Anatomic Variations of Neural Canal Structures of the Mandible Observed by 3-Tesla Magnetic Resonance Imaging

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Objective: Anatomical variations of the dental canal structures are present in a small proportion of the population and often go undiagnosed. In such cases, there could be an increased risk of complications during surgery and failure of anesthesia. The aim of this study was to search for anatomical anomalies in a relatively large random population by using 3-T high-field magnetic resonance imaging (MRI).

Methods: Sixty-four dentate patients were examined using a modified T2 space sequence. The scans were analyzed with respect to anatomical features, variations, and rarities of the mandibular canal, mental canal, incisive canal, and the nutrient canals.

Results: Sixteen anatomical variations were identified in the study, and some of those images are presented.

Conclusion: High-resolution MRI performed on a 3.0-T system can effectively visualize variations of the inferior alveolar nerve in dentate mandible of patients. Thus, MRI can be used in dentistry and oral surgery in vague or unclear cases, which could not be clarified by orthopantomography or even a computed tomographic scan, to improve patient care.

Key Words: mandible, inferior alveolar nerve, inferior dental canal, incisive canal, nutrient canals, MRI

(*J Comput Assist Tomogr* 2012;36: 150–153)

With the establishment of digital volume tomography and computed tomography (CT) in dental practice, diagnostic possibilities have been substantially simplified and expanded. The techniques of digital volume tomography and especially CT provide excellent resolution, good contrast between soft tissues and bones, and are nowadays a relatively inexpensive diagnostic method. However, those diagnostic methods are not always suitable for exact delineation of the neural structures in the mandible; and in some cases, their limit of discrimination between different tissues is reached. In particular, if the mandibular canal is just slightly sclerosed or has a lack of sclerosis, orthopantomography (OPG) quickly fails. In some cases, CT also fails to detect the important anatomic structures in such a constellation. Furthermore, CT will differentiate only poorly fine structures with a low soft tissue contrast. However, the exact knowledge of precise anatomical structures, and especially because of rare variations in the mandible, is an essential foundation to detect pathological processes in diagnosis and planning of surgery. Therefore, additional imaging techniques such as magnetic resonance imaging (MRI) would be useful to have. Magnetic resonance imaging has been established in many areas, including diagnosis in the head and neck. In addition, a few studies show that MRI is valuable for visualization and detection of dental diseases.[1] Because of their physical properties, soft tissue and bone marrow are better delineated by MRI, which provides a good foundation to discriminate fine anatomic details.

The neural structures of the mandible are an interplay between nerve bundles and passages through bone in distinctive patterns. After entering the mandible through the mandibular foramen, the neurovascular bundle normally runs through the ramus of the mandible in the caudal direction to the angle and then further through the body of the mandible to end finally in the mental foramen. On this course, it is surrounded by a bony tube, the mandibular canal, which splits up in the incisive canal and the mental canal below the second premolar. Whereas the mental canal ends in the mental foramen, the incisive canal moves on as a continuation of the mandibular canal to the anterior chin region.[2] Olivier[3] states that beyond this division of mental canal, there are no surrounding branching structures arising from the mental canal. To supply the teeth and the interdental space and gums, the mandibular canal and the incisive canal emit fine branches, the nutrient canals, which contain the rami dentales and septales of the inferior alveolar artery and the rami dentalis of the inferior alveolar nerve.[2] They vary in size, shape, and direction.

Diverse anatomical variations in dental structures have been described in many studies over almost 200 years. Multiple lower canals were first mentioned by Serres[4] in 1817 and confirmed by Robinson[5] in 1906. These structures develop at the end of the third embryonic month and can persist through adulthood. A basal vein emerges in the mesenchyme of the mandible in the region below the inferior dental nerve and the inferior alveolar artery.[6–8] The subsequent development of bony tissue between the vein, artery, and nerve leads to separation of the vein of the later mandibular canal. The venous canal, named after Serres,[4] starts to disappear in the eighth year but may persist into adulthood. Tsusaki[9] observed 2 canals early in development, which become united at birth: the alveolar venous mandibular canal and the nerve and artery alveolar. Robinson[5] described an additional channel that runs diagonally through the mandible, different from the Serres canal. Wadu[10] reported of an anastomosis of the incisive canals in the chin region where the incisive nerve of the mandible crosses the midline and contributes to the innervation of the opposite side. Publications of a duplicated incisive canal were not available at the time of the investigation.

