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Judul Artikel : A CBCT based cross sectional study on the prevalence and anatomical feature of C shaped molar among Jordanian.

Penulis : Taher Al Omari, Mustafa AlKhader, Ayfer Atav Ateş, **Dian Agustin Wahjuningrum**, Alaa Dkmak, Waheeb Khaled & Hazem Alzenate

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A CBCT based Cross Sectional Study on the Prevalence and Anatomical Feature of C Shaped Mol...

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Reviewer Comments:

Reviewer 1
The present study addresses the prevalence and characteristics of the mandibular C-shaped second molar on a Jordanian Sub-population.

The last sentence of the Abstract ("The prevalence of C-shaped molars detected by CBCT was similar to that among the Caucasian sub population.") is related to the Discussion section, not a conclusion of the direct assessment of the results in the field. I recommend to remove that sentence.

I cannot find the keywords. Sorry.

"may cause the formation of a rare anatomical variation that is described as a thin ribbon-shaped canal"… I would not call it rare but uncommon instead

The Introduction looks quite fine. The last sentence has both aim and rationale for the study. I recommend the authors to reformulate this important sentence. Report first the rationale (absence in Jordan) and then the aim, in this latest aspect try to be more clear because the authors are addressing more than just the global prevalence.

I recommend the authors to place the Material and Methods between the Introduction and the Results.

I know the authors had the STROBE into consideration, however I suggest the authors to also mention, use, and report the correct use of the "Preferred Reporting Items for Epidemiologic Cross-sectional Studies on Root and Root Canal Anatomy Using Cone-beam Computed Tomographic Technology" published in JOE in DOI 10.1016/j.joen.2020.03.020 I believe this small step will give an improvement in the reliability of the study methodology. If the authors wish they may use both STROBE and the JOE one.

How were the patients selected?

What was the sampling methods in the Methods?

In the inclusion criteria… was taken into account the impossibility to determine the tooth numbering (as exclusion)? This is relevant because the morphology is tooth specific.

Regarding the exclusion, how many were they? What was the exclusion rate?

Did the authors notices any possible source of bias?

Regarding the results, I suggest the authors to give the 95% confidence interval for the 12% prevalence.

The discussion looks fine, however I would recommend to highlight a little better the study strength, limitations and further research perspectives.

I believe one relevant study is missing in the references, which is a Worldwide study on this topic. The rest looks updated.

Reviewer 2
Ref: Submission ID 10ce33f8-172a-46c5-bc55-23a756e7e4ab
Manuscript Title: "The Prevalence and Anatomical Features of C-Shaped Mandibular Second Molars in the Jordanian Sub-population: A CBCT -Based Cross-Sectional Study"
Version: 1

Date: 9.5.2022
Reviewer: Assistant Professor Dr. Ranjdar Talabani
Reviewer's report:
Thank you for this study. There are big missing and diffusion regarding classification; reliability test and parameters including in the study specially age and sex factors. Is difficult to be published in highly indexed journal like "Scientific Reports".

1. It doesn't include conclusion in the abstract.
2. Age factor not considered in the study; the author mentioned that mean age was 40 years old how?
3. The result obtained from sex factor included in the study is not accurate because there are big differences in range between female to male (168 female to 75 males).
4. The author adopted classification for C shaped canal configuration based on
5. Most important missing point in this study is Reliability test (Kappa Value). This test showed the agreement between inters or intra examiner or observer accuracy result. This test mandatory is included at end of methodology.
6. It is highly recommended in such study; the authors present a table including other finding from different countries using CBCT to evaluate C shaped canal configuration.
7. In discussion; the authors mentioned "periapical radiograph"; it is not related to present study.

Reviewer 3
This is an interesting study about C-shaped root canal configuration in a certain sub-population.
The strength of this study is relatively large sample size using CBCT images.
However, it needs some minor corrections before publication.

Reviewer 4
This study is interesting but can be dramatically improved if you:
- Determine the types of morphological change in C-shaped canal configuration along the root, i.e. the change in the classification of the C-shape canal between the coronal, middle, and apical parts of the root.
- Determine the level of the interexaminer agreement as this would make the results more trustable.

Other suggestions to improve the paper:
- English editing is required.
- Method in the manuscript should be placed after the introduction.
- Add examples of illustration of 3D construction of the different types of the c-shape canals if you have from your own study.

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agustin wahjuningrum Dian <dian-agustin-w@fkg.unair.ac.id> 18 Agustus 2022 pukul 09.31
Kepada: ayfer atav ateş <atavatesayfer@gmail.com>, TAHER AL-OMARI <t_omari@yahoo.com>

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Scopus ID 57205320764
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TAHER AL-OMARI <t_omari@yahoo.com> şunları yazdı (18 Ağu 2022 14:07):

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Revision Quality Check: The Prevalence and Anatomical Features of C-Shaped Mandibular Second Molars in the Jordanian Sub-population: A CBCT -Based Cross-Sectional Study

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[Kutipan teks disembunyikan]

The Prevalence and Anatomical Features of C-Shaped Mandibular Second Molars in the Jordanian Sub-population: A CBCT -Based Cross-Sectional Study

Taher Al Omari[1], Mustafa AlKhader[2], Ayfer Atav Ateş[3], Dr Dian Agustin Wahjuningrum[4*], Alaa Dkmak[1], Waheeb Khaled[1], Hazem Alzenate[1]

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Abstract

The prevalence and anatomical features of C-Shaped Mandibular Second Molars (MSMs) studies are limited in Jordanian Sub-population. This study aims to evaluate the prevalence of C-shaped in MSMs using cone-beam computed tomography (CBCT). A cross-sectional study was conducted using three thousand scans collected over 8 years between 2011-2019, that reviewed for the presence of fully formed MSMs. A total of 2037 cases that have 2845 MSMs were evaluated for the presence of C-shaped canals at coronal, middle, and apical locations. An oblique slicing module perpendicular to the long axis of MSMs was used to evaluate the teeth. The type and frequency of C-shaped canals, as well as the correlations between sex and side (right / left) and between sex and groove direction (buccal / lingual) were measured via the chi-square test using SPSS software at the significance level of 95%. Total of 342 teeth in 243 patients had C-shaped molars, which comprised 12 % of the patient's teeth, 99 of them had a bilateral C-shaped canal with mean age of 40 years old and ratio of female to male was 2:1. ~~The prevalence of C-shaped molars detected by CBCT was similar to that among the Caucasian sub population.~~ Within the limitations of this study, the lingual groove and type 3 are the most common properties of MSM, which have C-shaped canals in the Jordanian population. –

Keywords: Anatomy, molar, root canal, tomography, mandibular

Introduction

Anatomical variation in teeth is a well-occurring phenomenon in human ~~'s~~ teeth. The failure of Hertwig's epithelial root sheath fusion in lower molars may cause the formation of an uncommon ~~rare~~ anatomical variation that is described as a thin ribbon-shaped canal[1]. Cooke & Cox were the first to report the C-shaped configuration in endodontic literature[2]. The occurrence of this variation differs among different populations; It can be lower than 5 % in certain populations[3,4] and as high as 40 % in the Chinese population[5].

