Safe zone for bone harvesting from the interforaminal region of the mandible

Omar Al-Ani
Phrabhakaran Nambiar
Kien O. Ha
Wei C. Ngeow

Authors' affiliations:
Omar Al-Ani, Kien O. Ha, Wei C. Ngeow,
Department of Oral & Maxillofacial Surgery,
Faculty of Dentistry, University of Malaya,Kuala Lumpur, Malaysia
Phrabhakaran Nambiar, Dept of General Dental Practice and Oral & Maxillofacial Imaging, Faculty of Dentistry, University of Malaya,Kuala Lumpur, Malaysia

Corresponding author:
Dr Wei C. Ngeow
Department of Oral & Maxillofacial Surgery
Faculty of Dentistry
University of Malaya
50603 Kuala Lumpur
Malaysia
Tel.: +603 79674862
Fax: +603 79674534
e-mail: ngeowy@um.edu.my

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Abstract
Aims: The mandibular incisive nerve can be subjected to iatrogenic injury during bone graft harvesting. Using cone beam computed tomography (CBCT), this study aims to determine a safe zone for bone graft harvesting that avoids injuring this nerve.

Methods: Sixty CBCT examinations of patients were included in this study. The examinations were taken using the i-CAT CBCT imaging system, applying a standardized exposure protocol. Image reconstruction from the raw data was performed using the SimPlant dental implant software. The distances of mandibular incisive canal (MIC) to the inferior border and the labial and lingual cortices of the mandible were measured at 3, 5, 7 and 9 mm mesial to the mental foramen.

Results: The MIC was visible in all (100%) CBCT images. The median distance and interquartile range from the lower border of the mandible was 9.86 (2.51) mm, curving downwards toward the inferior mandibular border at the symphysis menti. It was located closer to the buccal border of the mandible (3.15 [1.28] mm) than lingual cortex (4.78 [2.0] mm). The MIC curves toward the lingual side at the symphysis menti. There was gender difference in a number of these measurements. Current recommendation for chin bone graft harvesting can be applied to Asian subjects.

Conclusions: While acknowledging that there is human variability, this study provides an accurate anatomic location of the MIC, which in turn helps to determine a safe zone for chin bone graft harvesting. This information can become a useful guide in centers where CBCT is not available.

Bone grafting procedures are recognized as the standard of care in patients with insufficient bone volumes for implant insertion. The graft material can be a bone substitute or an autogenous bone. The latter is preferred clinically as it carries osteogenic protein, minerals and bone cells [De Long et al. 2007]. Autogenous bone can be harvested from both extra- and intraoral locations [De Andrade et al. 2001]. In outpatient dental practice, intraoral locations are favored for harvesting a sufficient amount of autogenous bone with the patient under local anesthesia. The symphysis (chin area) and the retromolar area in the mandible are common intraoral donor sites. In comparison to iliac crest or rib grafts, chin bone harvesting is associated with decreased morbidity, reduced hospitalization time, reduced operating time, and avoidance of scarring at the donor site [Sindet-Pedersen & Enemark 1988; Koole et al. 1992].

As a donor site, the mandibular symphysis is characterized by topographic accessibility and can provide a significant volume of cortico-cancellous bone for harvesting [Hunt & Jovanovic 1999]. However, a higher morbidity rate has been reported when compared to the ramus donor site (Misch 1997; von Arx & Kurt 1998). Reported complications include altered facial contour and prolapsed symphysis muscles (“chin droop”), in addition to potential postoperative neurosensory disturbance (NSD), which affects the areas innervated by mandibular incisive nerve in about 14% of patients (Hunt & Jovanovic 1999). Worse, this NSD can persist over a long period of time and has been reported to affect almost 7% of patients (Hunt & Jovanovic 1999; Nkenke et al. 2001; Raghoebar et al. 2007). NSD following bone harvesting surgeries is a complication that usually results from direct trauma to the mandibular incisive nerve (Hunt & Jovanovic 1999).

Housed within the the mandibular incisive canal (MIC), the mandibular incisive nerve is one of the terminal branches of the inferior alveolar nerve (Olivier 1928). Cadaveric studies have shown that this nerve has been found to be present in all specimens [Mar- dinger et al. 2000; Uchida et al. 2009; Kilic et al. 2010]. The mandibular incisive nerve...
provides innervation to the lower anterior teeth and first premolar, the labial bone and gingivae and the surrounding oral mucosa. In general, one pair of incisive nerve (and canal) is located between the right and left mental foramina, an area often described as the interforaminal region of the mandible. This nerve has increasingly been recognized as an important anatomical structure that needs to be taken into consideration when harvesting in the interforaminal area because of the significant risk of NSD.

