/3). A, C1 was expressed along root length. B, C2 was expressed along root length. C, C4 was expressed along root length. D, Configurational change found in coronal-to-apical direction (C4→C3→C1→C4).

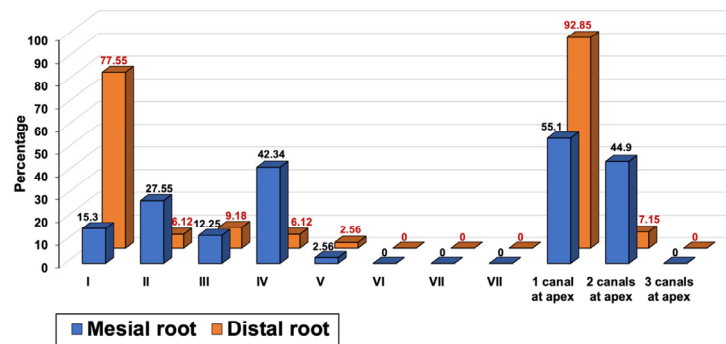


**Figure 4** Percentage of root canal morphology of mandibular second molars classified by Vertucci's guideline

Next, we examined the morphology of the root canals of non C-shaped mandibular second molars from our CBCT scan and determined 1) number of root canals in mesial and distal roots by using Vertucci's classification<sup>25</sup> and 2) number of root canal opening detected in each root. Of note, we found that non C-shaped mandibular second molars usually exhibited 2 canals in mesial root and 1 canal in distal root. Despite the typical presence of 2 canals in mesial root (84.70% of 196 evaluated teeth) categorized by Vertucci's classification according to Fig. 4, the incidence of finding either one or two canal openings at the root apex is approximately 50% (55.10% and 44.90%, respectively). In contrast, 77.55% of distal roots assessed by CBCT showed that Vertucci's type I configuration was the most abundant morphology found in our population. Other configurations i.e. Vertucci's type II, III, IV, and V were also detected by CBCT, although the prevalence of each type was less than 10%. Interestingly, the majority of distal roots (92.85%) exhibited one root canal opening at the apex.

## Discussion

Anatomical configuration of the root canal of mandibular second molars has a strong implication in endodontic treatment due to the variability of root canal morphology that might result in the subsequent modification of the treatment plan. Numbers of studies have reported that C-shaped canals could be clinically

found in mandibular second molars.<sup>2-4</sup> Essentially, the prevalence of C-shaped root canals ranges between 7.5% to 39% in mandibular second molars, depending on the ethnicity of studied group.<sup>5-16</sup> We reported, for the first time, the prevalence of finding mandibular second molars with the presence of C-shaped canals in Thai subpopulation by means of CBCT scan. Only 8.84% of studied mandibular second molars were classified as C-shaped molars using Fan's classification method. Interestingly, the prevalence reported here is subtly different from a previous report from an almost identical population in which the studied teeth included mandibular first, second, and third molars.<sup>9</sup> This discrepancy might possibly be resulted from the methods used between the different observations.

Considering racial characteristics of studied population, factors that contribute to the distinct profile of tooth roots among heterogenous population are not well understood. Most likely, genetic and environmental determinants are associated with the variable configurations of the teeth, as well as of jaw bones.<sup>26</sup> For instance, lengths of root canals in Asians were reported to be approximately 1.2 mm shorter than those measured in Caucasians.<sup>27</sup> Caucasoid, Mongoloid, and Negroid seemingly exhibit different tooth and bony profiles.<sup>28</sup> Variation of dental morphology is therefore found among population, including C-shaped mandibular second molars. Remarkably, C-shaped molars are most frequently found in Chinese population as reported to

date<sup>14</sup> for an unknown cause. A high prevalence of finding C-shaped molars in Chinese population has highlighted an extensive degree of genetic and environmental variations among Chinese population, relative to other populations, and might warrant further study.

Variability of root canal morphology can be examined by different technical methods i.e. conventional tooth clearing technique, and recently-developed radiographic techniques which include CBCT and micro-Computed Tomography (micro CT). In spite of their capabilities of detecting additional canals and configurational changes of the root, the sensitivity of each experimental tool might differ. Previous study revealed a significantly lower sensitivity of clearing technique, compared to CBCT, for detecting root canal morphological changes in the mesial root of mandibular molars.<sup>29</sup> In addition, micro CT was used as a standard tool in number of studies and it demonstrated the most accuracy in distinguishing root canal configurations.<sup>29,30</sup> Interestingly, CBCT displayed less errors in detecting numbers of root canal in multi-rooted teeth when compared to other types of CT i.e. peripheral quantitative CT and spiral CT.<sup>31</sup> The superiority of CBCT and micro CT to other techniques in studying root canal morphology suggests its future impact on the endodontic field as well as its clinical application for the more precise diagnosis of the apical disease and treatment planning in multi-rooted teeth, in which the clinical procedures are utterly challenging.

Among C-shaped mandibular second molars collected from selected Thai subpopulation, configurational change of the root canal tends to occur in a coronal-to-apical direction. We found the changes to be predominant at the orifice-to-coronal level (26.31%), following by coronal-to-middle level (20.05%), consistent with earlier studies demonstrating the varying number of canals and configurations at different radicular

levels.<sup>13,15,24,32,33</sup> A shift of canal configuration between two different levels of root canals is directly implicated in the endodontic treatment procedures since it might result in the occurrence of missed root canal. Likewise, the presence of two canals in either mesial or distal root of non C-shaped mandibular second molar and a possible change of canal morphology render mandibular second molars challenging to achieve a maximal cleaning of the root canal systems.

