Measurement of Anterior Loop Length for the Mandibular Canal and Diameter of the Mandibular Incisive Canal to Avoid Nerve Damage When Installing Endosseous Implants in the Interforaminal Region: A Second Attempt Introducing Cone Beam Computed Tomography

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Purpose: To measure and compare the anterior loop length (ALL) for the mandibular canal and the mandibular incisive canal diameter (ICD) at its origin in cadavers using anatomy and cone beam computed tomography (CBCT) to safely install endosseous implants in the most distal area of the interforaminal region.

Materials and Methods: The ALL and ICD were measured using CBCT in 4 cadavers, and using anatomy in 71 cadavers.

Results: The ranges and mean ± SD for the anatomic measurements were: ALL, 0.0 to 9.0 mm and 1.9 ± 1.7 mm; ICD, 1.0 to 6.6 mm and 2.8 ± 1.0 mm. The average discrepancies between CBCT and anatomic measurements were 0.06 mm or less for both the ALL and the ICD, which were less than the resolution of CBCT.

Conclusions: Because large variations in measurements were observed, both for ALL and ICD, no fixed distance mesially from the mental foramen should be considered safe. The ALL and the ICD can be estimated from the CBCT measurement. The preoperative CBCT measurement yields important information for each case.

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Sensory disturbances of the mental nerve region may arise after endosseous implants (hereafter, implants) are installed in the most distal area of the interforaminal region.[1] The causes are considered to include damage to the inferior alveolar nerve in the anterior loop of the mandibular canal anterior to the mental foramen (MF)[2,3] or a stretching injury of the inferior alveolar nerve because a fixture placed anteriorly to the MF can engage the incisive branch in the mandibular incisive canal.[4] To obtain significant information to prevent these causes, we measured the anterior loop length (ALL) and the incisive canal diameter (ICD) in cadaver samples anatomically in our first attempt.[5]

With advances in computer technology and x-ray computed tomography (CT), surgical simulation for implants is becoming practical.[6] Further, simulation on a photocurable plastic 3D model after CT imaging of the possible implant site[7] and computer-assisted intrasurgical navigation systems[8,9] are also used in practice. However, no literature has described any procedure to measure the ALL and the ICD anatomically, as well as virtually, by cone beam computed tomography (CBCT) to compare the values obtained.

In this study, we measured the ALL and the ICD in cadavers using anatomy and CBCT and compared the values obtained as a source for significant information in implant surgery. Using a larger number of samples, we pursued the analysis on the anatomic-obtained values for increased statistical validity, and further compared them with those measured virtually by CBCT, to evaluate the usefulness of the method of preoperative measurement.

Materials and Methods

MATERIALS

Seventy-one Japanese cadavers (140 hemimandibles [70 right and 70 left]) were examined (Table 1). The specimens were comprised of 38 males (75 hemimandibles) and 29 females (58 hemimandibles)

Table 1. DISTRIBUTION OF CADAVER SPECIMENS BY AGE AND GENDER

Age (yr)	Male	Female	Both
48-59	6 (12)	1 (2)	7 (14)
60-69	12 (23)	4 (8)	16 (31)
70-79	14 (27)	7 (14)	21 (41)
80-103	10 (20)	17 (34)	27 (54)
All	42 (82)	29 (58)	71 (140)

NOTE. Number of hemimandibles in each group is given in parentheses.

