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ORIGINAL ARTICLE

Anatomical and radiographic study of the mandibular retromolar canal

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Abstract *Background/purpose:* As the demand for surgical procedure in the retromolar area of the mandible has been increasing, the identification of the retromolar foramen (RMF) and canal involving the retromolar triangle (RMT) has become an issue of clinical concern. We examined the shape of the RMT, incidence of the RMF, and intraosseous trajectory of the retromolar canal (RMC).
Materials and methods: A total of 118 sides of dry mandibles, 22 sides of mandibles of 13 cadavers, and cone-beam computed tomography (CT) images of 100 patients were examined. Micro-CT data of 13 cadavers were reconstructed using imaging analysis software for the presence of an RMC. RMCs were classified into three types according to the courses. The width and location of the RMCs were evaluated.
Results: The shape of the RMT was classified into three categories, with the most common type being the triangular type (81.4%). Forty-seven retromolar foramina (33.6%) were observed in 140 sides of mandibles. The horizontal distances from the RMF to the second and third molars were 12.1 ± 3.3 mm and 5.8 ± 3.6 mm (mean ± standard deviation), respectively, and the distance from the mandibular foramen to the arising point of the RMC and the vertical distance from the RMF to the mandibular canal were 21.5 ± 11.2 mm and 15.3 ± 4.6 mm, respectively.
Conclusion: This study used various methods to obtain precise anatomical data on the RMT,

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foramen, and canal in Koreans. The reported findings may be helpful for the clinical management of patients.

Introduction

The retromolar triangle (RMT) is a depressed area formed by the bifurcation of the mandibular temporal crest and the posterior edge of the last mandibular molar. The gross anatomy of the RMT, which is an area of great importance in dental practice, varies greatly according to the presence of the mandibular third molar and alveolar bone resorption.[1] The retromolar canal (RMC) normally arises from the mandibular canal behind the third molar, and travels anterosuperiorly to the retromolar foramen (RMF), which is located within or around the RMT.[2] Several studies on the RMC and RMF have reported considerable diversity with a frequency from 1.7% to 72% depending on the study design and the race of the participants.[3–5] However, the precise location of these structures relative to each other does not appear to have been determined.

Knowledge of the location of the RMC and of its anatomical variations can facilitate surgical intervention and protect the patient from the potential complications thereof. The RMT is relevant to surgical procedures, such as extraction of an impacted third molar, dental implant treatment, bone harvesting as a donor site for bone graft surgery, and sagittal split ramus osteotomy.[6] Moreover, the content of the RMC is an issue of clinical concern in surgical procedures involving the RMT. The neurovascular content of the RMC has been evaluated in cadavers[5,7] and in clinical biopsy specimens.[8–11] According to these reports, the neurovascular bundle within the RMC contains predominantly thin nerve fascicles of myelinated nerve fibers branching from the inferior alveolar nerve, small arteries, and numerous venules accompanying those arteries. Therefore, damage to the RMC contents could lead to unexpected bleeding and iatrogenic nerve damage, potentially resulting in paresthesia.

In clinical practice, anatomical variations, such as supplemental or accessory canals and foramina, can only be detected by radiologic methods. However, conventional two-dimensional (2D) radiographs such as panoramic images are insufficient for detecting all anatomical structures, and in particular the presence of an RMC.[12] Sectional imaging, such as computed tomography (CT) and cone-beam CT (CBCT), has been used successfully in dentistry,[13] and CBCT systems are available for routine investigation in dental clinics. However, studies that have evaluated the location of the RMCs using CBCT images have found incidences ranging from 14.6% to 47.4%, with no agreement between the various reports.[6,12,14,15] Kawai et al[6] investigated the occurrence of the RMC in Japanese cadaver mandibles using CBCT images prior to dissection and macroscopic observation, and reported that the subsequent cadaver dissection revealed some RMCs that had not been identified in the CBCT images. Therefore, a more precise description of the anatomy of the RMC requires a high-resolution imaging modality and no movement of objects during imaging. Over the past few years, micro-CT systems have been used for the evaluation of the bony canal morphology because of their high resolution.[16] The system can also be used to assess the characteristics of the RMC/RMF both qualitatively and quantitatively.

