Observation of Bifid Mandibular Canal Using Cone-Beam Computerized Tomography

Munetaka Naitoh, DDS, PhD[1]/Yuichiro Hiraiwa, DDS[2]/Hidetoshi Aimiya, DDS[2]/Eiichiro Ariji, DDS, PhD[3]

Purpose: *Some variations of the mandibular canal (so-called bifid mandibular canal) have been reported using various radiography techniques; however, the occurrences of bifid mandibular canal were less than 1% according to panoramic radiographic surveys. The purpose of the present investigation was to clarify the rate and type of bifid mandibular canal in the mandibular ramus region, as observed using cone-beam computerized tomography (CBCT) images.* ***Materials and Methods:*** *One hundred twenty-two patients who had undergone preoperative imaging of dental implant treatment using CBCT were enrolled in the investigation. Two-dimensional (2D) images of various planes in the mandibular ramus region were reconstructed on a computer using three-dimensional visualization and measurement software. The course of the mandibular canal was observed and the length of the bifid canal was measured.* ***Results:*** *Bifid mandibular canal in the mandibular ramus region was observed in 65% of patients and 43% of sides. Bifid mandibular canal can be classified into four types: retromolar, dental, forward, and buccolingual canals.* ***Conclusion:*** *Bifid mandibular canal was observed at a high rate using CBCT.* INT J ORAL MAXILLOFAC IMPLANTS 2009;24:155–159

Key words: *bifurcation, cone-beam computerized tomography, dental implant, mandibular canal, retromolar*

The mandibular canal passes through the inferior mandible from the mandibular foramen to the mental foramen, involving the inferior alveolar artery and inferior alveolar nerve.[1] The location and configuration of the mandibular canal are important in surgical procedures involving the mandible, such as the extraction of an impacted third molar, dental implant treatment, and sagittal split ramus osteotomy.

Some variations of the mandibular canal (so-called bifid mandibular canal) have been reported using panoramic radiographs, computerized tomography (CT), and cone-beam CT (CBCT).[2–8] The occurrences of bifid mandibular canal have been reported as 0.08% by Grover and Lorton,[3] 0.35% by Sancbis et al,[5] 0.9% by Nortje et al,[2] and 0.95% by Langlais et al,[4] all of whom used panoramic radiographic surveys. Naitoh et al[7] reported that the presence of bifid mandibular canal was suggested on panoramic images in only two of five sides observed on multislice CT images. Three-dimensional (3D) anatomic structures are projected onto 2D film in panoramic radiography. Also, because images in the molar region overlap on opposite sides of the mandible, and those in the mandibular ramus region overlap on opposite sides of the mandible, soft palate, and pharynx on panoramic radiography, localization of the mandibular canal may be difficult.

Recently, a new CBCT machine has been equipped with a flat panel (FP) detector, replacing the incorporation of the image intensifier system (II system) and charge-coupled device sensor.[9] This FP detector can directly transform light rays into electric signals, providing images with less noise than with the II system.[10] In CBCT images, the clarity of the mandibular

[1]Associate Professor, Department of Oral and Maxillofacial Radiology, School of Dentistry, Aichi-Gakuin University; Member of Oral Implant Clinic, Dental Hospital, Aichi-Gakuin University, Nagoya, Japan.
[2]Researcher, Department of Oral and Maxillofacial Radiology, School of Dentistry, Aichi-Gakuin University, Nagoya, Japan.
[3]Professor and Chairman, Department of Oral and Maxillofacial Radiology, School of Dentistry, Aichi-Gakuin University, Nagoya, Japan

Correspondence to: Dr Munetaka Naitoh, Department of Oral and Maxillofacial Radiology, School of Dentistry, Aichi-Gakuin University, 2-11, Suemori-Dori, Chikusa-Ku, Nagoya 464-8651, Japan. Fax: +81-527592165. Email: mune@dpc.aichi-gakuin.ac.jp

