Risk assessment of inferior alveolar nerve injury for immediate implant placement in the posterior mandible: A virtual implant placement study

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ABSTRACT

Objectives: To investigate the prevalence and morphological parameters of lingual concavity, and whether these factors are related to a higher risk of inferior alveolar nerve (IAN) injury when performing an immediate implant surgery in posterior mandible region.

Methods: The CBCT images from 237 subjects (1008 teeth) were analysed the shape of the mandibles (C, P, U type), dimensional parameters of lingual concavity (angle, height, depth), and its relation to inferior alveolar canal (IAC) (A, B, C zone), RAC (distance from root apex to IAC) and probability of IAN injury. Multiple logistic regression modelling to determine the odds ratio of variables that made an important contribution to the probability of IAN injury and to adjust for confounding variables.

Results: The U type ridge (46.7%) and the most concave point located at C zone (48.8%) are most prevalent in this region. The mandibular second molar presents highest risk for IAN injury than other tooth type (p < 0.001), which were 3.82 times to occur IAN injury than the mandibular second premolar. The concave point located at A zone and B zone were 7.82 and 3.52 times than C zone to have IAN damage, respectively. The probability of IAN injury will reduce 26% for every 1 mm increase in RAC (p < 0.001).

Conclusions: The tooth type, morphological features of lingual concavities, and RAC are associated with risks of IAN injury during immediate implant placement.

Clinical significance: Pre-surgical mapping of the IAC and identification of its proximity relative to the lingual concavity in the posterior mandible regions may avoid unpleasant complications, specifically when performing immediate implant procedures.

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1. Introduction

While implant therapy has evolved into an integral part of daily dental practice, the attention is now directed towards simplification of the minimal invasive surgical procedure, and achieving pleasant aesthetic outcomes.1,2 Regarding timing of implant placement, although delayed placement is more commonly practiced than immediate placement, placing implants directly in extraction sockets offers considerable advantages over conventional implant treatment.3–8

Immediate implant placement into fresh extraction sockets has attracted attention since the first publication on this topic over 30 years ago.7 Despite clinical evidence that immediate implant placement leads to high implant survival rates6,7,10 this procedure is primarily recommended in sites with low aesthetic demand and favourable anatomy such as the premolar area.8 As a result of patients’ reservations and increasing of their acceptance towards implant therapy, placing immediate implants have given promising results on the benefits of immediate implants over delayed implant placement.1,6–8 The obvious social and economic advantages include shorter treatment time along with reduced surgical intervention; extraction sockets allow for ideal positioning of implants,4,6,10 conservation of bony structures,7 preservation of soft tissue6,11 meaning prosthetic treatment are simplified ensuring higher patient comfort and satisfaction.5,7,11

Although several evidence-based studies have presented clear clinical guidelines for implant procedures regarding patient selection and/or for optimal outcomes,5,10 certain risks and complications are inevitable.4,7,12–15 It has been shown that immediate implant placement beyond the alveolar housing may result in perforation of the lingual cortex;3,14,16 damaging vital anatomical structures such as neurovascular injuries12,15 especially in the posterior mandible region, which may result in inflammation, infection ultimate loss of implants, and even life threatening events.3,4,14,16–20 Accordingly, immediate implant placement should only be used in stringently evaluated situations and only be performed by experienced clinicians to reduce the chance of implant failure.5,7

Recently, cross-sectional information, such as conventional tomography, computed tomography systems, and magnetic resonance imaging,21–23 has been recognized as part of diagnosis and treatment planning as it provides vital information ensuring optimal placement and alignment of immediate implants during and after the procedure.3,4,14,16,19 Although the information concerning immediate implant placement and the significance of the lingual concavity in posterior mandible regions, more specifically the location and dimensional parameters of the lingual concavity, is related to the potential risk of inferior alveolar nerve (IAN) injury, there is still only limited amount of knowledge on this topic.

Therefore, the aims of this computer simulation study are to investigate the prevalence, and dimensional parameters of lingual concavities, and to determine whether the presence of lingual concavity is related to a higher risk of IAN injury when performing an immediate implant surgery in the posterior mandible region.

