A Comparative Study of Computed Tomography and Magnetic Resonance Imaging for the Detection of Mandibular Canals and Cross-Sectional Areas in Diagnosis prior to Dental Implant Treatment

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ABSTRACT

Background: Computed tomography (CT) is effective in the diagnosis of dental implants. However, it has the disadvantage of exposing patients to high doses of x-rays, and the mandibular canals cannot be detected by CT in some clinical cases.

Purpose: The purpose of this study was to examine the detectability of the anatomic morphology of the molar region in the lower jaw (where implantation is common) by CT and magnetic resonance imaging (MRI), to compare the data, and to determine the usefulness of MRI in diagnosis prior to dental implant treatments.

Materials and Methods: Eleven female subjects (average age, 59 years) who had partially edentulous mandibles (total of 19 sites) were included in the study. CT and MRI were performed with the same subjects, and the degrees of identification of the mandibular canal in the first and second molar regions were compared. Dimensional accuracy in the second molar region was also compared.

Results: With CT, the canals of the first molar regions were not identified in 11 of 19 sites; however, MRI identified the canals in all 19 sites. Using the kappa index, we found that the inter- and intraobserver identification reliabilities (0.84 and 0.87, respectively) were excellent, especially for MRI. Dimensional positioning of the canal in the second molar region was almost the same with MRI as with CT.

Conclusions: MRI is an alternative method in diagnosis prior to dental implant treatment in the mandibular molar region.

KEY WORDS: computed tomography, dental implant, magnetic resonance imaging, mandibular canal

Since computed tomography (CT) provides three-dimensional information about the morphology of the cross-sectional mandible, it is useful in diagnosis prior to dental implant treatment.[1] However, CT has the disadvantage of exposing patients to high doses of x-rays.[2] Another problem with CT that we have often experienced is unclear imaging of the mandibular canal in the first molar region of the lower jaw. On the other hand magnetic resonance imaging (MRI) does not expose patients to x-rays, and it has been widely used in the medical field for such diseases as osteoporosis[3,4] as well as in the maxillofacial field for examining temporomandibular joints, oral tumors,[5,6] and the behavior of inserted grafts.[7] Zabalegui and colleagues[8] and Gray and colleagues[9] reported on the usefulness of the MRI diagnostic method for examination before dental implantation, but such studies were limited.[9–13] MRI also has the advantage of giving clearer images of

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arbitrary cross sections without reconstruction and with fewer artifacts as compared to CT.[14] However, its clarity in regard to anatomic shape and its dimensional accuracy have not been reported on. Therefore the purpose of this study was to evaluate the possibility of MRI diagnosis for dental implant treatment. We examined and compared CT and MRI for their ability to detect the mandibular canals and for the dimensional accuracy of their imaging of the cross-sectional areas in the molar region of the lower jaw, where dental implantation is common.

MATERIALS AND METHODS

Subjects

The subjects were 11 patients chosen randomly from those who underwent CT examination before dental implantation at the Fukuoka Dental College Hospital in 2001 and 2002. The subjects underwent MRI with consent (Fukuoka Dental College ethical committee permission No. 34). Each patient had at least one partially edentulous site on the mandible (left or right) in the first and second molar regions. Nineteen sites (right or left) on the edentulous mandible were examined with both CT and MRI. The age of the patients ranged from 35 to 75 years, with a mean age of 59 years (Table 1).

CT and MRI Examination

Stents were prepared with transparent acrylic resin and standardized titanium pins (3, 5, and 8 mm, with a diameter of 1.5 mm) and were then inserted.[15] With the occlusal plane as the standard, CT was performed under a voltage of 120 kVp and an amperage of 130 mA with a Lemage Supreme™ CT scanner (GE Yokogawa Medical Systems, Tokyo, Japan).[1] Images of the transections in which markers were clearly identified were chosen from the data obtained. Lines perpendicular to the dental arch line were indicated at intervals of 2 mm, and multiplanar reconstruction was performed with the DentaScan® software program (GE Yokogawa), which displays the cross-sectional area perpendicular to the lines.

