Prevalence and anatomical characteristics of bifid and trifid mandibular canals: a computed tomography analysis

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Research Article

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Abstract

Purpose: To assess the prevalence and configuration of bifid (BMC) and trifid (TMC) mandibular canals using computed tomography, describing the anatomical characteristics of the accessory canals, especially of the retromolar type.

Methods: Computed tomographic scans of 123 patients were analyzed. BMCs were identified and the patterns of bifurcation were classified, including trifid canals. The width of accessory canals was measured. Retromolar canals were further classified according to their course and morphology, while their position and width were evaluated using linear measurements on CT/CBCT images.

Results: The majority part of patients (53.6%) presented at least one BMC or TMC. A percentage of 36.2% of mandibular canals were bifid, while 4.5% trifid. The forward canals (12.6%) and retromolar canals (10.2%) were the most common among BMCs. In relation to the retromolar canals, 60% were vertical and 40% curved, with a mean width of 1.03 ± 0.28mm.

Conclusion: BMCs and TMCs are common 3D radiographic findings, so that they should be considered as anatomical variants, not anomalies. Preoperative CT or CBCT evaluation should aid to identify these variations, analyzing the position and course.

Introduction

The mandibular canal (MC) is an anatomical structure with a great clinical importance since it is an intraosseous canal containing different structures which contribute to form the inferior alveolar bundle [14].

Determining the position and morphology of the mandibular canal could avoid damaging its neurovascular plexus during oral surgery. It is also advisable to identify its anatomical variations, such as Bifid Mandibular Canals (BMCs) and Trifid Mandibular Canals (TMCs).

Indeed, the mandibular canal could present several ramifications, dividing it into a main branch, which keep its path to the mental foramen, and one or more accessory branches, which have a different course in the mandible [1].

Several studies showed that accessory canals may contain neurovascular tissue [2, 5, 8]. A lesion of these structures during oral surgery could determine the onset of complications such as paresthesia, bleeding or traumatic neuroma [3].

One of the most frequent accessory canals is the retromolar canal, a type of BMCs which is often associated with surgical complications; this anatomical structure arises from the mandibular canal behind the third molar and travels antero-superiorly to the retromolar foramen, located in the retromolar fossa [20].

Different classification systems have been proposed for BMCs, based on the anatomical position and configuration of the accessory canals. The earliest classification systems, such as that of Nortje et al. and that of Langlais et al., were based on panoramic radiographs [19], while Naitoh et al. proposed a system based on computed tomographic scans (CT) [10].

Localization of accessory canals on panoramic radiographs is often difficult or not possible, due to the overlapping of buccal and oral bone structures and to the dimensional distortion given by the irregular magnification [10]. Instead, computed tomography provides three-dimensional images and allow an easier identification of position and width of accessory canals [4].

However, there are not classifications including the trifid canal type (TMCs), although many cases were reported in the past publications [15].

Hence, the aim of this study was to determine the prevalence and configuration of BMCs and TMCs using Computed Tomography (CT) and Cone-Beam Computed Tomography (CBCT). In addition, the anatomical characteristics of the accessory canals (i.e., retromolar type) were also reported.

Materials And Methods

A selection of CT and CBCT scans of patients treated at Department of Oral Surgery - University of Naples Federico II from May 2018 to January 2020 were retrospectively collected and evaluated. The inclusion criteria were the following:

- Male and female;
- Age ≥ 18 years;
- Computed tomographies performed for odontostomatological evaluations (i.e., tooth extraction, dental implant planning);
- Scans with a field of view (FOV) showing full lower arch.

The exclusion criteria were:

- Scans that did not clearly show the entire path of the mandibular canal (from mandibular foramen to mental foramen);
- Presence of osteolytic and/or osteosclerotic lesions in the posterior area of the mandible.

Analysis of the tomographic scans and data collection was performed by two clinicians (V.P. and L.G.). The inter examiner agreement was analyzed by kappa coefficient. A k-score of 0.90 was accepted for agreement. Any discrepancy between the two clinicians was resolved by discussion.

Evaluation and classification of accessory canals using CT/CBCT images

RadiAnt DICOM Viewer software (version 4.6.9; Medixant, Poznan, Poland) was used to process the projection data. For each evaluation site, the entire path of the mandibular canal was evaluated under free angulation of three-dimensional slices on multiplanar reconstruction (MPR) images.

When necessary, brightness and contrast of the images were adjusted to optimize the recognition and determination of the mandibular canal and any accessory canals.

For each evaluation site, the mandibular canal was classified as normal, bifid (BMC) or trifid (TMC), according to the number of accessory canals branching from it (none, one or two).

The BMCs were classified according to the classification of Naitoh et al.[10] (Table 1).

Table 1
Classification of Bifid Mandibular Canals (BMCs)

Canal type	**Description**
Retromolar canal (Type I)	Branches off the mandibular canal in ramus region, runs anterosuperiorly and opens at the retromolar foramen, in the retromolar region
Dental canal (Type II)	Bifurcates from the mandibular canal and reaches the root apex of the second or third molar
Forward canal (Type III)	Arises from the superior wall of the mandibular canal and runs forward parallel to the main canal, with or without confluence
Buccolingual canal (Type IV)	Arises from the buccal or lingual wall of the mandibular canal

The width of the accessory canals was measured immediately after bifurcation on the coronal CT-derived images.