There are currently only few cadaveric and radiographic studies detailing the presence and location of the mandibular incisive nerve and MIC in the anterior mandible [Mardinger et al. 2000; De Andrade et al. 2001; Jacobs et al. 2002, 2004; Mraiwa et al. 2003; Pommer et al. 2008]. Progressive changes have happened throughout the last decade, where conventional radiographic evaluation [Mardinger et al. 2000; Jacobs et al. 2004; Pires et al. 2009] for the presence of the MIC has been replaced by the use conventional spiral CT or cone beam computed tomography [CBCT] (Jacobs et al. 2002; Pires et al. 2009; Uchida et al. 2009; Makris et al. 2010). This has improved the visualization of the MIC from 1% to 56% [Mardinger et al. 2000; Jacobs et al. 2004; Pires et al. 2009] to between 83% and 100% [Jacobs et al. 2002; Pires et al. 2009; Uchida et al. 2009; Makris et al. 2010]. However, only few studies have determined the distance of the MIC to its adjacent landmark, namely the inferior border of the mandible and the buccal and lingual cortices [De Andrade et al. 2001; Mraiwa et al. 2003; Pommer et al. 2008; Pires et al. 2009; Makris et al. 2010]. Such a study is important to determine a safe zone for chin bone graft harvesting without injuring the MIC (Pommer et al. 2008).

It is the main aim of the present study to determine a safe zone for chin bone graft harvesting without injuring the MIC (Pommer et al. 2008). The authors also wish to:

- establish the relationship between the potential “safe zone” of the MIC with parameters and variables such as site, gender and ethnicity, and
- relate the measurements obtained to the recommended distance/zone for harvesting bone graft in the Discussion section of this article.

This study was undertaken using CBCT as it has recently been proved to be a useful tool in detecting the MIC [Pires et al. 2009; Uchida et al. 2009; Makris et al. 2010] and negate the need to find cadaveric bodies of Malay samples as their Muslim religion advocate burial within 24 h of demise.

Materials and methods

Materials

Cone beam computed tomograms were obtained with the i-CAT Imaging System (Imaging Sciences International Inc. Hatfield, PA, USA). All images were taken by the same technologist following a standardized protocol for patient positioning and exposure parameter setting (120 kVp, 3–7 mA, 20 s) and image acquisition at 0.3 mm voxel size. Images were obtained from 100 consecutive patients referred to the Oral Radiology Division of the Faculty of Dentistry, University of Malaya. The following were the inclusion and exclusion criteria used for selecting suitable images.

Inclusion criteria:
1. Dentate or edentulous Malay, Indian or Chinese patients between the ages 18 and 80 years.
2. Healthy, medically compromised or even those previously radiated patients but not involving the interforaminal region of the mandible.

Exclusion criteria:
1. Patients with history of trauma or pathology to the mandible.
2. Syndromic patients and patients with congenital disorders.
3. Patients aged below 18 or above 80 years.
4. Patients with history of surgical intervention to the interforaminal region like orthognathic surgery or chin bone harvesting procedures.
5. Patients of mixed racial origins.
6. Patients with existing pathological disorder at mandible, such as cysts, tumors, osteomyelitis, fibrous dysplasia etc.
7. The reformatted CBCT images, which appear distorted or blurred due to patients’ movements.

Methods

The visibility rating and dimensional measurements were performed by one researcher who is trained in oral and maxillofacial imaging interpretation.

The DICOM data obtained were imported into SimPlant (SimPlant 3D Pro version 13.1; Materialise Inc., Leuven, Belgium). The Sim-Plant software allows viewing of axial, cross-sectional, panoramic and 3D visualization of the jaw on the same screen. The anatomy of the whole mandible was assessed first in the axial, then coronal cross-sectional and lastly, in panoramic view.

A two-point rating scale was used to grade the visibility of the incisive canal: visible or not visible. All images were scored by the same observer, with 12 randomly selected samples reviewed again 2 weeks later to ensure reliability [see intrarater reliability below]. The visible MIC image was drawn onto the scan [Fig. 1].

Landmarks and base lines

Measurements of various parameters were done on the cross-sectional views. At each predetermined parameter for measurement (Table 1), a perpendicular line was drawn from the outer margin of the MIC, to the lower border of the mandible and buccal and lingual cortices [Fig. 2], and measurements were carried out at these three landmarks.

Intrarater reliability was done using Bland and Altman test for each of the 12 records outcomes [i.e., 144 measurements], done at 2 weeks interval. Measurements error, that is, the difference between the corresponding measurements expressed in terms of variance [S(i)] values was also calculated.

