RESEARCH

Vestibular bone thickness of the mandible in relation to the mandibular canal—a retrospective CBCT-based study

Silvio Valdec†, Jan M. Borm†, Stephanie Casparis, Georg Damerau, Michael Locher and Bernd Stadlinger*

Abstract

Background: The aim of this study was to assess vestibular bone thickness of the mandible in relation to the mandibular canal and position of the mental foramen in relation to the neighbouring teeth. Measurements were performed on radiographic cone-beam computed tomography (CBCT) images.

Methods: This retrospective study analysed 314 CBCTs, having been taken at the Clinic of Cranio-Maxillofacial and Oral Surgery, University of Zurich, Switzerland.

Results: CBCTs from 168 female and 146 male patients (median age 40.2 years) were analysed. Median bone thickness lateral to the nerve canal to the buccal mandibular cortical plate was ~ 4 mm immediately posterior to the mental foramen, increased to ≤ 6 mm over the next 30 mm, then decreased to ~ 3 mm at the level of the mandibular foramen. In two thirds of cases, both mental foramina were located near the second premolar (66.2% right, 67.7% left). Bone thickness and the position of the mental foramen showed marked intra- and interindividual variance.

Conclusions: A preoperative CBCT is recommended for detailed planning of surgical interventions that may reach the mandibular canal (e.g. wisdom teeth removal, root resection, implant placement, bone block harvesting).

Keywords: CBCT, Inferior alveolar nerve, Mental foramen, Bone transplantation, Dental implant

Background

When performing any kind of surgical procedure, a surgeon needs to be familiar with the possible variations in the anatomical configurations of both the mandibular canal and inferior alveolar nerve (IAN) [1–3]. This is particularly the case when performing root resections, removing wisdom teeth or harvesting autologous bone grafts.

Different techniques are described for reconstruction of missing areas of bone before or during implant insertion. Autogenous bone, i.e. a block graft, is often used. The block can be obtained intra- or extraorally [4, 5]. Extraoral bone harvesting, e.g. from the hip area (anterior superior iliac crest), requires general anaesthesia, causes higher costs and takes more time. Such a procedure is associated with a hospital stay (often of several days), temporary walking difficulties and an additional scar in the area of bone removal and sometimes with sensory disturbances in the thigh. Intraoral bone harvesting, which can be performed under local anaesthesia, may be suitable for obtaining a graft for localized bone defects [6–9]. The most common harvesting site is the vestibular retromolar area of the mandible in the area of the external oblique line. Anatomically, the IAN runs significantly close to the vestibular bone surface in the area of the ascending mandibular ramus. This nerve may be exposed during bone harvesting if the external oblique line is less pronounced or the bone block preparation extends below the course of the nerve. The nerve may also be exposed if the distal vertical incision is located in the area of the ascending mandibular ramus, because the IAN runs close to the buccal cortical plate before entering the mandibular body in a lingual direction. Other intraoral harvesting sites for bone blocks are the area of the premolars or the chin [10]. Various
Methods

Study design and data collection

Three hundred fourteen cone-beam computed tomograms (CBCTs) from 168 (53.5%) females and 146 (46.5%) males from the database of the Department of Cranio-Maxillofacial and Oral Surgery, Center of Dental Medicine, University of Zurich, Switzerland, from the years 2008 to 2013 were analysed. Patients were divided into 4 age groups: group 1 = 0–20 years, group 2 = 21–40 years, group 3 = 41–60 years and group 4 = 61 years and older.

Data and statistical analysis

SPSS 20.0 software (IBM) was used for statistical analysis. The medians, mean values, standard deviation and confidence intervals of all measurements (distance from the mandibular canal to the vestibular compact bone of the mandible and the position of the mental foramen) were calculated. Wilcoxon rank-sum test was used for comparing the means of all bone thickness measurements between men and women, the different age groups and the right and left sides of the mandible.
Results

The median age of the patients was 40.2 years (range 12.6–84.4 years). Patients were distributed almost evenly across the age groups (see Table 1).