These high variances reported between different populations are worth investigating, however, the difficulty of detecting the different anatomical classifications on conventional radiograph necessitates the need for advanced-imaging studies. Moreover, the presence of radiographic-fused roots on the conventional x-rays and panoramic reconstruction increases the prevalence of C-shaped molars by a factor of 17.2 times[6]. Many methods have been used to study the root canal morphology, such as the clearing technique, vulcanite casts duplicated, tooth sectioning, and microscopic evaluation, as well as radiographic micro–computed tomographic imaging and cone-beam computed tomography~~ie~~ (CBCT)[7-9]. Many of the morphological studies are conducted ~~by~~ using non-invasive methods such as CT and CBCT[5-8]. The advantages of using CBCT imaging for a study are its wide use and availability, the possibility to modify the visual field and the high resolution of ~~an~~ images and the high level of confidence in ~~of~~ the results[10]. Despite the advantages, most studies have relatively a small sample size. To date, the prevalence of C-shaped lower molar for the Jordanian subpopulation was reported to be 10 %[11].

In the literature there is no study evaluated the prevalence of the **C-Shaped Mandibular Second Molars in the Jordanian Sub-population conducted with CBCT. This cross-sectional study aims to verify prevalence and anatomical features of C-shaped mandibular**

second molars in this population ~~We herein conducted cross-sectional study to evaluate retrospectively the prevalence of C- shaped canals~~ using CBCT imaging technology~~, because there is no study conducted in Jordan to verify this result with CBCT.~~

Results

Patient flow and its characteristics

Out of 3000 patients a total of 2037 patients had fully formed MSMs; 243 patients had C-shaped molars. The patient group was comprised of 75 males and 168 females with a mean age of 40 years. The total number of C-shaped molars was 342 teeth out of 2845 teeth. The flow diagram shown in fig. 3. The prevalence of C-shaped canals in MSMs was 12.0%. Moreover, 99 patients had a bilateral C-shaped canal.

No statistically significant differences were detected for sex ($P > 0.05$) and side of occurrence (left vs. right side) ($P > 0.05$) of the C-shaped canals, however, statistically significant differences were detected for sex and groove direction ($P < 0.05$). Tables 1-3 shows the different C-shaped configurations at different levels of the root.

Discussion

In the current study, the prevalence and configuration of C-shaped canals in ~~second lower molars~~ MSM were evaluated in different parts (coronal, middle, apical) of the teeth. ~~CBCT images of 2037 patients were examined and 342 teeth out of 2845 teeth were included in the study due to the study's inclusion criteria.~~ The results of this study showed that the percentage of C-shaped canals in MSMs was 12 % in the Jordanian subpopulation, ~~in MSMs. Since the probability of the existence of C-shaped canals in other teeth is lower than the probability of being seen in the mandibular second molar, this study was conducted in the latter group of teeth~~[13].

The canal configuration may vary according to the ethnic population. Previous studies showed that the percentage of C-shaped canals in the second mandibular molar teeth ranges from 2.7% in the American population[2] to 44.5% in the Korean population[13]. The pooled proportion of C-shaped anatomy in mandibular second molars in East Asian countries (39.6%; 36.0–43.1%) was significantly higher compared with other ~~another~~ region[12]. The prevalence of C-shaped canals in the Brazilian population was 15.3%. This prevalence did not differ with gender or age. There was a significant prevalence of C-shaped canals in the mandibular second molars of the population studied[14]. This study in Emirates population showed wide variations in the root and canal morphology in mandibular second molars with a relatively high prevalence of C-shaped canal configuration 17.9%[15]. The results of this study showed that the value for the Jordanian population is 12 % which is between these percentages. This result is consistent with the study of Al-Qudah and Awawdeh[11] with a similar prevalence (10%) in the same sub-population and Ladeira *et al.*[15] with 15,3% in Brazilian population[16].

~~Periapical radiographs are widely used tools in clinics because they are practical, cheap, and have low radiation[17]. Determination of C-shape using periapical radiographs is challenging. In a study by~~ Wang *et al.*[14] showed that the identification of C-shaped canal systems of mandibular second molars was 34.64% with radiographic examination, and 39.18% with clinical examination. The incidence of C-shaped root canal diagnosed by radiographic method was statistically different from that by clinical examination and the combined examination[16]. However, it is challenging to obtain enough knowledge about the cross-sectional morphology and the canal system with two-dimensional radiographs ~~for clinicians~~[3]. It was well demonstrated ~~several times~~ that CBCT images had superior accuracy when compared to periapical radiographs when it comes to anatomical difficulties such as second mesio-buccal ~~second~~ canals of maxillary

molars and C shaped canals of mandibular molars[18-20]. CBCT imaging is a good way to understand the full anatomy of teeth and plan root canal treatment.

Previous studies[21-23] that changing the tomographic slice angulation or inclination will affect the visibility of anatomical structures like the mandibular canal, and that the visibility of the canal was better when the slice inclination was perpendicular to the canal. There is a new software (e-Vol DX, CDT Software, Bauru, Brazil) for visualizing the teeth anatomy using slice inclination perpendicular to the canal[24-27], Bueno *et al.*[25], used this technique in an observational study of the anatomy of various ~~different~~ teeth (maxillary central, mandibular molars and premolar). ~~, However, their study did not evaluate C-shape molars alone and could not give broad information about the different anatomical features.~~

Similarly, we generated perpendicular CBCT sections to the canals of MSMs by using the oblique slicing module, which enhances the detection of different anatomy and might be the reason for the slightly higher prevalence of C-shaped canals in comparison to other studies conducted on the same ~~the~~ ethnic group[11]. The definition of a C-shaped canal in endodontics has not been clarified yet and different classifications have been used in previous studies[3,28,29]. In this study, the CBCT images were evaluated with the modification ~~modified~~ used by Shemesh *et al.*[3]. Since we performed our study with CBCT, to avoid the low image quality in the apical part (2 mm), Type 5 of the Fan *et al.*[28] classification was excluded as proposed by Shemesh *et al.*[3]

According to the results of the present study, type 1 and 3 were the most common in the coronal part (29.2%, and 35.4%) respectively. whereas type 3 was the most common in the middle third (40.4 %) of the canal and type 4 for in the apical part (50.3%). The results regarding the coronal part are partially in agreement with Shemesh *et al.*[3] and Fan *et al.*[28] who reported that type 1 was the most frequent. Furthermore, a study by Seo and Park[30] showed that the frequency

of type 2 was higher than other types. This inconsistency between the studies can be explained by the ethnicity of the study population and various study designs. It may be an advantage for Jordanian clinicians because ~~that~~ shaping and cleaning the type 3 root canal system is easier than type 1 and 2[5].