2. Materials and methods

2.1. Image acquisition and patient confidentiality

All the participants in this study are patients requiring dental implant treatment in the Department of Dentistry, Tri-Service General Hospital, Taipei, Taiwan. Basic information regarding the subjects’ age, gender, and history of past treatment was recorded. All images were taken using a cone-beam computed tomography (CBCT) machine (NewTom 5G; QR, Verona, Italy) by board-certified radiologists from Nov 2009 to Jul 2013, and were not specifically acquired for this project. The CBCT scans were saved in the Digital Imaging and Communications in Medicine (DICOM) format with codes for corresponding names thus, the data was saved in an encrypted file confidentially protected yet retrievable if needed. The project and protocol were approved by the Institutional Review Board of Tri-Service General Hospital (TSGHIRB No. 2-102-05-064).

2.2. Inclusion and exclusion criteria

Images selected for this study had to fulfil the following inclusion criteria:

- one of permanent mandibular second premolar, permanent mandibular first molar, or permanent mandibular second molar had to be fully erupted;
- each tooth had to have fully formed apexes;
- the outline of the mandible, inferior alveolar canal (IAC) had to be easily identified;
- each tooth had to be normally positioned (the imaginary line connecting the cusp tip of canines, central grooves of premolars, and molars was generally smooth);
- opposing maxillary tooth were present to provide information for implant angulation;

Images were excluded if:

- images were unclear or incomplete due to scattering or other reasons;
- images had a missing tooth, an implant, or grafted alveolar ridge;

All images displayed on a 19-inch LCD monitor were reoriented and inspected by two examiners (Dr. M.-H. Lin, and Dr. L.-P. Mau). An intra-examiner calibration based on the anatomic diagnosis of CBCT images was performed to assess data reliability. After intra-examiner calibration, the two examiners separately evaluated the images, and any disagreement in the interpretation of images was discussed until a consensus was reached.

2.3. Assessment of the cross-sectional morphology

The qualified CBCT images were analysed by commercially available three-dimensional (3D) navigation software (ImplantMax® 4.0; Saturn Image, Taipei, Taiwan). If the tooth was present and met the inclusion criteria, a cross-sectional image of the region of interest (ROI), the centre section of
premolar teeth or centre of distal root in multi-rooted teeth, was assessed and measured.

2.4. Measurements of mandibular dimension and lingual concavity

2.4.1. Classification of mandibular cross-sectional morphology
To make it easier to identify ridge shape and recognize inferior nerve perforation risks, three types of mandibular cross-sectional morphology were determined according to the definition described by Chan et al. previously.2 Briefly, in terms of cross-sectional view of posterior mandible, the C (convergent) type was defined as the base of the ridge was wider than its crest part, and P (parallel) type was parallel ridge outlines of mandible bucco-lingually. The U (undercut) type was a ridge with narrow base to a wider crest with a prominent point on the lingual plate, thus cause a lingual undercut. Thus, the U (undercut) type ridge had a lingual undercut on the lingual plate. When no obvious lingual undercut was seen, the ridges were categorized into either the convergent ridge type (C type), or the parallel ridge type (P type) (Fig. 1).

2.5. ABC zone

The investigated teeth categorized as lingual concavity ridge type (U type) were further classified according to the position of the most concave point of the lingual concavity (point C) and its relation to the IAC (Fig. 2). The A, B, and C zones were defined as the area between root apex and IAN. A horizontal line parallel to the inferior border of the mandible 2 mm coronal to the superior border of the IAC (line A) was drawn. Another horizontal line defined as line B was drawn immediately adjacent to IAC. The zone between the horizontal extension of line A and line B was defined as a transition zone (B zone). The zone above the transition zone was A zone, whereas beneath the transition zone was C zone (Fig. 2). The location of the most concave point (point C) in each tooth was located and then classified as A, B or C zone (Fig. 2).

