Anatomical relationship between the sublingual fossa and the lateral lingual foramen


Abstract. This study investigated the locational relationship between the sublingual fossa (SF) and the lateral lingual foramen (LLF) in order to gain useful knowledge so that perforation of the lingual cortical bone and damage to the adjacent blood vessels can be avoided when placing an endosseous implant (implant) in the mandibular interforaminal region. The deepest point of the SF (SFP) and the LLF were identified in 38 Japanese cadaver mandibles (20 edentulous and 18 dentate) by computed tomography (CT) and physical measurement. Their locations were measured. In the edentulous cases, the SFP was located approximately 15 mm vertically from the alveolar crest in the direction of the mandibular lower margin in the canine and premolar regions, and the LLF was located within a 5 mm radius from the SFP. Thus, significant attention to the locational relationship between the SFP and the LLF, as seen on preoperative CT, is required when placing an implant ≥3.75 mm in diameter and ≥15 mm in length in this region.

Keywords: sublingual fossa; lateral lingual foramen; perforation; submental artery; bleeding.

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Haemorrhage during or following the installation of endosseous implants (hereafter, implants) in the mandible is reported to cause marked swelling of the floor of the mouth that can result in airway obstruction.1–3 This is often caused by either lingual cortical bone perforation from drilling, or the implant itself injuring the adjacent vessels. In a previous study by this group, in which it was noted that the presence of the sublingual fossa (SF) was a factor involved in the perforation of the lingual cortical bone, the SF was located and the depth measured anatomically, and it was found that the deepest point of the SF was located in the canine and premolar regions.4 This location corresponds to the implant sites in many cases of serious haemorrhage in the floor of the mouth,1–5 suggesting a high probability that the severe haemorrhage reported in these cases was caused by perforation of the lingual cortical bone and then injury to the adjacent vessels or vessels penetrating the lateral lingual foramen (LLF)4 in the canine and premolar regions.

This study focused on clarifying the locational relationship between the SF and the LLF by computed tomography (CT) and anatomical measurements in order to gain useful preventive knowledge so that such cases of serious haemorrhage can be avoided.

Materials and methods

Subjects

Thirty-eight Japanese cadavers (76 hemimandibles) were obtained from the Department of Anatomy at Saga Medical School and examined with the approval of the Ethics Committee of Saga Medical...
School. All of the cadavers were fixed in a 10% neutral formalin solution. Fifteen were male (30 hemimandibles) and 23 were female (46 hemimandibles). The age range at the time of death was 55–96 years (mean 78 ± 10 years). The 38 mandibles (76 hemimandibles) were divided into two groups: an edentulous group (20 mandibles, 40 hemimandibles) and a dentate group with at least one tooth remaining (18 mandibles, 36 hemimandibles).

CT measurement

The 38 mandibles (76 hemimandibles) were scanned with a Multislice CT device (SOMATOM Emotion 16-slice configuration; Siemens AG, Germany). Imaging parameters were the following: tube potential 130 kV, tube current 150 mA, scan time 1 s, gantry tilt 0, slice thickness 0.6 mm, beam pitch 1.0, reconstruction interval 0.6 mm, and reconstruction function H90s. The field of view was 150 mm, and the voxel size was 0.3 mm for the x and y axes and 0.6 mm for the z-axis. The mandible sample was fixed on an acrylic fixture device with the inferior mandibular margin (IMM) plane aligned in parallel with the scanning plane and scanned with the mid-sagittal plane of the sample aligned with the vertical midline of the gantry. The CT data were saved in Digital Imaging and Communications in Medicine (DICOM) format.

The CT data obtained were analyzed with software program Landmark System LAND marker Direct, version 6.11 (iCAT, Osaka, Japan), as described below.

First, among the slices vertical to the dental arch both mesially and distally from the mental foramen (MF), slices with possible SF were selected for measurement; the deepest point of the SF (SFP0) was defined on the lingual surface and the depth of the SF (SFD0) was measured on each slice (Fig. 1). The largest value among SFD0s was defined as the SFD; the corresponding SFP0 was defined as the SFP (Fig. 2A). The vertical distance between the alveolar crest (AC) and the SFP (AC–SFP; Fig. 2A) and the horizontal distance between the MF and the SFP (MF–SFP; Fig. 2B) were measured.

