

# C-Shaped Canal Configurations in Mandibular and Maxillary Second Molars: A CBCT Analysis in a Malaysian Population

N Mohammad, SH Omar, S Ravindran, AZ Muhamad, SNF Mohd Desa<sup>1</sup>, AHA Al-Kadhim<sup>2</sup>

Department of Conservative Dentistry and Prosthodontics, Faculty of Dentistry, <sup>1</sup>Department of Periodontology and Community Oral Health, Universiti Sains Islam Malaysia, Malaysia, <sup>2</sup>General Dentist, Pacific Smiles Dental, Mount Hutton, NSW, Australia

**Received:**  
26-Feb-2025;  
**Revision:**  
21-Jun-2025;  
**Accepted:**  
24-Jul-2025;  
**Published:**  
27-Sep-2025

## ABSTRACT

**Background:** C-shaped canals are a complex root canal variation, most frequently observed in mandibular second molars. Their atypical anatomy can make root canal treatment more difficult and may lead to complications if not properly identified. The use of Cone Beam Computed Tomography (CBCT) offers superior visualisation of canals morphology compared to conventional radiography. While the prevalence of C-shaped canals has been reported in various populations, there is limited data regarding their prevalence and configuration in the Malaysian's multiracial population. Understanding these morphological variations is essential for treatment planning and improving clinical outcomes. **Aim:** This cone beam computed tomography (CBCT) study aimed to determine the prevalence and configuration of C-shaped canals in permanent mandibular and maxillary second molars among the Malaysian population using the Modified Melton's classification. **Methods:** A total of 274 CBCT images involving 605 second maxillary ( $n = 269$ ) and second mandibular molars ( $n = 336$ ) were obtained from Oral Radiology Unit, Faculty of Dentistry, Universiti Sains Islam Malaysia. For each tooth, the canal configurations were evaluated at three different levels: 'coronal', 'middle', and 'apical'. The canal configurations were subsequently classified according to the Modified Melton's classification. The prevalence and canal configuration correlation between sex, ethnicities, and tooth positioning were determined using odds ratio ( $P = 0.05$ ). **Results:** The patients' ages ranged from 12 to 72 years old, with a mean age of  $29.47 \pm 11.53$  years. The patients were female (76.6%) with Malays or Bumiputera (78.8%) predominance. The prevalence of C-shaped canals found was 10.1% ( $n = 44$ ), and all were presented in second mandibular teeth. The most frequent C-shaped canals configuration found was C3-C3-C3 (29.5%). C-shaped canals were presented more likely when the patient is Chinese than other ethnicities with an odds ratio of 3.18 (95% CI, 1.562-6.488;  $P = 0.001$ ) and in fused roots than multirouted roots (OR = 173.43; 95% CI, 65.077-462.195;  $P < 0.001$ ). Sex was not associated with the prevalence of C-shaped canals in this study.

## INTRODUCTION

The knowledge and visualization of the internal anatomy of a root canal bring about an important significance to the success of a root canal treatment (Frank J. Vertucci. 1995).<sup>[1]</sup> Knowing the number of canals, its internal anatomy and variation can assist in a more predictable cleaning, shaping, and disinfection, thus resulting in a more successful outcome (Marco Versiani *et al.*, 2023).<sup>[2]</sup> The term C-shaped canal was first introduced in the literature by Cooke and Cox in 1979

to describe the cross-sectional morphology of roots that resembled the letter C (Cooke and Cox 1979).<sup>[3]</sup> The C-shaped canal proves to be a challenge when it comes to cleaning, shaping, and obturation, simply because it is

**Address for correspondence:** Dr. N Mohammad,

Department of Conservative Dentistry and Prosthodontics, Faculty of Dentistry, Universiti Sains Islam Malaysia, Malaysia.  
E-mail: norazlina79@usim.edu.my

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

**For reprints contact:** WKHLRPMedknow\_reprints@wolterskluwer.com

**How to cite this article:** Mohammad N, Omar SH, Ravindran S, Muhamad AZ, Mohd Desa SN, Al-Kadhim AH. C-shaped canal configurations in mandibular and maxillary second molars: A CBCT analysis in a Malaysian population. Niger J Clin Pract 2025;28:1066-75.

## Access this article online

### Quick Response Code:



**Website:** www.njcponline.com

**DOI:** 10.4103/njcp.njcp\_114\_25

**Conclusions:** The prevalence of C-shaped canals of the mandibular second molar in the Malaysian subpopulation in this study was 10.1% with the most frequent configuration of C3-C3-C3 at 29.5%. The Chinese ethnicities and tooth with fused roots were more frequently associated with the incidence of C-shaped canals. Identification of the C-shaped canal morphology allows the clinician to modify the canal preparation and obturation techniques to obtain a good endodontic treatment outcome, while also preventing any iatrogenic or procedural errors.

**KEYWORDS:** *C-shaped canals, canal morphology, cone beam computed tomography, second molars*

unclear if the orifice extends from the pulpal floor to the apical end (Jafarzadeh and Wu, 2007).<sup>[4]</sup>

There are two reasons explained by Manning (1990) for the occurrence of the C-shaped canal. Predominantly, it is due to the failure of the Hertwig's epithelial root sheath to fuse on the buccal or lingual root surface which brings about a C-shaped root.<sup>[5]</sup> The other reason for this is the deposition of cementum which coalesces and forms the C-shaped root (Manning 1990). Fan *et al.* stated that there is a chance of a root having a C-shaped canal morphology if it has fused roots, a longitudinal groove that is present on the buccal or lingual root surface and, last but not least, if it shows a C1, C2, or C3 configuration (Melton 1991 Classification) (Fan *et al.*, 2004).<sup>[6]</sup>