Retromolar canals were further classified into three categories based on their course and morphology, according to the classification of von Arx et al.[20] (Table 2).

Table 2
Classification of retromolar canals

Retromolar canal type	**Description**
Vertical (Type A)	Arises from the mandibular canal and runs vertically upwards, with a more or less straight and direct course, up to the retromolar foramen
Curved (Type B)	Arises from the mandibular canal, runs in an anterior direction and then curves supero-posteriorly towards the retromolar fossa
Horizontal (Type C)	Arises from the mandibular foramen and runs anteriorly in a horizontal direction to open on the anterior face of the mandibular branch or into the retromolar fossa

Furthermore, sagittal CT- or CBCT-derived images were used to determine position and width of retromolar canals [20]:

- Horizontal distance from midpoint of retromolar foramen to second molar (on the distal cementum-enamel junction or CEJ; Fig. 1A);
- Height of retromolar canal: vertical distance from the midpoint of the retromolar foramen to the upper border of the mandibular canal (Fig. 1B);
- Width of retromolar canal: measured at a level of 3 mm below the mesial aspect of the retromolar foramen (Fig. 1C).

In addition, two other distances were measured on the sagittal CT- or CBCT-derived images:

- Distance from the mandibular foramen to the branch point of the retromolar canal;
- Width of mandibular canal from which a retromolar canal branch off: measured immediately before bifurcation.

Scans were subjected to a second analysis using Simplant pro 18 software (version 18.0.0; Dentsply Implants NV, Hasselt, Belgium). This software was used to process the volumetric reconstructions and to visualize the mandibular canal and any accessory canals in three-dimensional space after having reconstructed them starting from axial, trans-axial and panoramic-like images.

The 3D rendering of the mandible allows to rotate the reconstruction without constraints, for a more accurate evaluation of the position and direction of the accessory canal and for a correct identification of any retromolar foramen.

Statistical analysis

Descriptive and comparative statistical analysis were performed by means of computer software (Microsoft Excel; Microsoft Corporation, Washington, DC, USA and IBM SPSS; SPSS Inc., Chicago, IL, USA).

The data were presented as like frequencies, means and standard deviations.

Differences in the prevalence rate of accessory canals according to gender, side and type were evaluated using the Chi squared test and Fisher’s exact test.

The analysis of variance (ANOVA) test was used to evaluate differences in width among accessory canal types. A value of $p < 0.05$ was considered statistically significant.

Results

The most part of computed tomography scans were requested for planning surgical extraction of one or both lower third molars, when the panoramic radiographs showed an intimate relationship between dental roots and mandibular canal. The process of collecting CT and CBCT scans resulted in the selection of 123 patients and 246 mandibular canals: 64 women and 59 men, with a mean age of 31.4 ± 11.62 years. A total of 53.6% patients (*n* = 66/123) had at least one bifid (Fig. 2) or trifid mandibular canal, with a prevalence in female patients of 46.8% (*n* = 30/64) and of 61% (*n* = 36/59) in male patients (Table 3).

Table 3
Frequencies of accessory canals (gender)

Gender	Accessory canals		Total	p-value [a]
	Present	Absent		
Male	36 (61%)	23 (39%)	59 (48%)	
Female	30 (47%)	34 (53%)	64 (52%)	0.148
Total	66 (53.6%)	57 (46.4%)	123 (100%)	

[a] p-value refers to the Fisher’s exact test

No significant differences in the prevalence of accessory canals for gender ($p \leq 0.05$).

In 66 patients with at least one bifid or trifid mandibular canal, 51.5% (*n* = 34/66) showed accessory canals bilaterally.

In 27 patients both mandibular canals were bifid, in 4 patients one canal bifid and the contralateral one trifid, and in only 3 patients both canals were trifid. The remaining 48.5% (*n* = 32/66) had one or two accessory canals only on right or left side.

The prevalence of BMCs and TMCs was, respectively, 50.4% (*n* = 62/123) and 6.5% (*n* = 8/123).

The prevalence on single sites (hemimandibles) was 36.2% (*n* = 89/246) for BMCs and 4.5% (*n* = 11/246) for TMCs (Table 4).

Table 4
Prevalence of bifid and trifid mandibular canals

Canal type	n	Percentage
Non-bifid canal	146	**59.3%**
Bifid mandibular canal (BMC)	89	**36.2%**
Retromolar canal (Type I)	25	10.2%
Dental canal (Type II)	15	6%
Forward canal (Type III)	31	12.6%
Buccolingual canal (Type IV)	9	3.7%
Not classifiable BMC	9	3.7%
Trifid mandibular canal (TMC)	11	**4.5%**
Total	246	**100%**

The most common variant among BMCs was the forward canal (type III;12.6%), followed by retromolar canal (type I; 10.2%), dental canal (type II; 6.2%) and buccolingual canal (type IV; 3.7%). Figure 3 shows the different types of accessory canals.

