Cone beam computerized tomography evaluation of incisive canal and anterior maxillary bone thickness for placement of immediate implants

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INTRODUCTION

The necessity for efficient and effective tooth replacement has led to the development of immediate implant placement in which anatomic conditions like the presence of nerves and vessels and bone thickness are vital factors. Cone beam computerized tomography (CBCT) can produce views and volumetric reconstructions of craniofacial structures which aids in accurate treatment planning. Variations of

Abstract

Purpose: Variation of dimensions of the nasopalatine canal and anterior maxillary bone thickness vary in relation to age, gender, edentulism, and ethnicity; thorough knowledge with regard to these landmarks is of vital importance prior to surgical procedures such as implant placement and local anesthesia in the anterior maxilla. Cone beam computerized tomography (CBCT) aids in accurate treatment planning in such situations. Subjects and Methods: A total of 300 participants were selected by the inclusion and exclusion criteria. CBCT was performed with Hyperion X9 CBCT Scanner. Images were reconstructed from the CBCT data using NNT image reconstruction software and visualized using multi-planar resolution screen. The dimensions of the nasopalatine foramen (NPF), the incisive canal (IC) and foramen, and anterior maxillary bone thickness were measured. Results: The mean diameter of NPF was found to be 3.27 mm, incisive foramen (IF) was 3.62 mm, IC was 2.12 mm. The average length of the IC was 10.66 mm. The IF was located at a mean distance of 13.81 mm away from the most anteroinferior point of the cortical plate of the labial bone of the maxilla. The anterior maxillary bone was the thickest at the nasal spine level (10.94 mm), and was the narrowest at lower labial alveolus (7.16 mm). The average anterior maxillary bone thickness was found to be 8.36 mm. Conclusion: Within the limitations of the study, it was found that gender and age are important factors that affected the characteristics of the IC and the amount of bone anterior to it.

Keywords: Anterior maxilla, bone thickness, cone beam computerized tomography, immediate implant, incisive canal dimensions

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dimensions of nasopalatine canal (NPC) and thickness of anterior maxillary bone vary in relation to age, gender, edentulism, and ethnicity. Therefore, the purpose of the study is to use CBCT to evaluate the above parameters in relation to age and gender in the eastern part of Indian population based on the null hypothesis that there is no statistically significant difference in the CBCT assessment.

SUBJECTS AND METHODS

The study was conducted in the Department of Prosthodontics and Department of Oral Medicine and Radiology, KIDS, Bhubaneswar.

The study was approved by the Institute Ethics Committee of KIMS, (Ref. No.: KIMS/KIIT/IEC/131/2015). Informed consent was obtained that the records will be used for research purpose and identity will remain anonymous.

The study group included 300 participants who were referred by different other dental specialties for CBCT, distributed into age groups 16–25, 26–35, 36–45, 46–55, and 56–65 years, having both maxillary central incisors without any clinical or radiological evidence of pathology; each group containing 60 participants with equal number of males and females.

The participants were selected from Odisha and neighboring states, i.e., eastern part of India. Patients having any pathology or fracture of anterior maxilla, missing central incisors, pregnant female patients and patients undergoing orthodontic treatment were excluded from the study.

CBCT was performed with Hyperion X9 CBCT Scanner (MyRay, US). All the images were taken by following a uniform code regarding positioning of the patient, the exposure parameter was 94 KvP, 8 mA for 18 s and image procurement was set at 0.3 mm voxel. All procedures were performed by the same radiographer to minimize statistical bias. Reconstruction of images was done from the data obtained during CBCT by using New Net Technologies (NNT) image reconstruction software and were visualised using multi-planar resolution screen and measurements performed.

Evaluation of diameter of nasopalatine foramen (NPF) was done at nasal opening of incisive canal (IC) and that of the incisive foramen (IF) was done at its oral entrance. The canal width was calibrated at the mid-point between the above mentioned positions [Figure 1]. The length of the IC was evaluated ranging from its nasal entrance to the palatal entrance [Figure 2].

The thickness of anterior maxillary bone labial to IC was evaluated at three different positions-at the plane of nasal spine, at the plane of most antero-inferior point of maxillary cortical plate and at equidistant amid the above two planes [Figure 2]. The measurements were estimated as a perpendicular length from outer wall of IC to outer cortical plate of anterior maxilla. Mean was computed based on these three values.

The mesio-distal diameter was measured in the axial section at the level of incisive fossa at its maximum diameter [Figure 3].

The position of IF was ascertained as length extending from IF to the extreme anteroinferior point of cortical plate of the maxillary labial bone [Figure 1].