The titanium pins were then removed from the stent used for CT, the hole diameters were adjusted to about 2 mm, and petroleum jelly was injected into the holes to prevent bubbles from forming. The upper region of the hole was sealed with inlay wax, and Vaseline was used as a stent marker for MRI. T1-weighted MRI was performed with a MAGNEX 150™ 1.5 T imager (Shimadzu Corporation, Kyoto, Japan). The imaging conditions were as follows: TR = 500 ms, TE = 15 ms, FOV = 150 to 260 mm, MAT = 256 × 256, and NEX = twice. Based on the horizontal plane, on which the stent marker made by the petroleum jelly was most clearly imaged, MRI of cross sections of the mandibular molar region was performed at a slice width of 2.5 mm perpendicular to the dental arch and with an overlap of 0.5 mm.

TABLE 1 Subjects' Gender, Age, and Imaged Site

Case	Gender	Age (yr)	Site
1	Female	53	L
2	Female	63	R and L
3	Female	61	R and L
4	Female	53	R and L
5	Female	67	R and L
6	Female	53	R and L
7	Female	64	R and L
8	Female	62	L
9	Female	35	L
10	Female	69	R and L
11	Female	75	R and L
Average age: 59		Total sites: 19	

R = right; L = left.

Evaluation of Detection of the Mandibular Canal

CT and MRI cross sections of the first and second mandibular molar regions where the stent marker was the most clearly imaged were chosen from the images of 19 mandibular molar regions in the 11 patients. The imaging levels of the mandibular canal were visually evaluated on a film viewer (Figure 1) by the first author (H. I.), who has had 4 years of experience as a prosthodontist, and were scored in the following manner: a score of 0 indicated that the mandibular canal could not be observed, a score of 1 indicated that the mandibular canal was unclear but could be detected, and a score of 2 indicated that the mandibular canal could be clearly detected.

After 1 week, a second measurement was made by the first author (H. I.). Another author, who has had 27 years of experience as a prosthodontist, evaluated the images by the same method used by the first author but on a different day. The kappa index was deter-