Statistical analysis

All data were gathered, entered and analyzed by using SPSS 16.00 [SPSSFW, SPSS, Chicago, IL, USA] software program. Descriptive results for each parameter were presented as median with interquartile range and corresponding confidence interval for median. Mann–Whitney U test or Kruskal–Wallis tests followed by Mann-Whitney test with Bonferroni correction were used to determine the influence of site, gender and ethnicity on the visibility of the MIC and the safe zone for chin bone harvesting. Statistical significance was accepted at the alpha level of 5%.
was undertaken.

adjusted to

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alleled precision.

allows identification of the canal with unpar-

such, this fully integrated planning tool

reformatted 3D image) on the screen. As

any of the axial, cross-sectional and pano-

tools allow the marking to be carried out in

identify the canal. The SimPlant software

dynamic range of the original 3D digital

visualize in any single static CBCT views

was found to emerge from the lower half of

border of the mandible.  

foramen.

The results were not normally distributed,

were variable, it does show some pattern that

at each site were 0.23% for the MIC-inferior

% difference of 0.28%, and the mean differences

accurate. The Bland and Altman reproducibil-

measurements is considered reliable and

suggested the present method of obtaining

measurement errors, s(i) were 0.05 mm or

The Malay seemed to have the largest dis-

ing downward toward the inferior mandibular

border at the symphysis menti. It was located
closer to the buccal border of the mandible

[3.15 [1.28] mm [CI = 3.01–3.60 mm]] than
5.06 mm]]. The average positions of the MIC
from the buccal cortex were 2.88 [1.32] mm
at IC3, 3.10 [1.14] mm at IC5, 3.37 [1.54] mm
at IC7 and 3.36 [1.62] mm at IC9 suggesting
that the MIC curves toward the lingual side
at the symphysis menti [Table 2]. The side of
mandible did not influence the results
obtained.

However, the gender of the subject signifi-
cantly affected all the median distances to
the inferior border of the mandible and the
buccal and lingual cortices (Mann-Whitney
U test; P < 0.05). The measurements were
larger in male for the distance of the MIC to
the inferior border of mandible and the buc-
cal cortex of the mandible. The respective
measurements for male subjects were 10.13
[2.48] and 3.47 [1.36] mm, in comparison to
9.62 [2.90] mm and 2.88 [1.19] mm for
female. However, measuring at 5.19 [1.53]
mm, female subjects presented with a larger
distance between the MIC and lingual cortex
than male [4.45 [2.05] mm].

Figure 3 shows the average apicocoronal
and buccolingual distances of the MIC at 4
points of measurement when analyzed
according to the ethnicity of the subjects.
Overall, the different ethnic groups shared a
similar innervation pattern with the MIC
curving inferiorly at the symphysis menti.
However, only the Malay and Indian’s MIC
showed slight tendency to slant toward the
lingual side. Its distance remained rather con-
sistent against the buccal plate in Chinese
samples.

There seems to be ethnic-influenced differ-
ences in the location of MIC at all the points
of measurement. Although the differences
were variable, it does show some pattern that
is related to a particular site of the mandible.

The Malay seemed to have the largest dis-
tance between the MIC and the buccal cor-
tex, and this is manifested significantly at
IC3, IC5 and IC7 against the Indian, and at

| P < 0.05). The significant P-value was
adjusted to <0.17 when Bonferroni correction
was undertaken.

Results

The MIC could be visualized in all 60 CBCT
images (120 sites) included and all of them
were found to emerge from the lower half of
the mental foramen. It was discovered that
most of the subjects’ canals were difficult to
visualize in any single static CBCT views
and as such the advantage of the inherent
dynamic range of the original 3D digital
images of the CBCT reformatted at the Sim-
Plant workstation was used to accurately
identify the canal. The SimPlant software
tools allow the marking to be carried out in
any of the axial, cross-sectional and pano-
ramic views and it will be automatically dis-
played in all the four views [including in the
reformatted 3D image) on the screen. As
such, this fully integrated planning tool
allows identification of the canal with unpar-
alleled precision.

The majority of the patients included were
dentate with only four patients being totally
edentulous. Edentulism was not a confound-
ing factor, most probably because of the
number of patients were low. Neither side
nor gender influences the visibility of the
MIC in the mental interforaminal region.
Furthermore, ethnicity of the subjects had no
effect on the visibility of the MIC in the in-
terforaminal region.

There was a good standardization and
reproducibility of the base lines and measure-
ments. The data analyzed for reliability of the
measurements showed a Cronbach alpha
coefficient of r = 0.91, and the value of the
measurement errors, s[i] were 0.05 mm or
less for all the compared data, which strongly
suggested the present method of obtaining
measurements is considered reliable and
accurate. The Bland and Altman reproducibil-
ity test for overall data resulted in a mean
difference of 0.28%, and the mean differences
at each site were 0.23% for the MIC-inferior
border of mandible, 0.30% for MIC-buccal
cortex and 0.34% for MIC-lingual cortex.