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from the Department of Anatomy of Saga Medical School and 4 males (7 hemimandibles) from the Department of Anatomy, the School of Life Dentistry, Nippon Dentistry University in Tokyo. All specimens had been stored in 10% neutral formalin. The specimens (age at death ranging from 48 to 103 years [mean, 75.4 years]), were divided into 4 age groups for statistical analysis: *1*) 48 to 59 years (7 cadavers; 14 hemimandibles); *2*) 60 to 69 years (16 cadavers; 31 hemimandibles); *3*) 70 to 79 years (21 cadavers; 41 hemimandibles); and *4*) 80 to 103 years (27 cadavers; 54 hemimandibles). These 140 hemimandibles were further subdivided into 2 groups in accordance with the dental status, as follows: *1*) a dentate group with 1 to 5 teeth (anterior teeth or premolar teeth) (93 hemimandibles); and *2*) an edentulous group with no teeth (47 hemimandibles). The heights were measured for 33 cadavers (65 hemimandibles); the mean height was 155 cm with a SD of $\pm$7.82 cm. The heights ranged between 140 and 170 cm, with 7 cadavers (14 hemimandibles) between 140 and 149 cm, 12 cadavers (24 hemimandibles) between 150 and 159 cm, and 14 cadavers (27 hemimandibles) between 160 and 170 cm. Cadavers with disorders that might have influenced the mandibular shape were excluded from the study. In each specimen, the mandible was detached from the cadaver and exposed completely.

MEASUREMENTS

By CBCT

CBCT images of a 20-mm area centering the MF of the 4 male cadavers (7 hemimandibles) from the Nippon Dentistry University were obtained using a dental panoramic x-ray CT scanner (PSR9000N; Asahi Roentgen Industries, Kyoto, Japan). At the time of acquisition, the mandible sample was placed on a flat acrylic experimental board with the inferior margin of the mandible (IMM) side downward. In our previous study, the IMM was defined as the inferior-most margin plane when the mandible was planed on the flat experimental table.[5] The acquisition parameters were as follows: tube volume, 80 kV; tube current, 8 mA; acquisition period, 20 seconds; and dental-CT mode. On the computer display connected to the CBCT system, plane α was determined as the plane where the perpendicular to the IMM passes through the anterior-most margin of the MF and plane β as the plane where the perpendicular to the IMM passes through the anterior-most margin of the mandibular anterior loop (coincident with the origin of the incisive canal). The ALL was defined as the shortest straight-line distance between planes α and β, and the ICD as the internal diameter of the incisive canal formed by plane β; both measurements were recorded (Figs 1, 2). Image distortion was corrected automatically on the computer display.

By Anatomy

In all hemimandible samples (n = 140), the buccal cortical and spongy bone around the MF was eliminated using a steel round bar and a sharp spoon, and the inferior alveolar neurovascular bundles and the incisive branch within the mandibular and incisive canals were confirmed.[5] The mandible sample was placed on a flat acrylic experimental board with the IMM side downward. The planes, A and B, were defined as in the CBCT measurement. We named the planes differently because planes A and B are not exactly the same as planes α and β as the latter are virtually defined. The ALL formed by planes A and B and ICD formed by plane B were measured.[5]

MEASURING DEVICES

The anatomic measurement of the ALL and ICD was carried out using measuring calipers (Castrivuejo 18-mm angled measuring caliper; Kohler, Neihausen, Germany) and vernier calipers (N10S; Mitutoyo Corporation, Kanagawa, Japan).[5]

MEASUREMENT ERRORS

The reproducibility of the measurements obtained was evaluated using a specimen selected randomly from those used in the CBCT study. The hemimandible was measured using CBCT using methods described previously for the CBCT. The measurements were obtained again 1 month later using the same sample and methods. The anatomic measurements were carried out on another day. Again, 1 month later, the same measurements were carried out on the same sample. The measurement errors obtained, which were calculated as the differences between corresponding measurements, were expressed in terms of s(i) values as follows:

$$s(i) = \sqrt{\frac{\sum (X_a - X_b)^2}{2N}}$$

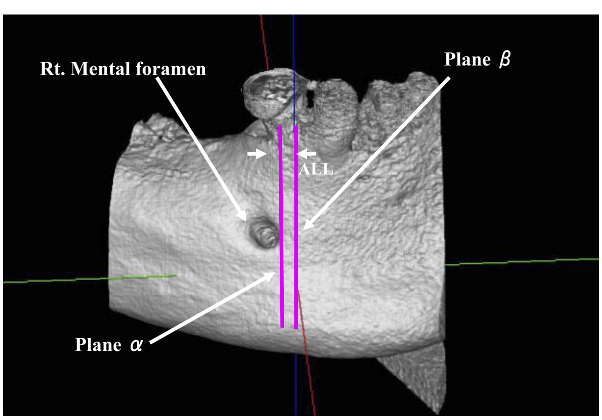

FIGURE 1. Reconstructed 3D CBCT image of the MF area of the mandible. Plane α was determined as the plane where the perpendicular to the IMM passes through the anterior-most margin of the MF and plane β as the plane where the perpendicular to the IMM passes through the anterior-most margin of the mandibular anterior loop (coincident with the origin of the incisive canal). The shortest linear distance between planes α and β was measured to be the ALL.

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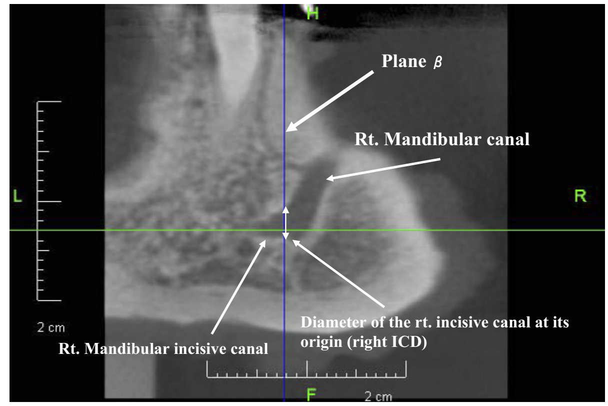

FIGURE 2. CBCT transverse image of the origin of the incisive canal. Plane β was determined on the computer display connected to the CBCT system and the diameter of the incisive canal at its origin (ICD) was measured.

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STATISTICAL ANALYSIS

All calculations were processed using SPSS statistical software, version 11.0J (SPSS, Chicago, IL). *P* values of .05 or less were considered statistically significant.

Anatomic Measurements

The prevalence of the anterior loop presence was calculated and an ALL distribution chart was pro-

Table 2. ANATOMIC AND CBCT MEASUREMENTS FOR COMPARISONS

Anatomy	CBCT
ALL measured using planes A and B (140/71)	
ICD measured on plane B (140/71)	
ALL measured using planes A and B (7/4)	ALL measured using planes α and β (7/4)
ICD measured on plane B (7/4)	ICD measured on plane β (7/4)

NOTE. Number of hemimandibles/cadavers for each measurement is given in parentheses.

Abbreviations: ALL, anterior loop length; CBCT, cone beam computed tomography; ICD, incisive canal diameter.

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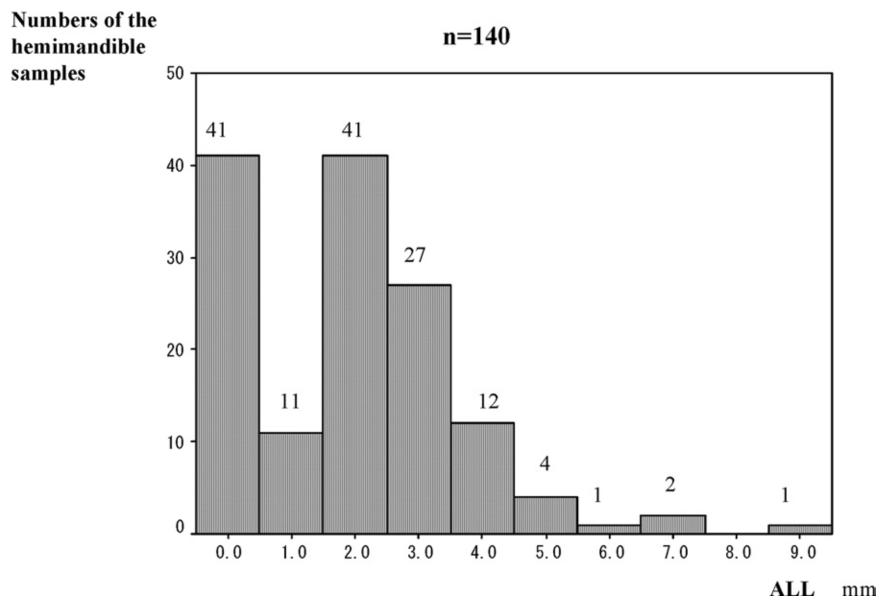

FIGURE 3. Distribution histogram of the ALL with a data class of 1.0 mm.