In the current study, both sides, right and left mandibular second molars were examined. Ninety-nine of the 243 patients had bilateral C-shaped second mandibular molars, which is 40.7 % of the patients, and therefore, we may conclude that we should be aware of C-shaped canals when the lower second molars are treated. According to our research' results, gender did not influence the side occurrence regarding C-shaped canals, which is in accordance with the studies by Zhang *et al.*[31] and Pawar *et al.*,[32] but gender did affect the groove direction. These anatomical features are important both in endodontics and periodontology. These grooves are difficult to clean, cause plaque to accumulate, and are periodontally important anatomical formations on the root surface[33] from the prospective of endodontics, the groove is considered a danger zone due to their low dentin thickness which ~~has a~~ tend~~ency~~ to perforate[34]. Clinicians should be mindful about the direction of this groove while performing root canal treatment. In our study, the lingual groove was frequently seen, like the findings of Fan *et al.*[28], but in contrast to those of Ladeira *et al.*[15]. Women exhibited more C-shaped mandibular molar than men. This result is similar to a worldwide study conducted by Zuben et al.

Using CBCT instead of micro-computed tomography (μCT) is one of the limitations of this study. Although μCT gives more information about the details of the morphology, this technology is used with extracted teeth[35,36], and extracted teeth that are generally pathological cannot simulate the Jordanian population's anatomical features of second molars. Moreover, a clearing method study with extracted teeth was done by Al-Qudah and Awawdeh[11] in the

Jordanian population. Thus, our study gives novel information about the same population.

The strength of this study is relatively large sample size using CBCT images. That~~The CBCT study with a large sample size~~ allows ~~for~~ more accurate assessment of the presence of C-shaped canals, however, the use of CBCT images acquired for different preposes other than endodontics and the collection of samples from two regions of Jordan limits the results to be standardized~~generalized~~. Future prospective study could be designed to evaluate the C-shaped molars by sample collected for endodontic evaluation from different geographical areas with specific parameters that allows for more accurate assessment of C-shaped molars in the Jordanian population. Comparing the methodology used for this study to new assessment tool (e-Vol DX, CDT Software, Bauru, Brazil) is worth to evaluates as it could be with similar benefits.

Conclusion

In conclusion, the lingual groove and type 3 are the most common properties of MSM, which have C-shaped canals in the Jordanian population. The prevalence of this morphology is 12%. Therefore, the clinicians should take these features into account and should combine CBCT and periapical radiography before starting endodontic treatment to reduce complications. In this manner, a successful endodontic treatment may be achieved. Finally, it should be noted that the use of the oblique slicing module enhances the visibility of different anatomical features related to the C-shaped canals detected.

Method

Study design

In tThis cross-sectional retrospective study, a pool of 3000 CBCT images collected from north and middle territories of Jordan were initially evaluated for fully formed mandibular second molars (MSMs). The images were collected over 8 years (2011-2019) in Jordan university of science and technology dental teaching hospital and CBCT 3D dental imaging centre/Amman. This work has been reported in line using STROBE guidelines was followed in preparing, analysing, and writing of this study[37]. This study was approved by the institutional review board of Jordan University of Science and Technology (6/140/2021).

Study population

Images were taken for various reasons not limited tofor endodontic purposeproposes. Teeth with artefacts, root canal treatment, posts and core, crowns and pathologies affecting the root were omitted from the study. KODAK 8100 and 9500 Cone Beam 3D System (Carestream, Rochester, NY) machines with a flat panel detector were used. CBCT scanning parameters for the 8100 CBCT machine were: 0.15-mm as the voxel size, 81 kV as a tube voltage, 6.3 mA as the tube current and 15s as the exposure time and representing two third of the sample size. Parameters for the 9100 CBCT machine were: 0.2-mm as the voxel size, 90 kV as the tube voltage, 10 mA as the tube current and 10.8s as the exposure time and representing two third of the sample size. Patients were asked to stop swallowing and to keep their teeth in maximum intercuspation. The occlusal plane was parallel to the floor and the field of view was 5x5 cm and 15x9 cm respectively.

Measurements and CBCT examination

The CBCT images were collected over eight years from 2011 until 2019 included in the study.

After a one-hour training session conducted by an oral radiologist with 12 years of experience, three graduate dentists, internally calibrated, were responsible for generating and simultaneously evaluating three cross-sectional CBCT slices perpendicular to the long axis for all MSMs. Thcirere primary task was to evaluate the presence of C-shaped canals isolated from MSMs.

To element any source of bias, an experienced radiologist evaluated all cases with disagreement and revise the initial images fulfilling the criteria.

Experienced radiologist evaluated the C-shaped canal cases following the example of Alfawaz *et al.*[38], the generated slices were coronal, middle and apical;- coronal section were taken 2 mm beneath the pulpal floor, where middle was calculated by dividing the full length of the root by 2 and apical was measured 2 mm above the radiographic apex (Fig. 1).

To generate the cross-sectional slices, the oblique slicing module of the CS 3D imaging viewer version 3.10.4.0. was used. The sagittal oblique images views were created by moving the green bar at MSM over the horizontal section then the yellow bar was moved on 90 degrees the long axis of each MSM and then moved vertically to the three previously determined sections (Fig. 1).

Shemesh *et al.*[3] classification, modified from Fan *et al.*[28] was use d to evaluate the CBCT images, C-shaped canals on the three cross-sectional slices were classified as following:

1. Type 1: continuous C with no separation or division (Fig. 2a)
2. Type 2: kidney shape semi-column (Fig. 2b)
3. Type 3: separate canals either two or three (Fig. 2c)
4. Type 4: funnel shape - one large canal (Fig. 2d).

The groove for each C-shaped root was also classified as buccal or lingual.