Statistical analysis

Statistical analysis was performed using SPSS 12.01 Windows software (SPSS Inc., Chicago, USA). Mean and standard deviation was calculated. Independent t-test and ANOVA was used for the comparison of quantitative data between gender [Figure 4] and different age groups [Figure 5]. The significance level was set at \(P < 0.05\). To get a statistically significant result, both male and female subgroups were taken as 30; so that,

\[(30 \text{ [male]} +30 \text{ [female]} \times 5 \text{ groups} = \text{Total 300}].\]

RESULTS

A total of 300 CBCTs were analyzed. The NPF showed a mean diameter of \(3.27 \pm 1.09\) mm, ranging from 1.50 to 8.40 mm but no significant difference observed between different age groups \((P > 0.05)\). However, there was gender
influence \( (P < 0.05) \), with males having 3.40 ± 1.21 mm and females having 3.14 ± 0.94 mm diameter [Table 1]. The mean diameter of the IF was 3.62 ± 0.80 mm. No significant gender difference was found in the diameter \( (P > 0.05) \); the male subjects (3.62 ± 0.77 mm) and female subjects (3.61 ± 0.82 mm) had almost the same mean dimension but with values ranging from 2 mm to 5.5 mm [Table 1]. As for the NPF, it showed slightly less diameter than that of the IF. This means that the incisive component of the NPC has the broader end nearer to the adjoining central incisors. However, no statistical significance of the dimensions of the IF according to different age groups was found [Table 2].

The IC has a mean width of 2.12 ± 0.80 mm. The canal diameter of male subjects (2.14 ± 0.77) was found to be greater than that of female subjects (2.10 ± 0.82) but was not statistically significant \( (P > 0.05) \) [Table 1]. Also there was no significant difference in this parameter with an increase in age [Table 2]. The average length of the IC was 10.66 ± 2.52 mm. There was a wide range in the length of IC (7.3–17.7 mm). A detailed search stated that IC length had a significant increased length in males \( (P < 0.05) \) [Table 1]. Age of the subjects had no effect on IC length and diameter \( (P > 0.05) \) [Table 2]. The IF was located at a mean distance of 13.81 mm away from the most anteroinferior point of the cortical plate of the maxillary labial bone ranging from 9.50 mm to 19.30 mm. Gender had a significant influence with regard to this parameter, with the mean for males being 14.09 ± 2.01 mm and that for females being 13.54 ± 2.07 mm [Table 1]. The position of IF was not affected significantly by increasing age \( (P > 0.05) \). In subjects between 16 and 25 age group, the IF was almost 14.62 ± 2.75 mm distant to the anteroinferior point of the cortical plate, but this value was only marginally over 13.04 mm for patients of age >45 years. There was no statistically significant difference between different age groups with regard to this parameter [Table 2].

The anterior maxillary bone had maximum thickness at level of nasal spine (10.94 ± 2.49 mm), and had the minimum
thickness at the lower labial alveolus (7.16 ± 1.54 mm), contributing a tapering presentation superio‑inferiorly. Mean bone width at anterior maxilla was determined by procuring mean of values recorded at the specific levels which was estimated as 8.36 mm. Therefore, the mean labial bone width in males and females was 8.54 mm and 8.18 mm, respectively, showing significant difference with \( P < 0.05 \) [Table 1].

Age had a significant effect on the mean bone thickness of the anterior maxilla, as it was thicker in subjects of less age group, for example, 11.08 mm in 16–25 years, but was decreased to 9.06 mm in subjects >45 years [Table 2].

**DISCUSSION**

Implant placement at the maxillary incisor site is an arduous endeavor owing to its esthetic and functional requirements, amidst limitations resulting from resorption of alveolar bone after loss of tooth and disparity in dimension and position of IC and IF. Although IC has been explored previously, there are only few researches illustrating the morphological diversity of this canal and few studies involving Asian subjects. There has been no combined study regarding the parameters of the NPF and anterior maxillary bone thickness, especially in the Indian population. Hence, the aim of the present study is to perform a supplemental evaluation regarding variations in dimensions of IF, IC and anterior maxillary bone thickness of Indian population, i.e., Asian group.

The dimensions of the IC were measured randomly irrespective of right and left side. The sagittal section in the CBCT which was most apt for the labio‑palatal measurement was considered.