The incidence of C-shaped canals in second mandibular molars is commonly found in the Asian population.<sup>[4]</sup> For example, a study conducted on Eastern Chinese reported a prevalence of up to 47.05%,<sup>[7]</sup> while 36.8% was observed in a Korean population.<sup>[8]</sup> In contrast, a study in Turkey showed a much lower prevalence of 8.9%.<sup>[9]</sup>

In Malaysia, a study by Nie YK (2013) examined 241 maxillary and mandibular molar teeth samples. The study found that 3.32% of mandibular second molar had C-shaped canals. Among the cases with C-shaped canals, 77.8% were found in the Chinese population, 11.1% in the Malay population, and none were observed in the Indian population. The C-shaped canals found were classified according to Melton's Classification (1991). Type III canals (Melton's classification) were seen the most (44.4%), followed by Type II (33.3%) and Type I (22.2%).<sup>[10]</sup> Another study by Kais Raad Abdulmajeed *et al.* reported a higher incidence of C-shaped canals in the mandibular second molar among the Malay community at 43.2% using the cone beam computed tomography (CBCT) technique.<sup>[11]</sup> Due to this huge disparity, more research needs to be conducted in a wider population of this country to determine the predilection and morphology of C-shaped canals in Malaysia.

There are several methods documented to identify C-shaped canals, namely, the clearing method, contrast

ink injection method, black ink infiltration method, modified root canal staining method (Weng *et al.*, 2009),<sup>[12]</sup> polyester cast resin technique (Melton *et al.*, 1991),<sup>[13]</sup> contrast medium enhanced digital radiography (Pioro *et al.*, 2021),<sup>[14]</sup> radiography coupled with clinical examination, and CBCT.<sup>[4]</sup> The CBCT requires a low dose of radiation, short exposure time (2-5 s), less expensive than conventional CT scanning and highly accurate.<sup>[15,16]</sup>

The C-shaped canal is known to have multiple variations. Melton classified them into three types. Category I depicts the continuous C shaped canal with no separation. Category II, also referred to as the "semicolon" (;)-shaped canal, is the canal configuration in which dentine separates one distinct canal from a buccal or lingual C-shaped canal in the same section. Last, category III shows two or more distinct and separate canals. In 2004, Fan *et al.* introduced the modified Melton's classification because the C-shaped canal can vary from orifice to the apex. In Melton's classification, there has been no clear description of the difference between categories II and II. Hence, a more comprehensive study was done to evaluate the length of the canal space. The canal was evaluated at 11 parts of the root and categorized according to the Modified Melton's Classification.<sup>[6]</sup>

At present, there are limited studies conducted in the Malaysian population determining the prevalence of C-shaped canals. However, these studies did not adapt the Modified Melton's Classification. The studies that are currently published for this population also show different results with regard to gender and racial predilection. Hence, this study aims to determine the prevalence of C-shaped canals in mandibular and maxillary molars among the Malaysian population using CBCT. The null hypothesis of the study is that there is no significant association between the presence of C-shaped canal and gender and race. The findings of this study will be important to educate clinicians on the types of C-shaped canals and the prevalence, thus helping them to plan and execute their treatment well while benefiting the patient on the whole.

## MATERIALS AND METHODS

This study evaluated the images of 274 maxillary ( $n = 269$ ) and mandibular ( $n = 336$ ) second molars, including the left and right second molars obtained from CBCT scans at the Oral Radiology Unit, Faculty of Dentistry, Universiti Sains Islam Malaysia. For each tooth, the canals were evaluated at three different levels, 'coronal', 'middle', and 'apical', and subsequently classified these slices according to the Modified Melton's classification. Sample size calculation was done using OpenEpi, with a total sample of 400 at 5% confidence interval.

### Inclusion criteria

This research included scans of healthy, untreated, fully developed permanent maxillary and mandibular second molars. The scans should have sufficient quality to visualize individual roots and canals. Only scans that captured the entire pulp chamber and root canal system were considered.

### Exclusion criteria

Teeth were excluded for the following reasons: maxillary and mandibular second molars with open apices, partially visualized teeth, teeth with crown-root caries, evidence of previous endodontic treatment, presence of posts and crowns, surgical or pathological alterations to tooth anatomy, or artifacts that hinder proper visualization of the tooth anatomy.

### Image acquisition

All scans were acquired by a CBCT unit in the Oral Radiology Unit, Faculty of Dentistry, Universiti Sains Islam Malaysia. The images were morphologically assessed using software, Romexis Viewer® (Planmeca, Helsinki, Finland). The exposure parameters of the CBCT images are: voxel size 75µm, FOV 5 × 5, 13mA, 80 kV. The images were examined using the manufacturer's software (Planmeca Romexis). The scans were initially taken for various reasons, including diagnosing impacted teeth, planning implantology and determining treatment for endodontic and orthodontic cases. All scans were analyzed retrospectively, and no new scans were obtained specifically for this study.

### Evaluation of scans

The scans were based on three (3) axial slices of the CBCT; a. 'coronal': 2 mm below the cemento-enamel junction, b. 'apical': 2 mm above the apex of the root, c. 'middle': average distance in between 'coronal' and 'apical'.

Each image was independently assessed in the axial, coronal, and sagittal planes by three calibrated examiners, who had undergone inter- and intraexaminer calibration

by using Cohen's Kappa test. The examiners were three endodontic and restorative specialists in interpreting and manipulating the CBCT. In cases of disagreement, the images were discussed until a consensus was reached. A final consensus was reached when the interexaminer agreement was found (0.89), which is considered as fully reliable.<sup>[17]</sup> Ten scans were initially assessed by all examiners by repeating the observation twice for calibration.

Each slice was evaluated and categorized according to the Modified Melton's Classification as shown below in Figure 1. The canal will be considered a C-shaped canal if the slices fulfill C1, C2, or C3 of the Modified Melton's Classification.