The results were not normally distributed,
so nonparametric analysis was employed.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC3</td>
<td>The distance from the inferior margin of incisive canal to the lowermost point of the mandibular inferior border at 3 mm mesial from the mental foramen.</td>
</tr>
<tr>
<td>IC5</td>
<td>The distance from the inferior margin of incisive canal to the lowermost point of the mandibular inferior border at 5 mm mesial from the mental foramen.</td>
</tr>
<tr>
<td>IC7</td>
<td>The distance from the inferior margin of incisive canal to the lowermost point of the mandibular inferior border at 7 mm mesial from the mental foramen.</td>
</tr>
<tr>
<td>IC9</td>
<td>The distance from the inferior margin of incisive canal to the lowermost point of the mandibular inferior border at 9 mm mesial from the mental foramen.</td>
</tr>
<tr>
<td>Ling</td>
<td>The distance from the lingual margin of incisive canal to the lingual cortex of the mandible at the corresponding landmarks above.</td>
</tr>
<tr>
<td>B</td>
<td>The distance from the buccal margin of incisive canal to the buccal cortex of the mandible at the corresponding landmarks above.</td>
</tr>
</tbody>
</table>

Table 1. Parameters for measurement

![Figure 2. Cross-sectional sagittal view of a cone beam computed tomography image as captured using SimPlant software. Measurement was done from the outer wall of the incisive canal (IC) to the most buccal, lingual and lower border of the mandible.](image-url)
IC5 against the Chinese. At IC3, the measurement for the Malay was 3.43 (1.09) mm while those for the Indian was 2.42 (1.12) mm [Mann–Whitney U test with Bonferroni correction; \( P < 0.001 \)]. At IC5, the measurement for the Malay was 3.58 (1.60) mm in comparison to the Indian’s at 3.06 (1.04) mm [Mann–Whitney U test with Bonferroni correction; \( P = 0.001 \)] and the Chinese’s 2.78 (1.28) mm [Mann–Whitney U test with Bonferroni correction; \( P = 0.003 \)]. At the last location, namely IC7, the measurement for the Malay was 3.66 (1.60) mm in comparison to the Indian’s at 3.20 (1.29) mm [Mann–Whitney U test with Bonferroni correction; \( P = 0.014 \)].

The MIC of the Malay, however, also appeared to be significantly closer to the inferior border of the mandible than the Chinese’s at two locations. At IC7, the Malay’s MIC-IBM measurement was 8.34 (2.95) mm against the Chinese’s 9.84 (2.52) mm [Mann–Whitney U test with Bonferroni correction; \( P = 0.01 \)] and IC9, these measurements were 8.08 (3.11) mm and 9.53 (2.06) mm respectively [Mann-Whitney U test with Bonferroni correction; \( P = 0.002 \)].

The Indian seemed to have the shortest distance between the MIC and buccal cortex and between the MIC and inferior border of the mandible at IC3. The distance between the MIC and buccal cortex of the Indian was significantly lower than the Malays’ [as described above], and their median distance between the MIC and inferior border of the mandible of 10.37 (2.20) mm was significantly lower than the Chinese’s of 11.12 (2.14) mm [Mann-Whitney U test with Bonferroni correction; \( P = 0.01 \)].

In summary and at one glance, it appeared that the Malay had a MIC, which was located further from the inferior border of mandible and lingual cortex.

Comparison of the MICs of various ethnic groups showed that the Chinese seemed to have a MIC, which was located further from the inferior border of mandible and lingual cortex.

Tables 3–5 provide detailed analyses of the location of the MIC of the Malay, Indian and Chinese samples at various points of measurement. In general, it can be concluded that these measurements were variable, with greater gender influence in the Indian (significant differences at seven locations) than the Malay or Chinese subjects (significant differences at 2 and 3 locations respectively). Of potential clinical significance is the finding that the MIC of Indian female seemed to be located closer to the buccal cortex than their male counterparts [Table 4]. In contrast, the MIC of Chinese female seemed to be located closer to the inferior border of the mandible when compared to their male counterpart [Table 5].

**Discussion**

The increase in reports of surgical complications throws a challenge to the old concept that considers the interfornaminal region as a “safe surgical site” [Misch et al. 1992]. For example, in a comparative study on the use of the chin as a source of autogenous bone, it was reported that 12% of teeth had pulpal canal obliteration and 4% had negative pulpal sensibility when bicortical bone grafts were obtained from this region [Hoppenreijs et al. 1992]. This prompted us to re-evaluate the anatomy of the interfornaminal region, in particular, the MIC (and nerve) of Asian patients, who inherently have smaller chin size than Caucasians [Hajniš et al. 1994]. This investigation is important as two current recommendations on safe zone for bone graft harvesting have been formulated based on Caucasians’ anatomy [Hunt & Jovanovic 1999; Pomer et al. 2008].

