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Bone dimension assessment for placement of implants in the interforaminal region of the mandible: A cone beam computed tomography study

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Abstract
Our study aimed to define the available native bone dimensions and safe limits for implant placement in the mandibular inter-foraminal region using CBCT imaging. 100 CBCT scans were evaluated for bone dimensions, anterior loop of the inferior alveolar nerve, the lingual foramina and canals. Mean bone height was 20.34±3.3mm. Range: 13.69-26.98mm. Mean unilateral ridge length was 19.44±1.8mm. Midline lingual foramina showed a 99% prevalence-single canal in 41 cases, 2 canals in 53 cases, 3 canals in 5 cases. The bucco-lingual width traversed by the lingual canal from lingual cortex was upto the middle third in the majority of cases (77%). The anterior loop was present in 45% of the population: bilaterally in 30% and unilaterally in 15%.The mean anterior extent was 2.68±0.8 mm and range was 1.01 to 4.36mm. So keeping a standard reference level of 6 mm of crestal bone width, majority of cases showed a possibility to place implants upto 15 mm in length in the inter-foraminal region. The implant osteotomy could be positioned far enough buccally to avoid lingual vessel trauma. A safe zone of 3.5-4 mm anterior to the mesial border of the mental foramen should be maintained to account for the presence of an anterior loop.

Keywords: Bone dimension, anterior mandible, anterior loop, Lingual foramina, interforaminal, implant

1. Introduction
The inter-foraminal region of the mandible is an important site for implant supported prosthetic options to rehabilitate failing dentitions [1] Long standing edentulism, prolonged use of ill- fitting removable prosthesis, the proximity of the inferior alveolar canal and resorption pattern of the mandible often rule out placing implants in the posterior mandible. Vertical augmentation, grafting and nerve repositioning may not always be predictable or feasible options. With sound biomechanical design, the anterior mandibular implants can provide adequate support and retention to restore the full arch. This is also a site for block graft harvesting [2]

Earlier tooth-retained over-dentures were the main option in preventive prosthodontics. However the drawbacks were the requirements of ideal tooth condition and location, and a tendency for decay and gingival inflammation. An Implant supported over-denture is not subject to these factors and has shown to be a better long term treatment option [3].

These days multiple options of implant supported prosthesis, fixed-metallic or removable acrylic or fixed-hybrid prosthesis are available. The choice of prosthesis depends on the availability and quality of bone, inter-arch space, vertical dimension, neutral zone, condition of the patient and tissues, affordability, neuromuscular, TMJ considerations et cetera. Due to the vertical cantilever component in case of a full fixed prosthesis however the hybrid or acrylic prosthesis remains the best alternative for restoring a ridge with vertical deficit. Also in case of overdentures parallel placement of the implants is a must to prevent frequent prosthetic complications such as denture loosening or fracture [4].

Adverse implant surgical complications such as uncontrolled bleeding and paresthesia are best prevented by having a thorough knowledge of the anatomy and variations. Earlier, mostly morphometric studies on human cadaver mandibles were done [5]. Panoramic radiography was used without complete accuracy to gauge some structures like the anterior loop of the inferior alveolar nerve. Lingual foramina and accessory canals could not be distinguished in 2-D imaging. Only CT scans could be used non-invasively.

With the availability of Cone Beam Computed Tomography it is possible to study large samples more accurately and feasibly. The aim of this study is to provide a detailed insight into the bone dimensions and define the boundaries for implant placement in the mandibular inter-foraminal region in the Indian population.

2. Materials and Methods

This single blind retrospective study was approved by the ethical committee and the methodology reviewed by an independent statistician. A hundred CBCT scans (Promax 3D CBCT unit, Planmeca) of patients with partially edentulous or dentulous mandible were randomly selected for this study. The study population consisted of 53 male and 47 female patients in the age group of 20-60 years. Cases with complete edentulism, ridge resorption and intra-osseous lesions or pathology in the mandible were excluded from the study.

Measurements were performed on the installed software digital scale (PlanmecaRomexis viewer software) and standardized by accurate tracing of the arch form and use of fixed reference planes (Fig 1).