The present study searches for and examines anatomical variations of the entire course of the canal structures and the outlets in the dentate mandible. Imaging has been done by modern high-field 3-tesla (3-T) MRI. The study demonstrates that MRI is a valuable diagnostic method for getting additional information about detailed structures present in the mandible.

MATERIALS AND METHODS

Selection of Patients in the Study Group

A total of 64 patients (39 women and 25 men) took part in the study. They have undergone a routine examination of the head/neck by MRI. Unspecific pain of the cervical spine or

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Received for publication September 5, 2011; accepted November 17, 2011.
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The authors report no conflicts of interest.

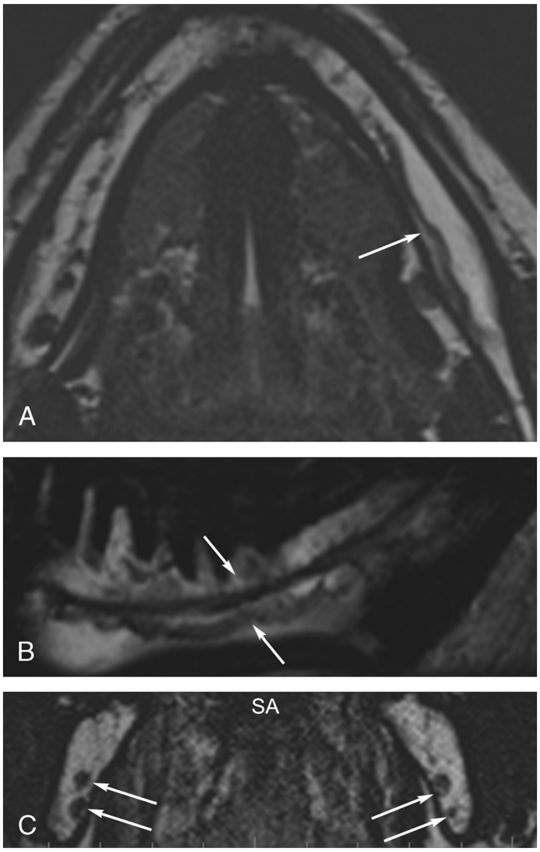

FIGURE 1. T2-weighted images show variation in the mandibular canal. A, Axial image. Winding canal on the left mandible (indicated by the arrow). B, Parasagittal reconstructed image shows winding and double mandibular canal (arrows). C, Coronal reconstructed image shows duplicate mandibular canals on both sides (pairs of arrows).

headache was one of the main indications of the subject group. Patients with more than 1 or 2 missing teeth and not fully dentate in the anterior portion of the mandible were excluded. A very small number of patients had strong artifacts caused by medical dental wires, which made an evaluation impossible. Those patients were excluded from the study. Informed consent was obtained from all patients included in this study.

MRI Examination

The MRI examination was performed in a 3-T Magnetom Verio MRI (Siemens, Erlangen, Germany) in axial orientation parallel to the occlusal plane by using the Siemens head and neck coil. For optimal visualization of the channel structures, we used an optimized 3-dimensional T2 space sequence with the following parameters: repetition time, 1000 ms; echo time, 132 ms; slice thickness, 0.64 mm; field of view, 184 × 205; flip angle, 105 degrees; acquisitions, 1.5; matrix, 288 × 320; slice oversampling, 14.3%; time, 6 minutes 24 seconds. Owing to the high resolution, the small layer thickness, and the use of isovoxel, it was possible to reconstruct the images in all planes.

Analysis of the Images

The images were analyzed descriptively by 2 radiologists with respect to anatomical features, variations, and rarities of the mandibular canal, mental canal, incisive canal, and the nutrient canals. The frequencies of the variations were noted. The evaluation was performed dynamically with the help of the axial and coronal planes, the reconstructed cross-sectional images, and the use of minimum intensity projection.

RESULTS

Different planes of the scans were reconstructed to illustrate and clarify the findings. The dynamic view and use of the minimum intensity projection technology contributed to the traceability of the structures of note. Overall, in 25% of the 64 patients, variations were found. There were 4 patients (6.25%) who showed a double unilateral incisive canal, 3 patients (4.6%) presented a double mandibular canal (Fig. 1B), and one of them was on both sides (Fig. 1C).