The present study (1) carried out an anatomical and morphometric analysis of the RMT/RMF, (2) investigated the incidence of the RMF in Korean cadaver mandibles, (3) described the microanatomy of the RMC using three-dimensional (3D) reconstruction of micro-CT images, and (4) evaluated how frequently the RMC is visible on CBCT images.

Materials and methods

A total of 118 sides of dry, adult Korean mandibles from 59 cadavers (i.e., 59 right sides and 59 left sides) of unspecified sex and age were obtained from the Department of Anatomy of Pusan National University (Yangsan, Korea). The single inclusion criterion was that the first permanent molars or their identifiable socket needed to be present on each mandible bilaterally. Twenty-two sides of mandibles from 13 embalmed Korean adult cadavers (11 males and 2 females, with a mean age at death of 65.3 years) were also evaluated.

The RMT was identified and demarcated on 140 mandible sides. The boundaries of the RMT were defined by the bifurcation of the mandibular temporal crest and the posterior edge of the last mandibular molar. The maximum height and width (sagittal and transverse distances) were measured using a digital caliper with a sensitivity of 0.01 mm (Model CD-15CP; Mitutoyo, Kawasaki, Japan). All measurements were made by the same person in triplicate, and the mean values of these three measurements are reported. The RMTs were classified into three categories based on their shape, according to the classification of Suazo et al.[17]

The RMF was identified macroscopically; its diameter was determined using round stainless-steel orthodontic wires with a diameter of 0.5 mm. The wires should enter the RMF without excessive force and exhibit minimal play. Any foramina having a diameter of less than 0.5 mm were not considered as the RMF.

Micro-CT images and 3D reconstruction

Twenty-two sides of mandible from 13 cadavers were scanned using a micro-CT system (SkyScan 1076 in-vivo X-ray microtomograph; SkyScan, Kontich, Belgium) with a

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slice thickness of 35 μm. The serially obtained 2D images were saved in JPEG format for easy image control, and were three-dimensionally reconstructed using two types of imaging software: OnDemand3D (Cybermed, Seoul, Korea) and Reconstruct (http://synapses.clm.utexas.edu/tools/reconstruct/reconstruct.stm).[18]

CBCT images

One hundred Korean patients (30 males and 70 females; mean age, 52 years) who underwent preoperative CBCT imaging for dental implant treatment at Pusan National University Dental Hospital (PNUDH) between August 2011 and April 2012 were enrolled with approval from the Institutional Review Board of PNUDH (E-2012019). Images were obtained using a CBCT scanner (Pax-Zenith 3D, Vatech, Gyeonggi-do, Korea) with the following settings: field of view, 20 cm $\times$ 19 cm; tube voltage, 90 kVp; tube current, 4.0 mA; scan time, 24 seconds; and isotropic voxel size, 0.30 mm. The DICOM files were reformatted to 3D images using 3D imaging software (OnDemand3D; Cybermed).

Image evaluation

The CBCT and micro-CT images were evaluated in a darkened room. The longitudinal plane and the mandibular canal on the retromolar area and perpendicular plane were reconstructed from volumetric CBCT/micro-CT data using image-analysis software (OnDemand3D; Cybermed). The presence and buccolingual and mesiodistal locations of the RMF/RMC were confirmed by these images. The existence of the RMC was defined when it branched off from the mandibular canal and also exited as the RMF on the retromolar surface.