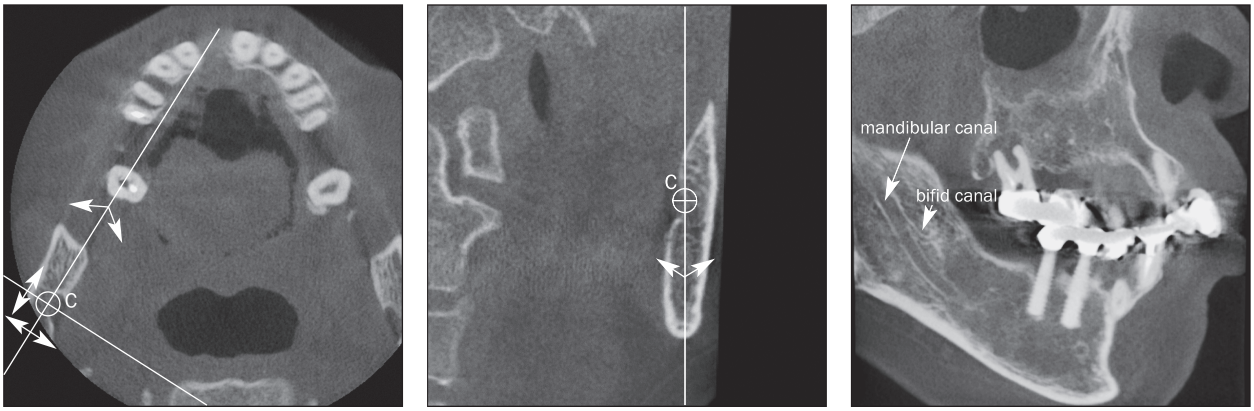

Fig 1 Reconstruction of the images of longitudinal sections. To reconstruct useful images using OsiriX software, the center of rotation of longitudinal sections (C) was set at the mandibular foramen in the axial image (*left*). Then, longitudinal sections were horizontally rotated, and the center was moved buccolingually and postanteriorly by degrees. Moreover, when necessary, longitudinal sections (*right*) were rotated vertically in cross-sectional images (*middle*).

canal may therefore be improved. The purpose of the present investigation was to clarify the rate and type of bifid mandibular canal observed in the mandibular ramus region using CBCT images.

MATERIALS AND METHODS

Subjects

A total of 160 patients underwent preoperative imaging for dental implant treatment between April 2007 and December 2007 using CBCT. Seventeen patients in whom bone blocks were harvested from the retromolar region were excluded. Also, 21 patients in whom hemilateral or bilateral mandibular foramen/foramina were not included in the exposure field were excluded. Therefore, a total of 122 patients (88 women and 34 men) were enrolled in this investigation. The mean age was 50.8 years (range 17 to 78 years, SD 15.1 years).

CBCT

A CBCT unit (Alphard VEGA; Asahi Roentgen, Kyoto, Japan) with a FP detector was used. The exposure volume was set at 102 mm in diameter and 102 mm in height (I-mode), and the voxel size was $0.2 \times 0.2 \times 0.2$ mm^3 (spatial resolution: 2.5 line pairs/mm). The scan was set at 80 kV and 5 mA, as recommended by the manufacturer. The occlusal plane of each patient was set parallel to the floor base using ear rods and a chinrest. DICOM files of axial images were saved to a magneto-optical disk.

Observation of the Mandibular Canal

Two oral and maxillofacial radiologists, with experience of 24 years (MN) and 4 years (HA), reconstructed and observed the images as follows. Two-dimensional images of various planes, mainly longitudinal, in the mandibular ramus region were reconstructed on a computer (Macintosh G4, Apple Computer, Cupertino, CA) using 3D visualization and measurement software (OsiriX, OsiriX Foundation, Geneva, Switzerland).[11] On the display, the center of rotation of longitudinal sections was initially set at the mandibular foramen in axial images. Then, longitudinal sections were rotated horizontally, and the center was moved buccolingually and postanteriorly by degrees. Moreover, when necessary, longitudinal sections were rotated vertically in cross-sectional images (Fig 1). The density and contrast of images were adequately adjusted to clarify the mandibular and bifid mandibular canals. Subsequently, the course of the mandibular canal was observed and the bifid mandibular canal was classified. Further, the length of the bifid canal was measured. When a secondary bifurcation of the bifid canal was observed, the longer secondary canal was selected for classification and measurement.