Furthermore, the evaluation of the collective showed 2 winding mandibular canals (Figs. 1A, B), and a mandibular canal twinned on the anterior stretch (Fig. 2A). Three patients had a branch out of the mental canal for supplying the tooth (Fig. 2B). In 4 cases, a double incisive canal was found unilaterally (Fig. 2C); and in 1 case, an incisive canal was found bilaterally (Fig. 3A).

One patient presented large caudolingual branches below the mental foramen (Fig. 3B). Another patient shows a right mandibular canal lateral to the teeth (Fig. 3C). A medial incisor supplied by the other side was also observed (Fig. 4). Table 1 summarizes the anatomic variations found in high-field MRI.

DISCUSSION

The planning of dental implants and other surgical procedures of the mandible requires accurate anatomical presentation of the region. The correct position of the mandibular canal and

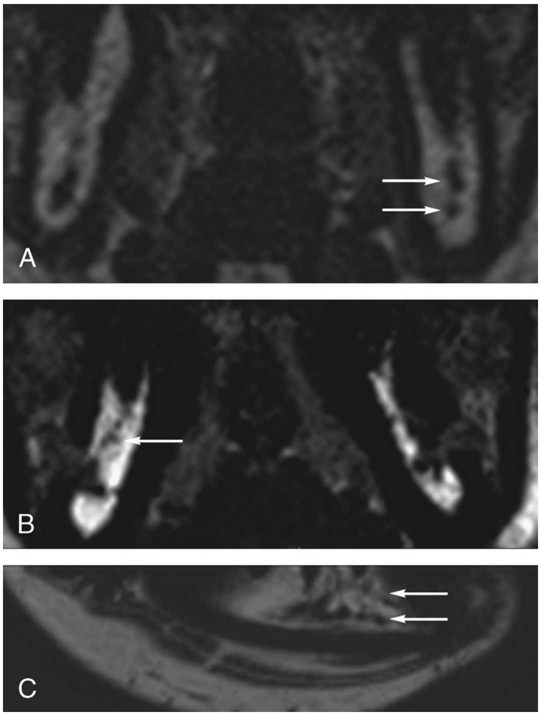

FIGURE 2. T2-weighted images show variation in the mandibular, mental, and incisive canals. A, Coronal reconstructed image shows on the anterior stretch a twinned mandibular canal on the left side (arrows). B, Coronal reconstructed image reveals a branch out of the mental canal (arrow). C, Parasagittal reconstructed image shows a double incisive canal in the anterior chin region (arrows).

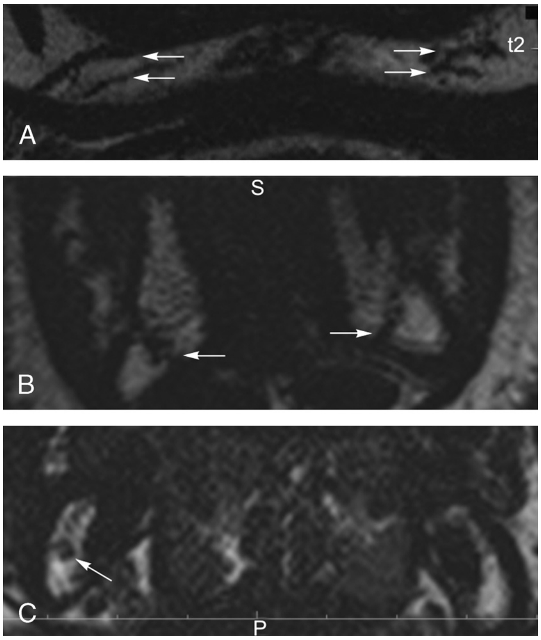

FIGURE 3. T2-weighted images show variation in the incisive and mandibular canals and the caudolingual disposals. A, Panorama-reconstructed image shows a double incisive canal on both sides (pairs of arrows). B, Coronal reconstructed image reveals large caudolingual outlets from the mandibular canal (arrows). C, Coronal reconstructed image shows a mandibular canal lateral to the teeth (arrow).

the type of variation are of great interest for physicians. By preoperative knowledge of the position of neural structures, complications such as injury to the neurovascular bundle can be avoided. Consequences of damaging the nerves due to clinical intervention can be severe. They range from impairment, paresthesias to pain and may also have legal consequences.

For small surgical procedures, such as wisdom tooth extraction, OPG is routinely used, but it has the disadvantage of distortion.[11] For greater surgery, that is, split osteotomy or nerve lateralization, CT has established itself but has the disadvantage of high radiation exposure and artifacts caused by dental materials.