2.6. RAC, concavity angle, height and depth

The distance from root apex to inferior alveolar canal (RAC) was measured as a vertical distance from the level of the each
examined root tip to the superior border of the IAC as described by Froum et al. previously. In the concavities classified as U type ridge, the dimensional parameters of the lingual concavity were measured as previously described by Chan et al. The concavity angle, in degrees, was determined by the angulations between line A and line C, where line C is the connection of point C and point P (the most prominent point lingually). The height of concavity (mm) was determined by measuring the vertical distance from point P to an imaginary line extending from point C, which was parallel to the inferior border of mandible. The linear concavity depth (mm) was also measured as the horizontal distance between point C and point P (Fig. 2).

### 2.7 Determination of IAN injury by the placement of a virtual implant

A single parallel root-form implant was virtually placed along with the investigated tooth root with 4 mm of implant anchorage in native bone, which was considered as the minimal requirement to achieve primary stability to ensure immediate implant survival. The diameter of implant was selected from an implant database available in the software to mimic the size of the investigated tooth root. The IAN injury was judged when virtual implant made contact with the IAN in the cross-sectional images (Fig. 3).

### 2.8 Statistical Analysis

The mean values and standard deviations of each measurement were calculated. Comparison between the mean values was performed with one sample T test. The multiple logistic regression modelling to determine the odds ratio of variables that made an important contribution to the probability of IAN injury and to adjust for confounding variables. All statistical analysis was performed using a statistical package SPSS for Windows (Version 18.0; SPSS, Inc, Chicago, IL). The level of statistical significance was set at \( p < 0.05 \).

### 3. Results

A total of 237 subjects, consisting of 119 (50.2%) males and 118 (49.8%) females, mean age 45.6 ± 14.6 years (age range: 12–84 years), whose images met the inclusion criteria, were selected for further analysis. Of the 1008 qualified teeth assessed using CBCT scan images, 395 (39.2%) were mandibular second premolars, 297 (29.5%) were mandibular first molars, and 316 (32.3%) were mandibular second molars (Table 1). Of the three different types of ridge morphology, the U type ridge was the most common of all examined images, and 46.7% of this study group fell into this category. The second most common was the parallel group (P type), comprising 32.3% of qualified images and C type ridge was only presented in 21.0%. However, when investigating each specific tooth type, the most common ridge morphology was P type ridge for second premolar, whereas U type ridge was most common for first molar (57.5%), and second molar (62.3%), respectively (Table 1). Significant difference existed between each type of ridge morphology and tooth type (\( p < 0.001 \)) (Table 1).

### Table 1 – Frequency distribution of three types of cross-sectional posterior mandibular morphology.

<table>
<thead>
<tr>
<th>Tooth type</th>
<th>C type</th>
<th>P type</th>
<th>U type</th>
<th>Total (%)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM2</td>
<td>134 (33.9)</td>
<td>159 (40.3)</td>
<td>102 (25.8)</td>
<td>395 (100)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>M1</td>
<td>56 (18.9)</td>
<td>70 (23.6)</td>
<td>171 (57.5)</td>
<td>297 (100)</td>
<td></td>
</tr>
<tr>
<td>M2</td>
<td>22 (7.0)</td>
<td>97 (30.7)</td>
<td>197 (62.3)</td>
<td>316 (100)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>212 (21.0)</td>
<td>326 (32.3)</td>
<td>470 (46.7)</td>
<td>1008 (100)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: PM2, mandibular second premolar; M1, mandibular first molar; M2, mandibular second molar.
Table 2 - Frequency distribution of most concave point of lingual concavity relative to the inferior alveolar nerve of each tooth type.

<table>
<thead>
<tr>
<th>Tooth type</th>
<th>A zone n (%)</th>
<th>B zone n (%)</th>
<th>C zone n (%)</th>
<th>Total</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM2</td>
<td>12 (11.8%)</td>
<td>44 (43.1%)</td>
<td>46 (45.1%)</td>
<td>102</td>
<td>0.616</td>
</tr>
<tr>
<td>M1</td>
<td>21 (12.3%)</td>
<td>59 (34.5%)</td>
<td>91 (53.2%)</td>
<td>171</td>
<td></td>
</tr>
<tr>
<td>M2</td>
<td>25 (12.7%)</td>
<td>80 (40.6%)</td>
<td>92 (46.7%)</td>
<td>197</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>58 (12.3%)</td>
<td>183 (38.9%)</td>
<td>229 (48.8%)</td>
<td>470</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: PM2, mandibular second premolar; M1, mandibular first molar; M2, mandibular second molar.