The RMCs were classified into three categories based on their course and morphology (Figure 1), according to the classification of von Arx et al[12]: Type A, a vertical course; Type B, a curved course; and Type C, a horizontal course. In addition, the following linear measurements were made on sagittal CBCT and micro-CT images (Figure 2): the distance from the mandibular foramen to the arising point of the RMC, the vertical distance (height) from the midpoint of the RMF to the upper border of the mandibular canal, and the horizontal distances from the midpoint of the RMF to the distal edge of the last tooth or socket of the second and third molars.

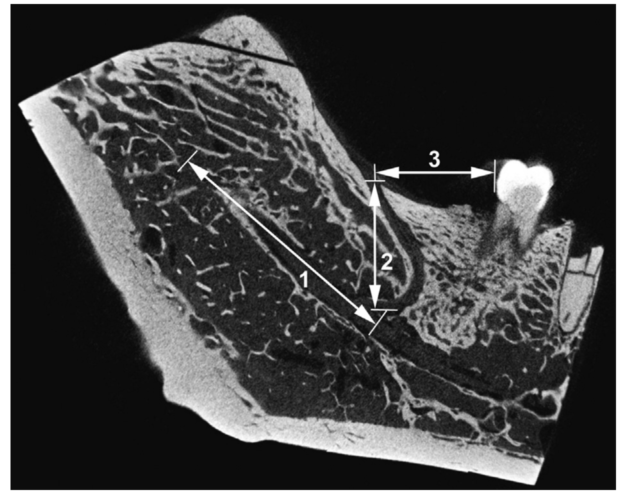

Figure 2 Linear measurements made of the retromolar canal (RMC): 1, distance from the mandibular foramen to the arising point of the RMC; 2, height of the RMC; and 3, horizontal distance from the midpoint of the retromolar foramen to the second or third molar.

Histological evaluation

A histological study was performed to confirm the contents of the RMC. Twenty-two hemimandibles were dissected, and the RMFs clearly visible in one of several specimens were stained. The bone fragment including the RMC was fixed with neutral-buffered formalin, decalcified with 10% EDTA for 2 months, sectioned at a thickness of 5 μm using a microtome, and stained with hematoxylin–eosin.

Statistical analyses

The collected values were analyzed statistically using the Statistical Package for Social Science software version 18.0 (SPSS, Chicago, IL, USA). The data are presented as

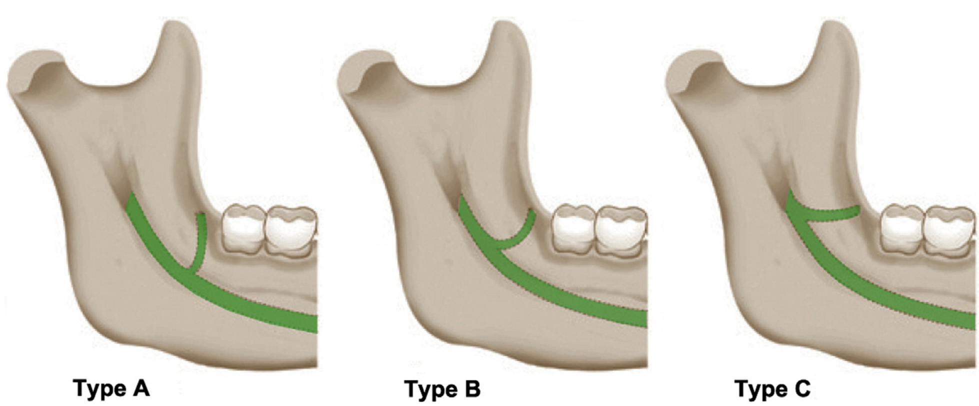

Figure 1 Schematic illustrations of the three types of the retromolar canal. Type A, a vertical course; Type B, a curved course; and Type C, a horizontal course.

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mean ± standard deviation values, and the threshold for statistical significance was set at $P < 0.05$.