This study employs CBCT images instead of using cadaveric specimens as various studies have shown that measurements obtained from CBCT images are comparable to direct cadaveric measurements [Doran et al. 2004; Kamburoğlu et al. 2009; Uchida et al. 2009; Maloney et al. 2011]. More recently, Maloney et al. (2011) has shown that results obtained using SimPlant dental software were accurate and were not different from direct cadaveric measurement or measurement using the original iCAT CBCT software. This approach for study will negate the need for Malay cadavers as they are impossible to obtain due to their Muslim religion that requires deceased persons to be buried within 24 h.

**Table 2.** Median with interquartile range and corresponding confidence interval of the distance of the mandibular incisive canal (MIC) to various landmarks

<table>
<thead>
<tr>
<th>Position</th>
<th>Median with interquartile range</th>
<th>Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC3</td>
<td>10.82 (1.79) mm</td>
<td>5.18 (2.70) mm</td>
</tr>
<tr>
<td>IC5</td>
<td>10.27 (2.16) mm</td>
<td>4.63 (1.77) mm</td>
</tr>
<tr>
<td>IC7</td>
<td>9.29 (2.55) mm</td>
<td>4.61 (1.96) mm</td>
</tr>
<tr>
<td>IC9</td>
<td>9.10 (2.99) mm</td>
<td>4.92 (1.72) mm</td>
</tr>
</tbody>
</table>

**Fig. 3.** Median distances of the mandibular incisive canal [MIC] to the inferior border of mandibular or the buccal and lingual cortices in 3 ethnic groups at 3, 5, 7 and 9 mm from the mental foramen. IBM, inferior border of mandible; L, lingual cortex; B, buccal cortex.
The median distances with interquartile range and corresponding confidence interval of the mandibular incisive canal to the inferior border (IBM) and buccal and lingual cortices of the mandible in Malay subjects

<table>
<thead>
<tr>
<th>Site</th>
<th>Male</th>
<th>Female</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC3</td>
<td>10.77 (1.56) mm</td>
<td>10.88 (2.26) mm</td>
<td>10.77 (1.77) mm</td>
</tr>
<tr>
<td></td>
<td>(9.92–11.30 mm)</td>
<td>(9.88–11.60 mm)</td>
<td>(10.14–11.39 mm)</td>
</tr>
<tr>
<td>Buccal</td>
<td>3.47 (0.96) mm</td>
<td>3.30 (1.30) mm</td>
<td>3.43 (1.09) mm</td>
</tr>
<tr>
<td></td>
<td>(3.01–3.66 mm)</td>
<td>(2.82–3.78 mm)</td>
<td>(2.93–3.53 mm)</td>
</tr>
<tr>
<td>Lingual</td>
<td>3.92 (1.85) mm</td>
<td>4.38 (3.21) mm</td>
<td>4.26 (2.5) mm</td>
</tr>
<tr>
<td></td>
<td>(3.25–4.72 mm)</td>
<td>(3.71–6.51 mm)</td>
<td>(3.65–4.95 mm)</td>
</tr>
<tr>
<td>IC5</td>
<td>10.79 (2.44) mm</td>
<td>10.15 (4.24) mm</td>
<td>10.60 (3.02) mm</td>
</tr>
<tr>
<td></td>
<td>(9.55–11.30 mm)</td>
<td>(7.29–10.27 mm)</td>
<td>(9.28–10.98 mm)</td>
</tr>
<tr>
<td>Buccal</td>
<td>3.59 (0.90) mm</td>
<td>3.56 (1.60) mm</td>
<td>3.58 (1.60) mm</td>
</tr>
<tr>
<td></td>
<td>(3.22–4.37 mm)</td>
<td>(2.88–6.65 mm)</td>
<td>(3.37–3.80 mm)</td>
</tr>
<tr>
<td>Lingual</td>
<td>4.10 (1.74) mm</td>
<td>4.14 (2.60) mm</td>
<td>4.14 (1.80) mm</td>
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<tr>
<td></td>
<td>(2.97–4.53 mm)</td>
<td>(3.23–5.10 mm)</td>
<td>(3.34–4.53 mm)</td>
</tr>
<tr>
<td>IC7</td>
<td>8.21 (2.61) mm</td>
<td>8.69 (4.36) mm</td>
<td>8.34 (2.95) mm</td>
</tr>
<tr>
<td></td>
<td>(7.80–10.04 mm)</td>
<td>(7.61–10.21 mm)</td>
<td>(7.73–9.47 mm)</td>
</tr>
<tr>
<td>Buccal</td>
<td>3.84 (1.27) mm</td>
<td>3.45 (1.65) mm</td>
<td>3.66 (1.60) mm</td>
</tr>
<tr>
<td></td>
<td>(3.41–4.39 mm)</td>
<td>(2.73–4.06 mm)</td>
<td>(3.27–4.12 mm)</td>
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<tr>
<td>Lingual</td>
<td>4.06 (1.52) mm</td>
<td>4.76 (2.79) mm</td>
<td>4.37 (2.16) mm</td>
</tr>
<tr>
<td></td>
<td>(3.30–4.58 mm)</td>
<td>(3.48–5.51 mm)</td>
<td>(3.51–4.87 mm)</td>
</tr>
<tr>
<td>IC9</td>
<td>8.23 (3.48) mm</td>
<td>8.08 (3.34) mm</td>
<td>8.08 (3.11) mm</td>
</tr>
<tr>
<td></td>
<td>(6.87–9.46 mm)</td>
<td>(6.33–8.97 mm)</td>
<td>(6.98–9.9 mm)</td>
</tr>
<tr>
<td>Buccal</td>
<td>4.17 (0.94) mm</td>
<td>3.34 (1.04) mm</td>
<td>3.71 (1.26) mm</td>
</tr>
<tr>
<td></td>
<td>(3.53–4.33 mm)</td>
<td>(2.93–3.82 mm)</td>
<td>(3.37–4.08 mm)</td>
</tr>
<tr>
<td>Lingual</td>
<td>4.18 (2.60) mm</td>
<td>5.34 (2.15) mm</td>
<td>4.55 (2.2) mm</td>
</tr>
<tr>
<td></td>
<td>(3.86–5.03 mm)</td>
<td>(4.46–6.43 mm)</td>
<td>(4.17–5.49 mm)</td>
</tr>
</tbody>
</table>