The LLF was defined as a foramen on the lateral lingual surface that was different from those around the mental spine on the mandibular midline. The LLF was identified in each sample; the vertical distance between the AC and the LLF (AC–LLF; Fig. 3A), the horizontal distance between the MF and the LLF (MF–LLF; Fig. 3B and C), the vertical distance between the SFP and the LLF (SFP–LLF; Fig. 4A) and the horizontal distance between the SFP and the LLF (SFP–LLF; Fig. 4B and C) were measured.

A positive value was assigned to MF–LLF when the LLF was located mesially relative to the MF (Fig. 3B), while a negative value was assigned when it was located distally relative to the MF (Fig. 3C). In the samples with negative MF–LLF values, the horizontal diameter of the MF was measured (Fig. 3C). In the samples with multiple LLFs in a hemimandible, the largest LLF was selected.

Physical measurement

Both the SF and the LLF were identified by CT in 24 of the 76 hemimandibles. These samples were cleared of soft tissues to identify the SF and the LLF grossly (Fig. 5A and B). The mandible sample was placed on a flat experimental table and the IMM was defined as the reference plane. Lines (red lines in Fig. 5A) were drawn vertically to the dental arch on the lingual side of the mandibles in the range in which the SF was present; the deepest point of the SF (SFP0) was defined along each line and the depth of the SF (SFD0) was measured with a mini digital tread depth gauge (MDDG; MonotaRo, Japan). SFP0, corresponding to the longest SFD0 in the SFD0s for the multiple lines (red lines in Fig. 5A), was defined as the SFP (Fig. 5B). Callipers (N10S; Mitutoyo Corporation, Kanagawa, Japan) were used to measure the linear distance between the SFP and the LLF (SFP–LLF, Fig. 5B).

All CT and physical measurement procedures were performed by one expert examiner.

Identification of the vessel penetrating the LLF

Prior to the removal of soft tissues for physical measurement, the origin of vessels penetrating the LLF was identified grossly in 15 mandibles (30 hemimandibles) selected from the 38 mandibles.

Statistical analysis

All statistical analyses were conducted using SPSS statistical software, version 11.0J (SPSS Japan, Tokyo, Japan). P-values of <0.05 were considered statistically significant. The χ2 test was used to compare the frequencies of the presence of SF and LLF in all samples. The range, mean, and standard deviation (SD) of the measurement values related to the location of the SFP and LLF were calculated for all samples and by gender and dental status.

Fig. 1. Orthoradial views of slices with the sublingual fossa (SF). The SF depth is measured on each view. The most prominent superior and inferior points (red-encircled black dots) of the depression on the lingual side are joined with a straight line (white line). The perpendicular distance from this straight line to the depression on the lingual surface is greatest at the intersection of the perpendicular line and the cortical bone surface of the lingual side (SFP0) (indicated by a black-encircled white dot); the distance is defined as the depth of the SF (SFD0; distance between the black and white arrows). The inferior mandibular margin (IMM) plane is used as the reference plane. Li: lingual side.
Fig. 2. Measurement sites related to the sublingual fossa (SF) on the CT images. (A) Orthoradial view of the slice with the deepest point of the SF (SFP; black-encircled white dot). The greatest depth of the SF (SFD; distance between the black and white arrowheads) is the largest value of SFD0. The vertical distance between the alveolar crest (AC, green-encircled black dot) and the SFP (black-encircled white dot) is measured (AC–SFP). (B) Axial view at the mental foramen (MF) level. The red lines represent the slice vertical to the dental arch passing through the most mesial margin of the MF and that passing through the SFP (red-encircled black dot), respectively. The linear distance indicated by the double-headed black arrow is measured as the horizontal distance MF–SFP.