The remaining 9 mandibular canals (3.7%; *n* = 9/246) were not classified, because of a path not included in the adopted classification: in eight evaluation sites an accessory branch departing from the inferior wall of mandibular canal and running antero-inferiorly, while in one hemimandible a Temporal Crest Canal (TCC) has been observed (Figs. 4, 5).

No significant differences in the prevalence of different types of accessory canals for gender ($p = 0.145$) and right or left side ($p = 0.742$) were found.

The mean width and standard deviation of different types of accessory canals was reported in Table 5. The mean width of retromolar canals (1.44 ± 0.65 mm) was significantly greater than anterior canals (1.08 ± 0.26 mm; $p = 0.043$). Furthermore, no significant differences were observed in the width of the other types of accessory canal.

Table 5
Mean width and standard deviation of accessory canals

Canal type	Mean width	SD	Range
Bifid Mandibular Canal (BMC)	1.22 mm	± 0.45 mm	0.56–3.01 mm
Retromolar canal (Type I)	1.44 mm [a]	± 0.65 mm	0.66–3.01 mm
Dental canal (Type II)	1.27 mm	± 0.38 mm	0.63–2.01 mm
Forward canal (Type III)	1.08 mm [a]	± 0.26 mm	0.57–1.49 mm
Buccolingual canal (Type IV)	1.19 mm	± 0.40 mm	0.65–1.82 mm
Not classifiable BMC (excluding TCC)	1.00 mm	± 0.28 mm	0.56–1.48 mm
Trifid Mandibular Canal (TMC)	1.18 mm	± 0.35 mm	0.62–1.80 mm
Total	1.21 mm	± 0.44 mm	0.56 – 3.01 mm

[a] Statistically significant ($p < 0.05$)

A percentage of 15.5% of patients ($n = 19/123$) showed at least one retromolar canal and, of these, six patients present it on both sides. Therefore, a total of 25 retromolar canals (10.2%) were detected with CT and CBCT images in 246 sites (Fig. 6).

In relation to their morphology, 60% had a vertical pattern ($n = 15/25$, type A), while 40% had a curved course ($n = 10/25$, type B); horizontal pattern (type C) was not identified.

The data related to the main position and width of the retromolar canals were summarized in Table 6.

Table 6
Linear measurements of the retromolar canals

Distance	Mean	SD	Range
Horizontal distance from midpoint of retromolar foramen to second molar	15.7 mm	3.5 mm	11–29.3 mm
Height of retromolar canal	12.9 mm	2.7 mm	9.6–21.5 mm
Width of retromolar canal	1.03 mm	0.28 mm	0.45–1.47 mm
Distance from the mandibular foramen to the branch point of the retromolar canal	12.18 mm	5.32 mm	2.7–23.3 mm
Width of mandibular canal from which the retromolar canal branch off	3.12 mm	0.67 mm	1.96–4.44 mm

The distance from the midpoint of the retromolar foramen to the second molar was 15.7 ± 3.5 mm (range 11-29.3 mm). The height of the retromolar canal was 12.9 ± 2.7 mm (range 9.6–21.5 mm). The width was 1.03 ± 0.28 mm (range 0.45–1.47 mm). The distance from the mandibular foramen to the bifurcation point was 12.18 ± 5.32 mm (range 2.7 23.3 mm). The width of the mandibular canal from which the retromolar canals branch off was 3.12 ± 0.67 mm (range 1.96–4.44 mm).

Discussion

The present retrospective observational study analyzed the prevalence and morphological characteristics of bifid and trifid mandibular canals using CT and CBCT. A high prevalence of these anatomical variants was reported. Previous studies[11, 12, 17] analyzed the accessory canals of the mandibular canal, considering CT or CBCT a suitable modality for a detailed evaluation. In other words, tomographic scans, provide high-resolution three-dimensional images and they can detect accessory canals with narrow width and those that bifurcate in buccal or lingual direction [21].

In order to correctly evaluate the canals that branch out in a more posterior position of the mandibular canal, near the mandibular foramen, only tomographic scans which allowed an analysis of the whole mandible were included. Mandibles with osteolytic or osteosclerotic lesions in the posterior region were excluded because the pathology could have modified the original anatomy.

Finally, the retromolar canal (type I) has been subjected to a more accurate analysis since it represents one of the most frequent types of bifurcation and more often associated with surgical complications [18].

In agreement to previous studies [7, 9, 16] (i.e., prevalence rate of BMCs ranging from 15.6–66.5%), the prevalence of BMCs was 50.4%. However, this outcome is in contrast respect to those reported by Naitoh et al.[10] and Orhan et al.[12].

In the present investigation the prevalence of trifid mandibular canals (TMCs) was 6.5%. These results are in agreement to those reported in a previous study, in which a prevalence of 5.8% [15] was reported.

The classification proposed by Naitoh et al.[10] was adopted to analyze the anatomical variant of BMCs. Forward (type III) and retromolar (type I) canals were the most frequent types recorded, with a percentage of 34.83% and 28.09%, respectively. These data are confirmed by Naitoh et al.[10] and Orhan et al.[12], which found a higher frequency of type III and I canals with a prevalence of 59.6% and 29.8% for forward canals, respectively, and of 29.8% and 28.1% for retromolar canals, respectively.