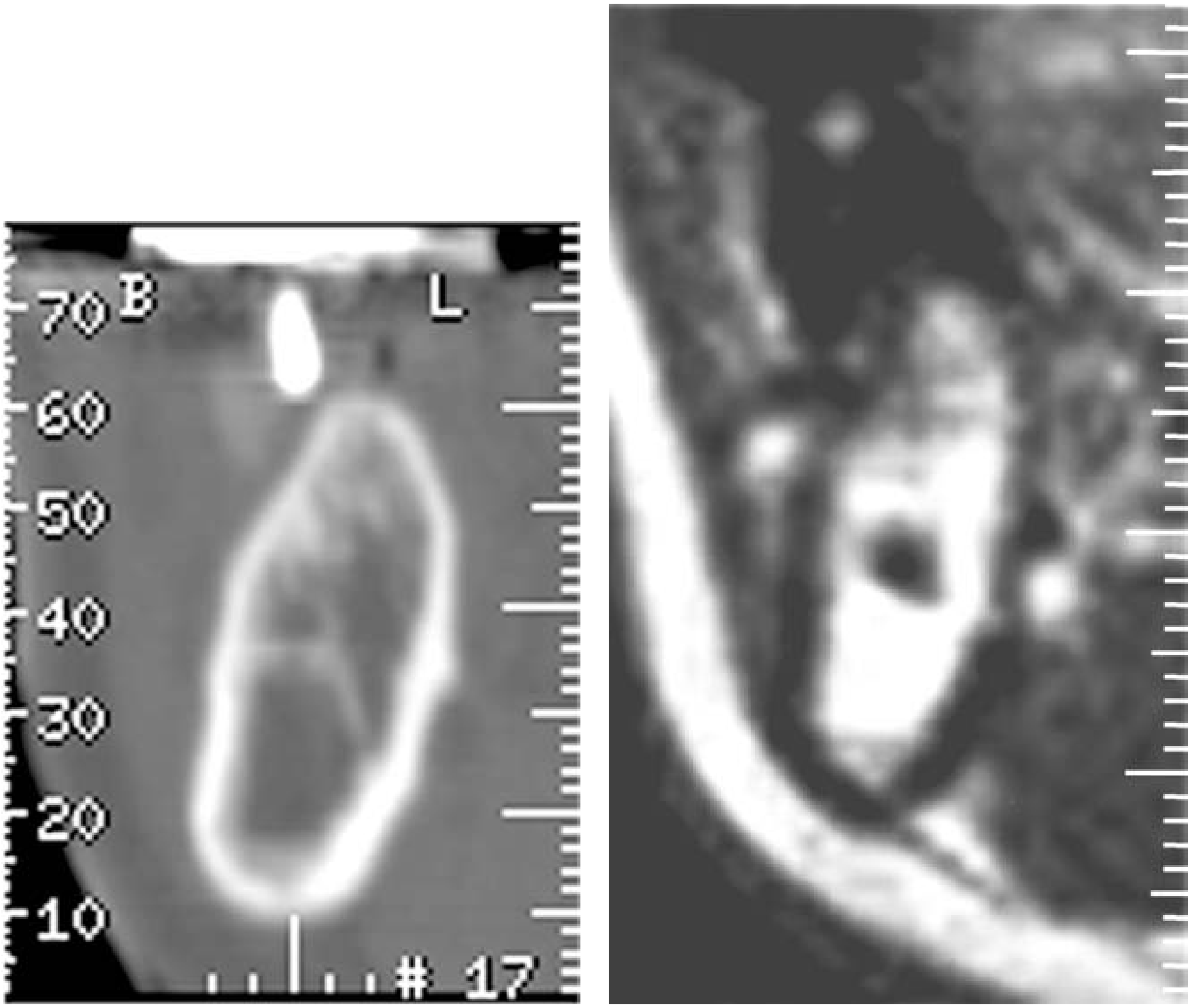

Figure 1 *A*, Cross-sectional computed tomography scan of the first mandibular molar region in a 51-year-old female; the mandibular canal is clearly distinguished (score: 2). *B*, Cross-sectional magnetic resonance image of the same region in the same patient; the mandibular canal is not observed (score: 0).

mined by the intra- and interobserver factors and the imaging methods of CT and MRI.

Evaluation of Dimensional Accuracy of Cross-Sectional Area of the Mandible

Since the detectability of the mandibular canal in the first molar region was low with CT (Table 2), the second molar region was used to evaluate the dimensional accuracy of the cross-sectional area of the mandible. CT and MRI scans of 17 sites in nine patients' second mandibular molar regions, in which the mandibular canal could clearly be detected (ie, scores of 1 and 2) with CT, were measured on a film viewer. The magnification of the CT image was 1.1; that of the MRI scan was 1.2. Perpendicular lines were drawn from the mandibular canal center to the alveolar crest, the lower border of the mandible, the buccal border, and the lingual border; these lines were then measured with a plastic caliper (Figure 2). The resulting distances were converted into actual values.

Statistical Analysis

The inter- and intraobserver imaging reliability of the mandibular canal was examined by using Cohen's kappa index. The imaging differences between CT and MRI in terms of the first and second molar regions were examined with the Mann-Whitney *U* test. A *p* value of less than .05 was regarded as significant.

TABLE 2 Detection of Mandibular Canal at First and Second Molar Regions by Computed Tomography and Magnetic Resonance Imaging

	CT (*N* = 19)		MRI (*N* = 19)	
Score	M1	M2	M1	M2
2	2*	6*	17	17
1	6	11	2	2
0	11*	2*	0*	0*

CT = computed tomography; M1 = first molar region; M2 = second molar region; MRI = magnetic resonance imaging.
*$p < .05$.

The differences in the distances from the mandibular canal center to the alveolar crest, the lower border, the buccal border, and the lingual border as measured on the CT and magnetic resonance (MR) images were examined with the paired *t*-test. The correlation of the distances was examined with Pearson's correlation coefficient. Statistical analysis was performed with StatView® IV software (Abacus Concept Inc., Berkeley, CA, USA) for Macintosh personal computers.