Fig. 3. Measurement sites related to the lateral lingual foramen (LLF) on the CT images. (A) Orthoradial view of a slice with the LLF. The vertical distance between the alveolar crest (AC, green-encircled black dot) and the upper margin of the LLF (AC–LLF; indicated with the double-headed arrow) is measured. (B) and (C) Axial views at the mental foramen (MF) level. Cases in which the LLF is located on the mesial side (B) and distal side (C) of the MF. In (B), the red lines represent the slice vertical to the dental arch passing through the most mesial margin of the MF and that passing through the most distal margin of the LLF. In (C), the red lines represent the slice vertical to the dental arch passing through the most distal margin of the MF and that passing through the most mesial margin of the LLF. The linear distance indicated by the double-headed black arrow is measured as the horizontal distance MF–LLF (B and C). The horizontal diameter of the MF (shown by the red double-headed arrow) is measured (C).
**Fig. 4.** Measurement sites related to the sublingual fossa (SF) and the lateral lingual foramen (LLF) on CT images. (A) Orthoradial view of a slice with the LLF. The vertical distance between the SFP-equivalent level (white arrow) and the top margin of the LLF (SFP–LLF-Ver, indicated by the black double-headed arrow) is measured. (B) and (C) Axial views at the LLF level. (B) A case in which the SFP is located on the mesial side of the LLF is shown; the red lines represent the slice vertical to the dental arch passing through the SFP and that passing through the most mesial margin of the LLF. (C) A case in which the SFP is located on the distal side of the LLF is shown; the red lines represent the slice vertical to the dental arch passing through the SFP and that passing through the most distal margin of the LLF. The linear distance shown by the two black arrowheads is measured as SFP–LLF-Hor (B and C).

**Fig. 5.** Physical measurement: the mandibular lingual side cleared of soft tissues. (A) The sublingual fossa (SF) area is encircled with the white line. The red lines are drawn perpendicular to the dental arch on the lingual cortical bone surface with the SF. The red encircled black dots show the most prominent superior and inferior points relative to the lingual side depression, respectively. The black dotted lines connect these two red-encircled black dots. When the perpendicular distance between the black dotted line and the depression on the lingual surface is largest, the intersection of the perpendicular line (red arrow) and the lingual cortical bone surface is defined as SFP0 (white-encircled black dot); the distance is defined as the depth of the SF (SFD0; distance of the red arrow). (B) SFP0 corresponding to the largest SFD0 is the deepest point of the SF, which is indicated as SFP (white-encircled black dot). The lateral lingual foramen (LLF) is observed on the lower side of the SFP. The linear distance between the SFP and the LLF (SFP–LLF) indicated by the double-headed black arrow is measured.
The unpaired t-test was used for comparison of the measurement values related to the location of the SFP and LLF, by gender and by dental status.

Results

The frequencies of the SF and the LLF in all samples are presented in Table 1. The SF was present in 48.7% and the LLF in 52.6%. Both the SF and the LLF were present in 31.6%, the SF only was present in 17.1%, and the LLF only was present in 21.1%. Neither was present in 30.3%. Comparison of the SF and the LLF in frequency reached statistical significance, demonstrating their correlation ($P < 0.05$).

The CT and physical measurements (range, mean, and SD) of all the samples with the SF and LLF are presented in Tables 2–4, for the total samples, by gender, and by dental status, respectively. Only one hemimandible among the 40 with the LLF showed a negative value of $-2.3$ mm for MF–LLF. The horizontal diameter of the MF in that hemimandible was 2.0 mm. The comparison by gender revealed significantly higher values for SFD and AC–LLF in the male group compared to the female group ($P < 0.05$). The comparison by dental status revealed a significantly smaller value of AC–LLF in the edentulous group than in the dentate group ($P < 0.01$).

A vessel was found penetrating the LLF in 23 of the 30 hemimandibles, and its origin was the submental artery.

Discussion

This analysis of the frequency of the SF and the LLF in all samples revealed a correlation of the frequency between the two: cases with the SF are likely to also have the LLF (Table 1). This finding may be related to mandibular development: the SF might be deeper due to the influence of the nutrient vessel penetrating the mandible though the LLF.