Statistical Analysis

Differences in the rate of bifid mandibular canal presence between men and women were evaluated using chi-square statistics. Also, differences in length between types of bifid canals were evaluated using the Mann-Whitney *U* test. Differences were considered significant at $P < .05$.

Fig 2 *Classification of bifid mandibular canals.*

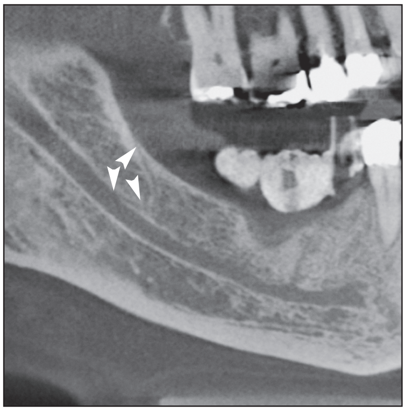

Fig 2a Retromolar canal (type 1) in a 69-year-old man. The retromolar canal, which bifurcated from the mandibular canal in the right mandibular ramus region, courses forward at first, reaching the retromolar region after the crook (*white arrowheads*).

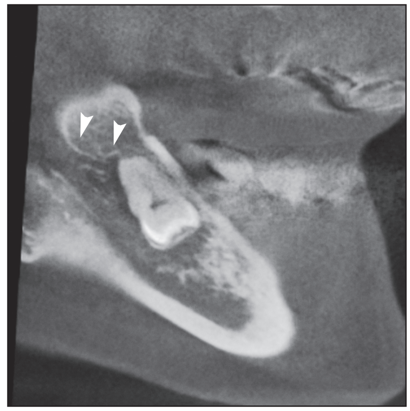

Fig 2b Dental canal (type 2) in a 53-year-old woman. The dental canal, which bifurcated from the mandibular canal in the right mandibular ramus region, coursed forward, reaching the root apex of the third molar (*white arrowheads*).

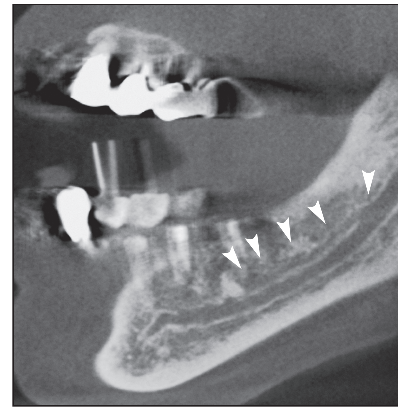

Fig 2c Forward canal without confluence (type 3) in a 72-year-old woman. The forward canal, which bifurcated from the mandibular canal in the left mandibular ramus region, coursed forward to the second molar region (*white arrowheads*).

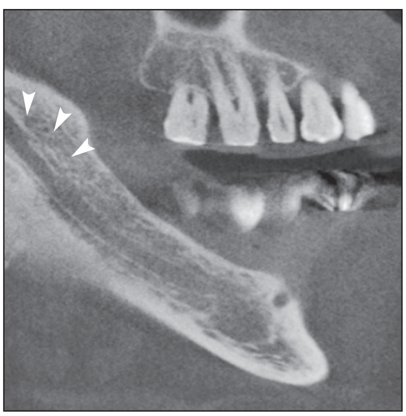

Fig 2d Forward canal with confluence (type 3) in a 57-year-old man. The forward canal, which bifurcated from the mandibular canal in the right mandibular ramus, coursed anteriorly and then joined up with the main mandibular canal (*white arrowheads*).