An LCD monitor with the installed dedicated CS 3D imaging viewer was used to view

the images, and the screen settings were adjusted to optimize the images for evaluation.

The chi-square test was used to measure the frequency and type of the C-shaped canals, the correlations between sex and side (right or left) and between sex and groove direction (buccal or lingual). IBM SPSS Statistics software (version 20.0; IBMCorp., Armonk, NY, USA) wSPSS software was used with a significance level of P = 0.05.

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Acknowledgements

Not applicable

Informed Consent Statement:

Not applicable

Ethics declaration: present study was approved by the institutional ethics committee Jordan University of Science and Technology And was conducted according to the guidelines of the Declaration of Helsinki.

Author contributions

T.A.O conception, design, data acquisition, analysis, and interpretation, drafted, and critically revised the manuscript; M.A conception, design, data analysis and interpretation, drafted, critically revised the manuscript; A.A.A and D.A.W drafted, and critically revised the manuscript, A.D , W.K and H.A data analysis and interpretation, critically revised the manuscript; H.A managed the data, including quality control, and all authors contributed substantially to its revision.

Data availability statement

The data underlying this article will be shared on reasonable request to the corresponding author.

Competing interests

The author(s) declare no competing interests.

Figure

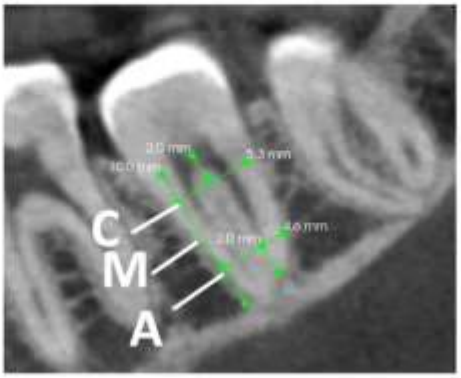

Fig. 1. Representative sagittal CBCT view of a mandibular second molar generated by oblique slicing module. exemplifying the three axial levels at which the evaluation was performed. Coronal (C), middle (M), and apical (A).

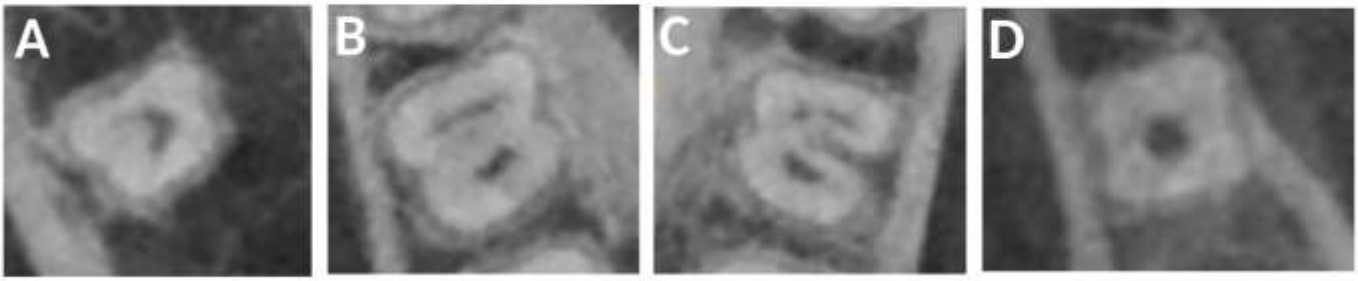

Fig. 2. Example of oblique slicing module perpendicular to the long axis of a mandibular second molar. A: Type 1— Continuous C with no separation or division, B: Type 2— kidney shape semi-column, C: Type 3— separate canals either two or three, D: Type 4— funnel shape - one large canal.

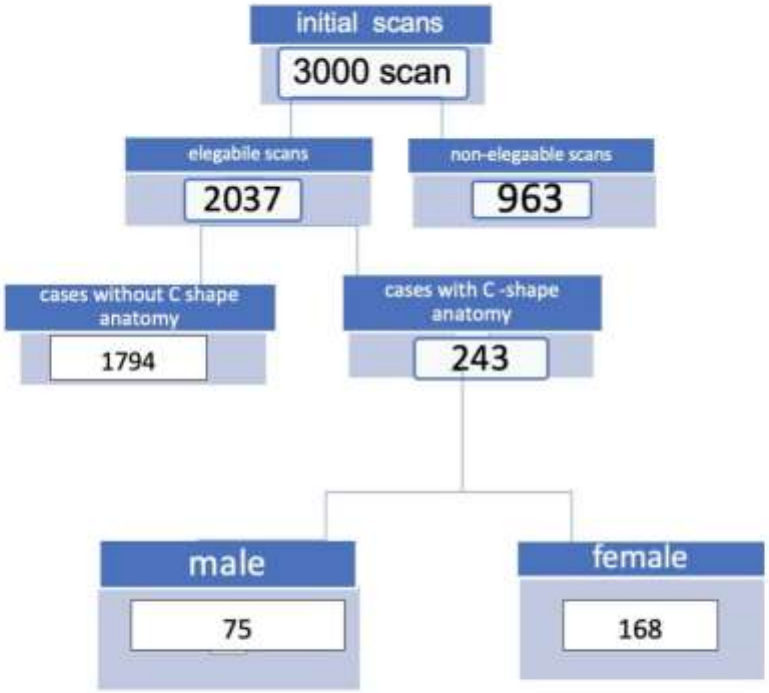

Fig. 3. Flow diagram for the eligible cases

Tables

Table 1: Analysis of the gender, side, and groove distribution of C-shaped canals in mandibular molars in the population

		No. of included cases	c-shape canal (%)
Gender	Female	342	237 (69.3%)
	Male	342	105 (30.7%)
Side	Right	342	183 (53.5%)
	Left	342	159 (46.5%)
Groove	Buccal	342	72 (21.1%)
	Lingual	342	270 (78.9%)

Table 2: Analysis of the relationship between gender and side & groove

		Female (%)	Male (%)	Total (%)
Side	Right	126 (36.8%)	57 (16.7%)	183 (53.5%)
	Left	111 (32.5%)	48 (14%)	159 (46.5 %)
Groove	Buccal	59 (17 %)	13 (4%)	72 (21%)
	Lingual	178 (52%)	92 (27 %)	270 (79%)
Total		237	105	342

Table 3: Classification of C-shaped mandibular second molars by modified Fan's classification

	Type 1 (%)	Type 2 (%)	Type 3 (%)	Type 4 (%)	total
Coronal third	100 (29.2%)	56 (16.4%)	121 (35.4%)	65 (19.0%)	342
Middle third	84 (24.6%)	58 (17.0)	138 (40.4%)	62 (18.1%)	342
Apical third	43 (12.6%)	23 (6.7%)	104 (30.4%)	172 (50.3%)	342

Reviewer 1
The present study addresses the prevalence and characteristics of the mandibular C-shaped second molar on a Jordanian Sub-population.