Table 2. Measurements for all samples (range and mean ± standard deviation (SD), in millimetres).

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Range</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFD</td>
<td>$n = 37$</td>
<td>0.4–2.4</td>
</tr>
<tr>
<td>AC–SFP</td>
<td>$n = 37$</td>
<td>5.9–26.4</td>
</tr>
<tr>
<td>MF–SFP</td>
<td>$n = 37$</td>
<td>0–12.7</td>
</tr>
<tr>
<td>AC–LLF</td>
<td>$n = 40$</td>
<td>8.1–34.5</td>
</tr>
<tr>
<td>MF–LLF</td>
<td>$n = 40$</td>
<td>–2.3 to 14.9</td>
</tr>
<tr>
<td>SFP–LLF-Ver</td>
<td>$n = 24$</td>
<td>0–9.2</td>
</tr>
<tr>
<td>SFP–LLF-Hor</td>
<td>$n = 24$</td>
<td>0–8.3</td>
</tr>
<tr>
<td>SFP–LLF</td>
<td>$n = 24$</td>
<td>0–19.1</td>
</tr>
</tbody>
</table>

SFD, greatest depth of the sublingual fossa; AC, alveolar crest; SFP, deepest point of the sublingual fossa; MF, mental foramen; LLF, lateral lingual foramen; Ver, vertical; Hor, horizontal.

For all samples and depending on gender and dental status, the mean SFD measurement ranged from 1.1 to 1.5 mm. The sample with the deepest SF measured only 2.4 mm. However, a previous study by this group, in which the SF was measured directly, showed a depth of 5.8 mm in the sample with the deepest SF. The depth of the SF may have considerable variation. The comparison by gender showed a significantly deeper SFD in the male group than in the female group, possibly due to the greater mandibular development in males.

Regarding the horizontal location relative to the MF, the SFP was located at 0.0–12.7 mm mesially from the MF, and the LLF was located –2.3 to 14.9 mm from the MF. A previous study of mandibles in the East Asian population, including the Japanese, showed that the MF was essentially on the extended longitudinal axis of the mandibular second premolar. On the basis of this observation, the dental region corresponding to the SFP and LLF locations was estimated as follows. According to the investigation by Kamijo, the mean mesiodistal crown diameter of the permanent tooth in the Japanese population is 6.7 mm for the mandibular canine, 6.9 mm for the mandibular first premolar, and 7.1 mm for the mandibular second premolar. Assuming there is no misalignment of the teeth, the mandibular second premolar root is not curved, and the centre of the MF is on the extended longitudinal axis of the second premolar, then the horizontal distance between the centre of the MF and the mesial proximal surface of the second premolar should be $7.1/2 = 3.55$ mm, and the horizontal distance between the centre of the MF and the mesial proximal surface of the first premolar should be $3.55 + 6.9 = 10.45$ mm. The horizontal distance between the centre of the MF and the mesial proximal surface of the canine should be $10.45 + 6.7 = 17.15$ mm. Therefore, the dental region corresponding to all the SFP and LLF locations found mesially relative to the MF in this study was estimated to be the canine to the premolar region. The sole hemimandible that showed a negative LLF location relative to the MF had the LLF located at 2.3 mm from the most distal margin of the MF, which had a horizontal diameter of 2 mm. Thus, this sample has a 1 mm distance between the centre and the most distal margin of the MF, and the LLF at 3.3 mm distal to the MF centre. As described previously, if the MF centre is on the extended axis of the second premolar, the horizontal distance between the MF centre and the distal proximal surface of the second premolar should be

Table 3. Measurements by gender (range and mean ± standard deviation (SD), in millimetres).