The study data were captured using Microsoft Excel 2021 (Microsoft Corp., Redmond, WA, USA). Statistical analysis was performed using SPSS version 26.0 software program (IBM Corp., Armonk, NY, USA).

**Table 1: Characteristics of patients (n=274)**

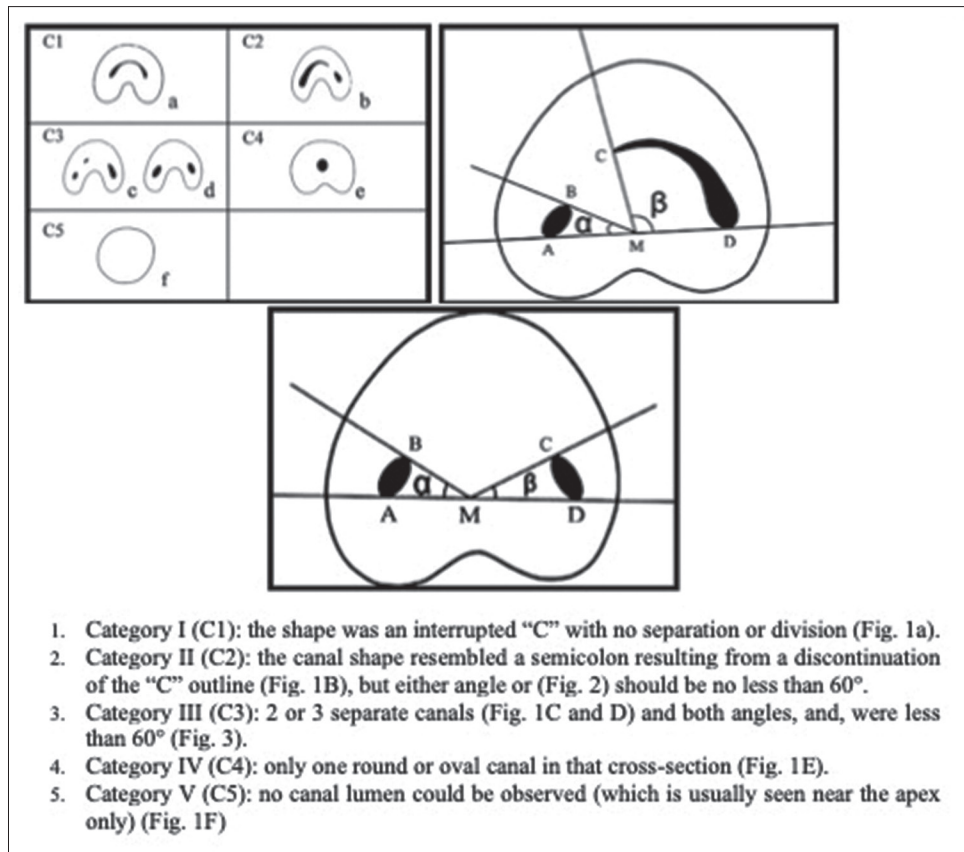
| Variable     | Range                | Mean (SD)     |         |
|--------------|----------------------|---------------|---------|
| Age          | (12, 72)             | 29.47 (11.53) |         |
| Gender       | Male                 | Female        |         |
| <i>n</i> (%) | 64 (23.4)            | 210 (76.6)    |         |
| Ethnicity    | Malay and Bumiputera | Chinese       | Indian  |
| <i>n</i> (%) | 216 (78.8)           | 51 (18.6)     | 7 (2.6) |

**Table 2: C-shaped canals in mandibular second molars distribution among gender and ethnicity (n=44)**

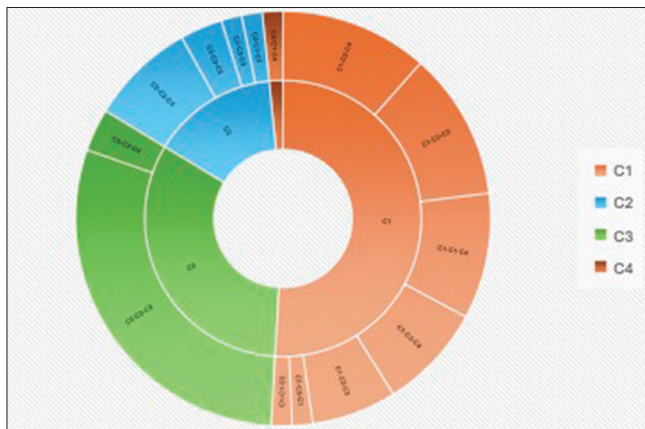
| C-shaped canals      | Right, n (%) | Left, n (%) | Both, n (%) | Total, n (%) |
|----------------------|--------------|-------------|-------------|--------------|
| Gender               |              |             |             |              |
| Male                 | 3 (6.8)      | 1 (2.3)     | 6 (13.6)    | 10 (22.7)    |
| Female               | 9 (20.5)     | 14 (31.8)   | 11 (25.0)   | 34 (77.3)    |
| Ethnicity            |              |             |             |              |
| Malay and Bumiputera | 8 (18.2)     | 10 (22.7)   | 10 (22.7)   | 28 (63.6)    |
| Chinese              | 4 (9.1)      | 5 (11.4)    | 7 (15.9)    | 16 (36.4)    |
| Indian               | 0            | 0           | 0           | 0            |

**Table 3: Prevalence of C-shaped canals and fused roots of mandibular and maxillary second molars (n=605)**

| Prevalence               | n (%)     |
|--------------------------|-----------|
| C-shaped canals          | 61 (10.1) |
| Maxillary second molars  | 0         |
| Mandibular second molars | 61 (10.1) |
| Fused roots              | 89 (14.7) |
| Maxillary second molars  | 23 (3.8)  |
| Mandibular second molars | 66 (10.9) |



**Figure 1:** Canal configurations according to the Modified Melton's Classifications



**Figure 2:** C-shaped canal configurations of second mandibular molars

Root number, canal configuration, and prevalence of C-shaped canals were expressed as percentages of the total number of included teeth. The significance level was set at  $P < 0.05$  in all cases.