The last sentence of the Abstract ("The prevalence of C-shaped molars detected by CBCT was similar to that among the Caucasian sub population.") is related to the Discussion section, not a conclusion of the direct assessment of the results in the field. I recommend to remove that sentence.

Done

I cannot find the keywords. Sorry.
Done

Keywords added after abstract as follows;
Keywords: Anatomy, molar, root canal, tomography, mandibular

"may cause the formation of a rare anatomical variation that is described as a thin ribbon-shaped canal"… I would not call it rare but uncommon instead

Done

The Introduction looks quite fine. The last sentence has both aim and rationale for the study. I recommend the authors to reformulate this important sentence. Report first the rationale (absence in Jordan) and then the aim, in this latest aspect try to be more clear because the authors are addressing more than just the global prevalence.

I recommend the authors to place the Material and Methods between the Introduction and the Results.

I know the authors had the STROBE into consideration, however I suggest the authors to also mention, use, and report the correct use of the "Preferred Reporting Items for Epidemiologic Cross-sectional Studies on Root and Root Canal Anatomy Using Cone-beam Computed Tomographic Technology" published in JOE in DOI 10.1016/j.joen.2020.03.020 I believe this small step will give an improvement in the reliability of the study methodology. If the authors wish they may use both STROBE and the JOE one.

How were the patients selected?

What was the sampling methods in the Methods?

In the inclusion criteria… was taken into account the impossibility to determine the tooth numbering (as exclusion)? This is relevant because the morphology is tooth specific.

Regarding the exclusion, how many were they? What was the exclusion rate?

Did the authors notices any possible source of bias?

Regarding the results, I suggest the authors to give the 95% confidence interval for the 12% prevalence.

The discussion looks fine, however I would recommend to highlight a little better the study strength, limitations and further research perspectives.

I believe one relevant study is missing in the references, which is a Worldwide study on this topic. The rest looks updated.

Done

Women exhibited more C-shaped mandibular molar than men. This result is similar to a worldwide study conducted by Zuben et al.
Reference: von Zuben, M., Martins, J. N., Berti, L., Cassim, I., Flynn, D., Gonzalez, J. A., ... & Ginjeira, A. (2017). Worldwide prevalence of mandibular second molar C-shaped morphologies evaluated by cone-beam computed tomography. Journal of endodontics, 43(9), 1442-1447.

Reviewer 2
Ref: Submission ID 10ce33f8-172a-46c5-bc55-23a756e7e4ab
Manuscript Title: "The Prevalence and Anatomical Features of C-Shaped Mandibular Second Molars in the Jordanian Sub-population: A CBCT -Based Cross-Sectional Study"
Version: 1
Date: 9.5.2022
Reviewer: Assistant Professor Dr. Ranjdar Talabani

Reviewer's report:
Thank you for this study. There are big missing and diffusion regarding classification; reliability test and parameters including in the study specially age and sex factors. Is difficult to be published in highly indexed journal like "Scientific Reports".

1. It doesn't include conclusion in the abstract.

Done

Within the limitations of this study, the lingual groove and type 3 are the most common properties of MSM, which have C-shaped canals in the Jordanian population.

2. Age factor not considered in the study; the author mentioned that mean age was 40 years old how?
3. The result obtained from sex factor included in the study is not accurate because there are big differences in range between female to male (168 female to 75 males).
4. The author adopted classification for C shaped canal configuration based on
5. Most important missing point in this study is Reliability test (Kappa Value). This test showed the agreement between inters or intra examiner or observer accuracy result. This test mandatory is included at end of methodology.
6. It is highly recommended in such study; the authors present a table including other finding from different countries using CBCT to evaluate C shaped canal configuration.
7. In discussion; the authors mentioned "periapical radiograph"; it is not related to present study.

Done

Removed the following sentences;

Periapical radiographs are widely used tools in clinics because they are practical, cheap, and have low radiation[17]. Determination of the C-shaped canal system using periapical radiographs is challenging.

Reviewer 3
This is an interesting study about C-shaped root canal configuration in a certain sub-population.
The strength of this study is relatively large sample size using CBCT images.
However, it needs some minor corrections before publication.

Reviewer 4
This study is interesting but can be dramatically improved if you:
- Determine the types of morphological change in C-shaped canal configuration along the root, i.e. the change in the classification of the C-shape canal between the coronal, middle, and apical parts of the root.
- Determine the level of the interexaminer agreement as this would make the results more trustable.

Other suggestions to improve the paper:
- English editing is required.
- Method in the manuscript should be placed after the introduction.
- Add examples of illustration of 3D construction of the different types of the c-shape canals if you have from your own study.

scientific reports

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OPEN

A CBCT based cross sectional study on the prevalence and anatomical feature of C shaped molar among Jordanian

Taher Al Omari[1], Mustafa AlKhader[2], Ayfer Atav Ateş[3], Dian Agustin Wahjuningrum[4]✉, Alaa Dkmak[1], Waheeb Khaled[1] & Hazem Alzenate[1]

The prevalence and anatomical features of C-Shaped Mandibular Second Molars (MSMs) are rarely studied in Jordanian sub-population. This study then took a part to evaluate the prevalence of C-shaped in MSMs using cone-beam computed tomography (CBCT) in the Jordanian sub-population. It used a cross-sectional design and three thousand scans collected over eight years between 2011 and 2019. The data were then reviewed for whether they were fully formed of MSMs. A total of 2037 cases that had 2845 MSMs were evaluated to identify C-shaped canals at coronal, middle, and apical sites. An oblique slicing module perpendicular to the long axis of MSMs was used to evaluate the teeth. The type and frequency of C-shaped canals, as well as the correlations between sex and side (right/left) and between sex and groove direction (buccal/lingual) were measured using the chi-square test on SPSS software at the significance level of 95%. A total of 342 teeth of 243 patients were C-shaped molars, which comprised 12% of the patient's teeth and 99 of them as a bilateral C-shaped canal with mean age of 40 years and sex ratio of 2:1 between female and male. With the limitations of this study, the lingual groove and type 3 were the most common properties of MSM. Besides, the Jordanian population mostly had C-shaped canals.

