RESEARCH

Bifid mandibular canal: confirmation of limited cone beam CT findings by gross anatomical and histological investigations

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Objectives: The aims of this study were (1) to assess the validity of limited cone beam CT (CBCT) in detecting the distribution of bifid mandibular canals in the retromolar region by comparing its findings with those of panoramic radiography and spiral CT imaging, and (2) to confirm the contents of such canals depicted on limited CBCT images by using gross anatomical and histological methods.

Methods: Bilateral bifid mandibular canals of a Japanese cadaver were investigated. The canals depicted on panoramic radiography, spiral CT and limited CBCT images were compared. Cross-sectional limited CBCT images of these canals were compared with gross anatomical sections of the mandible and their contents were confirmed histologically.

Results: The spiral CT and limited CBCT images showed the bilateral bifid mandibular canals in the retromolar region whereas the panoramic radiographs indicated the presence of only the left bifid mandibular canal. The canal distribution was more distinct in the limited CBCT images than in the spiral CT images and the cross-sectional limited CBCT images were consistent with the gross anatomical sections. Histologically, the canals contained several nerve bundles and arteries among which the largest nerve and artery were of a similar size.

Conclusion: Limited CBCT is valuable for assessing the distribution of bifid mandibular canals. It is clinically significant to accurately localize a bifid mandibular canal of the retromolar region because it contains a nerve bundle and artery.

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Introduction

A bifid mandibular canal is a structural variation of the mandibular canal. The presence of bifid mandibular canals was disputed with panoramic radiography before CT became popular and classification of a bifid mandibular canal on panoramic radiographs was described.^{1,2} With regards to different types of bifid mandibular canals, a canal originating near the mandibular foramen and distributing retromolar region could be particularly at risk of damage during dentoalveolar surgery such as extraction of an impacted third molar and sagittal split ramus osteotomy. This region is also used as a donor site for harvesting bone blocks.

Bifid mandibular canals had been considered rare in studies using panoramic radiography, in which their occurrence on panoramic radiographs was reportedly less than 1%,^{1–4} whereas recent investigations using cone beam CT (CBCT) have suggested that the presence of bifid mandibular canals are more frequent. The occurrence of bifid mandibular canals in the retromolar regions was reported as approximately 20% by Kuribayashi et al⁵ and about 30% by Naitoh et al⁶ and Orhan et al.⁷

Bifid mandibular canals may cause complications in all dental procedures but the most common complication is supposedly sensory impairment during and after surgery.^{8,9} Orhan et al⁷ described the presence of a branched nerve bundle during a surgical third molar extraction of the patient with bifid mandibular canal. Sanchis et al⁴ reported that the presence of bifid mandibular canals is associated with increased difficulty

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in achieving mandibular anaesthesia with the conventional inferior alveolar nerve block. These reports suggested the presence of branched nerve bundles in the bifid mandibular canal which is clinically significant. By contrast, some literature suggested that bifid mandibular canals might be associated with blood vessels only rather than with both blood vessels and nerves.^{1,3} No study has confirmed their contents compared with those depicted on CT images and their clinical significance remains a presumption.

Improvement in the resolution of CT images has provided detailed structural variation of mandibular canal distribution which had not been observed previously. These CT image findings should be confirmed anatomically to suggest their clinical significance. The aims of this study were:

1. To assess the validity of limited CBCT in detecting the distribution of bifid mandibular canals in the retromolar region by comparing its image findings with those of panoramic radiography and spiral CT.
2. To confirm the contents of such canals depicted on limited CBCT imaging using gross anatomical and histological methods.

Material and methods

The cadavers employed for this investigation were donated in accordance with the national cadaveric regulation and preserved with 10% neutral-buffered formalin. The present study was conducted as per the cadaveric regulations established by the Tsurumi University School of Dental Medicine, Yokohama, Japan.

Detection of bifid mandibular canals by panoramic radiography, spiral CT and limited CBCT

We obtained one cadaver that indicated the presence of bifid mandibular canals in the retromolar region through five cadaveric investigations using spiral CT imaging. The cadaver, a 30-year-old male with complete dentition, additionally underwent panoramic radiography and limited CBCT imaging.

The spiral CT scans were performed using RADIX-Prima (Hitachi Medical Co., Tokyo, Japan) with operating exposure conditions of 120 kV, 100 mA, 1.0 s per rotation, 1.0 mm slice thickness, 1.0 mm per rotation table speed and 512 × 512 matrix. After image acquisition, we reconstructed them at 0.5 mm intervals. Panoramic radiography was performed using Hyper-XF (Asahi Roentgen Ind. Co., Ltd, Kyoto, Japan) with the operating exposure condition of 80 kV, 12 mA and 12 s. PSR9000N (Asahi Roentgen Ind. Co., Ltd) was used for the limited CBCT scans; it can capture an imaging area in a column of 41 mm diameter and 40 mm height in the dental CT mode with 400 axial images of 0.1 mm³ cubic voxel. The exposure condition was 90 kV, 10 mA and 20.0 s.