RESULTS

Inter- and Intraobserver Reliability

The kappa index values for interobserver reliability of the CT images were 0.61 in the first molar region and 0.53 in the second molar region. The corresponding index values for the MR images were 1.00 and 0.77. The intraobserver reliability of the CT images was 0.72 in the first molar region and 0.76 in the second molar region while that of the MR images was 0.64 in the first molar region and 1.00 in the second molar region

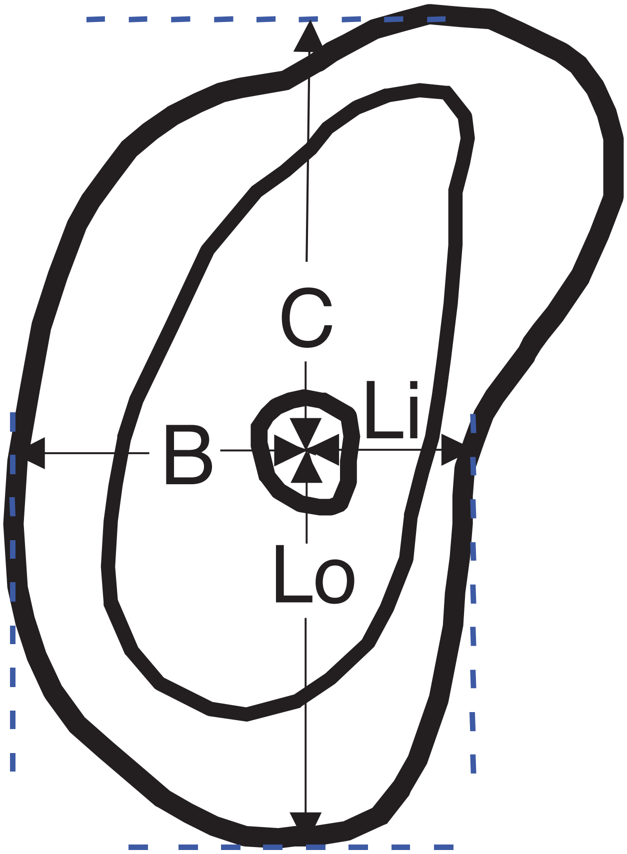

Figure 2 Evaluation of the dimensional accuracy of the cross-sectional area in the second molar region. *A*, Magnetic resonance cross-sectional image of the second mandibular molar region in a 53-year-old female. *B*, Diagram showing the distances from the mandibular canal center to the alveolar crest (C), the lower border of the mandible (Lo), the buccal border (B), and the lingual border (Li).

TABLE 3 Intra- and Interobserver Reliability (Kappa Index)

	Region	Intraobserver	Interobserver
CT	M1	0.72	0.61
	M2	0.76	0.53
MRI	M1	0.64	1.00
	M2	1.00	0.77

CT = computed tomography; M1 = first molar region; M2 = second molar region; MRI = magnetic resonance imaging.

(Table 3). Since all of these kappa index values almost correspond to excellent (> 0.8) or substantial (> 0.6) levels,[16] the evaluated data are reliable, and the first author's data were used.

Detectability of the Mandibular Canal

CT could not detect the mandibular canal (score: 0) in 11 of the 19 first molar regions or in 2 of the 19 second molar regions, resulting in a significant difference in detection between the regions ($p = .0019$). On the other hand MRI detected the mandibular canal in all of the 19 first and second molar regions. Detectability was significantly higher with MRI than with CT in both the first and second molar regions ($p < .001$ and $p = .0003$, respectively) (see Table 2).

Dimensional Accuracy in the Cross-Sectional Areas of the Mandibles

The differences between CT and MRI in regard to the distances from the mandibular canal center to the alveolar crest, lower border, buccal border, and lingual border in the second molar regions of the mandible were small, and the mean differences in these areas were 0.4 mm ($p = .8264$), 0.3 mm ($p = .6884$), 0.3 mm ($p = .4596$), and 0 mm ($p = .9795$), respectively. The differences were not significant ($p > .05$). There were closer positive correlations between the CT and MRI distances (r: alveolar crest, 0.868; lower border, 0.812; buccal border, 0.687; lingual border, 0.868), indicating that the mandibular canal was imaged in almost the same position in both CT and MRI scans. This finding suggests that the cross-sectional morphology of the mandible was also imaged similarly on both CT and MRI scans.