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duced (Table 2). The value ranges, mean values, and SD of the ALL and ICD measurements were calculated for all specimens, and further categorized by right/left side, gender, height, age, and dental status. The range, mean value, and SD of the ALL for specimens with an anterior loop were calculated. The prevalence of the specimens with an ALL of 5 mm or longer was calculated as well as that of the specimens with an ICD of 5 mm or larger. To compare all measured values for right/left hemimandible, gender, height, age, and dental status, 2-group comparisons were carried out using the unpaired t test and multiple-group comparisons were made using ANOVA. For the multiple comparison tests after ANOVA, the least significant difference (LSD) test was used.

Comparison Between the CBCT and Anatomic Measurements

The mean and SD were calculated on the ALL and ICD obtained by CBCT and anatomic measurements for all 7 hemimandibles (Table 2). Mean discrepancies between the corresponding measurements were calculated and paired t tests were applied for statistical comparison.

Results

MEASUREMENT ERRORS

The measurement errors were 0.03 mm or less for the measurements by the CBCT and anatomic measurements.

ANATOMIC MEASUREMENTS

An anterior loop was present in 99 of 140 hemimandibles from 71 cadavers (prevalence, 71%). The ALL distribution histogram is shown in Figure 3. The class width is 1.0 mm. The value ranges, mean values, and SD of the ALL and ICD for all specimens, right/left side, gender, height, age, and dental status are shown in Table 3. The range, mean value, and SD for samples with an anterior loop were 0.8 to 9 mm and 2.7 ± 1.3 mm. The specimen with the longest ALL (9 mm) is shown in Figure 4. Figure 5 shows the specimen with the largest ICD (6.6 mm), as reported in our previous study.[5] Eight of 140 samples had an ALL of 5 mm or longer (prevalence, 6%) and 6 of 140 samples had an ICD larger than 5 mm (prevalence, 4%).

Statistical comparison showed no significant differences in the ALL for the right/left side, age, or dental status ($P > .05$). However, the ALL in males was significantly longer than in females ($P < .01$). ANOVA carried out for the ALL in each height group showed a significant difference ($F = 3.35$, $P = .04$), and by LSD, the 160 to 170 cm height group had significantly larger values than the 140 to 149 cm height group ($P < .05$).

No statistically significant difference existed in the ICD based on the right/left side, gender, height, age, or dental status ($P > .05$).

COMPARISON BETWEEN THE CBCT AND ANATOMIC MEASUREMENTS

For the CBCT measurements obtained with 7 samples from 4 cadavers, the mean value and SD were 2.2 ± 0.8 mm for the ALL and 2.2 ± 0.4 mm for the ICD. For the anatomic measurements with the same samples, the mean value and SD were 2.2 ± 0.8 mm for the ALL and 2.2 ± 0.4 mm for the ICD. The mean discrepancies between the CBCT and anatomic mea-