* Mann-Whitney U test shows gender difference (P = 0.013).  
† Mann-Whitney U test shows gender difference (P = 0.018).

<table>
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<th>Site</th>
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<tr>
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<td>(9.92–11.46 mm)</td>
<td>(8.83–10.91 mm)</td>
<td>(9.73–10.97 mm)</td>
</tr>
<tr>
<td>Buccal</td>
<td>2.78 (1.01) mm</td>
<td>2.08 (1.01) mm</td>
<td>2.42 (1.12) mm</td>
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<tr>
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<td>(2.30–3.07 mm)</td>
<td>(1.75–2.61 mm)</td>
<td>(2.17–2.77 mm)</td>
</tr>
<tr>
<td>Lingual</td>
<td>4.78 (3.64) mm</td>
<td>5.95 (2.60) mm</td>
<td>5.69 (3.32) mm</td>
</tr>
<tr>
<td></td>
<td>(3.19–5.95 mm)</td>
<td>(5.55–7.19 mm)</td>
<td>(4.53–6.25 mm)</td>
</tr>
<tr>
<td>IC5</td>
<td>9.84 (2.30) mm</td>
<td>10.24 (2.58) mm</td>
<td>10.04 (2.30) mm</td>
</tr>
<tr>
<td></td>
<td>(8.77–10.80 mm)</td>
<td>(9.12–10.56 mm)</td>
<td>(9.41–10.53 mm)</td>
</tr>
<tr>
<td>Buccal</td>
<td>3.37 (0.68) mm</td>
<td>2.40 (0.95) mm</td>
<td>3.04 (1.04) mm</td>
</tr>
<tr>
<td></td>
<td>(3.02–3.68 mm)</td>
<td>(2.15–3.04 mm)</td>
<td>(2.74–3.37 mm)</td>
</tr>
<tr>
<td>Lingual</td>
<td>4.29 (1.29) mm</td>
<td>5.44 (1.14) mm</td>
<td>4.94 (1.90) mm</td>
</tr>
<tr>
<td></td>
<td>(3.8–4.96 mm)</td>
<td>(4.77–5.79 mm)</td>
<td>(4.29–5.42 mm)</td>
</tr>
<tr>
<td>IC7</td>
<td>9.32 (1.86) mm</td>
<td>9.20 (2.71) mm</td>
<td>9.22 (2.22) mm</td>
</tr>
<tr>
<td></td>
<td>(8.90–10.95 mm)</td>
<td>(8.25–10.40 mm)</td>
<td>(8.95–9.99 mm)</td>
</tr>
<tr>
<td>Buccal</td>
<td>3.70 (1.34) mm</td>
<td>2.64 (1.12) mm</td>
<td>3.20 (1.29) mm</td>
</tr>
<tr>
<td></td>
<td>(3.03–2.03 mm)</td>
<td>(2.30–3.34 mm)</td>
<td>(2.71–3.53 mm)</td>
</tr>
<tr>
<td>Lingual</td>
<td>4.22 (1.44) mm</td>
<td>5.20 (2.10) mm</td>
<td>4.64 (1.94) mm</td>
</tr>
<tr>
<td></td>
<td>(2.75–5.01 mm)</td>
<td>(4.43–5.87 mm)</td>
<td>(3.94–5.20 mm)</td>
</tr>
<tr>
<td>IC9</td>
<td>9.34 (2.36) mm</td>
<td>8.68 (3.18) mm</td>
<td>9.24 (2.52) mm</td>
</tr>
<tr>
<td></td>
<td>(7.94–9.63 mm)</td>
<td>(7.18–9.62 mm)</td>
<td>(7.98–9.52 mm)</td>
</tr>
<tr>
<td>Buccal</td>
<td>4.12 (0.91) mm</td>
<td>2.50 (1.14) mm</td>
<td>3.32 (2.05) mm</td>
</tr>
<tr>
<td></td>
<td>(3.64–4.44 mm)</td>
<td>(2.13–3.21 mm)</td>
<td>(2.93–4.12 mm)</td>
</tr>
<tr>
<td>Lingual</td>
<td>4.12 (1.50) mm</td>
<td>5.52 (1.17) mm</td>
<td>4.97 (1.73) mm</td>
</tr>
<tr>
<td></td>
<td>(3.63–4.97 mm)</td>
<td>(5.04–5.84 mm)</td>
<td>(4.25–5.52 mm)</td>
</tr>
</tbody>
</table>