DISCUSSION

To prevent dental implant failure (such as mandibular nerve injury), it is necessary to perform a preoperative close examination, for which imaging is essential.[17–19] Panoramic imaging is useful for preoperative screening because of the wide imaging area, and it is commonly used for examinations before dental implantation. However, panoramic imaging cannot indicate the positional relationship between buccolingual anatomic structures, including the mandibular canal. To evaluate these positional relationships, it is necessary to perform general tomography and/or CT. Since CT has many advantages, such as usefulness for examination of the morphology of arbitrary cross sections in the mandible, it has been widely used for the examination.[20] The accuracy of morphologic measurements of the cross-sectional mandible on CT-reconstructed images is also high.[21,22] Even though devices and methods for reducing exposure to x-rays (such as dental CT) have advanced,[23] x-ray exposure cannot be neglected.[22,24] On the other hand MRI provides images without the problem of exposing patients to x-rays. However, the use of MRI examinations before implantation has been limited despite MRI's high contrast and spacial resolution.[25–27] Methods and software for preoperative MRI examinations have not yet been developed as they have for CT, and only a few studies on stent materials have been reported.[15]

In the present study cross-sectional T1-weighted MR images were selected, and the bone marrow was shown in clear areas (white) with high signal intensity. The surrounding cortical bone (which is mainly composed of calcium compounds) and its proton density were low and dark (black), indicating low signal intensity. The mandibular canal was dark (black) with low signal intensity inside bone marrow that had high signal intensity, indicating a flow void phenomenon without signals due to blood flow (see Figures 1 and 2). In the first molar region, the canals were not identified with CT in 11 of 19 sites; however, they were identified with MRI in all 19 sites (see Table 2). MRI clearly demonstrated the mandibular canal in the first molar region of the mandible, which could not be clearly observed with CT. These results indicate that the mandibular canal could not be imaged by CT but could be imaged with MRI through low signal intensity in bone marrow with high signal intensity. In the molar regions that received a score of 1 with MRI (see Table 2), the regions around the mandibular canal showed low signal intensity (black) similar to that shown by the mandibular canal, making identification of the mandibular canal difficult. In such cases, a calcification-like state, which may be the cause of the low signal intensity on MRI, was observed with CT. Since the canal detectability and kappa index value for MRI were high (see Tables 2 and 3), MRI must be suitable for clear imaging of the mandibular canal. Since information regarding the methods for using MRI is limited, we used T1-weighted imaging and followed the finding of Murakami and colleagues,[10] who reported that since the detectability of lesions (tumor, inflammation) by T2-weighted imaging was high but that the signal-to-noise ratio was low, the mandibular canal and the alveolar bone could not be clearly imaged. It was also reported that since the contrast between the mandibular canal and bone marrow was reduced because of a higher signal intensity in the former and a lower signal intensity in the latter in proton-density–weighted imaging as compared with T1-weighted imaging, the mandibular canal could not be clearly imaged. Further research is needed to determine the reasons for the low detectability of the canal in the first molar region with CT.

Recently MRI devices have advanced to a higher resolution,[28–30] giving MRI the advantage of presenting clearer images of arbitrary cross sections without reconstruction and with fewer artifacts than with CT.[14] However, its accuracy has not been reported.[8,9] The present study showed that the mandibular canal was imaged in almost the same position by CT and by MRI, thus suggesting that MRI offers dimensional accuracy. However, in the present study MRI was performed with an FOV of 150 to 260 mm and a 256×256 matrix, with a resolution level of 1 mm. CT was performed with an FOV of 150 mm and a 512×512 matrix, with a resolution level of 0.3 to 0.5 mm. This indicated that the resolution of the MRI used in this study was not higher than that of CT. Although the distinction level of images was lower with MRI than with CT, MRI was useful in diagnosis prior to dental implantation, for which evaluation at a level of 1 mm is required. MRI also has several disadvantages: high cost, long imaging time, possible artifacts due to body movement, inapplicability to patients with implanted magnetic objects or pacemakers, inappropriateness for claustrophobic patients, and possible artifacts caused by metal. Even though MRI has such disadvantages, our results suggest that it is an alternative method of imaging in diagnosis prior to dental implantation in the lower mandible.

CONCLUSIONS

The mandibular canal in all 19 molar regions was imaged with MRI. This suggests that MRI is useful for examination of the mandibular canal in the molar region. The mandibular canal in the second molar region was imaged in almost the same position by both MRI and CT. This suggests that the cross-sectional morphology of the mandible is also represented similarly in the two imaging methods. From these results, we can conclude that MRI is an alternative method for use in diagnosis prior to dental implantation in the mandibular molar region.

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