Anatomical variation in teeth is a natural phenomenon in human teeth. The failure of Hertwig's epithelial root sheath fusion in lower molars may cause an uncommon anatomical variation, a thin ribbon-shaped canal[1]. Cooke and Cox were the first researchers who reported the C-shaped configuration in endodontic literature[2]. The occurrence of this variation differs among different populations; it can be lower than 5% in certain populations[3,4] and as high as 40% in the Chinese population[5].

This anatomical variations in human teeth between different populations are worth investigating; however, detecting the variations on a conventional radiograph requires advanced-imaging studies. Moreover, the presence of radiographic-fused roots on the conventional x-rays and panoramic reconstruction increases the prevalence of C-shaped molars by a factor of 17.2 times[6]. Many methods have been used to study the root canal morphology, such as the clearing technique, vulcanite casts duplicated, tooth sectioning, and microscopic evaluation, as well as radiographic micro–computed tomographic imaging and cone-beam computed tomography (CBCT)[7–9]. Many of the morphological studies are conducted using non-invasive methods such as CT and CBCT[5–8]. CBCT has its own advantages and disadvantages. Some of its advantages are that it is widely used and available to modify the visual field, the high-resolution images and the high confidence level[10]. Despite the advantages, most studies using the CBCT method have relatively a small sample size. To date, the prevalence of C-shaped lower molars in the Jordanian subpopulation was reported to be 10%[11].

None of literature evaluates the prevalence of the C-Shaped mandibular second molars (MSM) in the Jordanian sub-population using the CBCT method. Therefore, this cross-sectional study aimed to verify the prevalence and anatomical features of C-shaped mandibular second molars in this population using CBCT imaging technology.

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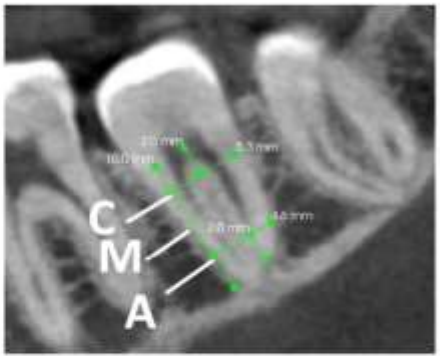

Figure 1. Representative sagittal CBCT view of a mandibular second molar generated by oblique slicing module. Exemplifying the three axial levels i.e., coronal (C), middle (M), and apical (A) at which the evaluation was performed.

Methods

Study design. In this cross-sectional retrospective study, a pool of 3,000 CBCT images collected from north and middle territories of Jordan were initially evaluated for whether they were fully formed of mandibular second molars (MSMs). The images were collected over 8 years (2011–2019) at the Dental Teaching Hospital of Jordan University of Science and Technology and CBCT 3D Dental Imaging Center/Amman. This work has been reported in line with previous research using STROBE guidelines[12] and investigating preferred reporting items for epidemiologic cross-sectional studies on root and root canal anatomy using cone-beam computed tomographic technology.[13] The study procedures started from preparing, data analysis, and writing of this study. As the present study did not interfere with the psychological or physical of patient. This study was approved, and the informed consent is waived by Ethical Clearance Commission of the Institutional Review Board of Jordan University of Science and Technology (6/140/2021).

Study population. Patients aged between 18 and 65 years were included in the analysis. Images were taken for various reasons not limited to endodontic purpose. Teeth with artefacts, root canal treatment, posts and core, crowns, pathologies affecting the root and impossibility to determine the tooth numbering were omitted from the study. KODAK 8100 and 9500 Cone Beam 3D System (Carestream, Rochester, NY) machines with a flat panel detector were used. CBCT scanning parameters for the 8100 CBCT machine were 0.15-mm as the voxel size, 81 kV as a tube voltage, 6.3 mA as the tube current and 15 s as the exposure time, representing two third of the sample size. Parameters for the 9500 CBCT machine were 0.2-mm as the voxel size, 90 kV as the tube voltage, 10 mA as the tube current and 10.8 s as the exposure time. Patients were asked to stop swallowing and to keep their teeth in maximum intercuspation. The occlusal plane was parallel to the floor, and the field of view was 5 × 5 cm and 15 × 9 cm, respectively.

Measurements and CBCT-based 3D examination on Kodak Dental Imaging Software. The CBCT sample images were collected over eight years from 2011 until 2019. After one-hour training conducted by a maxilla-facial radiologist with 12 years of experience, three graduate dentists, internally calibrated, were responsible for generating and simultaneously evaluating three cross-sectional CBCT slices perpendicular to the long axis for all MSMs. Their primary task was to evaluate the presence of C-shaped mandibular second molars. After the first selection of teeth, to remove any source of bias, the experienced radiologist and calibrated endodontist evaluated all cases in a darkened room. Kappa test was used for intrarater reliability. The interobserver reliability was high for all evaluated teeth related to C-shaped canals identification (Cohen's Kappa of > 0.91) and classification (100% of agreement).

The observers evaluated C-shaped canal scans following the examples from Alfawaz et al.[14]. The generated slices were coronal, middle and apical; coronal sections were taken 2 mm beneath the pulpal floor, where the middle floor was calculated by dividing the full length of the root by 2, and apical was measured 2 mm above the radiographic apex (Fig. 1).

To generate the cross-sectional slices, the oblique slicing module of the CS 3D imaging viewer version 3.10.4.0. was used. The sagittal oblique image views were created by moving the green bar at MSM over the horizontal section, and then the yellow bar was moved up to 90 degrees to the long axis of each MSM and vertically to the three previously determined sections (Fig. 1).

Shemesh et al.[3] mentioned some following classifications, modified from Fan et al.[15] to evaluate the CBCT images. Within the same framework, this current study classified C-shaped canals as three cross-sectional slices.

1) Type 1: continuous C with no separation or division (Fig. 2a)
2) Type 2: kidney-shaped semi-column (Fig. 2b)
3) Type 3: separate canals either two or three (Fig. 2c)

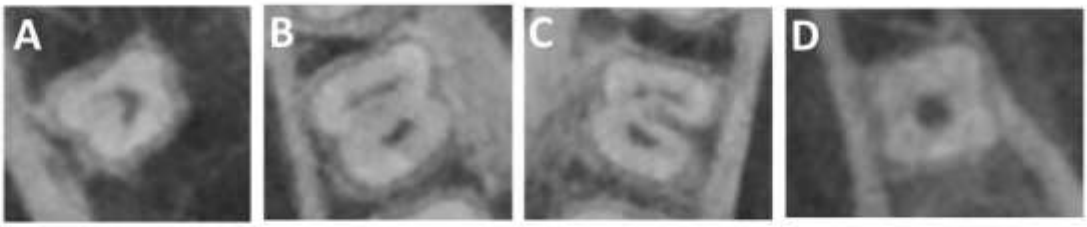

Figure 2. Example of oblique slicing module perpendicular to the long axis of a mandibular second molar. (**A**) Type 1—Continuous C with no separation or division, (**B**) Type 2—kidney-shaped semi-column, (**C**) Type 3—separate canals either two or three, (**D**) Type 4—one funnel-shaped large canal. (*B* buccal, *L* Lingual).