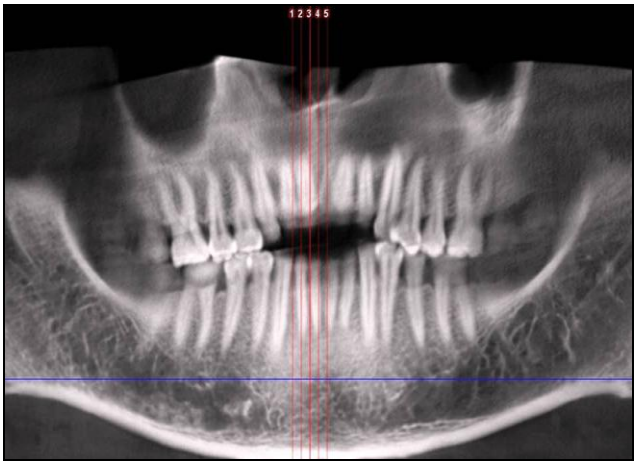

Fig 1: Reference planes for measurement-Vertical midline Section and Horizontal plane through the mental foramina

The following parameters were studied (Fig 2 and 3)-Bone height measured from the most crestal point with 6 mm width to the lower border of the mandible, this particular width required for placement of regular or wide platform implants.

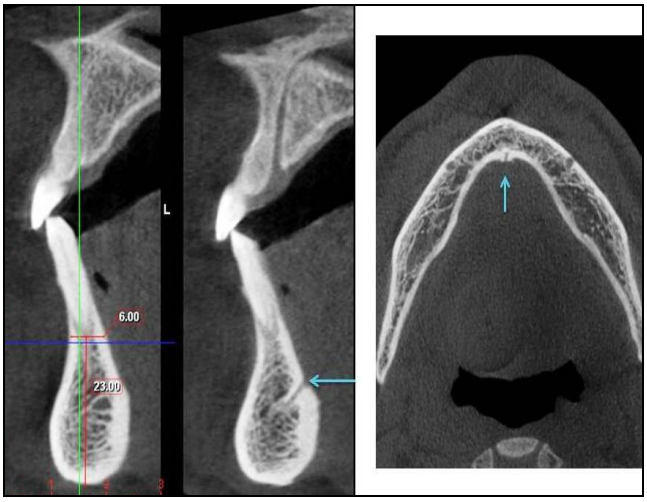

Fig 2: Measurement of Bone Height and Lingual canal.

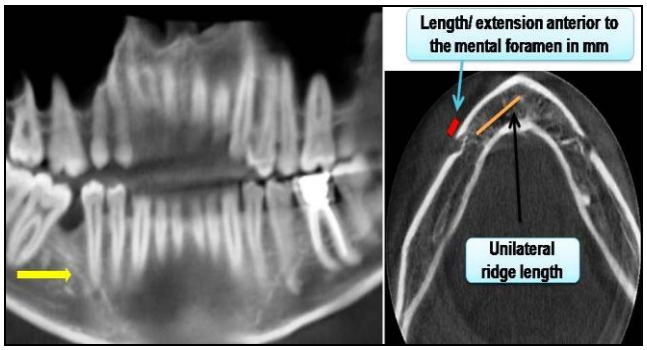

Fig 3: Anterior Loop and ridge length.

Also the foramina in vertical cross section, thelingual foramina in horizontal section, the presence of the anterior loop, side of the loop, length of the loop(LL) anterior to the mental foramen and the available horizontal ridge length(RL) from the midline to the anterior border of the loop/mental foramen. Variations in anatomy are also documented.

Statistical Analysis-Descriptive statistics were used to describe the findings and comparisons between male and female subjects. An independent statistician reviewed and analysed the results and confirmed the conclusions. The data was analysed using Statistical Package for Social Sciences (SPSS version 16 software, SPSS Inc, Chicago, Illinois, USA). To compare quantitative variables like bone height, loop length and ridge Length, unpaired t-test was used. To compare differences in proportions of attributes like lingual foramina, traversed width, and presence of anterior loop and loop Side, Chi-square test was used. Correlation was evaluated using Pearsons test. P-values <0.05 were considered statistically significant.

3. Results

Bone height (BH) -The mean bone height is 20.34±3.3 mm (Range-13.69-26.98mm) (Table1) with males presenting with some more vertical bone height (independent samples t-test, t-(98) =2.026, p=0.045) (Table 2). In some cases a deep facial depression was present so there is inadequate width of bone in the middle region from the crest to the lower border. In such cases the width apical to the defect was considered.