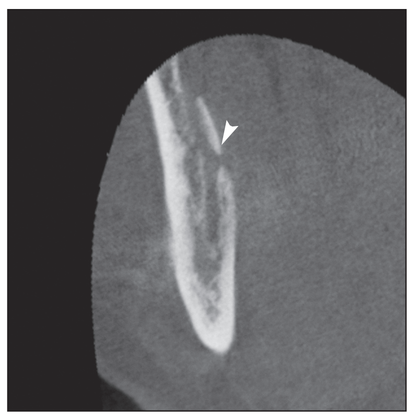

Fig 2e Lingual canal (type 4) in a 59-year-old man. The lingual canal, which bifurcated from the mandibular canal in the right mandibular ramus, coursed lingually and then penetrated through the lingual cortical bone (*white arrowhead*).

Fig 2f Buccal canal (type 4) in a 51-year-old woman. The buccal canal, which bifurcated from the mandibular canal in the right mandibular ramus, coursed buccoinferiorly (*white arrowhead*).

RESULTS

Bifid mandibular canals in the mandibular ramus region were observed in 79 of the 122 patients (55 women and 24 men; 64.8% of the population) and 105 of 244 sides (43.0%). There was no significant difference between genders. One bifid canal was observed in 96 sides, and two canals were seen in nine sides.

One hundred twelve of 114 bifid canals originated from the superior wall of the mandibular canal, one originated from the buccal wall, and one originated from the lingual wall. Thus, the bifid mandibular canal could be classified into four types: type 1 = retromolar canal; type 2 = dental canal (second and third molars); type 3 = forward canal with/without confluence to the main mandibular canal; and type 4 = buccolingual canal (Fig 2). The retromolar canal (type 1) was defined as such when the foramen of the canal was observed on the bone surface of the retromolar region. The dental canal (type 2) was classified when the end of the canal reached to the root apex of the second or third molar. The other bifid canal (type 3) arising from the superior wall of the mandibular canal was defined as the forward canal. The forward canal was included with/without confluence to the main mandibular canal. The buccolingual canal (type 4) was defined as a bifid canal arising from the buccal or lingual wall of the mandibular canal.

Table 1 Rate of Bifid Mandibular Canal Presence		
Classification	In all patients (%)	In all sides (%)
1: Retromolar canal	25.4	13.5
2: Dental canal	7.4	4.1
3: Forward canal	44.3	27.9
4: Buccolingual canal	1.6	0.8

Table 2 Rate of Different Types of Bifid Mandibular Canal in 114 Bifid Canals		
Classification	No. of canals	Rate (%)
1: Retromolar canal	24	29.8
2: Dental canal	10	8.8
Third molar	8	7.0
Second molar	2	1.8
3: Forward canal	68	59.6
With confluence	5	4.5
Without confluence	63	55.3
4: Buccolingual canal	2	1.8

The results regarding the types of bifurcations are shown in Tables 1 and 2. In nine sides with two bifid canals each, types 1 and 2 were observed in one patient, types 1 and 3 in one patient, types 2 and 3 in two patients, and types 3 and 3 in five patients. The retromolar canal was observed in 34 of 114 bifid mandibular canals (29.8%), dental canal in 10 canals (8.8%), forward canal in 68 canals (59.6%), and buccolingual canal in two canals (1.8%). The mean length of bifid canals was 1.48 cm (range: 0.72 to 2.45 cm) in retromolar canals, 0.89 cm (range: 0.16 to 2.30 cm) in dental canals, 0.96 cm (range: 0.14 to 2.50 cm) in forward canals, and 0.16 cm (range: 0.15 to 0.17 cm) in buccolingual canals. Significant differences in length were noted between the retromolar canal and the other types and between the forward and buccolingual canals. The dental canal reached to the root apex of the second molar in two canals and the third molar in eight canals.