Table 3 - Measurements of cross-sectional dimension of lingual concavity morphology, mean distance from root apex to inferior alveolar canal (RAC), and probability of inferior alveolar nerve damaged of each tooth type.

<table>
<thead>
<tr>
<th>Number of tooth, total</th>
<th>PM2</th>
<th>M1</th>
<th>M2</th>
<th>Total</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAC (mm)</td>
<td>6.1 ± 2.7</td>
<td>7.0 ± 2.9</td>
<td>4.3 ± 2.7</td>
<td>5.8 ± 2.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Inferior alveolar nerve damaged (n, %)</td>
<td>195 (49.4%)</td>
<td>105 (35.4%)</td>
<td>221 (69.9%)</td>
<td>521 (51.7%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Number of tooth, U type</td>
<td>102</td>
<td>171</td>
<td>197</td>
<td>470</td>
<td></td>
</tr>
<tr>
<td>Concavity angle (°)</td>
<td>68.0 ± 7.8</td>
<td>60.6 ± 8.9</td>
<td>58.4 ± 7.7</td>
<td>61.3 ± 8.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Concavity height (mm)</td>
<td>10.0 ± 2.8</td>
<td>9.6 ± 3.6</td>
<td>10.0 ± 3.6</td>
<td>9.9 ± 3.4</td>
<td>0.36</td>
</tr>
<tr>
<td>concavity depth (mm)</td>
<td>4.3 ± 1.9</td>
<td>5.3 ± 1.6</td>
<td>6.0 ± 1.8</td>
<td>5.4 ± 1.9</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Abbreviations: PM2, mandibular second premolar; M1, mandibular first molar; M2, mandibular second molar; RAC, distance from root apex to inferior alveolar canal.

In U type ridge, the A, B, C zone was further classified by analysing the cross-sectional view of each investigated tooth (Fig. 2). Although the majority of the most concave point was located at C zone (48.8%), with 45.1% in the second premolar, 53.2% in the first molar, and 46.7% in the second molar (Table 2), no significant difference of the frequency of ABC zone was noted between each tooth type (p = 0.616, Table 2).

The mean RAC (mm) for each tooth type, ranged from 6.1 ± 2.7 for the second premolar, 7.0 ± 2.9 for the first molar, and 4.3 ± 2.7 for the second molar (p < 0.001) (Table 3). The IAN was deemed to be injured when the virtual implant placement came in contact with the mandibular canal on cross-sectional images. IAN exposure was observed on dental 3D CT images in 521 cases (51.7%) and of these exposures, IAN injury was most likely to occur at the second molar (69.9%) compared to the second premolar (49.4%) and first molar (35.4%) (Table 3). The dimensional parameters of lingual concavity are summarized in Table 3 and described as follows. The concavity angle (°) was 68.0 ± 7.8 for the second premolar, 60.6 ± 8.9 for the first molar, and 58.4 ± 7.7 for the second molar. The vertical heights (mm) of lingual concavity in second premolar, first molar and second molar were 10.0 ± 2.8, 9.6 ± 3.6, and 10.0 ± 3.6, respectively and the linear concavity depths (mm) measured were 4.3 ± 1.9, 5.2 ± 1.6, and 6.0 ± 1.8, respectively (Table 3). The RAC, probability of IAN damaged, concavity angle, and concavity depth exhibited significant difference between each tooth type (all p < 0.001), whereas concavity height did not (Table 3).