* Mann-Whitney U test shows gender difference (P = 0.027).  
† Mann-Whitney U test shows gender difference (P = 0.022).  
‡ Mann-Whitney U test shows gender difference (P = 0.001).  
§ Mann-Whitney U test shows gender difference (P = 0.002).  
¶ Mann-Whitney U test shows gender difference (P = 0.001).  
‖ Mann-Whitney U test shows gender difference (P = 0.002).  
† Mann-Whitney U test shows gender difference (P = 0.001).  
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¶ Mann-Whitney U test shows gender difference (P = 0.001).  
‖ Mann-Whitney U test shows gender difference (P = 0.001).
et al. (2001), Pommer et al. (2008), Pires et al. (2009) and Makris et al. (2010) in Caucasians. Pires et al. (2009) reported a mean distance of 2.4 mm to the buccal plate while De Andrade et al. (2001) reported a distance of 2.67 mm and 2.64 mm to the right and left buccal plate respectively, range 2.67 mm and 2.64 mm to the right and left.

Table 5. The median distances with interquartile range and corresponding confidence interval of the mandibular incisive canal to the inferior border (IBM) and buccal and lingual cortices of the mandible in Chinese subjects

<table>
<thead>
<tr>
<th>Site</th>
<th>Gender</th>
<th>Male</th>
<th>Female</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC3</td>
<td>IBM</td>
<td>12.26 (3.01) mm</td>
<td>10.61 (1.16) mm</td>
<td>11.12 (2.14) mm</td>
</tr>
<tr>
<td></td>
<td>Buccal</td>
<td>3.26 (1.78) mm</td>
<td>2.56 (0.87) mm</td>
<td>2.82 (1.24) mm</td>
</tr>
<tr>
<td></td>
<td>Lingual</td>
<td>5.08 (2.77) mm</td>
<td>5.64 (1.21) mm</td>
<td>5.45 (1.81) mm</td>
</tr>
<tr>
<td>IC5</td>
<td>IBM</td>
<td>10.72 (2.43) mm</td>
<td>9.93 (1.60) mm</td>
<td>10.14 (2.16) mm</td>
</tr>
<tr>
<td></td>
<td>Buccal</td>
<td>2.78 (1.33) mm</td>
<td>2.78 (1.17) mm</td>
<td>2.78 (1.28) mm</td>
</tr>
<tr>
<td></td>
<td>Lingual</td>
<td>5 (2.08) mm</td>
<td>5.19 (1.30) mm</td>
<td>5.10 (1.48) mm</td>
</tr>
<tr>
<td>IC7</td>
<td>IBM</td>
<td>10.06 (2.60) mm</td>
<td>9.59 (2.13) mm</td>
<td>9.84 (2.52) mm</td>
</tr>
<tr>
<td></td>
<td>Buccal</td>
<td>3 (1.80) mm</td>
<td>2.92 (1.47) mm</td>
<td>2.92 (1.61) mm</td>
</tr>
<tr>
<td></td>
<td>Lingual</td>
<td>4.86 (2.46) mm</td>
<td>4.88 (0.96) mm</td>
<td>4.88 (1.76) mm</td>
</tr>
<tr>
<td>IC9</td>
<td>IBM</td>
<td>10.50 (2.02) mm</td>
<td>9.40 (2.71) mm</td>
<td>9.53 (2.06) mm</td>
</tr>
<tr>
<td></td>
<td>Buccal</td>
<td>2.96 (1.19) mm</td>
<td>2.92 (1.33) mm</td>
<td>2.92 (1.23) mm</td>
</tr>
<tr>
<td></td>
<td>Lingual</td>
<td>5.07 (1.84) mm</td>
<td>4.78 (1.56) mm</td>
<td>4.94 (1.64) mm</td>
</tr>
</tbody>
</table>