DISCUSSION

The location and configuration of mandibular canal variations are important in dental implant treatment. In panoramic image surveys, the occurrence of bifid mandibular canal presence was reported to range from 0.08% to 0.95%.[2–5] On CBCT images, however, bifurcation was observed in 65% of patients. There are obvious limitations in identifying the occurrence of a bifid mandibular canal via the observation of 2D panoramic images. Recently, some cases with a bifid mandibular canal have been identified using CT or CBCT. Bifid mandibular canal presence might be observed in detail using CBCT. CBCT has some major advantages regarding image quality compared to CT. The voxel size is small ($0.2 \times 0.2 \times 0.2$ mm^3), and in CT the slice thickness is thicker (0.5 to 1.0 mm). Also, radial metal artifacts, which are often observed at the level of the occlusal plane in CT, greatly hamper observation of the bifid mandibular canal in the mandibular ramus. In the present study, the exposure volume (field of view) was selected as 102 mm in diameter and 102 mm in height to include the designated implant site and anterior region of the mandibular ramus for harvesting bone blocks. Iwai et al[12] reported that the effective dose of the same exposure volume in Alphard units was 0.13 mSv using the 2005 International Commission on Radiological Protection (ICRP) tissue-weighting factors. Ludlow et al[13] reported that the effective dose using the 2007 ICRP recommendations for CBCT exposure was 3 to 28 times higher than the average dose for a panoramic radiograph. Also, the effective doses of CT for each jaw were recommended to be less than 0.5 mSv using the 1990 ICRP recommendations.[14] MacDonald-Jankowski and Orpe[15,16] reported that a higher spatial resolution and lower radiation dose could be achieved using a smaller exposure volume. An adequate exposure volume has to be selected according to the purpose of imaging diagnosis.

The bifid mandibular canal was classified into four types using CBCT images and previous radiographic and anatomic studies.[2,4,16] The classification of bifid canals, especially retromolar (type 1) and dental (type 2), may be clinically important. Within the retromolar canal, the artery branched from the inferior alveolar artery, and nerves derived from the inferior alveolar nerve trunk were observed.[17,18] Kodera and Hashimoto[18] reported that the retromolar nerve branched off to the buccal mucosa and the buccal gingiva of the mandibular premolar and molar regions in a Japanese cadaver. Recently, the retromolar region was used as a donor site for harvesting bone blocks.[19–21] To safely harvest bone blocks from the retromolar region, preoperative imaging using CBCT may be needed. Also, the identification of dental canal presence may be important in extraction and root canal treatment of teeth.

The rate of occurrence in the retromolar foramina/canal ranged from 12% to 33% of mandibles on macroscopic observation in previous reports.[18,22,23] In CBCT images, a retromolar canal (type 1) was observed in 25.4% of patients and 13.5% of sides. The occurrence rate in CBCT images was similar to that seen in dry mandibles. The internal diameter of the retromolar foramen was reported to range from

0.2 mm to more than 1.0 mm.[18] In CBCT images, the mean length of retromolar canals was 1.6 cm, and the retromolar canal in many cases coursed forward from the bifurcated point at first, and then coursed posteriorly and superiorly after the crook, reaching the retromolar region. A forward canal of more than 2.0 cm, which was observed in eight canals, reaches near to the second molar region. A forward canal confluent with the main mandibular canal (type 3), which was observed in 7% of forward canals, was considered similar to the type reported using panoramic images by Langlais et al.[4]

Further studies are needed to characterize the mental foramen, mandibular incisive canal, genial spinal bony canal, and mylohyoid sulcus in detail using CBCT images.

CONCLUSION

Bifid mandibular canal presence was observed at a high rate (65% of patients) using CBCT, and the retromolar canal was observed in 25% of patients.

ACKNOWLEDGMENT

We thank Dr A. Katsumata from the Asahi University School of Dentistry for his advice regarding the analysis of CBCT images.