Results

Morphometry of the RMT

The measured transverse and sagittal lengths of the RMT were found to be 7.6 ± 1.8 mm and 10.8 ± 2.4 mm, respectively. The RMT was classified into three types according to its shape (drop, tapering, and triangular forms), as partially described by Suazo et al.[17] Of the 140 mandibular sides, the drop form was found in 12, the tapering form in 14, and the triangular form in 114 (Figure 3).

Frequency and location of the RMF

In total, 47 RMFs (33.6%: 17 right, 18 left, and 12 bilateral) were detected in 140 mandibular sides (Figure 4). The RMFs were located on the right side of the mandible in 23 cases (32.9%) and on the left side in 24 cases (34.3%). Thirty-two of the 47 RMFs (68.1%) were found within the RMT. Based on a midsagittal line through the RMT, the RMF tended to be on the buccal side ($n = 26$) more than on the lingual side ($n = 21$), but the difference was not statistically significant. Meanwhile, of the 200 mandibular sides examined on CBCT, an RMC was present in 23 (11.5%).

Morphometry and histological evaluation of the RMC

The linear measurements taken from the CBCT and micro-CT images are summarized in Table 1. The distance from the mandibular foramen to the arising point of the RMC was 21.5 ± 11.2 mm (range, 9.6–35.2 mm), the vertical distance (height of the RMC) from the midpoint of the RMF to the upper border of the mandibular canal was 15.3 ± 4.6 mm (range, 9.6–21.7 mm), and the distances between the RMF and the distal edge of the last tooth (or socket) were 12.1 ± 3.3 mm and 5.8 ± 3.6 mm for the second and third molars, respectively.

The RMCs were divided into three categories, Types A–C, according to their direction and course. The canal had a curved course (Type B, 62.7%) in most RMCs, and a vertical course (Type A) in 37.3%; Type C, a horizontal course, was not identified in any of the images (Figure 5).

The 3D reconstruction from micro-CT images revealed the part of mandible containing the RMC (Figures 6 and 7). The RMC arose anterosuperiorly from the mandibular canal behind the third molar and then curved posterosuperiorly to the RMF, which is located on the lingual side of the RMT.

The neurovascular bundle was well-defined in the decalcified histological sections (Figure 8). The artery with its thick wall and the veins with thin walls were readily distinguished. There were numerous nerves in the RMC, and the nerve or its branches were located mainly in the periphery of the canal.

Discussion

Anatomical variations in the form of the accessory foramina and canals of the mandible can cause surgical complications if not properly identified. The RMC is a rare anatomical variation found in the RMT, which is a small, triangular-shaped region posterior to the third molar tooth in the mandible.[8] The neurovascular content of the RMC is an issue of clinical concern in surgical procedures involving the retromolar area.

The morphometric characteristics of the RMT are described herein. The RMT was classified into three types (tapering, drop, and triangular forms) according to its

Figure 3 Classification of the retromolar triangle according to its shape (green): (A) drop form, (B) tapering form, and (C) triangular form.