Association between selected variables and probability of IAN injury of each investigated tooth were further identified (Table 4). After adjusting for other factors, results showed that immediate implant placement at the mandibular second molar was 3.82 times (odds ratio = 3.82; 95% CI: 1.25–11.73; p = 0.019) more likely to cause IAN injury compared to the second premolar. Results also show that when the most concave point is located in A zone, and B zone, it is 7.82 (odds ratio = 7.82; 95% CI: 2.92–20.88) and 3.52 (odds ratio = 3.52, 95% CI: 1.78–7.02) times more likely to cause IAN injury compared to the C zone, respectively. The probability of IAN injury will reduce 26% for every 1 mm increase in RAC (odds ratio = 0.74; 95% CI: 0.65–0.85) (Table 4).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Odds ratio</th>
<th>95% CI</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooth type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM2 (reference group)</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>0.64</td>
<td>0.18–2.28</td>
<td>0.49</td>
</tr>
<tr>
<td>M2</td>
<td>3.82</td>
<td>1.25–11.73</td>
<td>0.019</td>
</tr>
<tr>
<td>ABC zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C zone (reference group)</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B zone</td>
<td>3.52</td>
<td>1.78–7.02</td>
<td>&lt;0.001</td>
</tr>
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<td>A zone</td>
<td>7.82</td>
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<td>RAC</td>
<td>0.74</td>
<td>0.65–0.85</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Concavity dimension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angle</td>
<td>0.92</td>
<td>0.83–1.02</td>
<td>0.10</td>
</tr>
<tr>
<td>Height</td>
<td>1.07</td>
<td>0.80–1.42</td>
<td>0.66</td>
</tr>
<tr>
<td>Depth</td>
<td>1.77</td>
<td>1.14–2.75</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Abbreviations: PM2, mandibular second premolar; M1, mandibular first molar; M2, mandibular second molar; RAC, distance from root apex to inferior alveolar canal.
Immediate implant placement into fresh extraction sockets, particularly in regions such as the posterior mandible area where aesthetics is not a primary concern, has been documented to be a predictable treatment modality. However, varying anatomy of an individual’s posterior mandible, certain sites and morphologies of lingual concavities and diverse positioning of IAC can pose a challenge for successful immediate implant placement. In this study, the most prevalent cross-sectional ridge type in posterior mandible region is U type ridge (46.7%) (Table 1). When further investigating which zone point C (most concave point of lingual concavity) was most likely located, C zone had been the most prevalent, accounting for 48.8% of all investigated teeth (Table 2). By using virtual implant placement, the probability of IAN injury was 51.7%, with higher risk for IAN injury occurring at the second molars compared to other teeth (Table 3). The mean concavity angle, height, and depth of all investigated tooth were 61.3 ± 8.9°, 9.9 ± 3.4 mm, and 5.4 ± 1.9 mm, respectively (Table 3). Of the analysed variables, the tooth type, ABC zone, RAC, concavity angle, and concavity depth presented significant impact on IAN injury (Table 4).

4. Discussion

Immediate implant placement into fresh extraction sockets, particularly in regions such as the posterior mandible area where aesthetics is not a primary concern, has been documented to be a predictable treatment modality. However, varying anatomy of an individual’s posterior mandible, certain sites and morphologies of lingual concavities and diverse positioning of IAC can pose a challenge for successful immediate implant placement. In this study, the most prevalent cross-sectional ridge type in posterior mandible region is U type ridge (46.7%) (Table 1). When further investigating which zone point C (most concave point of lingual concavity) was most likely located, C zone had been the most prevalent, accounting for 48.8% of all investigated teeth (Table 2). By using virtual implant placement, the probability of IAN injury was 51.7%, with higher risk for IAN injury occurring at the second molars compared to other teeth (Table 3). The mean concavity angle, height, and depth of all investigated tooth were 61.3 ± 8.9°, 9.9 ± 3.4 mm, and 5.4 ± 1.9 mm, respectively (Table 3). Of the analysed variables, the tooth type, ABC zone, RAC, concavity angle, and concavity depth presented significant impact on IAN injury (Table 4).

Immediate implant placement at the mandibular second molar was 3.82 times more likely to damage IAN compared to those at second premolar (p = 0.019) (Table 4). Additionally, when the most concave point was located at A zone, and B zone were 7.82 and 3.52 times than C zone to have IAN damage. The probability of IAN injury will reduce 26% for every 1 mm increase in RAC (p < 0.001) (Table 4).