The physical principle of MRI requires no ionizing radiation and allows the direct acquisition of information in any plane.[12] Except for a few medical contraindications (such as artificial heart valves and cardiac pacemakers), sequential studies can thus be carried out safely for the patient. In addition to the representation of the anatomical topography, pathological lesions of the lower jaw may be shown with dental MRI.[13] In the literature, some authors already stated that low-field MRI techniques have definite potential for preoperative assessment for dental interventions and gives the dental surgeon confidence to operate in areas where an OPG cannot be relied on to identify the positions of vital structures accurately.[14–16] A poorly sclerosed mandibular canal would be impossible to locate clearly in a planning CT for dental implant surgery. However, if an intervention would be carried out, the nerve could be injured. A complementary MRI examination, as described, could thus lead to adjust the intervention due to the additional information. For this purpose, further comparative studies should be carried out to compare a preoperative CT scan with MRI to rule out the practical benefits.

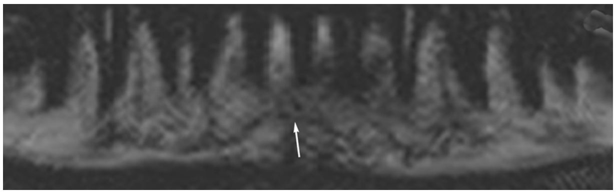

FIGURE 4. T2-weighted panorama-reconstructed image shows variation in the medial incisor. The medial incisor supplied by the other side is indicated by the arrow.

TABLE 1. Summary of Anatomical Variations Detected

	Sum*	Figures
Winding mandibular canal	2	1A, B
Double mandibular canal, unilateral	1	1B
Double mandibular canal, bilateral	1	1C
On anterior stretch twinned mandibular canal	1	2A
Branch out of the mental canal	3	2B
Double incisive canal, unilateral	4	2C
Double incisive canal, bilateral	1	3A
Large caudolingual disposals below the mental foramen	1	3B
Right mandibular canal lateral to the teeth	1	3C
Medial incisor supplied by the other side	1	4
Total	16	

*The number of times a particular variation was observed among the 64 patients in the study.

Reports of high-field MRI are very rare. We present the first report of the successful application of 3-T MRI for topographic evaluation of the mandible to detect anatomical variations of the entire course of the canal structures and the outlets in the dentate mandible.

A good contrast of the neurovascular bundle is achieved by using T2-weighted sequences[17] as already shown in low–field strength scanners. We used modified high-resolution T2-weighted space sequence to provide a very good delineation of the canal structures with the opportunity for multiplanar reconstruction that set the foundation for accurate search for anatomical variations. Cadaver studies show that in most cases, only one main canal is found in the lower jaw. However, by 3-T MRI, we found unilateral and bilateral double canals in a significant number of cases, shown in Figures 2, 3, and 4. In the literature, those cases are often described as bifid, multiple, or accessory canals.[18–30] In addition, trifid canals of the mandible have been described.[23,31,32] According to Grover and Lorton,[33] the bifid mandibular nerve can be a possible cause of inadequate anesthesia. In that case, the possibility of anesthetizing a second more inferiorly placed foramen should be considered, and an alternative site for placement of anesthetic solution should be contemplated.

The frequency of the double canals mostly detected in orthopantomograms ranges from 0.08 to 8.3%.[20,33–39] Large-scale MRI studies, particularly in variations of high-field MRI, are not available to our knowledge. The fine anastomosis of the 2 incisive canals where the incisive nerve of the mandible crosses the midline and contributes to the innervation of the opposite side, described by Wadu[34] in his cadaver study, could also be demonstrated in high-field MRI, which is of particular interest in the implantation of the anterior jaw. Furthermore, a winding canal, a mandibular canal running lateral to the teeth, a canal with large caudolingual branches, and a duplicated incisive canal in the anterior chin region were found, which to our knowledge has not been reported in the literature before.

In conclusion, high-resolution MRI performed on a 3.0-T system can effectively visualize variations of the inferior alveolar nerve in dentate mandible of patients. Actually, MRI is not a routinely used method in dentistry; but there are some major advantages as we demonstrated in this study. In our opinion, MRI should be performed in vague or unclear cases, which could not be clarified by OPG or even a CT scan.

The current study clearly demonstrated that the application of MRI technologies in dentistry and oral surgery can improve patient care.

ACKNOWLEDGMENT

The authors thank Editage for providing editorial.

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