REFERENCES

1. Clemente CD. Cranial nerves. In: Gray H (ed). Anatomy of the Human Body, ed 30. Philadelphia: Lea & Febiger, 1985:1165–1169.
2. Nortje CJ, Farman AG, Grotepass FW. Variations in the normal anatomy of the inferior dental (mandibular) canal: A retrospective study of panoramic radiographs from 3612 routine dental patients. Br J Oral Surg 1977;15:55–63.
3. Grover PS, Lorton L. Bifid mandibular nerve as a possible cause of inadequate anesthesia in the mandible. J Oral Maxillofac Surg 1983;41:177–179.
4. Langlais RP, Broadus R, Glass BJ. Bifid mandibular canals in panoramic radiographs. J Am Dent Assoc 1985;110:923–926.
5. Sancbis JM, Penarroba M, Soler F. Bifid mandibular canal. J Oral Maxillofac Surg 2003;61:422–424.
6. Claeys V, Wackens G. Bifid mandibular canal: Literature review and case report. Dentomaxillofac Radiol 2005;34:55–58.
7. Naitoh M, Hiraiwa Y, Aimiya H, et al. Bifid mandibular canal. Implant Dent 2007;16:24–32.
8. Rouas P, Nancy J, Bar D. Identification of double mandibular canals: Literature review and three case reports with CT scans and cone beam CT. Dentomaxillofac Radiol 2007;36:34–38.
9. Naitoh M, Hirukawa A, Katsumata A, Saburi K, Okumura S, Ariji E. Imaging artifact and exposure conditions in limited-volume cone-beam computed tomography: Comparison between an image intensifier system and a flat panel detector. Oral Radiol 2006;22:69–74.
10. Baba R, Ueda K, Okabe M. Using a flat-panel detector in high-resolution cone-beam CT for dental imaging. Dentomaxillofac Radiol 2004;33:285–290.
11. Rosset A, Spadola L, Ratib O. OsiriX: An open-source software for navigating in multidimensional DICOM images. J Digit Imag 2004;17:205–216.
12. Iwai K, Nishizawa K, Mishima A, Kobayashi K. Estimation of an effective dose of a subject by X-ray computed tomography device 3DCT Alphard 3030 [in Japanese]. Abstracts and program, the 48th Annual Congress of Japanese Society for Oral and Maxillofacial Radiology, 2007:66.
13. Ludlow JB, Davies-Ludlow LE, Mol A. Dosimetry of recently introduced CBCT units for oral and maxillofacial radiology. Abstracts and program, 16th International Congress of Dentomaxillofacial Radiology, 2007:97.
14. Harris D, Buser D, Dula K, et al. EAO guidelines for the use of diagnostic imaging in implant dentistry. Clin Oral Implants Res 2002;13:566–570.
15. MacDonald-Jankowski DS, Orpe EC. Computed tomography for oral and maxillofacial surgeons. Part 2: Cone-beam computed tomography. Asian J Oral Maxillofac Surg 2006; 18:85–92.
16. MacDonald-Jankowski DS, Orpe EC. Some current legal issues that may affect oral and maxillofacial radiology. Part 2: Digital monitors and cone-beam computed tomography. J Can Dent Assoc 2007;73:507–511.
17. Carter RB, Keen EN. The intramandibular course of the inferior alveolar nerve. J Anat 1971;108:433–440.
18. Kodera H, Hashimoto I. A case of mandibular retromolar canal: Elements of nerves and arteries in this canal [in Japanese]. Kaibougaku Zashi 1995;70:23–30.
19. Khoury F. Augmentation of the sinus floor with mandibular bone block and simultaneous implantation: A 6-year clinical investigation. Int J Oral Maxillofac Implants 1999;14:557–564.
20. Yildirim M, Spiekermann H, Handt S, Edelhoff D. Maxillary sinus augmentation with the xenograft Bio-Oss and autogenous intraoral bone for qualitative improvement of the implant site: A histologic and histomorphometric clinical study in humans. Int J Oral Maxillofac Implants 2001;16:23–33.
21. Nkenke E, Radespiel-Troger M, Witfang J, Schultze-Mosgau S, Winkler G, Neukam FW. Morbidity of harvesting of retromolar bone grafts: A prospective study. Clin Oral Impl Res 2002; 13:514–521.
22. Lofgren AB. Foramina retromolaria mandibulae: A study on human skulls of nutrient foramina situated in the mandibular retromolar fossa. Odont Tidskr 1957;65:552–570.
23. Sagne S, Olsson G, Hollender L. Retromolar foramina and canals in the human mandible. Dentomaxillofac Radiol 1977;6:41–45.