All the CT images were transmitted to a personal computer in Digital Imaging and Communications in Medicine (DICOM) format and reconstructed into multiplanar reconstruction (MPR) images using DICOM viewer ExaVision SX version 1.13 (Ziosoft, Tokyo, Japan). The MPR images were viewed in bone mode (window width 4000; window level +900) on the limited CBCT images under favourable viewing conditions on the helical CT images and by an oral radiologist. The window level and width for observing such images cannot be standardized owing to the fact that limited CBCT has a low reliable CT number.

The obtained panoramic radiography, spiral CT and limited CBCT images of the bifid mandibular canals were compared. The dimensions of the main and bifid mandibular canals were measured on the limited CBCT images; their maximum horizontal and vertical widths were measured on cross-sectional images at the distal root axis of the third molar where the bifid canal was located closest to the root apex.

Comparison between limited CBCT images and gross anatomical sections

The mandible was removed from the cadaver and divided into three blocks for the anterior and bilateral posterior regions on the basis of the mental foramina. Each posterior mandibular block was marked between the first and the second molars with 3 min spots using a dental bur to obtain slices perpendicular to the dentition. The dissected mandible was scanned by limited CBCT again (exposure factors of 70 kV, 10 mA and 13.3 s) to obtain cross-sectional images corresponding to the gross anatomical sections.

After the scan, the bilateral posterior mandibular blocks were serially cut using a diamond band-saw (EXACT BS 3000, Meiwa, Osaka, Japan). The gross anatomical sections were then compared with the cross-sectional limited CBCT images.

Histological observation of the contents of bifid mandibular canals

Partial blocks of cancellous bone containing the mandibular canal were obtained for microscopic observations. They were dehydrated with an ascending alcohol series and 100% acetone, decalcified and embedded in paraffin in the conventional manner. Serial cross-sections of the specimens (6 µm slice thickness) were prepared using a microtome and mounted on glass slides. Each section was washed in xylol and stained with haematoxylin and eosin. The sections were observed by light microscopy.

Results

Bifid mandibular canals on a panoramic radiograph, spiral CT and limited CBCT images

The panoramic radiographs showed three canal walls that indicated the presence of bifurcation of the man-

dibular canal on the left side whereas the right side showed no distinct radiographic findings (Figure 1).

The spiral CT and limited CBCT images indicated the presence of bilateral bifid mandibular canals that originated from the main canal at the mandibular ramus region. They extended forward to the third molar and then ran posterosuperiorly to the retromolar pad (Figures 2 and 3). However, their path was not distinct on the spiral CT images because discrimination between the trabecular bone and the canal wall was difficult. On the other hand, the limited CBCT images clearly depicted the distribution of the bifid mandibular canals. The exit point of the bifid mandibular canals, such as the retromolar foramen, was not observed on any CT images.

The horizontal-by-vertical size of the main mandibular canal as measured on sectional limited CBCT images at the distal root axis of the third molar was 3.7×4.6 mm on the right side and 3.0×4.5 mm on the left side. The dimensions of the bifid mandibular canals were 2.6×2.7 mm and 2.4×1.7 mm, respectively.

Comparison between limited CBCT images and gross anatomical sections

Figure 4 shows a side-by-side comparison of a cross-sectional limited CBCT image and gross anatomical section of the right side. Tiny bony trabeculae visible on the gross anatomical sections were depicted on the limited CBCT sections. The area at the crook of the bifid mandibular canals on the limited CBCT images indicated the presence of a neurovascular bundle in the canals.

Histological observation of bifid mandibular canals

Histologically, the inferior alveolar nerve trunk was observed accompanying many arteries, veins and nerve fibres that gathered in the connective tissue and

presented at the upper and lateral side of the main nerve trunk (Figure 5). The upper neurovascular bundles in the connective tissue were separated into the bifid canal. The bifid mandibular canals contained many nerve bundles and arteries of various sizes, among which the largest nerve and artery were of a similar size.

Discussion

We encountered a case with bifid mandibular canals in the retromolar region among five cadaveric cases which is consistent with the frequency on CBCT images reported so far.⁵⁻⁷ It has been suggested that certain characteristic radiographic features may aid in identifying suspected bifid mandibular canals on panoramic radiography.^{4,10} Auluck *et al*¹⁰ recommended panoramic radiography over three-dimensional imaging for the diagnosis of bifid mandibular canals, owing to reduced costs and radiation dose. In this study, the panoramic radiographs indicated the presence of only the left bifid mandibular canal, which was depicted as a canal wall parallel to the main canal; however, the distribution of this canal was not revealed. Panoramic radiographs rarely depict such canals and are possibly indicative of pseudo findings.^{10,11} Naitoh *et al*¹² reported the presence of bifid mandibular canals on panoramic radiographs in only two of five sides observed on multislice CT images. The application of CT and CBCT has overcome the disadvantages of two-dimensional radiographs for assessing the configuration of the mandibular canal.