The prevalence of dental (type II; 16.85%) and buccolingual (type IV; 10.11%) canals was in present study lower than type I and III, according to Naitoh et al. which reported a rate of 8.8% for type II and 1.8% for type IV.

In addition, we also found some anatomical variants (3.7%; $n = 9/246$) not described by the adopted classification [10]. In eight hemimandibles, the accessory canal originates from the inferior wall of mandibular canal and running antero inferiorly.

Moreover, a very rare anatomical variation (Temporal Crest Canal, TCC) was recorded in one patient. This anatomical variation was described in 1986 by Ossenberg et al. [13] It originates from an accessory mandibular foramen, positioned anteriorly and cranially to the mandibular foramen, runs first antero-inferiorly and then antero-superiorly and opens at a bony foramen located in the anterior region of the temporal crest.

Probably, TCC conveys the long buccal nerve and the associated blood vessels, pierces the temporalis tendon and travels to the cheek and mandibular buccal gingiva [6, 13].

The data on width and position of the retromolar canals of our study are in agreement with the results reported by von Arx et al.[20], who applied the same measurement modalities, detecting a horizontal distance from midpoint of retromolar foramen to second molar of 15.2 ± 2.4 mm, a height of retromolar canal of 11.4 ± 2.7 mm and a width of retromolar canal of 1 ± 0.31 mm.

In the present investigation, a total of 123 CT or CBCT scans was retrospectively collected and analyzed. Unfortunately, the small sample available represents a limit of the study.

Another limitation is the collection of tomographic scans only of patients who had performed it for surgical purposes (possible selection bias) and in different radiological centers, with different radiological exposure settings, positioning and methodology (CT or CBCT).

Conclusion

Within the limits of the present study, bifid and trifid mandibular canals have an important clinical relevance, in relation to their prevalence and their morphological characteristics.

Outcomes of this study suggest performing an accurate radiographic diagnosis using CT or CBCT in order to avoid possible surgical complications.

Declarations

Ethical approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the University of Naples “Federico II” (No. 286/20).

Informed consent Informed consent for processing personal data was obtained from all participants included in the study.

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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Author contributions L Ramaglia: research conception and design, project development. A Blasi: data analysis. L Galasso: scans selection and analysis, data collection. V Pezzella: scans selection and analysis, data collection. A Cuozzo: manuscript writing. V Iorio-Siciliano: manuscript writing, review of the original draft.