From our CBCT scanning results derived from 215 extracted mandibular second molars, the majority of canal configurations exhibited non C-shaped canals with 8.84% of studied teeth having C-shaped root canals. It is also noteworthy that mandibular molars might exhibit an aberrant root canal configurations as previously reported. A clinical survey in mandibular molars by using CBCT has shown that the percentages of finding an additional, separate root in mandibular first and second molars were 2.6% and 1.78%, respectively in Israeli population.<sup>34</sup> Considering the incidence of finding additional features of root canal in mandibular molars, the use of CBCT in investigating root canal anatomy from numbers of studies mentioned above might be beneficial for the clinicians and might give meaningful information required for clinical judgements. Importantly, clinicians should also be aware that other rare variations of the root canal anatomy might usually exist in mandibular second molars, despite a low incidence of C-shaped canals reported from the majority of studies investigated in diverse population, in order to achieve the most successful treatment outcome.

We reported the prevalence of C-shaped canal in mandibular second molars in Thai population by an in vitro application of CBCT. We identified 8.84% of 215 extracted mandibular second molars having anatomically C-shaped canals. Non C-shaped canals found in mandibular second molars usually displayed 2 canals in the mesial root and 1 canal in the distal root. However, merging and separating of the root canals can be found. In addition, we demonstrated the use of CBCT as a

diagnostic tool useful for detecting a variation of root canal morphology and possibly helps provide clinical information with regard to the root canal anatomy of mandibular second molars.

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# การศึกษาวิเคราะห์ลักษณะรูปร่างของคลองรากฟันกรามล่างซี่ที่สองของกลุ่มประชากรย่อยในประเทศไทยโดยใช้เครื่องมือถ่ายภาพรังสีส่วนตัดชนิดโคนบีม

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## บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาจำแนกลักษณะรูปร่างของคลองรากฟันในฟันกรามล่างซี่ที่สองของกลุ่มประชากรย่อยในเขตภาคตะวันออกเฉียงเหนือของประเทศไทย โดยใช้เครื่องมือถ่ายภาพรังสีส่วนตัดชนิดโคนบีม ฟันกรามล่างซี่ที่สองที่ถูกถอนเป็นจำนวนทั้งสิ้น 215 ซี่ถูกนำมาตรวจด้วยเครื่องมือถ่ายภาพรังสีส่วนตัดชนิดโคนบีม ภายหลังการสร้างภาพสามมิติ ฟันทั้งหมดจะผ่านการวิเคราะห์ด้วยโปรแกรมคอมพิวเตอร์ไวท์พอกซ์ อิมเมจจิง 3.0 ลักษณะรูปร่างของคลองรากฟันจะถูกจัดแบ่งกลุ่มตามการจำแนกรูปร่างคลองรากฟันของ Fan นอกจากนี้ ภาพถ่ายรังสีตัดขวางของคลองรากฟันจะถูกวิเคราะห์รูปร่างที่คลองรากฟัน 4 ระดับ ฟันกรามล่างซี่ที่สองจำนวน 19 ซี่จากทั้งหมด 215 ซี่ (ร้อยละ 8.83) ถูกจัดกลุ่มเป็นฟันกรามที่มีคลองรากฟันรูปร่างตามเกณฑ์การจำแนกของ Fan โดยในกลุ่มนี้พบว่า ตามความยาวของรากฟัน สามารถพบลักษณะรูปร่างคลองรากฟันตั้งแต่ประเภทที่หนึ่งถึงห้า (C1-C5) แม้อุบัติการณ์ของการพบลักษณะรูปร่างคลองรากฟันประเภทที่หนึ่ง (C1) จะมากที่สุดที่ตำแหน่งรูเปิดคลองรากฟัน (ร้อยละ 55.50) และพบว่าในฟันจำนวน 6 ซี่จากทั้งหมด 19 ซี่ (ร้อยละ 31.57) มีการเปลี่ยนแปลงลักษณะรูปร่างคลองรากฟันไปทางปลายราก โดยครึ่งหนึ่งของฟันกรามที่ไม่พบคลองรากฟันรูปร่างตัวซีพบว่ามี 2 คลองรากในรากฟันด้านใกล้กลางซึ่งมีความแปรปรวนของจำนวนรูเปิดบริเวณปลายรากฟัน ในขณะที่รากฟันด้านไกลกลางจะพบเพียงหนึ่งคลองรากฟันและพบหนึ่งรูเปิดบริเวณปลายรากฟัน การศึกษานี้รายงานอุบัติการณ์ของการพบคลองรากฟันรูปร่างตัวซีในฟันกรามล่างซี่ที่สองของกลุ่มประชากรย่อยในประเทศไทยที่ค่อนข้างต่ำ แม้ว่าโอกาสในการพบคลองรากฟันรูปร่างตัวซีในประชากรชาวเอเชียจะสูง ในการรักษาคลองรากฟันโดยเฉพาะฟันที่มีหลายรากควรคำนึงถึงลักษณะทางกายวิภาคปกติและลักษณะรูปร่างคลองรากฟันที่ต่างจากปกติ โดยเครื่องมือถ่ายภาพรังสีส่วนตัดชนิดโคนบีมอาจเป็นเครื่องมือที่มีประโยชน์และช่วยในการตรวจวินิจฉัยลักษณะรูปร่างของคลองรากฟันและทำให้ขั้นตอนการรักษามีความสะดวกมากขึ้น

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