## RESULTS

A total of 274 patients were included in this study, and their characteristics are presented in Table 1. The patients' ages ranged from 12 to 72 years old, with a mean age of  $29.47 \pm 11.53$  years. The patients were

predominantly female (76.6%), and in terms of ethnicity, they were mostly Malays or Bumiputera (78.8%).

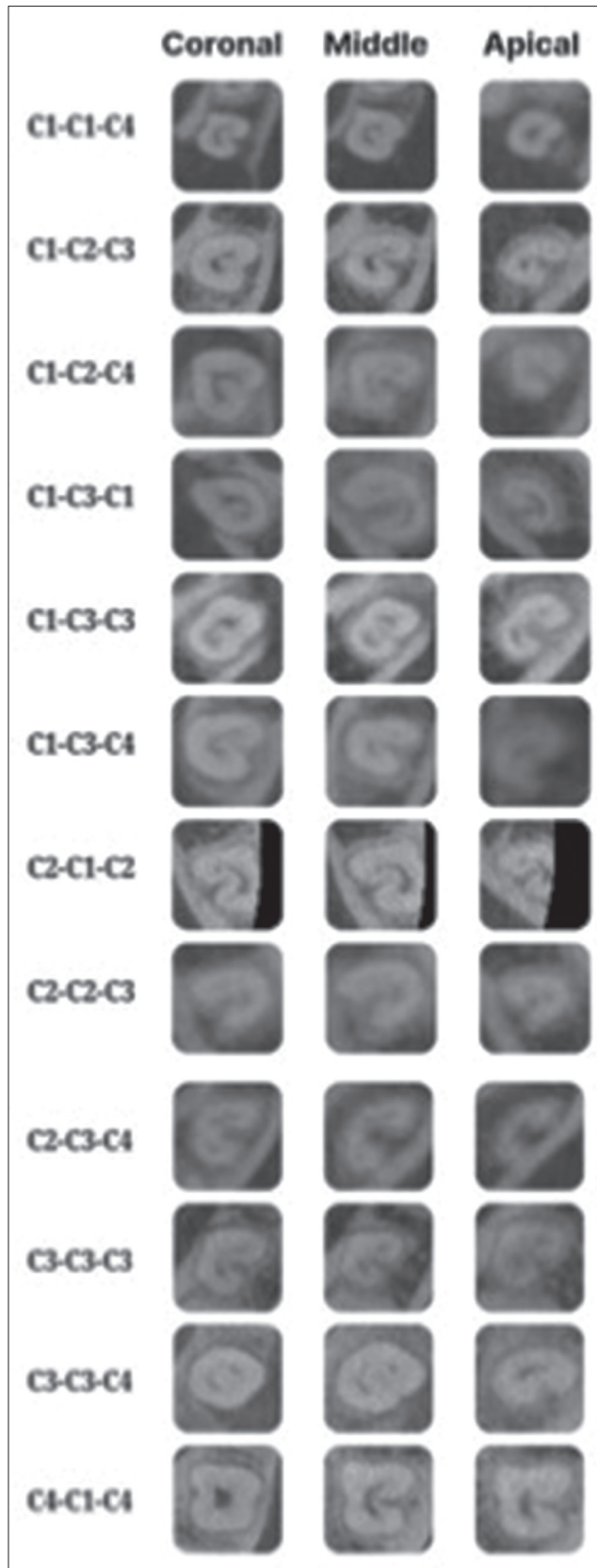
Forty-four patients presented with C-shaped canals, and the distribution among gender and ethnicity is presented in Table 2.

A total of 605 second molars were examined from the radiograph, and the prevalence of C-shaped canals (10.1%) and fused roots (14.7%) is presented in Table 3. All C-shaped canals were in the mandibular second molars.

The C-shaped canals configuration is presented in Table 4 and Figure 2. The most frequent C-shaped canals configuration seen in this study was C3-C3-C3 (29.5%). The representative CBCT images for the canal configurations are illustrated in Figure 3.

The C-shaped canal of second molars at different root levels is presented in Table 5. The most common classification in cervical third was C1 (50.82%) and C3 in both middle and apical thirds, 54.10% and 59.20%, respectively. Further information on C-shaped second molars at different root levels by gender and ethnicity is presented in Tables 6 and 7, respectively.

Table 8 shows the factors associated with C-shaped canals on second molars. C-shaped canals are more



**Figure 3:** The CBCT image of C-shaped canal configurations at the coronal, mid-canal and apical canal of mandibular molar

**Table 4: C-shaped canals configuration of mandibular second molars ( $n=61$ )**

| Canals configuration | <i>n</i> (%) |
|----------------------|--------------|
| C1-C1-C3             | 1 (1.6)      |
| C1-C1-C4             | 6 (9.8)      |
| C1-C2-C3             | 7 (11.5)     |
| C1-C2-C4             | 7 (11.5)     |
| C1-C3-C1             | 1 (1.6)      |
| C1-C3-C3             | 4 (6.6)      |
| C1-C3-C4             | 5 (8.2)      |
| C2-C1-C2             | 1 (1.6)      |
| C2-C2-C3             | 5 (8.2)      |
| C2-C3-C3             | 1 (1.6)      |
| C2-C3-C4             | 2 (3.3)      |
| C3-C3-C3             | 18 (29.5)    |
| C3-C3-C4             | 2 (3.3)      |
| C4-C1-C4             | 1 (1.6)      |