Table 3. ANATOMIC MEASUREMENTS

Group	ALL (mm)			ICD at Its Origin (mm)		
	Range	Mean	SD	Range	Mean	SD
All (n = 140)	0.0-9.0	1.9	1.7	1.0-6.6	2.8	1.0
Side						
Right (n = 70)	0.0-4.7	1.7	1.3	1.0-6.6	2.8	1.1
Left (n = 70)	0.0-9.0	2.1	1.9	1.0-6.2	2.9	1.0
Gender						
Male (n = 82)	0.0-9.0	2.2†	1.7	1.0-6.6	2.9	1.1
Female (n = 58)	0.0-7.0	1.5†	1.6	1.0-5.3	2.7	0.9
Height (cm)						
140-149 (n = 14)	0.0-3.8	1.5*	1.3	1.5-3.3	2.2	0.5
150-159 (n = 24)	0.0-7.0	2.2	1.9	1.7-4.5	2.6	0.8
160-170 (n = 27)	0.0-9.0	2.9*	1.8	1.5-4.2	2.7	0.9
Age (yr)						
48-59 (n = 14)	0.0-4.7	2.6	1.4	2.0-4.1	2.9	0.8
60-69 (n = 31)	0.0-7.0	1.6	1.7	1.0-6.6	3.3	1.4
70-79 (n = 41)	0.0-6.8	2.1	1.6	1.4-6.2	2.9	1.0
80-103 (n = 54)	0.0-9.0	1.8	1.7	1.0-4.8	2.5	0.8
Dental status						
Dentate (n = 93)	0.0-9.0	2.1	1.8	1.0-6.6	2.9	1.1
Edentulous (n = 47)	0.0-5.1	1.6	1.4	1.1-4.4	2.6	0.8

Abbreviations: ALL, anterior loop length; CBCT, cone beam computed tomography; ICD, incisive canal diameter; n, number of hemimandibles.

*$P < .05$.

†$P < .01$.

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surements were 0.05 mm for the ALL and 0.06 mm for the ICD. Statistical comparison by the paired *t* test showed no significant differences in the ALL or ICD between the CBCT and anatomic measurements.

Discussion

RELIABILITY OF MEASUREMENTS

The measurement error rates for the CBCT and anatomic measurements were 10% or less of the SD of the entire samples. The reliability of measurements was thus considered high.

ANATOMIC MEASUREMENTS

In previous studies, Bavits et al,[10] Solar et al,[11] Mardinger et al,[12] Kuzmanovic et al,[13] and Kieser et al[14] measured the ALL using cadavers and Rosenquist[15] used living patients. The longest ALL reported was 5 mm, as reported by Solar et al.[11] Recently, however, Hwang et al[16] reported the mean and SD of the ALL were 5.0 ± 1.8

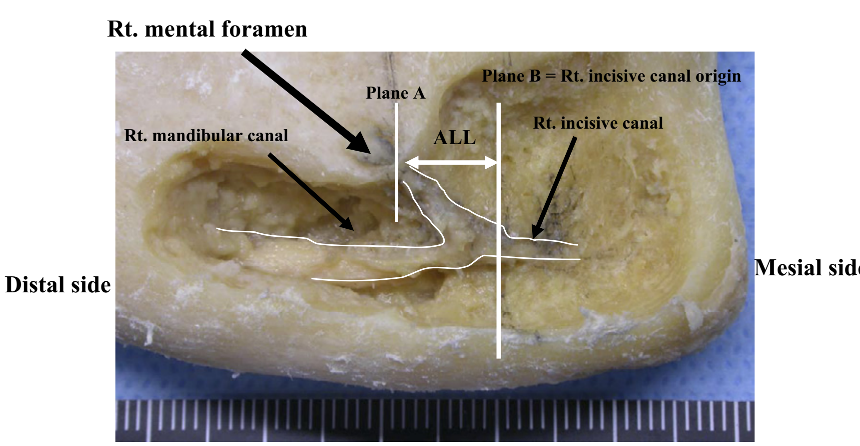

FIGURE 4. The sample with the longest ALL of 9 mm.