\*Mann-Whitney U test shows gender difference (P = 0.027).

\*Mann-Whitney U test shows gender difference (P = 0.017).

\*Mann-Whitney U test shows gender difference (P = 0.033).

et al. (2001), Pommer et al. (2008), Pires et al. (2009) and Makris et al. (2010) in Caucasians. Pires et al. (2009) reported a mean distance of 2.4 mm to the buccal plate while De Andrade et al. (2001) reported a distance of 2.67 mm and 2.64 mm to the right and left buccal plate respectively, range 2.67 mm ± 2.64 mm to the right and left buccal plate respectively, range 2.67 mm and 2.64 mm to the right and left. In contrast, Pommer et al. (2008) and Makris et al. (2009) in Caucasians.

Therefore, based on the current result, the MIC will be spared if bone graft cut is made at 5 mm from the inferior border of the mandible, as suggested by Hunt & Jovanovic (1999) and not lower as suggested by Pommer et al. (2008). However, clinician must be aware that the range of distribution of the MIC has been variable, with Mraiwa et al. (2003) reporting a range between 2.7 and 15 mm from the inferior border of mandible and De Andrade et al. (2001) reporting a range of 7–14 mm. This current study found a 95% confidence interval of between 9.33 and 10.44 mm, but a minimum distance of 3.30 mm in one subject, suggesting the clinician can still cause injury to the MIC if the decision is made solely on average distance. This finding again highlights the importance of presurgical CBCT or CT scans, and the use of an ultrasound bone surgical device.

Clinicians should also look out for the main trunk of the MIC during harvesting of cancellous bone to avoid injuring it. In addition, the sole use of autogenous bone from the chin may potentially be inadequate in Asian patients if the surgeon is to avoid the MIC. So, there may be a need to use a combination of autogenous bone and bone substitute material.

This findings of this study suggested that there are some ethnic features that influence the location of the MIC, and this fact may be of importance in clinical practice. The Malay and Indian subjects showed slight tendency for the MIC to slant toward the lingual side. However, the MIC remained rather consistently away from the buccal plate in Chinese subjects. This study also suggests that the Malay had a MIC, which was located further away from the buccal cortex, but closer to the lower border of mandible and lingual cortex. In comparison, the Chinese seemed to have a MIC that was located further from the
inferior border of mandible and lingual cortex. Further studies with larger sample size are needed to verify these observations.

Lastly, this study found that gender of the subject significantly affected all the median distances to the inferior border of the mandible and the buccal and lingual cortices more than ethnicity of the subjects. The measurements were larger in male for the distance of the MIC to the inferior border of mandible and the buccal cortex of the mandible, consistent with the notion that male subject have more prominent chin that is bigger in nature. The authors, however, did not measure the jaw size and jaw relationship to determine if a correlation exists.

Conclusion
The MIC was visible in all (100%) CBCTs, i.e. 120 sites. The high detection rate of the MIC using CBCT and SimPlant dental software indicates the potential high preoperative value of CBCT scan for the purpose of preoperative planning. The median distance and interquartile range from the lower border of the mandible was 9.86 (2.51) mm, curving downwards toward the inferior mandibular border at the symphysis menti. It was located closer to the buccal border of the mandible (3.15 [1.28] mm) than lingual cortex (4.78 [2] mm). The MIC curves toward the lingual side at the symphysis menti. There was gender but not site related differences in all these measurements. The influence of ethnicity is variable. While acknowledging that there is human variability, this study provides an accurate anatomic localization of the MIC, which in turn helps to determine a safe zone for chin bone graft harvesting. The recommendation of Hunt & Jovanovic (1999) can be applied to Asian subjects. The results hopefully can become a useful guide in centers where CBCT is not available. When such a facility is available, it is recommended that clinicians make use of it to overcome the shortfalls observed in conventional radiography.

References