**Table 5: C-shaped canal of mandibular second molars at different root levels ( $n=61$ )**

| Root level | C1, <i>n</i> (%) | C2, <i>n</i> (%) | C3, <i>n</i> (%) | C4, <i>n</i> (%) |
|------------|------------------|------------------|------------------|------------------|
| Cervical   | 31 (50.82)       | 9 (14.75)        | 20 (32.79)       | 1 (1.64)         |
| Middle     | 9 (14.75)        | 19 (31.15)       | 33 (54.10)       | 0                |
| Apical     | 1 (1.64)         | 1 (1.64)         | 36 (59.02)       | 23 (37.70)       |

**Table 6: C-shaped canal of mandibular second molars at different root levels by gender ( $n=61$ )**

| Root level        | C1, <i>n</i> (%) | C2, <i>n</i> (%) | C3, <i>n</i> (%) | C4, <i>n</i> (%) |
|-------------------|------------------|------------------|------------------|------------------|
| Male ( $n=16$ )   |                  |                  |                  |                  |
| Cervical          | 13 (81.25)       | 0                | 3 (18.75)        | 0                |
| Middle            | 3 (18.75)        | 7 (43.75)        | 6 (37.50)        | 0                |
| Apical            | 0                | 0                | 9 (56.75)        | 7 (43.75)        |
| Female ( $n=45$ ) |                  |                  |                  |                  |
| Cervical          | 18 (40.00)       | 9 (20.00)        | 17 (37.78)       | 1 (2.22)         |
| Middle            | 6 (13.33)        | 12 (26.67)       | 27 (60.00)       | 0                |
| Apical            | 1 (2.22)         | 1 (2.22)         | 27 (60.00)       | 16 (35.56)       |

**Table 7: C-shaped canal of mandibular second molars at different root levels by ethnicity ( $n=61$ )**

| Root level                      | C1, <i>n</i> (%) | C2, <i>n</i> (%) | C3, <i>n</i> (%) | C4, <i>n</i> (%) |
|---------------------------------|------------------|------------------|------------------|------------------|
| Malay and Bumiputera ( $n=38$ ) |                  |                  |                  |                  |
| Cervical                        | 12 (31.58)       | 7 (18.42)        | 18 (47.37)       | 1 (2.63)         |
| Middle                          | 3 (7.89)         | 9 (23.68)        | 26 (68.42)       | 0                |
| Apical                          | 1 (2.63)         | 1 (2.63)         | 28 (73.68)       | 8 (21.05)        |
| Chinese ( $n=23$ )              |                  |                  |                  |                  |
| Cervical                        | 19 (82.61)       | 2 (8.70)         | 2 (8.70)         | 0                |
| Middle                          | 6 (26.09)        | 10 (43.48)       | 7 (30.43)        | 0                |
| Apical                          | 0                | 0                | 8 (34.78)        | 15 (65.22)       |

likely when the patient is Chinese than non-Chinese with an odds ratio of 3.18 (95% CI, 1.562-6.488;  $P = 0.001$ )

**Table 8: Factors associated with C-shaped canals on mandibular second molars (n=274)\***

| Variables                           | Odds ratio | 95% CI         | P                   |
|-------------------------------------|------------|----------------|---------------------|
| Gender                              |            |                |                     |
| Male vs female <sup>0</sup>         | 0.96       | 0.445-2.067    | 0.914               |
| Ethnicity                           |            |                |                     |
| Malay vs non-Malay <sup>0</sup>     | 0.39       | 0.194-0.787    | 0.009 <sup>a</sup>  |
| Chinese vs non-Chinese <sup>0</sup> | 3.18       | 1.562-6.488    | 0.001 <sup>a</sup>  |
| Root (n=605)                        |            |                |                     |
| Fused vs normal <sup>0</sup>        | 173.43     | 65.077-462.195 | <0.001 <sup>a</sup> |

\*n=274 unless stated otherwise. <sup>0</sup>The former was compared with latter (the reference) to calculate odds ratio and 95% CI.

<sup>a</sup>Significant at  $P < 0.05$

and in fused roots than normal roots (OR = 173.43; 95% CI, 65.077-462.195;  $P < 0.001$ ).

## DISCUSSION

Identification of C-shaped canals prior to root canal treatment is crucial for establishing an accurate diagnosis, locating orifices, and determination of canal configurations. Diagnosis of C-shaped canal using conventional radiographs is challenging due to the image superimposition and the two-dimensional (2D) limitation in assessing the dynamics of canal anatomical variations. The C-shaped canal configuration may change as it runs from coronal to apical, hence in this study, CBCT was used in facilitating the understanding of the 3D canal anatomy. Comprehensive knowledge of the tooth internal anatomy through CBCT prior to RCT allows the clinician to perform a conservative access cavity directed toward the canal orifices, conduct thorough shaping and cleaning of the canal spaces, and achieve a 3D obturation. CBCT also allows the clinician to recognize the anatomical danger zone, thus preventing procedural errors and avoiding mishaps during postplacement. Clinical assessment of C-shape canal anatomy alone is unreliable even under the operative microscope due to its varied shape along the root length.<sup>[18]</sup> The most common root morphology of maxillary and mandibular second molars observed in this study was multiple rooted with separate canals. Higher prevalence of mandibular teeth presented with fused roots compared to maxillary teeth at 10.9% and 3.8%, respectively. The result of this study is similar to other studies which reported an incidence of 8.7% to 14.2% of second mandibular molars having single root.<sup>[19]</sup> The present study reported 10.1% prevalence of C-shaped root canal configurations in the Malaysian population, which is higher than the 3.73% incidence observed by Nie *et al.*<sup>[10]</sup> but lower than the 43.2% documented by Abdulmajeed.<sup>[11]</sup> One study reported a high prevalence of C-shaped canals in a Korean population at 36.8%,<sup>[9]</sup> while another found a 38.6% prevalence in Chinese population.