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Figures

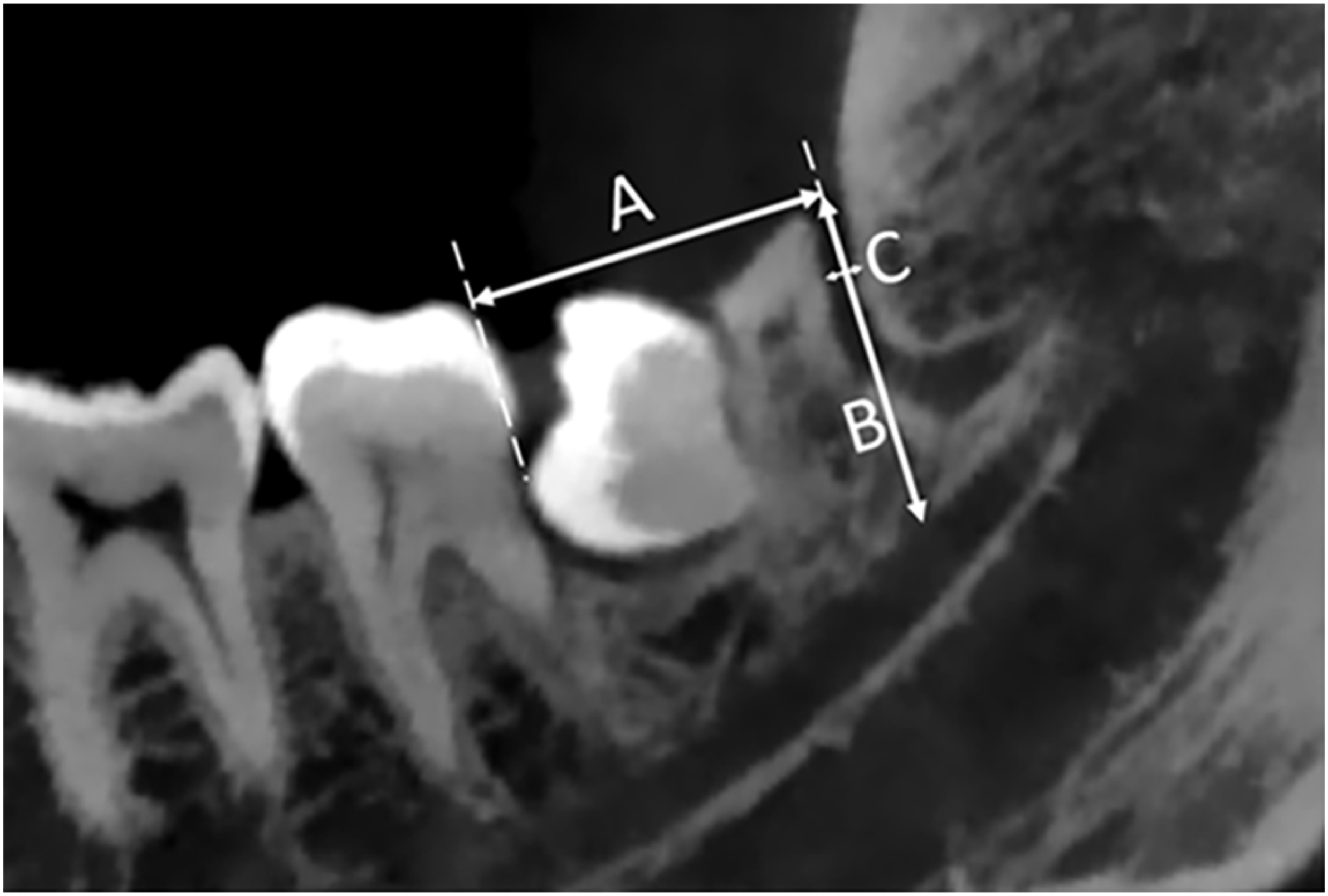

Figure 1

Illustration of linear measurements taken of the retromolar canal: Horizontal distance from retromolar canal to second molar (A); Height of retromolar canal (B); Width of retromolar canal (C)

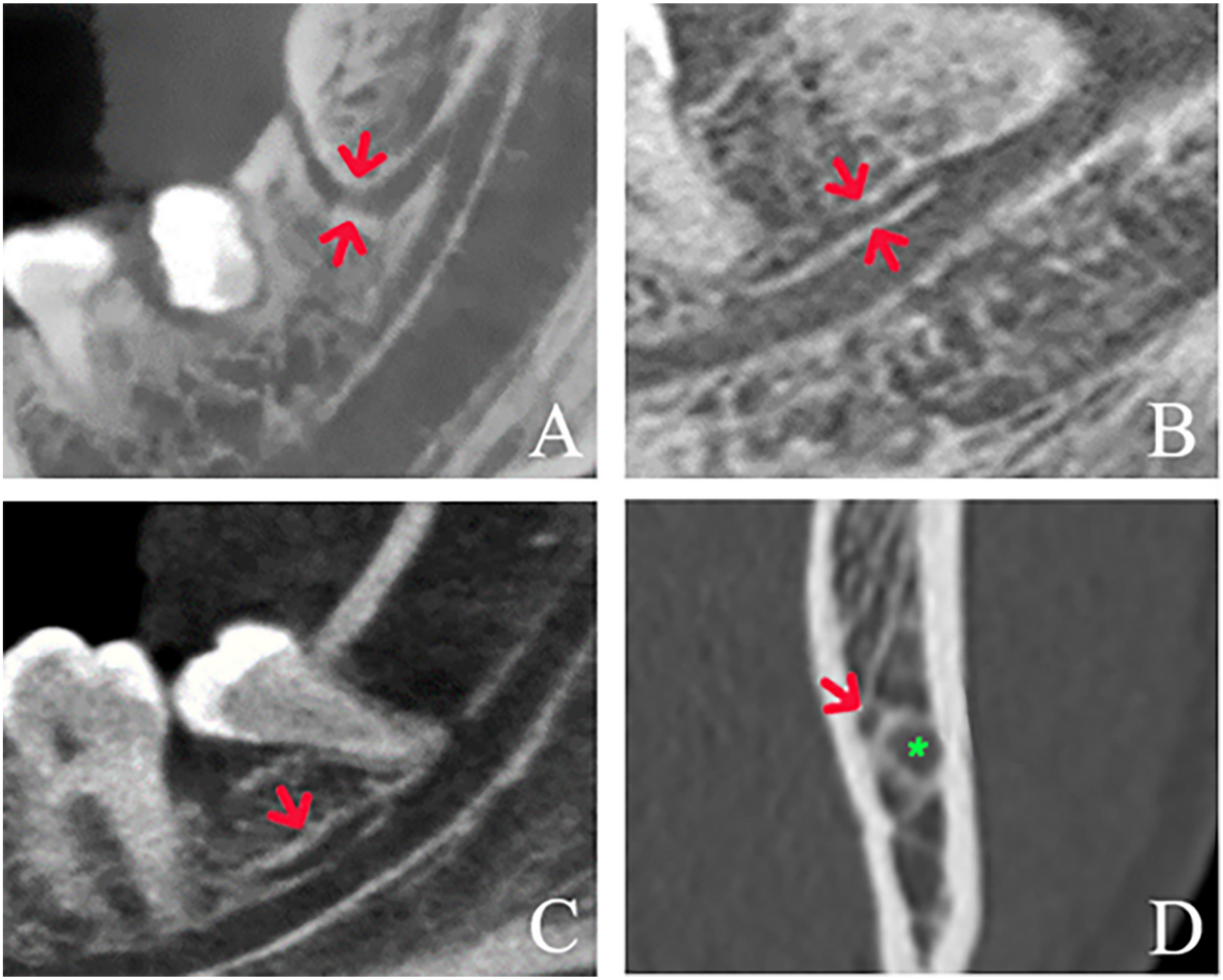

Figure 2

Multiplanar Reconstruction CT images showing different types of BMCs: A) Retromolar canal (red arrows); B) Dental canal (red arrows); C) Forward canal (red arrow); D) Buccolingual canal (red arrow). Green asterisk indicates the mandibular canal