Figure 3 clearly shows the median vestibular bone thicknesses (bt) at 2-mm intervals throughout the anterior to posterior course of the canal on both the right (bt2 r to bt66 r) and left (bt2 l to bt66 l) side of the mandible. The maximum distance between the mental and mandibular foramina was 6.6 cm. As shown in Fig. 3, the vestibular bone thickness on both sides is approximately 4 mm immediately behind the mental foramen, increases to 6 mm in further distal course and is approximately 3 mm towards the posterior at the mandibular foramen. Some individual measurements differed significantly from the median values. For example, immediately posterior to the right mental foramen, the bone thickness ranged from 1.6 to 8 mm.

We found some highly significant differences ($p < 0.001$) in bone thickness between the right and left side of the mandible in both men and women (see Fig. 4). Bone thickness also varied significantly between both men and women ($p < 0.05$), particularly in the first 30 mm posterior to the mental foramen (bt14 r to bt26 r and bt12 l to bt28 l).

Bone thickness did not differ between the age groups among men. However, among women, significant differences were found in the first 40 mm posterior to the mental foramen on both sides of the mandible when comparing age groups 2 and 3, 3 and 4, and 2 and 4 ($p < 0.01$ in all cases).

In all CBCTs, the mental foramen was visible on the right and left side of the mandible and in two thirds of the cases (66.23% right, 67.66% left) was located near the second premolar. The location was not completely symmetrical: the foramen was more often mesial to the second premolar on the right side (27.87%) than on the left side (24.09%) and significantly more often distal to the second premolar on the left side (8.25%) than on the right side (5.91%) ($p < 0.001$) (see Figs. 5 and 6). Further analysis showed that gender did not affect the location of the foramen.

Discussion

The IAN is an important anatomical structure whose course affects the preoperative planning of a bone graft or implant insertion in the mandible. Knowledge on the bone thickness between the lateral wall of the mandibular canal and the lateral mandibular compact bone as well as of the position of the mental foramen facilitates decision-making [24]. Furthermore, for many other surgical procedures, the overall dimension of the mandible is crucial. This is the case in the removal of wisdom teeth, in the application of buccal mini screws for orthodontic anchorage and of course in orthognathic surgery [25–27]. Therefore, this study used CBCTs to assess the intrasosseous course of the IAN, the bone thickness

| Table 1 Number of men and women in each age group (group 1, 0–20 years old; group 2, 21–40 years old; group 3, 41–60 years old; group 4, 61 and older) |
|---------------------------------------------------------------|
| Age group | 1 | 2 | 3 | 4 | Total |
| Sex        |   |   |   |   |       |
| Male       | 41 | 36 | 39 | 30 | 146   |
| Female     | 44 | 51 | 35 | 38 | 168   |
| Total      | 85 | 87 | 74 | 68 | 314   |

Fig. 1 Measurement of mandibular bone thickness, defined as the distance between the lateral wall of the mandibular canal and the lateral mandibular compact bone (solid turquoise line)

Fig. 2 Definition of the position of the mental foramen
between the lateral wall of the mandibular canal and the buccal border of the mandibular cortical plate and the position of the mental foramen in relation to the neighbouring teeth. The findings were evaluated for men and women and different age groups, and both sides of the mandible were compared.

Analysing bone thickness, our CBCT-based study measured the distance between the mandibular canal and the buccal bone surface of the mandible. The measurement of other distances like, e.g. the length between the mandibular canal and the lingual, apical and cranial mandibular bone surface, was performed in various

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**Fig. 3** Left (l) and right (r) mandibular bone thickness in all patients

**Fig. 4** Left (l) and right (r) mandibular bone thickness (bt) in the four age groups (group 1, 0–20 years old; group 2, 21–40 years old; group 3, 41–60 years old; group 4, 61 and older) in men (0) and women (1)
Fig. 5 Position of the left mental foramen

Fig. 6 Position of the right mental foramen
cadaver studies [28–30]. These studies show a 2.1–5.8-
mm distance between the lingual bone surface to the
mandibular canal, 8.2–21.3 mm for the upper border (al-
veolar crest) to the mandibular canal and 6.2–11.8 mm
for the lower border to the mandibular canal as summa-
ized by von Arx and Lozanoff [31]. Chrcanovic et al.
performed preoperative measurements of the distances
between the buccal and lingual bone surface to the man-
dibular canal using CBCTs, underlining the clinical rele-
vance of the distance between the buccal wall and the
mandibular canal due to an increased risk of nerve dam-
age at short distances [32, 33].