<sup>[20]</sup> In the current study, maxillary and mandibular molars exhibiting a fused root structure demonstrated a higher propensity for C-shaped canal configurations compared to those with multiple roots, as indicated by a notably elevated odds ratio of 173.43. These findings are consistent with Yang *et al.*, 2021 who observed that 75.2% of C-shaped canals were associated with fused roots, while teeth with two roots showed a lower incidence of this anatomical variation. Hence, when performing root canal treatment on single-rooted maxillary or mandibular teeth, dental practitioners should anticipate and be prepared to manage the challenges presented by C-shaped root canal morphology.

Previous studies revealed that the prevalence of C-shaped configurations in maxillary and mandibular second molars had an ethnic difference which is higher in Asian populations (29-44%) compared to Western population (8.9%),<sup>[9,20,21]</sup> as tabulated in Table 9. Malaysia is a multiracial country with the majority of Malay and Bumiputera population, followed by Chinese, Indian, and other races. In this study, the prevalence of C-shaped root canals found is 10.1% with a higher prevalence in Chinese population at 31.3%, followed by Malay and Bumiputera at 12.96% and none observed among Indian population. The Chinese in this population are more likely to be associated with the incidence of C-shaped canals compared to Malay and other Bumiputera with an odds ratio of 3.18. This is consistent with the results from previous studies. Studies show that C-shaped root canals occur in about 3.73% of the Malaysian population.<sup>[10]</sup> 100% of the molars in the study with C-shaped root canal configurations in the study were mandibular molars, and 77.8% of those belonged to the Chinese racial group at 14.6%, slightly lower than the findings from our study. Studies conducted in China have reported a higher prevalence rate ranging from 31.5% to 42% in extracted teeth,<sup>[18]</sup> which corroborated the result of our study. Another global study found that China had the highest prevalence of C-shaped mandibular second molars (44%) compared to other regions.<sup>[22]</sup> It is important to note that these studies may have different methodologies and sample sizes, which can influence the reported prevalence.

Previous study showed that female patients showed higher prevalence of C-shaped root canals than males.<sup>[23,24]</sup> Similarly, higher prevalence was found in this study with 77.3% in female and 22.7% in male. Bilateral occurrence of C-shaped canals was reported at 80.4-82%,<sup>[23,25]</sup> while other studies among Saudi population reported lower bilateral incidence at 53%<sup>[26]</sup> and 64.1% in Iraqi population.<sup>[24]</sup> However, this variable was not measured in this study.

**Table 9: C-shaped canal configuration in mandibular second molars from previous studies**

| Reference                              | Region/<br>race | Teeth studied                         | Number<br>of teeth | Prevalence of<br>C-shaped canal | Classification                                                                                                                                                                  | Unilateral/bilateral<br>occurrence                        |
|----------------------------------------|-----------------|---------------------------------------|--------------------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| Martins JNR.,<br><i>et al.</i> , 2017  | Caucasian       | Mandibular<br>second molars           | 1088               | 8.5%                            | C1 (21.1%)<br>C2 (23.4%)<br>C3 (38.1%)                                                                                                                                          | -                                                         |
| Abdulmajeed<br><i>et al.</i> , 2018    | Malay           | Mandibular<br>second molars           | 86                 | 50%                             | Type I (34.69%)<br>Type II (28.57%)<br>Type III (18.37%)<br>Type IV (18.37%)                                                                                                    | -                                                         |
| Yang <i>et al.</i> ,<br>2021           | Korean          | Mandibular<br>second molars           | 2508               | 36.8%                           | C1 (35.8%)<br>C2 (23.4%)<br>C3 (38.1%)                                                                                                                                          | Bilateral (75.2%)                                         |
| Zheng <i>et al.</i> ,<br>2011          | China           | Mandibular<br>second molars           | 688                | 38.6%                           | C1 (72.5%)<br>C2 (18.1%)<br>C3 (7.8%)                                                                                                                                           | Bilateral (81%)<br>Left side (12.5%)<br>Right side (6.3%) |
| Nie <i>et al.</i> , 2013               | Malaysian       | Maxillary and<br>mandibular<br>molars | 241                | 3.74%                           | Type I (22.2%)<br>Type II (33.3%)<br>Type III (144.4%)                                                                                                                          | -                                                         |
| Wang <i>et al.</i> ,<br>2012           | China           | Mandibular<br>second molar            | 1146               | 39.18%                          | C1 (22.94%)<br>C2 (48.11%)<br>C3a (15.59%)<br>C3b (13.36%)                                                                                                                      | -                                                         |
| Yang <i>et al.</i> ,<br>2022           | China           | Mandibular<br>second molar            | 1200               | 35.6%                           | Mesial root:<br>Type I (22.5%)<br>Type II (28.9%)<br>Type III (14.6%)<br>Type IV (7.9%)<br>Distal root:<br>Type I (95.6%)<br>Type II (0.68%)<br>Type III (1.6%)<br>Type IV (2%) | Bilateral 80.4%                                           |
| Abdalahman<br><i>et al.</i> , 2022     | Iraq            | Mandibular<br>second molars           | 368                | 17.4%                           | C1 (15.6%)<br>C2 (56.3%)<br>C3 (23.4%)<br>C4 (18.4%)                                                                                                                            | Bilateral (64.1%)                                         |
| Mashyakh<br><i>et al.</i> , 2020       | Saudi           | Mandibular<br>second molars           | 367                | 7.9%                            | C1 (23.0%)<br>C2 (20.7%)<br>C3 (35.6%)<br>C4 (18.4%)                                                                                                                            | Bilateral (53%)<br>Left side (37%)<br>Right side (10%)    |
| Nouroloyouni<br>A., <i>et al.</i> 2023 | Iran            | Mandibular<br>second molars           | 478                | 3.7%                            | C1 (5%)<br>C2 (20%)<br>C3 (20%)<br>C4 (10%)                                                                                                                                     | -                                                         |

Contd...