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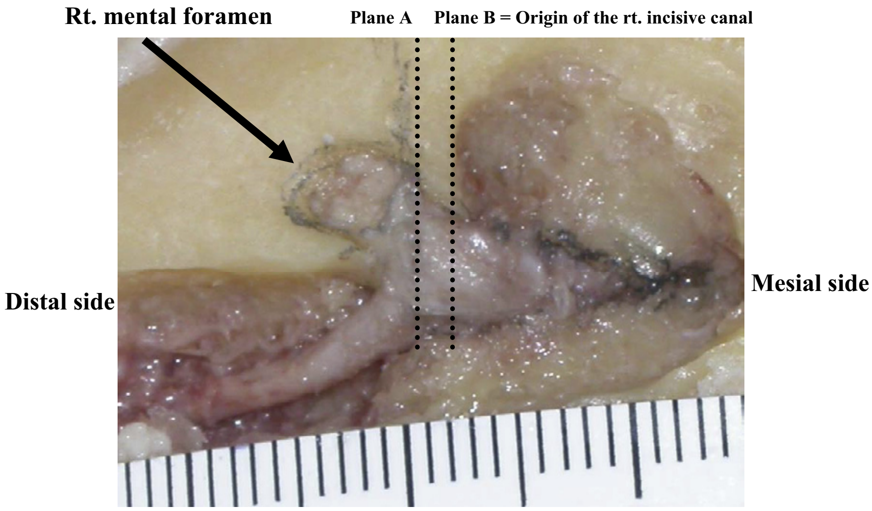

FIGURE 5. The sample with the largest ICD of 6.6 mm (modified from our previous study[5]).

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mm. Further, the longest ALL measured in our previous study was 6 mm.[5] This time we obtained the longest ALL of 9 mm, and 8 of 140 hemimandibles had a 5 mm or longer ALL (prevalence, 6%). Accordingly, before surgery to place an implant on the mesial side close to the MF, it is necessary to hypothesize the case where the length of the loop from the MF is 5 mm or longer. The statistical comparison of the ALL in this study showed no significant differences in the comparison for side, age, or dental status. However, because there were statistically significant gender and height differences in the ALL, suggesting the male or tall samples had a longer loop length, gender, and physique may play a role.

When installing implants mesially from the MF, not only the ALL, but the ICD should be considered.[17] As noted by Hirsch et al,[4] when the ICD is large, the incisive branch in the canal may be involved in the drilling for implant or in installing an implant, resulting in stretching the inferior alveolar nerve main trunk to damage it. Magnusson[18] recommends when installing implants in the most distal interforaminal area that drilling commences from a location approximately 5 mm mesially from the MF in the absence of an anterior loop, or from a location approximately 5 mm mesially from the most anterior point of the loop when an anterior loop is present, if the ALL and ICD are considered. However, the largest ICD in this study was confirmed to be 6.6 mm, which is the same value as confirmed in our first attempt.[5] Although the statistical analysis showed no significant difference in the ICD, 6 samples out of 140 had a diameter of 5 mm or larger (prevalence, 4%). Moreover, this study, as well as our previous study,[5] showed large variations both in the ALL and ICD because the SDs of the entire samples listed in Table 3 also were larger than in the previous studies.[10-15,17] Therefore, no fixed idea should preoperatively determine the safe distance to be a certain millimeter mesially from the MF.

CBCT MEASUREMENTS

Computed tomography is the best method to obtain minimally invasive and correct preoperative measurement of the ALL and ICD in living patients.[6-8] When oral and maxillofacial surgeons install implants in the mesial area of the MF, they must familiarize themselves with anatomic information obtained by measuring the ALL and ICD on a case-by-case basis via preoperative CT scans. Recently, CBCT, which has an approach different from spiral CT,[19] has come to be used widely. CBCT allows comparatively less radiation and higher resolution (PSR9000N has a spatial resolution of 0.1 mm homogeneous voxel) than spiral CT.[20] In this study, the differences between the CBCT and anatomic measurements of the ALL and ICD were smaller than the level of resolution and thus not significant. Therefore, the CBCT measurements for the ALL and ICD are considered to be sufficiently reliable.

Because there may be large variations in the ALL and the ICD, one should not have any preoperative concept that a fixed distance mesially from the MF will be safe for implant placement. It is important to measure the ALL and the ICD preoperatively using CBCT images for each case.

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