In this study, the cross-sectional morphology of posterior mandible was determined by the outline of alveolar bone proper and lingual concavity as previously described. Considerable heterogeneity in the measurements of mandible morphology was noticeable when comparing different studies because of several classification systems were proposed regarding the cross-sectional morphology of mandible. Each classification system has its own characteristics, and utility value. Quirynen et al. reported, in the interferaminal region, the round shape mandible was most frequently observed (69.5%), but a lingual concavity was rare (2.4%). In this study, the measurements were conducted in the posterior mandible region and lingual concavity (U type) was most common (46.7%), which differed from previously published results. Watanabe et al. demonstrated that the round type (round shape on both buccal and lingual side) (59–61%) was the most common in the posterior region, followed by lingual concavity type (36–39%), whereas Chan et al. reported the U type (lingual concavity) was the most prevalent, accounting for 66% of the study population. A similar study was also conducted in Taiwan where Ou et al. investigated the edentulous ridge morphology of 60 Taiwanese patients’ mandibular first molar, and lingual concavity (U type; 50%) was most prevalent. This divergence might be attributed to the study design, regions of interest, classification systems, dentate status, and ethnicity. Based on the results of the studies mentioned above, a significant number of examined subjects had lingual concavity, which may increase the potential risk of complications (Table 4). Therefore, additional radiographic examination, such as multislice cross-sectional scanning would be helpful in pre-surgical diagnosis and treatment planning.

The classification systems regarding the morphological features of jaw bone images in posterior edentulous mandible have been proposed previously. For the first time, the position of the most concave point of lingual concavity (point C) and its relation to IAC in the posterior mandible region (A, B, C zone) is categorized. This classification system is beneficial in evaluating the dimensions of lingual concavities and chances of IAN injury while placing immediate implant in posterior mandibular regions, and may also be useful in assessing potential risks of lingual plate perforation. Although the dimension of lingual concavities of the posterior mandible region had been investigated, diverse results between investigated individuals were obtained because of various factors affecting the morphology of this region. In general, the dimension of the concavity depends on the size of submaxillary gland, the location of IAN, and its relationship to the mylohyoid ridge. These anatomic factors may limit available bone for implant placement and lead to potential complications. Notably, those with a severe slope of the lingual cortex, might confer increased risks of IAN sensory disturbance, lingual perforations or fenestrations, thus requiring alternative treatment strategies (e.g., usage of reduced-size dental implant). Most importantly, vascular branches of the submental, sublingual, and mylohyoid arteries located along the medial side of the mandibular lingual concavity may lead to life-threatening complications if injured.

In the present study, the morphological features of lingual concavity including concavity angle, depth, and RAC, show significant difference between each tooth type (all p < 0.001) (Table 3). These morphological differences could have critical impact on treatment planning before surgery, or jeopardize vital structure such as the IAN during immediate implant placement. It should be emphasized that the IAN is one of the most commonly injured nerve which can be attributed to multifactorial reasons, including traumatic local anaesthetic injections, implant site preparation or placement, or inadvertent surgical technique. Among these factors, over penetration of the drill, or positioning the implant close to the IAC may subsequently cause haemorrhage into the canal or contamination of drilling debris, which may compress against the IAN and cause ischaemia. Although dental implant is one of the most common etiological factors of IAN injury, proper distance between the implant and the mandibular canal would ensure the integrity of IAN. Froum et al. reported that if RAC < 6 mm, the risk for inferior alveolar nerve injury during immediate implant placement may increase. However, in some cases, the risk of IAN injury was not increased when RAC < 6 mm, and alveolar housing for implant placement was still available in our study. Thus, in addition to RAC, the relation between the most concave point of lingual concavity and IAC (ABC zone) would provide more reliable information for assessing possibility of IAN injury during immediate implant placement. Furthermore, the bone mineral density, bone thickness, and the resistance of the bone surrounding the IAC may play a role during implant site preparation and placement. Consequently, accurate determination of the bone mass enclosing the canal prior to the implant procedure,
and avoidance of excessive force when approaching the canal could minimize the risk of injury to the IAN.\textsuperscript{31}

The tooth type has significant impact on the risk of IAN injury ($p < 0.001$) (Table 3). In this study, for the first time, the result revealed that immediate implant placement at mandibular second molars was 3.82 times more likely to cause IAN injury compared to those at second premolars (Table 4). This result was comparable to those reported in other studies, where the probability of IAN injury at the mandibular second molar (73%) was higher than second premolar (65%), with the lowest at the first molar (53%).\textsuperscript{31} The detection frequency of such variations within the posterior mandible area seems to advocate a profound dissection of the lingual site by additional cross-sectional images.