Table 9: Contd...

| Reference                | Region/<br>race | Teeth studied               | Number<br>of teeth | Prevalence of<br>C-shaped canal                 | Classification                                                                                                          | Unilateral/bilateral<br>occurrence |
|--------------------------|-----------------|-----------------------------|--------------------|-------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|------------------------------------|
| Pan <i>et al.</i> , 2019 | Malaysian       | Mandibular<br>second molars | 376                | 31.4%                                           | Mesial root:<br>Type I (17.7%)<br>Type II (4.2%)<br>Type IV (78.1%)<br>Distal root:<br>Type I (96.9%)<br>Type IV (3.1%) |                                    |
| Current study            | Malaysian       | Mandibular<br>second molars | 336                | Total: 10.1%<br>Chinese: 31.3%<br>Malay: 12.96% | Cervical C1 (50.82%)<br>Middle C3 (54.19%)<br>Apical C3 (59.20%)                                                        |                                    |

This study provides comprehensive insights into the C-shaped canal morphology of maxillary and mandibular molars in the Malaysian population, using CBCT imaging. According to Fan *et al.*'s classification, studies by Kim *et al.* (2016) and Abdalrahman *et al.* (2022) identified the C2 type as the most frequently observed C-shaped configuration. However, this finding contrasts with earlier research, which indicated that the C1 and C3 types were the most prevalent at the orifice level. The current study revealed that the majority of canal orifices exhibit a C1 configuration at the coronal part, transitioning to C2 and C3 configurations in the middle and apical regions. Notably, when the canal configuration presents as C3 at the coronal level, it typically maintains this morphology throughout the length of the canal. This specific anatomical configuration accounts for 29.5% of the observed C-shaped canals, followed by the C1-C2-C3 and C1-C2-C4 configurations, both at 11.5%. In contrast, Zheng *et al.* reported that only 12 teeth (5.5%) did not exhibit a change in canal configuration from the orifice to the apical area. On the other hand, they found that the frequency of C1 and C2 morphologies decreased from the orifice to the apical region, while that of C3 and C4 increased, which aligns with the current study findings.

The prevalence of various canal configurations at different cross-sectional levels has been demonstrated to differ across population. This investigation uncovered distinct patterns of canal morphology across the different ethnic groups and gender in Malaysian population. The Chinese population more commonly demonstrated a C2-C2-C4 configuration, while the Malay and other Bumiputera groups exhibited a predominant C3-C3-C3 configuration along the entire canal length. Similar observations to the Chinese canal configuration in this study were reported in an Iranian population whereby the C2 configuration was predominantly seen in the orifice, coronal, and middle levels, while C3 and C4 morphologies were more common apically.<sup>[27]</sup>

Additionally, the canal configuration presented different patterns between males and females. Males displayed variations in the middle canal, either C2 or C3 (C1-C2/C4-C3). In contrast, females were more likely to exhibit C1 or C2 configurations at the orifice, followed by a C3 configuration in the middle and apical regions (C1/C2-C3-C3). Identifying the precise canal configuration as it transitions from the orifice to the apical region enables effective shaping and cleaning of the root canal system. Such knowledge is critical for the dental practitioner to anticipate and effectively manage the complex root canal anatomy encountered in clinical practice, particularly among populations with higher preposition to C-shaped canal configurations.<sup>[28]</sup> Notably, the C1 and C2 canal configurations are generally more challenging to shape and clean compared to the C3 and C4 configurations.<sup>[20]</sup> The intricate morphology of these C-shaped canals characterized by narrow and irregular areas can create areas that harbor microorganisms, dentine debris, and necrotic pulp tissue. Effectively shaping and cleaning these decontaminated regions during canal preparation poses a significant risk for the success of the root canal treatment.

The result of this study demonstrated that CBCT imaging can enable practitioners to identify variations and comprehensively assess the anatomy from a 3D perspective and thus should be regarded as the gold standard for diagnosing and treating C-shaped canal configurations. However, the use of CBCT must be justified as it involves a higher radiation dose compared to conventional radiographic techniques.

## CONCLUSION

The prevalence of C-shaped canals was 10.1% ( $n = 44$ ), and all cases were identified in mandibular second molar. The most common configuration observed was C3-C3-C3 accounting for 29.5% of cases. C-shaped canals were more frequently found in patients of

Chinese ethnicity and in fused roots compared to multirrooted roots. Overall, this CBCT-based study offers valuable insights into the complex anatomical variations of C-shaped canal morphology within Malaysian population, highlighting notable differences based on ethnicity and gender.

### Acknowledgement

In conducting this study, the authors gratefully acknowledge Universiti Sains Islam Malaysia (USIM) in providing the research fund (Research code: *PPPI/FPG/0122/USIM/12822*).

### Author contribution

Dr Norazlina, Dr Hajar, Dr Sushmitha and Dr Aws contributed to the research concept, study design, writing the original draft and reviewing and editing the final manuscript. Dr. Ahmad Zaim and Dr. Siti Nur Farhanah contributed to the data collection, statistical analysis and writing and reviewing the original draft. All authors read and approved the final manuscript.

### Ethical approval

Ethical approval was obtained by the Faculty of Dentistry, Universiti Sains Islam Malaysia (USIM) ethics committee [Reference USIM/JKEP/2022-209].

### Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

### Financial support and sponsorship

Nil.

### Conflicts of interest

The authors deny any conflict of interest exist related to this study.