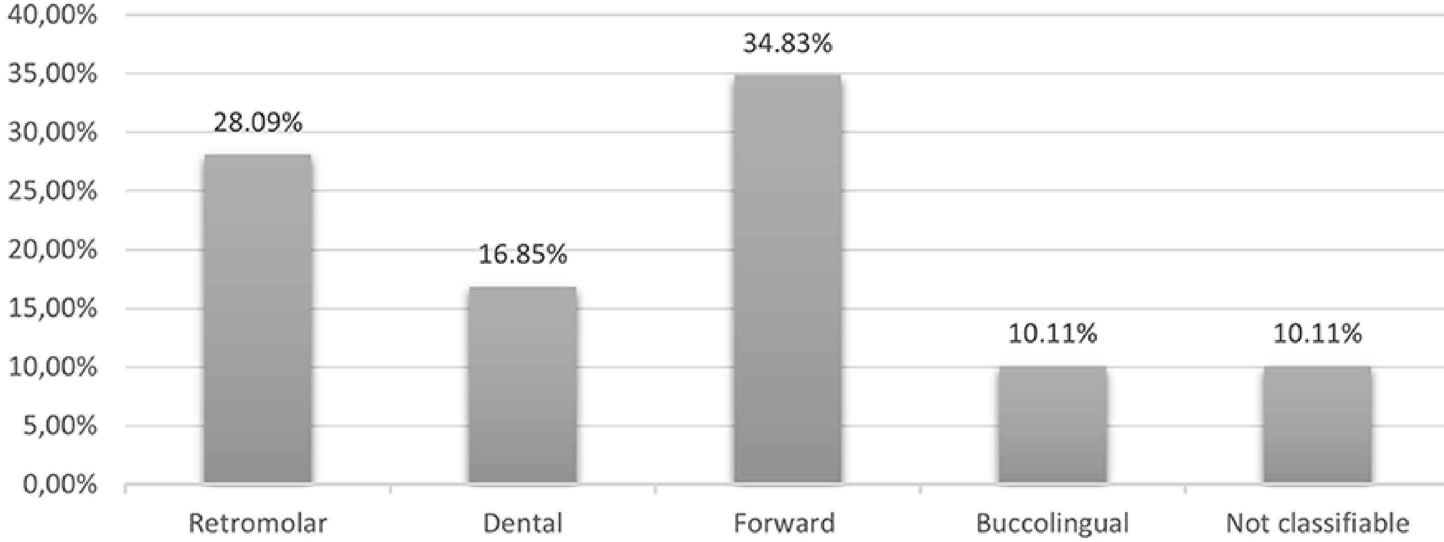

Figure 3

Rates of Different Types of accessory canal in 89 BMCs

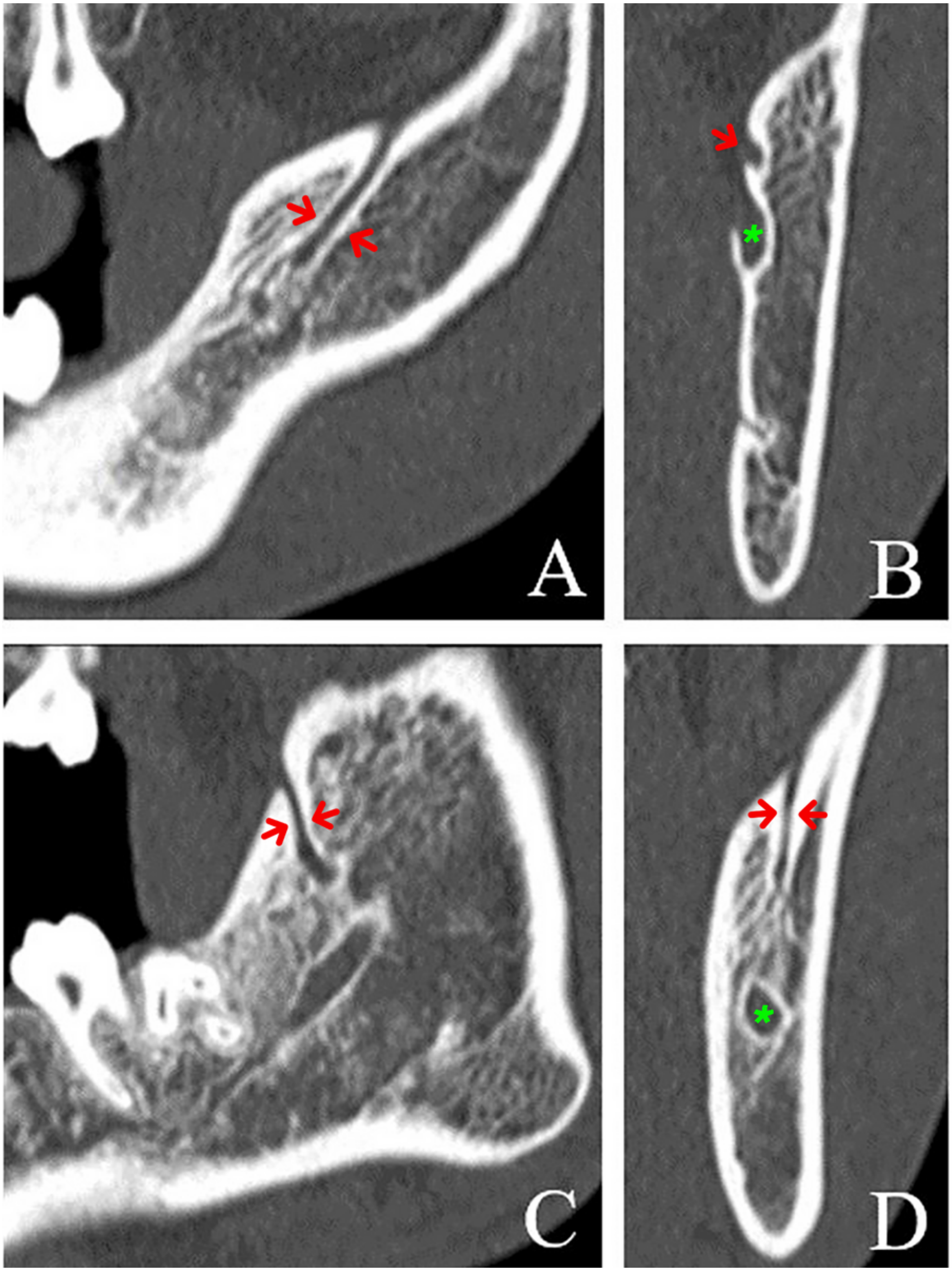

Figure 4

Temporal Crest Canal (TCC): A) Sagittal CT cut showing initial course of TCC (red arrows); B) Coronal CT cut showing the mandibular foramen (green asterisk) and the accessory foramen (red arrow); C) Sagittal CT cut showing the last part of TCC (red arrows); D) Coronal CT cut showing