In a study comparing measurements between cadavers
and CT images, the distance between the upper edge of
the mandibular canal and the alveolar ridge showed pos-
sible over- and underestimations. The quantification
showed a possible overestimation of up to 1.05 mm and
a possible underestimation of up to 1.36 mm [34]. This
discrepancy is of relevance in preoperative planning.
Intraoperatively, a risk of bone block harvesting is the
damage to the IAN, depending on the depth or angulation
of the osteotomy. Hanser and Dolliveux describe further com-
lications like bone overheating and damage due to chisel
placement. Such complications can be avoided, knowing
about the patient’s individual anatomy with regard to the
mandibular canal and the osteotomy [35].

In the present study, the median bone thickness be-
tween the mandibular canal and the buccal surface of
the mandibular cortical plate was approximately 4 mm
immediately posterior to the mental foramen. This dis-
tance increased up to 6 mm in the first 30 mm posterior
to the mental foramen and decreased to about 3 mm at
the most posterior measurement at the level of the man-
dibular foramen. Large inter-individual differences in
bone thickness were found. The findings of this study in-
dicate that the vestibular bone thickness, i.e. the vestibu-
lar distance to the mandibular canal, is generally greatest
30 mm posterior to the mental foramen.

Significant differences in bone thickness between the
right and left mandibular side support the known asym-
metry of the two halves of the face [36]. The significant
differences between men and women, mainly in the re-

gion of the first 30 mm posterior to the mental foramen,
indicate that the mandible is wider in the area of the
mental foramen in men. In contrast to women, males
did not show significant age-related differences in bone
thickness within this study.

In two thirds of the cases, the mental foramen was lo-
cated in the region of the second premolars (66.2% right,
67.7% left) (see Figs. 5 and 6). Interestingly, the location
was not completely symmetrical; the mental foramen
was distal to the second premolar significantly more of-

ten on the left side than on the right side and mesial
to the second premolar more often on the right side

than on the left side. This finding is in agreement with
those of Phillips et al. [37] and Pyun et al. [38]. In the
present study, gender showed no effect on the position
of the mental foramen; however, there was a trend to-
wards an effect for age.

**Conclusions**
The results of this study support the relevance of a pre-
operative CBCT to allow detailed planning of a surgical
intervention that may potentially touch the area of the
mandibular canal. This applies to surgical procedures
like wisdom tooth removal, root resection, implant
placement and bone block harvesting. A CBCT allows
the exact determination of the horizontal bone thickness
vestibular to the IAN, and this may avoid potential dam-
age to the nerve.

**Abbreviations**
bt: Bone thickness; CBCT: Cone-beam computed tomography; DICOM: Digital
Imaging and Communications in Medicine; IAN: Inferior alveolar nerve

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**Authors’ contributions**
SV and BS wrote the ethics application. JB and SC performed the data
collection. JB performed the data analysis and prepared the manuscript
together with SV. BS, DG and ML designed the study, controlled the study
and corrected the manuscript. SV and BS edited the manuscript. All authors
read and approved the final manuscript.

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**Availability of data and materials**
The original datasets supporting the findings are available.

**Ethics approval and consent to participate**
The study was approved by the cantonal ethics committee of the canton of
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**Consent for publication**
Not applicable.

**Competing interests**
Silvio Valdec, Jan Borm, Stephanie Casparis, Georg Damara, Michael Locher
and Bernd Stadlinger declare that they have no competing interests.

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