The mean horizontal length of the ridge anterior to the canal/ foramen (RL) upto the midline was found to be 19.44±1.8mm. (Table 1) with no statistically significant difference with respect to gender. (Table 2)

There exists no correlation between bone height and ridge length. (r=0.048, p=0.637)

The midline lingual foramen and canal was found to be present in 99% of cases with one exception where it was present away from the midline. The number of lingual foramina extending into a canal varied between persons. Forty-one persons had a single midline lingual foramina whereas 53 persons had 2 foramina and 5 persons had 3 midline lingual foramina.

The percentage distance traversed from lingual to buccal was recorded. In 77% the lingual canal terminated in the middle third of the bone width bucco-lingually and in the buccal third in 22% of the cases. In one case it terminated within the lingual third itself. An exceptional additional midline buccal canal was observed in one of the cases which extended from the buccal towards lingual and terminated in the middle third region.

In resorbed ridges the lingual foramen and canal was located very close to the crest.

Additional accessory lingual vessels and canals were observed in 23 persons-in the premolars regions bilaterally.

An anterior loop was found to be present in 45% of the cases. The side of the loop varied. Thirty persons showed bilateral anterior loops.15 had unilateral loops with 8 having a right side loop and 7 having a left side loop. The anterior loop was just as frequently present in males as in females.

The range of loop length was found to be between 1.01-4.36 mm. The mean length of the loop extending anterior to the mental foramen was found to be 2.68±0.8mm. (Table 1), without a significant difference between male and females subjects. (Table 2)

The mental foramina showed some variations. In majority of the persons there was a single foramina. However 4 persons had 2 mental foramina on one side of the mandible that is presence of an accessory mental foramina unilaterally-2 of whom had a buccal canal running distally from the mental foramen and terminating in a separate accessory foramen. Two persons showed this variation on the right side while 2 were on the left side. (Fig 4).

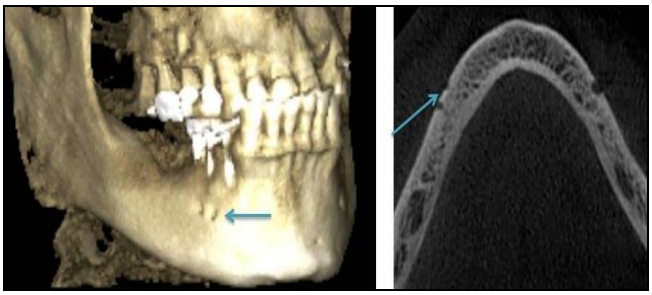

Fig 4: Accessory Mental Foramina

4. Discussion

The interforaminal region of the mandible with variable degrees of buccal and lingual concavities and narrow dimensions needs a more apical implant position for placing wider platform implants. Implants have to be placed in a prosthetically favourable position with adequate surrounding native bone while avoiding impingement on the vital neurovascular structures such as the anterior loop of the inferior alveolar nerve and the position of the lingual vessels.

In this study the bone height and ridge length were measured with the intention to place 3 to 4 inter-foraminal implants. The ridge height was found to range from 13.6mm to 26.98mm, the average being 20.34±3.3mm, the value for males being significantly more than for females. This shows that keeping a safety margin of 1 mm from the lower border, implants upto 15 mm in length can be placed in majority of cases. This was similar to the value of 21.1±4.3 observed by Madrigal *et al.* 2008 [6].

The ridge length determines the number and dimensions of the implants that can be placed. In a previous study on inter-foraminal distance in Indian population using digital radiographic measurements the value was 38.9 mm [7]. We recorded 19.44 mm unilaterally so doubling the distance gives a similar finding. There was no significant gender variation for this dimension. Also, no correlation between the bone height and ridge length was found.

In this limited zone, penetration of the lingual cortex can give rise to uncontrollable bleeding, hematoma formation and life threatening airway compromise [8]. As the arteries enter the lingual cortex through the lingual foramina located in the midline approximating the genial tubercles.

Lingual foramina and continuing canals vary in number, position and extent to which they traverse the bone from the lingual to the facial aspect. They can be superior or inferior to the genial spines and are named accordingly. The content was found to be the sublingual artery and submental artery for the superior and inferior canals respectively. Sometimes there is an anastomosis of the two. A single foramen is typically located superior to the genial spines. 72% of these midline canals were directed downwards to the labial side over a distance of 6.5 mm. There were also many lateral lingual foramina and canals [9]. In a study done in an Indian population-a single branch from the left sublingual artery was seen to enter this midline foramen, thereafter the artery anastomosed with the right sublingual artery, forming an arch here [10].