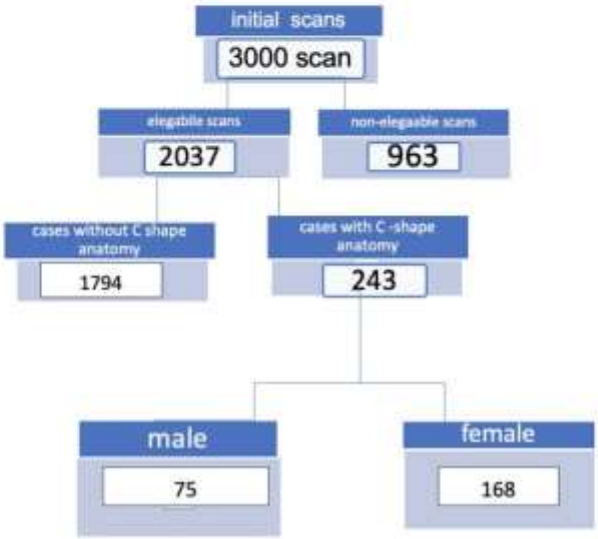

Figure 3. Flow diagram for the eligible cases.

4) Type 4: one funnel-shaped large canal (Fig. 2d).

The groove (developmental depression in root surface) for each C-shaped root was also classified as buccal or lingual.

An LCD monitor with the installed dedicated CS 3D imaging viewer was set along with the screen settings adjusted to optimize the images for evaluation.

The chi-square test was used to measure the frequency and types of the C-shaped canals, the correlations between sex and side (right or left) and between sex and groove direction (buccal or lingual). IBM SPSS Statistics software (version 20.0; IBMCorp., Armonk, NY, USA) was used to proceed the data analysis with a significance level of 0.05.

Ethics declaration. This present study was approved by the Institutional Ethics Committee of Jordan University of Science and Technology and was conducted according to the Guidelines of the Declaration of Helsinki.

Results

Patients' characteristics. Out of 3000 patients, a total of 2037 patients had fully formed MSMs, and 243 patients had C-shaped molars. The selected patients consisted of 75 males and 168 females with a mean age of 40 years. The total number of C-shaped molars was 342 teeth out of 2845 screened teeth. The flow diagram shown in Fig. 3. The prevalence of C-shaped canals in MSMs was 12.0%, while 99 patients had bilateral C-shaped canals.

No statistically significant differences were detected for sex ($p > 0.05$) and side of occurrence (left vs right side) ($p > 0.05$) on the formulation of C-shaped canals; however, statistically significant differences were detected between sex and groove direction ($p < 0.05$). Table 1 shows the analysis of the gender, side, and groove distribution of C-shaped canals in the population. Table 2 shows the analysis of the relationship between gender, side, and groove. Additionally, Table 3 indicates the classifications of C-shaped mandibular second molars modified from Fan's classifications.

	Number of included cases	C-shaped canal (%)
Gender		
Female	342	237 (69.3%)
Male	342	105 (30.7%)
Side		
Right	342	183 (53.5%)
Left	342	159 (46.5%)
Groove		
Buccal	342	72 (21.1%)
Lingual	342	270 (78.9%)

Table 1. Distribution analysis of gender, side, and groove distribution of C-shaped canals in mandibular molars of the Jordanian population.

	Female (%)	Male (%)	Total (%)
Side			
Right	126 (36.8%)	57 (16.7%)	183 (53.5%)
Left	111 (32.5%)	48 (14%)	159 (46.5%)
Groove			
Buccal	59 (17%)	13 (4%)	72 (21%)
Lingual	178 (52%)	92 (27%)	270 (79%)
Total	237	105	342

Table 2. Analysis of the relationship between gender, side, and groove.

	Type 1 (%)	Type 2 (%)	Type 3 (%)	Type 4 (%)	Total
Coronal third	100 (29.2%)	56 (16.4%)	121 (35.4%)	65 (19.0%)	342
Middle third	84 (24.6%)	58 (17.0)	138 (40.4%)	62 (18.1%)	342
Apical third	43 (12.6%)	23 (6.7%)	104 (30.4%)	172 (50.3%)	342

Table 3. Classifications of C-shaped mandibular second molars based on the modified Fan's classifications.

Discussion

In this current study, the prevalence and configuration of C-shaped canals in MSMs were evaluated in different parts (coronal, middle, apical) of the teeth. The results of this study showed that the percentage of C-shaped canals in MSMs was 12% in the Jordanian subpopulation.

The canal configuration may vary according to the ethnic population (Table 4). Previous studies showed that the percentage of C-shaped canals in the second mandibular molar teeth ranged from 2.7% in the American population[2] to 44.5% in the Korean population[16]. The pooled proportion of C-shaped mandibular second molars in East Asian countries (39.6%; 36.0–43.1%) was significantly higher than in other regions[13]. The prevalence of C-shaped canals in the Brazilian population was 15.3%, but it did not differ by gender or age. There was a significant prevalence of C-shaped canals in the mandibular second molars of the population studied[17]. Wide variations in the root and canal morphology of mandibular second molars were found in Emirates population with a relatively high prevalence of C-shaped canal configuration (17.9%)[18]. A more recent study showed the prevalence of C-shaped canal configuration in Iraqi sub-population was 17.4% which is similar to Emirates population and more than Jordanian sub-population. While the female/male ratio was similar to the current study. In Iraqi sub-population, a higher prevalence was found in women than men (10.4%)[19]. In both studies, women exhibited more C-shaped mandibular molars than men. This result is similar to a global study conducted by von Zuben et al.[20].

The results of this study showed that the value or the Jordanian population is 12% which is between these percentages. This result is consistent with a study conducted by Al-Qudah and Awawdeh[11] discovering a similar prevalence (10%) in the same sub-population and less prevalence than a study by Ladeira et al.[18] where 15.3% were found in Brazilian population[21].

Table 4 shows the prevalence of C-shaped molars in different countries.