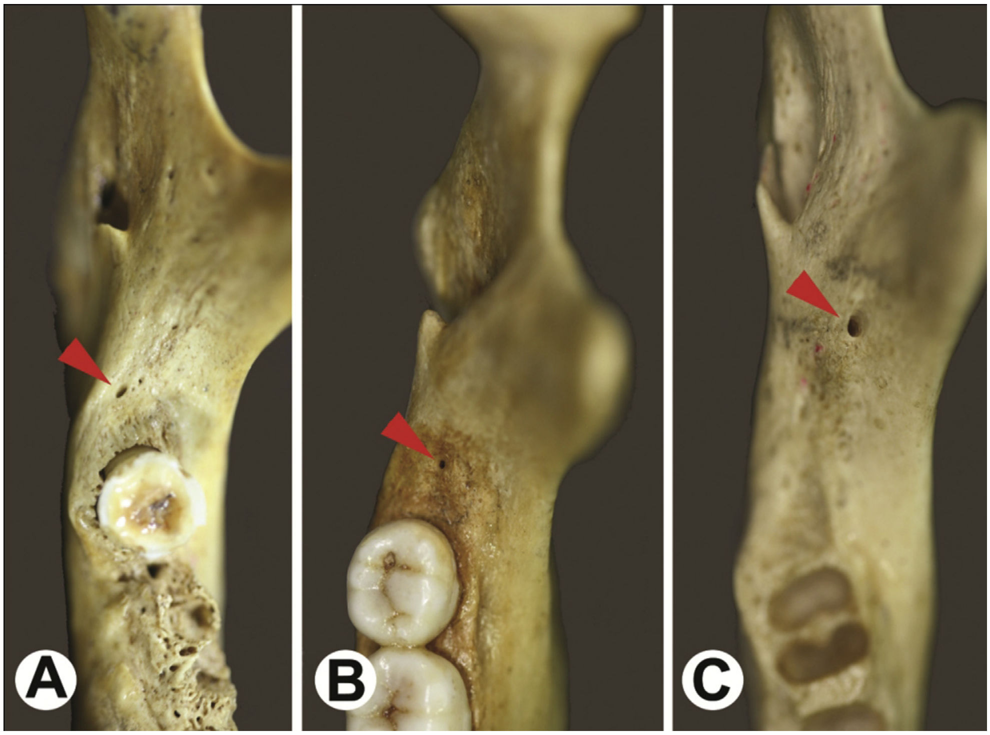

Figure 4 Photographs showing the retromolar foramen (RMF, red arrowheads). (A) RMF located in the retromolar foramen (RMT) and on the lingual side of the midsagittal line of the RMT. (B) RMF located in the RMT and on the midsagittal line of the RMT. (C) RMF located outside the RMT and on the buccal side of the midsagittal line of the RMT.

shape, as described previously in part by Suazo et al.[17] The authors of that study reported that the most frequent type, the triangular form, had a prevalence of 80%[17]; in close agreement with that study, the prevalence of the triangular form in our study was 81.4%. The shape of the RMT varied greatly according to the presence (or not) of the posterior teeth of the mandible. When the third or second molars were present, the RMT tended to have a triangular form.

Table 1 Measured distances between the retromolar foramen and adjacent structures.

Measurement	Mean ± standard deviation (mm)	Range (mm)
Distance from the mandibular foramen to the arising point of the RMC	21.5 ± 11.2	9.6–35.2
Vertical distance from the midpoint of the RMF to the upper border of the mandibular canal	15.3 ± 4.6	9.6–21.7
Horizontal distance from the midpoint of the RMF to the distal edge of the second molar	12.1 ± 3.3	6.5–19.0
Horizontal distance from the midpoint of the RMF to the distal edge of the third molar	5.8 ± 3.6	3.0–18.5

RMC = retromolar canal; RMF = retromolar foramen.

The incidence of the RMF has been reported to vary from 7.7% to 66% depending on the study design.[19,20] The incidence of the RMF in this study was 33.6% (47 of 140 mandibular sides), which is close to that reported by both Hu et al[21] and Kawai et al[6]; all of these results were obtained from Northeast Asians. It appears that the incidence of the RMF varies hugely between races, and Ossenberg[3] reported that the rate in a North American population was lower than in other populations, such as those from Northeast Asia, Europe, and Africa.

The most common 3D diagnostic imaging modality used to study mandibular anatomy is CBCT.[22] Naitoh et al[23] observed a bifid mandibular canal in the mandibular ramus region in 65% of CBCT images, while Kuribayashi et al[2] reported that 47 of 301 (15.6%) patients studied with CBCT had bifid mandibular canals. In CBCT images, a bifid mandibular canal was observed on 18 of 38 sides and an RMC was seen in three canals (7.9%) by Naitoh et al.[22] In fact, the criteria for a precise radiological classification of a bifid canal such as an RMC are not clear.[14] However, three recent studies focused on the radiological detection and incidence of the RMC by CBCT. von Arx et al[12] provided a detailed description of the courses, morphologies, and dimensions of 31 RMCs on 121 mandibular sides (25.6%), Kawai et al[6] described the frequency, location, and content of 34 RMFs on 90 mandibular sides (37%), and Lizio et al[14] reported that 34 RMCs were detected on 233 CBCT images (14.6%). In this study, the RMC was present in 23 of 200 CBCT images (11.5%). The low incidence of the RMC in this study compared with previous studies may be