In our study the midline lingual foramina were present in 99% of the sample, similar to the findings obtained by Mcdonnell *et al.* 1994. In their study the bucco-lingual distance traversed was found to be 50% [11]. In our study too, 77% showed the canal extending to the middle of the bucco-lingual span. While in 22% of cases it terminated in the buccal third. This shows that placement of the anterior interforaminal implants should be done as close to the buccal cortex as possible. In one variant case an additional buccal canal was observed originating in the midline and directed lingually. Special care should be taken in resorbed ridges as here the lingual foramen and canal is located very close to the crest as observed in our study.

Haemorrhage has also been reported in the mandibular premolar lingual region [12].

In our study 23% of cases had additional lingual canals in the premolar region bilaterally which could result in complications if perforated.

There is a large variation in the location and configuration of the mandibular canal and related structures. In the anterior loop variation the terminal portion of the Inferior alveolar nerve instead of dividing and directly exiting the mental foramen travels anteriorly crossing the mental foramen and then doubles back to exit the mental foramen. The nerve synapses at this juncture anterior to the mental foramen and damage can lead to paraesthesia, pain or numbness. Inability to perceive the sensation in the lower lip could also result in lip injury.

The anterior loop is an intramedullary structure and cannot be seen clinically or easily identified on 2D radiographs. Panoramic radiography revealed the prevalence to be low as 12% by Misch and Crawford (1990) [13], to as high as 40%. As reported by Ngeow *et al*. 2009 [14]. They also reported maximum presence of the loop bilaterally and in a few cases right side followed by left which was minimum. In a study on Indian Population the prevalence was found to be 19% (Arora 2013) [15]. Cadaveric dissections found the prevalence to be 11-28% [16, 17]. Surgical exploration *in vivo* revealed a 24% prevalence[18]Apostolakis (2012) on CBCT evaluation has revealed a prevalence of 48% which is close to the value of 45% obtained in our study [19]. The loop length was found to be 0.5-1 mm in cadaveric dissections [16]. In our study the mean length was found to be 2.68±0.8mm, ranging from 1.01-4.36 mm. So a safe zone of 3.5-4 mm is required anterior to the medial border of the mental foramen. This is in agreement with the recommended limits by several authors [20, 21]. The length could even be upto10 mm [22]

A single mental foramen is usually located buccally in the first to second premolar region of the mandible, midway

between the crest and the lower border [23]. Sometimes there may be accessory mental foramina, with reported prevalences of 6-10% [24]. In our study 4 persons had 2 mental foramina on one of the sides. 2 of the foramina were terminations of an accessory buccal nerve canal running distally from the main mental foramen.

5. List of Abbreviations

- CBCT-Cone Beam Computed Tomography
- TMJ-Temporo-mandibular Joint
- CT-Computed Tomography
- BH-Bone Height
- LL-Loop Length
- RL-Ridge Length

6. Table

Table 1: Mean, Standard deviation and ranges for the quantitative variables-Bone height, Ridge length, Loop length.

Variable	N	Mean	SEM	Std Dev	Normal lower limit	Normal upper limit	Population lower limit	Population upper limit
Bone Height (BH)	100	20.34	0.34	3.39	13.69	26.98	19.67	20.99
Ridge length (RL)	100	19.44	0.18	0.18	15.83	23.05	19.08	19.80
Loop length (LL)	46	2.68	0.13	0.85	1.00	4.36	2.43	2.93

Table 2: Quantitative variable comparison according to gender

Variable	Males-Mean	Males-Stddev	Females- mean	Female- Stddev	P value
Bone Height (BH)	20.97	3.46	19.62	3.20	0.045
Ridge length (RL)	19.61	1.79	19.24	1.90	0.321
Loop length (LL)	2.89	0.92	2.43	0.71	0.072

7. Conclusion

Several factors need to be considered prior implant treatment planning for a long term success, the available native bone dimensions being a key factor. The majority of cases with a crestal width of 6 mm, can be treated using implants upto 15 mm in length. Keeping a safe zone of 3.5-4 mm anterior to the mesial border of the mental foramen will avoid impingement on the anterior loop of the mental nerve. The implants should be bodily centered towards the buccal aspect of the ridge to prevent trauma to the lingual canal and vasculature. A mean horizontal ridge length of 19 mm unilaterally will allow for placement of 3-4 interforaminal implants in most cases.

8. Acknowledgements

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9. Conflict Of Interest

The authors declare that there was no conflict of interest

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