the TCC opening at a bony foramen (red arrows) and the mandibular canal (green asterisk)

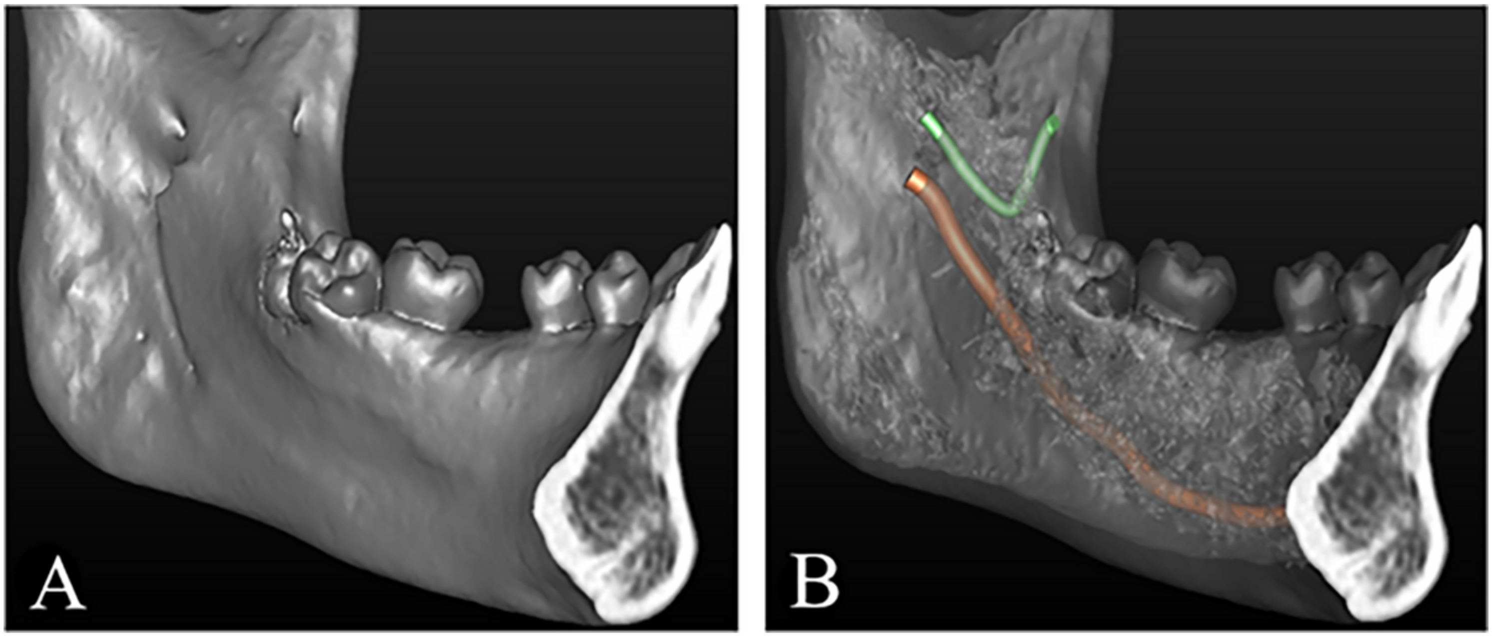

Figure 5

Temporal crest canal (TCC): A) Volumetric reconstruction showing the accessory foramen, positioned anteriorly and cranially to the mandibular foramen, and the exit foramen of the TCC; B) Volumetric reconstruction with a transparency kernel that highlights the courses of the TCC and the mandibular canal