### REFERENCES

- Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. *Endodontic Topics* 2005;10:3-29.
- Versiani MA, Martins J, Ordinola-Zapata R. Anatomical complexities affecting root canal preparation: A narrative review. *Aust Dent J* 2023;68 Suppl 1:S5-23.
- Cooke HG 3<sup>rd</sup>, Cox FL. C-shaped canal configurations in mandibular molars. *J Am Dent Assoc* 1979;99:836-9.
- Jafarzadeh H, Wu YN. The C-shaped root canal configuration: A review. *J Endod* 2007;33:517-23.
- Manning SA. Root canal anatomy of mandibular second molars. Part II. C-shaped canals. *Int Endod J* 1990;23:40-5.
- Fan B, Cheung GS, Fan M, Gutmann JL, Bian Z. C-shaped canal system in mandibular second molars: Part I--Anatomical features. *J Endod* 2004;30:899-903.
- Chen C, Zhu T, Wu H, Zhao X, Leng D, Wang J, *et al.* Prevalence and correlation of C-shaped root canals of mandibular premolars and molars in Eastern Chinese individuals. *Sci Rep* 2022;12:19779.
- Yang SE, Lee TY, Kim KJ. Prevalence and morphology of C-Shaped canals: A CBCT analysis in a Korean population. *Scanning* 2021;2021:9152004. Erratum in: *Scanning* 2022;2022:9841276.
- Helvacioğlu-Yigit D, Sinanoğlu A. Use of cone-beam computed tomography to evaluate C-shaped root canal systems in mandibular second molars in a Turkish subpopulation: A retrospective study. *Int Endod J* 2013;46:1032-8.
- Nie YK, Bakar WZ, Alam MK. The occurrence of C-shaped root canal in Malaysian population. *Bangladesh J Med Sci* 2013;12:286-90.
- Abdulmajeed KR, Mustafa NS, Kashmoola MA, Jabbar OA, Ab Razak LS, Noor SN. The diagnosis and determination of C-shaped canal in lower second molar. *J Int Dent Med Res* 2018;11:810-8.
- Weng XL, Yu SB, Zhao SL, Wang HG, Mu T, Tang RY, *et al.* Root canal morphology of permanent maxillary teeth in the Han nationality in Chinese Guanzhong area: A new modified root canal staining technique. *J Endod* 2009;35:651-6.
- Melton DC, Krell KV, Fuller MW. Anatomical and histological features of C-shaped canals in mandibular second molars. *J Endod* 1991;17:384-8.
- Chaintiou Piorno R, Consoli Lizzi EP, Gualtieri AF, Rodríguez PA. C-Shaped canal system in mandibular premolars evaluated by cone-beam computed tomography in a population of the Autonomous City of Buenos Aires, Argentina. *Arch Oral Biol* 2021;123:105040.
- Neelakantan P, Subbarao C, Ahuja R, Subbarao CV, Gutmann JL. Cone-beam computed tomography study of root and canal morphology of maxillary first and second molars in an Indian population. *J Endod* 2010;36:1622-7.
- Matherne RP, Angelopoulos C, Kulild JC, Tira D. Use of cone-beam computed tomography to identify root canal systems *in vitro*. *J Endod* 2008;34:87-9.
- Mahmood Talabani R. Assessment of root canal morphology of mandibular permanent anterior teeth in an Iraqi subpopulation by cone-beam computed tomography. *J Dent Sci* 2021;16:1182-90.
- Wang Y, Guo J, Yang HB, Han X, Yu Y. Incidence of C-shaped root canal systems in mandibular second molars in the native Chinese population by analysis of clinical methods. *Int J Oral Sci* 2012;4:161-5.
- Martins JNR, Mata A, Marques D, Caramês J. Prevalence of C-shaped mandibular molars in the Portuguese population evaluated by cone-beam computed tomography. *Eur J Dent* 2016;10:529-35.
- Zheng Q, Zhang L, Zhou X, Wang Q, Wang Y, Tang L, *et al.* C-shaped root canal system in mandibular second molars in a Chinese population evaluated by cone-beam computed tomography. *Int Endod J* 2011;44:857-62.
- Martins JNR, Marques D, Silva EJNL, Caramês J, Mata A, Versiani MA. Prevalence of C-shaped canal morphology using cone beam computed tomography - a systematic review with meta-analysis. *Int Endod J* 2019;52:1556-72.
- von Zuben M, Martins JN, Berti L, Cassim I, Flynn D, Gonzalez JA, *et al.* Worldwide prevalence of mandibular second molar C-shaped morphologies evaluated by cone-beam computed tomography. *J Endod* 2017;43:1442-7.
- Yang L, Han J, Wang Q, Wang Z, Yu X, Du Y. Variations of root and canal morphology of mandibular second molars in Chinese individuals: A cone-beam computed tomography study. *BMC*

- Oral Health 2022;22:274.
24. Abdalrahman K, Talabani R, Kazzaz S, Babarasul D. Assessment of C-shaped canal morphology in mandibular and maxillary second molars in an Iraqi subpopulation using cone-beam computed tomography. *Scanning* 2022;2022:4886993.
  25. Kim SY, Kim BS, Kim Y. Mandibular second molar root canal morphology and variants in a Korean subpopulation. *Int Endod J* 2016;49:136-44.
  26. Mashyakhy MH, Chourasia HR, Jabali AH, Bajawi HA, Jamal H, Testarelli L, *et al.* C- shaped canal configuration in mandibular premolars and molars: Prevalence, correlation, and differences: An *in vivo* study using cone-beam computed tomography. *Niger J Clin Pract* 2020;23:232-39.
  27. Nouroloyouni A, Moradi N, Salem Milani A, Noorolouny S, Ghoreishi Amin N. Prevalence and morphology of C-shaped canals in mandibular first and second molars of an Iranian population: A cone-beam computed tomography assessment. *Scanning* 2023;2023:5628707.
  28. Pan JY, Parolia A, Chuah SR, Bhatia S, Mutalik S, Pau A. Root canal morphology of permanent teeth in a Malaysian subpopulation using cone-beam computed tomography. *BMC Oral Health* 2019;19:14.