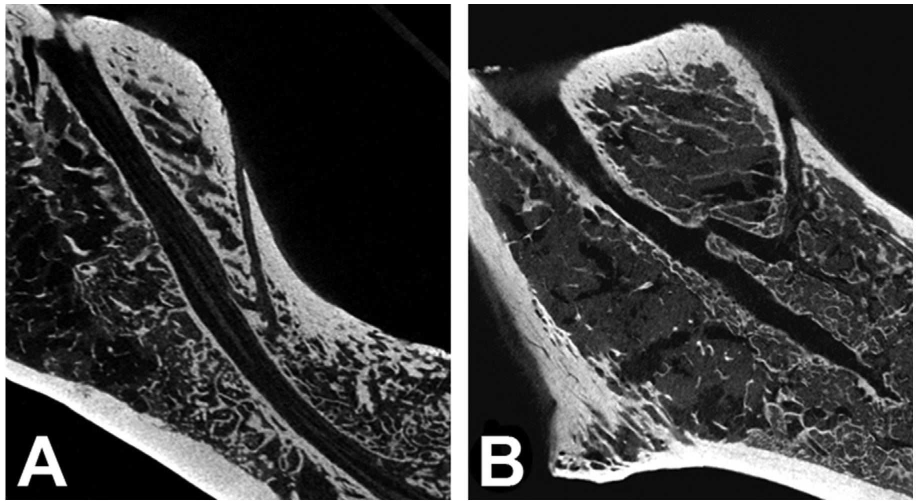

Figure 5 Classification and examples of the retromolar canal: (A) Type A, vertical course; and (B) Type B, curved course.

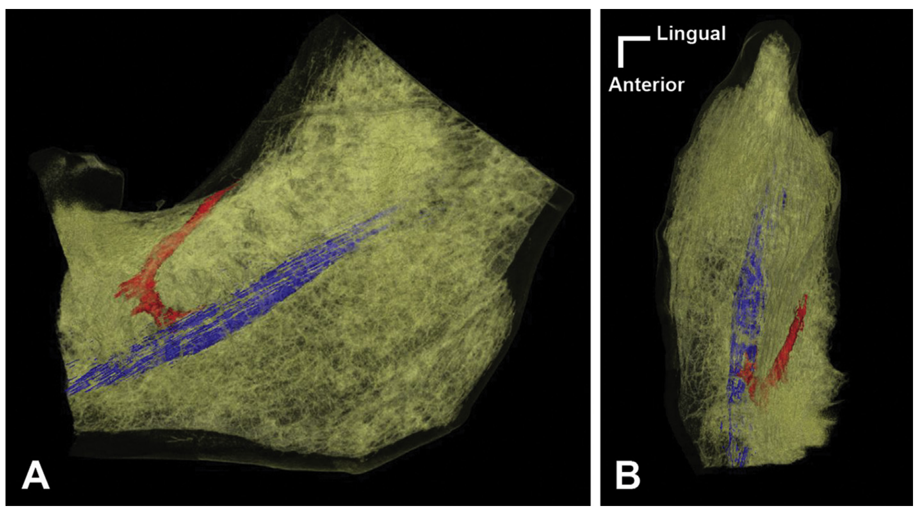

Figure 6 Three-dimensional (3D) reconstruction of a retromolar canal (RMC) on the right side of a mandible created using OnDemand3D. The RMC (red) arose anterosuperiorly from the mandibular canal (blue) behind the third molar and then curved posterosuperiorly to the retromolar foramen, which is located within the retromolar triangle. (A) Lingual view, (B) superior view.

explained by restrictions associated with the inclusion criterion applied in this present study (only retromolar radiolucent images with a diameter ≥0.5 mm) and other radiological variables such as a bigger voxel size (0.3 mm; (compared with voxel sizes of 0.08–0.125 mm in previous studies).