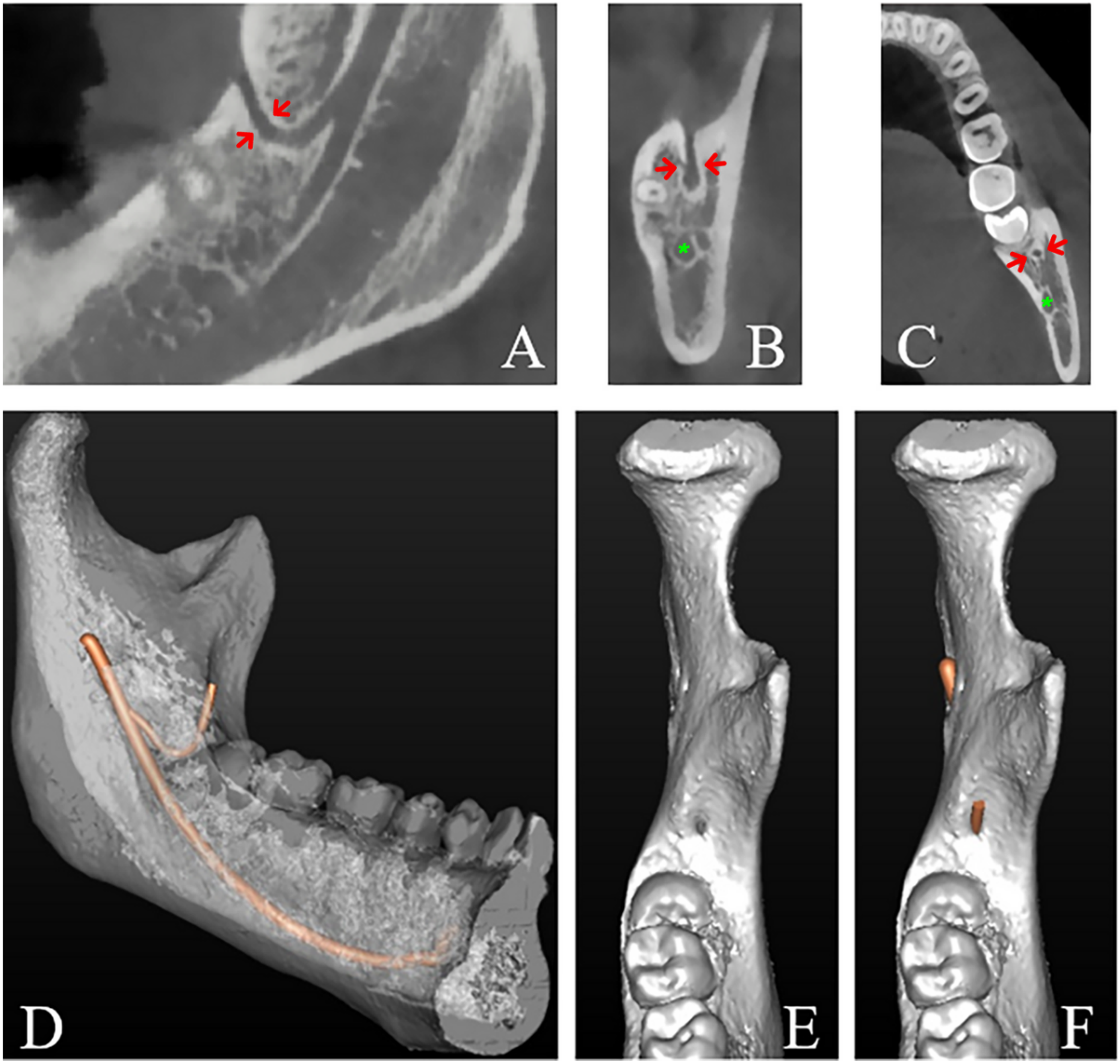

Figure 6

A) Sagittal CT cut showing a vertical retromolar canal (red arrows) from the bifurcation point to the retromolar foramen; B) Coronal CT cut showing the last section of the retromolar canal (red arrows) and its opening (retromolar foramen) and the mandibular canal (green asterisk); C) Axial CT cut showing a section of retromolar canal (red arrows) and a section of the mandibular canal (green asterisk); D) Volumetric reconstruction with a transparency kernel that highlights the entire course of the retromolar canal; E) Detail of the volumetric reconstruction showing the retromolar foramen; F) Detail of the volumetric reconstruction showing the vascular-nerve bundle that crosses the retromolar foramen