In this study, it is certain that varying degrees of lingual concavities are associated with increased risk of IAN injury, and present challenges for successful immediate implant placement at posterior mandible region. Accurate assessment of the morphology and bone quality of the mandible accompanied with correct location of the IAC vertically and bucco-lingually by multislice cross-sectional images will be helpful in preoperative diagnosis and avoidance of associated complications. For that reason, it is mandatory for clinicians to have a solid basic knowledge about biological prerequisites and clinical procedures to allow successful immediate implant treatment and in particular, to understand the importance in applying all background information about intra-operative risk factors and possible etiological risk factors to prevent unsatisfactory results.

In spite of the high survival rate of immediate implant placement reported, it should only be used in stringently evaluated situations and performed by experienced clinicians to reduce the risks of implant failure.\textsuperscript{6,7} Actually, the most common diagnostic radiographic modalities used to assist clinicians were intraoral periapical and panoramic radiography.\textsuperscript{23,32} Recently, Frei et al. and Vazquez et al. demonstrated that cross-sectional imaging did not have any major impact on the implant size determination in mandibular posterior region and may not be necessary for preoperative evaluation for implant placement.\textsuperscript{8,14} Up to date, two-dimensional radiographic examination, such as panoramic and periapical films can still be considered as a safe, quick, simple, low-cost, and low-dose presurgical diagnostic tool for preoperative implant treatment planning in mandibular posterior region,\textsuperscript{23,32–34} and subjects who plan to receive immediate implant surgery may not need to receive CBCT exam as a routine pre-surgical assessment.\textsuperscript{23} However, cross-sectional images would also be useful in providing more precise information regarding the location of the anatomical structures (i.e., inferior alveolar canal) in vertical and horizontal planes, morphology of the alveolar bone, and the quality of the alveolar bone.\textsuperscript{23,32} The International Congress of Oral Implantologists (ICOI) consensus report suggests CBCT should be considered as an imaging alternative of conventional radiography to assess the true three-dimensional information as indicated below\textsuperscript{23}: (1) computer-aided implant planning and placement including flapless techniques; (2) implant placement in a inadequate bone volume or quality, undeterminable proximity to vital structures, and insufficient inter-radicular spacing; (3) pre- and post-advanced bone grafting evaluation (e.g., sinus lift, ridge splitting, block grafting); (4) history or suspected trauma, foreign bodies, maxillofacial lesions, and/ or developmental defect; (5) post-implant complications evaluation. It should be noted that a standard film and/or even direct visual inspection does allow accurate judgement of IAN position, provide essential coronal information of previously extracted tooth site and then reduce the risk of inferior alveolar nerve injury by experienced clinicians. Thus, all three-dimensional examinations, as all other radiographic examinations, must be justified on an individualized needs basis and the benefits for each CBCT scan must outweigh the potential risks.\textsuperscript{23,32} Future studies should also aim to improve pre-surgical diagnosis by non-invasive approaches, propose adequate therapeutic strategies for implant site preparation, and identify factors for positive treatment outcomes without unpredictable complications.

5. Conclusion

Within the limits of this study, it was concluded that tooth type, morphological features of lingual concavities, and RAC is associated with risks of IAN injury during immediate implant placement. The clinical significance of this study determines that chances of avoiding unpleasant complications can be increased through pre-surgical mapping of the IAC and identification of its proximity relative to the lingual concavity in the posterior mandible regions, specifically when using immediate implant procedures.

Conflict of interest

The authors declare that they have no conflict of interests.

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