In this study, the incidence of an RMF was 33.6% according to macroscopic examination of cadaver mandibles,

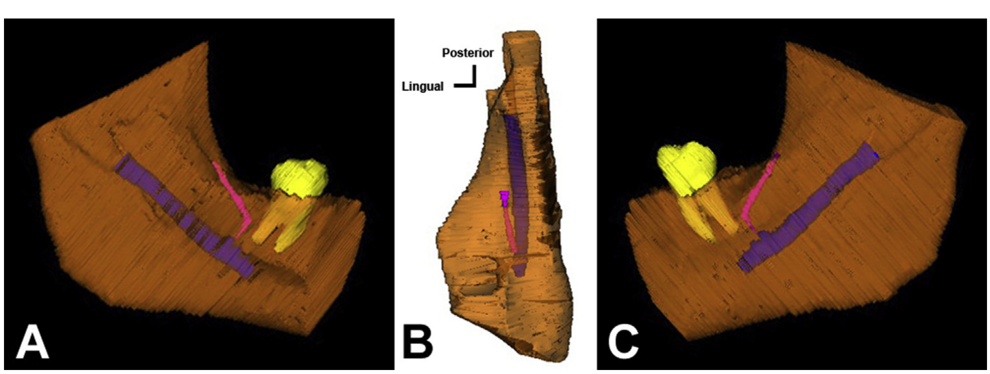

Figure 7 Three-dimensional reconstruction of the retromolar canal on the left side of the mandible using the Reconstruct software. (A) Lingual view, (B) superior view, (C) buccal view.

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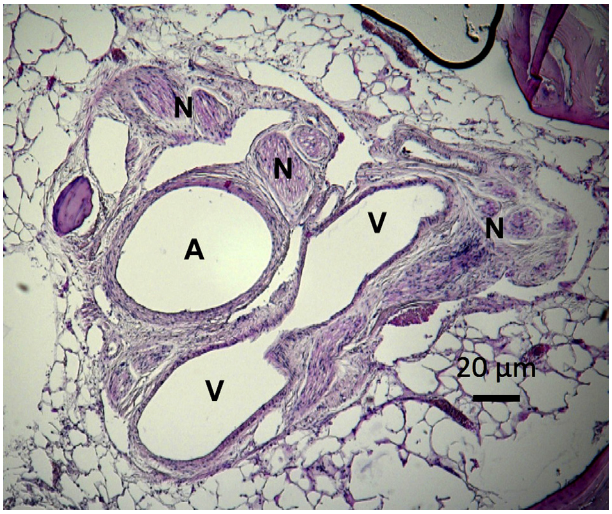

Figure 8 Histology of the retromolar canal. A = artery with a thick wall; N = nerves, which could be readily distinguished; V = veins with thin walls.

whereas the incidence of an RMC/RMF on CBCT was 11.5%. This finding demonstrates that the ability to detect an RMC using CBCT is limited compared with direct anatomical observation. However, we agree that CBCT is the best method for identifying this anatomical variant in the clinic, and may be useful when a preliminary radiographic survey shows no clear relationship between the inferior alveolar nerve and the other anatomical structures in the mandibular molar area.

This study used various methods to establish precise anatomical data for the RMT, RMF, and RMC in Koreans. The results of this study provide useful information for surgical interventions and may protect patients from complications. The presence of an RMC may warn clinicians about the possibility of inadequate anesthesia and bleeding in the retromolar region.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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