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Male group</th>
<th>Female group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>Mean ± SD</td>
<td>Range</td>
</tr>
<tr>
<td>SFD</td>
<td>0.4–2.4</td>
<td>1.5 ± 0.6$^*$</td>
</tr>
<tr>
<td>AC–SFP</td>
<td>5.9–26.4</td>
<td>15.6 ± 5.3</td>
</tr>
<tr>
<td>MF–SFP</td>
<td>0–12.7</td>
<td>6.2 ± 4.0</td>
</tr>
<tr>
<td>AC–LLF</td>
<td>9.3–34.5</td>
<td>21.9 ± 6.2$^*$</td>
</tr>
<tr>
<td>MF–LLF</td>
<td>0–13.6</td>
<td>5.4 ± 4.3</td>
</tr>
<tr>
<td>SFP–LLF-Ver</td>
<td>0–19.2</td>
<td>5.9 ± 5.4</td>
</tr>
<tr>
<td>SFP–LLF-Hor</td>
<td>0–7.6</td>
<td>2.4 ± 2.8</td>
</tr>
<tr>
<td>SFP–LLF</td>
<td>0–9.1</td>
<td>7.0 ± 5.3</td>
</tr>
</tbody>
</table>

SFD, greatest depth of the sublingual fossa; AC, alveolar crest; SFP, deepest point of the sublingual fossa; MF, mental foramen; LLF, lateral lingual foramen; Ver, vertical; Hor, horizontal.

$P < 0.05$. 

Table 1. Number of hemimandible samples with and without the sublingual fossa (SF) and lateral lingual foramen (LLF) ($N = 76$).

<table>
<thead>
<tr>
<th>With SF</th>
<th>Without SF</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>16</td>
<td>40</td>
</tr>
</tbody>
</table>

| Without LLF | 13 | 23 | 36 |

$P = 0.037$. 


7.1/2 = 3.55 mm. Therefore, the dental region corresponding to the LLF location found in this sample was also estimated to be the second premolar region.

Regarding the vertical location relative to the AC, the mean AC–SFP distance measured in the present study was 15.3 mm and the mean AC–LLF distance was 19.3 mm for all samples. The mean AC–SFP values depending on gender and dental status, ranged from 15.0 to 15.6 mm, with no significant difference between groups. In contrast, the mean AC–LLF was 21.9 mm for the male group, 17.1 mm for female group, 15.7 mm for the edentulous group, and 22.8 mm for the dentate group. The AC–LLF was significantly shorter and vertically closer to the AC in the female and edentulous groups, compared to the male and dentate groups, respectively. Trikeriotis et al.\textsuperscript{11} measured AC–LLF on CT images of 50 cases and reported that the mean ± SD was 16.45 ± 5.01 mm for the edentulous group and 23.4 ± 3.08 mm for the dentate group; these measurements are similar to those obtained in the present study. Mardinger et al.\textsuperscript{15} performed locational measurements of the lingual peri-mandibular vessels in 12 human cadavers. They reported that the mean vertical distance between the AC and the vessel was 15.6 mm in the canine region and 15.3 mm in the MF region.

In the present study, the mean SFP–LLF–Ver, SFP–LLF–Hor, and SFP–LLF values of the edentulous group were less than 5 mm. Five previously reported cases of severe haemorrhage in the floor of the mouth had recorded implant sizes of >3.75 mm in diameter and >15 mm in length and there was vessel injury following lingual cortical bone perforation.\textsuperscript{1–5}

Therefore, in edentulous cases, if perforation of the lingual cortical bone near the SFP occurs, injury to the vessels adjacent to or penetrating the LLF is likely when placing an implant with a diameter ≥3.75 mm and a length ≥15 mm in the canine and premolar regions.

All vessels found penetrating the LLF in the present study originated from the submental artery. This finding is consistent with that reported by Nakajima et al.\textsuperscript{8}

This study has the limitation of a racial bias, because the 38 samples used were all from Japanese persons. Future studies on samples from other human groups are required for comparison.

Funding
None.

Competing interests
None.

Ethical approval
Ethical approval was given by the Ethics Committee of Saga Medical School (approval number 24-2).

Patient consent
Not required.

References

Address:
Yuki Uchida
Uchida Dental Clinic
2-27-5 Chihaya
Higashi-ku
Fukuoka 813-0044
Japan
Tel: +81 92 681 0555; Fax: +81 92 671 3434
E-mail: 1672219701@fcom.home.ne.jp