Wang et al.[17] showed that the identification with radiographic examination showed 34.64% of C-shaped canal systems in mandibular second molars, and that using clinical examination showed 39.18%. The amount of C-shaped root canals diagnosed by radiographic method was statistically different from that by clinical examination and the combined examination[21]. However, it is challenging to obtain enough knowledge about the

Investigators	Race	Overall prevalence of C-shaped canals in mandibular first molar (%)	Overall prevalence of C-shaped canals in mandibular second molar (%)
Shemesh et al.[3]	Israel	0.16	4.6
Silva et al.[4]	Brazilian	1.7	3.5
Zheng et al.[5]	Chinese		39
Nejaim et al.[6]	Brazilian	2.39	14.32
Pan et al.[9]	Malaysian		48.7
Jin et al.[13]	Korean	–	44.5
Wang et al.[14]	Chinese	–	41.27
Ladeira et al.[18]	Brazilian	–	15.3
Khawaja et al.[16]	Emirati		17.9
Zhang et al.[31]	Chinese	29	29
Pawar et al.[32]	Indian	–	13.2
Alfawaz et al.[38]	Saudi	0.19	9.1
Abdalrahman et al	Iraqi	–	17.4

Table 4. Incidence of C-shaped root canal configuration mentioned by in vivo studies.

cross-sectional morphology and the canal systems with two-dimensional radiographs[3]. While CBCT images had more superior accuracy when compared to periapical radiographs that involve anatomical difficulties such as second mesiobuccal canals in maxillary molars and C-shaped canals in mandibular molars[22–24]. CBCT imaging is a good way to understand the full anatomy of teeth and plan root canal treatment.

Previous studies[25–27] showed that changing the tomographic slice angulation or inclination could affect the visibility of anatomical structures, for example in the mandibular canals. The visibility of the canals was better when the slice inclination was perpendicular to the canal. Some new software (e-Vol DX, CDT Software, Bauru, Brazil) has been developed to visualize the teeth anatomy using slice inclination perpendicular to the canal[28–31]. Bueno et al.[24] used this technique in an observational study on the anatomy of various teeth (maxillary central, mandibular molars and premolar).

Similarly, we generated perpendicular CBCT sections to the canals of MSMs by using the oblique slicing module, which enhanced the detection of different anatomy. Using this method in this current study likely resulted in the slightly higher prevalence of C-shaped canals than other studies conducted to the same ethnic group[11]. The C-shaped canal in endodontics has not clearly been defined yet, and different classifications of the canals have been used in previous studies[3,15,32]. In this current study, the CBCT images were evaluated according to modification criteria used by Shemesh et al.[3]. Since we performed our study with CBCT method, to avoid the low image quality in the apical part (2 mm), we followed Shemesh et al. to exclude category 5 of the Fan et al.[15] classifications[3].

According to this current study, type 1 (29.2%) and 3 (35.4%) were the most common in the coronal part. In addition, type 3 (40.4%) was the most common in the middle third of the canal, and type 4 was the most noticeable in the apical part (50.3%). The results related to the coronal part are partially relevant to what Shemesh et al.[3] and Fan et al.[15] found. They reported that type 1 was the most frequent. On the other hand, a study by Seo and Park[33] showed that the frequency of type 2 was higher than other types. In Iraqi sub-population, type 2 was the most common in contrary to Jordanian sub-population where type 3 was the most common[19]. This inconsistency of certain images between the studies is likely influenced by the ethnicity of the study population and the use of various study designs. However, it may be an advantage for Jordanian clinicians because shaping and cleaning the type 3 root canal system is easier than type 1 and 2[5].

In this current study, both right and left mandibular second molars were examined. Ninety-nine of the 243 patients or 40.7% of the patients had bilateral C-shaped second mandibular molars; therefore, we should be aware of C-shaped canals when treating the lower second molars. According to our research results, gender did not influence the side occurrence of C-shaped canals. This finding is in accordance with the studies conducted by Zhang et al.[34] and Pawar et al.[35]. However, this current study found gender did affect the groove direction. These anatomical features are important both in endodontics and periodontology. These grooves are difficult to clean, cause plaque to accumulate, and are periodontally important anatomical formations on the root surface[36]. From the perspective of endodontics, the groove is considered a danger zone due to their low dentin thickness which tends to perforate[37]. Clinicians should be mindful about the direction of this groove while performing root canal treatment. In our study, the lingual groove was frequently seen, and previous research by Fan et al.[15] showed similar result. However, this finding is in contrast to research by Ladeira et al.[18].

The use of CBCT instead of micro-computed tomography (μCT) is one of the limitations of this study. Although μCT gives more information about the details of the morphology, this technology is used for extracted teeth[38,39]. While extracted teeth that are generally pathological cannot simulate the anatomical features of second molars in Jordanian population. Despite this limitation, this study holds more contribution to research compared to previous research which used a clearing method with extracted teeth[11] of the Jordanian population. Thus, our study gives novel information about the same population.

The strength of this study is that it used a large sample size using CBCT images and conducted evaluation by both the endodontist and radiologist. These advantages allow more accurate assessment of C-shaped canals;

however, this study has other limitations related to data standardization which are the use of CBCT images acquired for different purposes other than endodontics and the collection of samples from two regions of Jordan. Future prospective research could be designed to accurately evaluate the C-shaped molars by sampling CBCT images collected for endodontic purpose from different geographical areas with specific parameters for the Jordanian population. Comparing the assessment method used for this study to new assessment tools (e-Vol DX, CDT Software, Bauru, Brazil) is worth to investigate in future research.

Conclusion

In conclusion, the Jordanian population mostly had the lingual groove and type 3 properties of MSM with C-shaped canals. The prevalence of this morphology was 12%. Therefore, the clinicians should take these features into account and should combine CBCT and periapical radiography before starting endodontic treatment to reduce complications. With the thoughtful considerations on the features, a successful endodontic treatment may be achieved. Finally, it should be noted that the use of the oblique slicing module enhances the visibility of different anatomical features related to the detected C-shaped canals.

Data availability

The data used in this article are shared upon request to the corresponding author.

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Author contributions

T.A.O. managed the research conceptualization, design, data acquisition, analysis, and interpretation, writing draft, and critical revision of the manuscript; M.A. was responsible for the research conceptualization, design, data analysis and interpretation, writing draft, and critical revision of the manuscript; A.A.A. and D.A.W. drafted and critically revised the manuscript; A.D., W.K. and H.A. performed data analysis and interpretation, and revision of the manuscript; H.A. managed the data, including the data quality control. All authors contributed substantially to the revision of this manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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