Naitoh *et al*¹³ reported that multislice CT and CBCT images are equally useful for detecting the presence of bifid mandibular canals. In this study, the presence of the bilateral bifid mandibular canals was noted on both

Figure 1 Panoramic radiograph indicating the bifid mandibular canal only on the left side, (a) right side and (b) left side. A canal wall parallel to the main canal walls is observed on the left side (arrow)

Figure 2 CT (a,b) and limited cone beam CT (c,d) images of the right bifid mandibular canal. The canal (arrows/arrowheads) is depicted on the sagittal (a,c) and serial cross-sectional images from the medial direction (b,d)

spiral CT and limited CBCT images; however, the distribution of these canals was not distinctly depicted on the spiral CT images owing to their lower resolution compared with the limited CBCT images. The cross-sectional limited CBCT images showed features that coincided with those of the gross anatomical sections and the trabecular bone and bifid mandibular canal walls could be discriminated on the images.

The human inferior alveolar nerve commonly has three branches with smaller branches forming the nerve plexus to the mandibular teeth. The first branch, the retromolar branch, originates at the initial part of the inferior alveolar nerve; it lies parallel to the main trunk and then turns upwards to innervate the third molar and retromolar region. The second branch, the molar branch, leaves the main trunk or retromolar branch and runs parallel to the main trunk until it gives off dental branches. The third branch, the incisor branch, originates at the anterior loop of the main trunk and runs to the midline area where it gives off dental branches. Chavez-Lomeli *et al*¹⁴ demonstrated that the fetal mandible had three separated mandibular canals innervating three groups of mandibular teeth. They

suggested that the presence of the bifid mandibular canal might be caused by incomplete fusion of these canals.

Dieck and Fujita¹⁵ described how the inferior alveolar nerve is composed of a large nerve bundle and smaller ones when it enters the mandibular foramen; parts of the smaller bundles enter the retromolar canal while the large bundle enters the main mandibular canal. The present histological survey obtained similar findings and verified that the bifid mandibular canal contained nerve bundles. Kim *et al*¹⁶ verified the topography of the neurovascularisation in the mandibular canal—the inferior alveolar vessel travelled above the inferior alveolar nerve with the inferior alveolar artery being lingual to the inferior alveolar vein, which was also confirmed in our study. However, the neurovascular positional relationship of the mandibular canal was not applied for the bifid canal in which nerve bundle, artery and vein were each observed in all directions.

Regarding arteries, a relatively large artery was observed even in the bifid mandibular canals. A branch of the mandibular canal running upwards to the retromolar region, called the retromolar canal, is known

Figure 3 CT (a,b) and limited cone beam CT (c,d) images of the left bifid mandibular canal. The canal (arrows/arrowheads) is depicted on the sagittal (a,c) and serial cross-sectional images from the medial direction (b,d)

Figure 4 Right-side bifid mandibular canal observed on (a) the sagittal limited cone beam CT (CBCT) image. Comparison of a (b) CBCT sectional image with (c) a gross anatomical section. The sectional position is shown in the sagittal limited CBCT image (c). The crook of the bifid mandibular canal is observed in both sections (arrow)

Figure 5 Paraffin-embedded histological section corresponding to the inset in the limited cone beam CT image. n, nerve; a, artery

to penetrate the cortical bone through a foramen.¹⁷ Kodera and Hashimoto¹⁸ reported that the artery in the

retromolar canal bifurcates to the buccal and facial arteries after it exits from the retromolar foramen. Injury to the artery in the perimandibular retromolar region can lead to excessive bleeding when there is a bifid mandibular canal and retromolar foramen. Kodera and Hashimoto¹⁸ and Bilecenoglu and Tuncer⁸ used osteological methods and reported the occurrence of retromolar canals as about 20% and 25%, respectively. The number of bifid mandibular canals detected by CBCT imaging nearly matched the frequency of retromolar canals observed osteologically.^{5–7}

Our survey revealed that the bifid mandibular canal of the retromolar region was distributed close to the third molar and contained nerve bundles concurrent with an artery, suggesting that complications such as traumatic neuroma, paresthesia, anaesthesia, bleeding and haematoma might occur owing to damage of this canal. It should be considered, especially regarding dentoalveolar surgery involving the retromolar area such as extraction of the impacted mandibular third molars or sagittal split ramus osteotomies.

In conclusion, limited CBCT imaging is valuable for assessing the distribution of bifid mandibular canals. It is clinically significant to accurately localize a bifid mandibular canal before dentoalveolar surgery, especially when their presence is suspected by panoramic radiography.

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