• Nasopalatine foramen – Present data are consistent with those published by Al‑Amery et al.[2] in which the width of right NPF shows a statistical significance between genders with a mean diameter of 6.54 mm and 5.56 mm for males and females respectively. The diameter of NPF in the present study was found to be greater than those by Özçakır‑Tomruk et al.[1] similar to that by López Jornet et al.[9] less than that by Al‑Amery et al.[2] probably attributing the difference to morphological variation in the sub‑population as well as differences in sample size in respective studies

• Incisive foramen – No significant difference was found in relation to the diameter of the IF with regard to gender and age groups in the present study. The mean width of the IF in the present study was 3.61 mm which is different from that of 2.90 mm in Arabs by Tözüm et al.[10] and 3.49 mm in Koreans by Kim et al.[11] Mraiwa et al.[12] reported that mean labiopalatal width of IF in males was 3.05 mm and in females was 3.49 mm. In Mongoloid population, Al‑Amery et al.[2] reported that mean labiopalatal width of IF in males was 3.05 mm and in females was 2.56 mm; mesiodistal width in males was 3.55 mm and in females was 3.44 mm. This difference might be due to the difference in race among the population groups. The mean IC width of 3.61 mm was comparable to that described by Liang et al.[13] who disclosed a discrepancy of 3.3 mm in cadavers to 3.6 mm in CT scans. This measurement is also similar to that reported in dentate Japanese,[13] whereby the labio‑palatal and mesiodistal width was 2.8 mm and 3.3 mm, respectively

• Canal diameter – In the present study, diameter at the mid‑point does not exhibit any statistical significance in relation to gender or age groups. However, studies by Guncu et al.[4] Esmaeili et al.[14] have reported greater diameter (4.4–4.6 mm) in Caucasians. Guncu et al.[4] reported IF mean diameter of 2.79 mm in males and 2.40 mm in females. In Mongoloid population, Al‑Amery et al.[2] reported that mean labiopalatal width of IF in males was 3.05 mm and in females was 2.56 mm; mesiodistal width in males was 3.55 mm and in females was 3.44 mm. This difference might be due to the difference in race among the population groups. The mean IC width of 3.61 mm was comparable to that described by Liang et al.,[13] who disclosed a discrepance of 3.3 mm in cadavers to 3.6 mm in CT scans. This measurement is also similar to that reported in dentate Japanese,[13] whereby the labio‑palatal and mesiodistal width was 2.8 mm and 3.3 mm, respectively

• Incisive canal length – The present study validates the wide diversification in length of IC that is unaffected by age, but influenced by gender, greater in males compared to females; with a mean length of 16.33 mm which is close to that described by Kim et al.[11] The

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**Table 1: Represents the parameters according to gender**

| Parameter                        | Gender | Mean±SD          | \( P \) |
|----------------------------------|--------|------------------|--------|
| Naso‑palatine foramen diameter   | Male   | 3.40±1.21        | 0.035  |
|                                  | Female | 3.14±0.94        |        |
|                                  | Overall| 3.27±1.09        |        |
| Incisive foramen (L‑P) diameter  | Male   | 3.62±0.77        | 0.908  |
|                                  | Female | 3.61±0.82        |        |
|                                  | Overall| 3.61±0.80        |        |
| Incisive foramen (M‑D) diameter  | Male   | 3.78±1.03        | 0.063  |
|                                  | Female | 3.42±1.05        |        |
|                                  | Overall| 3.61±1.05        |        |
| Canal diameter                   | Male   | 2.14±0.77        | 0.654  |
|                                  | Female | 2.10±0.82        |        |
|                                  | Overall| 2.12±0.80        |        |
| Incisive canal length            | Male   | 10.67±2.51       | 0.035  |
|                                  | Female | 10.66±2.55       |        |
|                                  | Overall| 10.66±2.52       |        |
| Incisive foramen location        | Male   | 14.09±2.01       | 0.019  |
|                                  | Female | 13.54±2.07       |        |
|                                  | Overall| 13.81±2.05       |        |
| \( L_1 \)                        | Male   | 11.28±2.51       | 0.017  |
|                                  | Female | 10.59±2.44       |        |
|                                  | Overall| 10.94±2.49       |        |
| \( L_2 \)                        | Male   | 7.30±1.47        | 0.002  |
|                                  | Female | 6.71±1.79        |        |
|                                  | Overall| 7.00±1.66        |        |
| \( L_3 \)                        | Male   | 7.04±1.64        | 0.170  |
|                                  | Female | 7.29±1.43        |        |
|                                  | Overall| 7.16±1.54        |        |
| Average anterior maxillary bone thickness, \( L_{anx} \) | Male   | 11.28±2.51       | 0.017  |
|                                  | Female | 10.59±2.44       |        |
|                                  | Overall| 10.94±2.49       |        |

SD: Standard deviation
Table 2: Represents the parameters according to age group

| Age group          | Mean±SD   | P        |
|--------------------|-----------|----------|
| Naso palatine foramen | 3.70±1.02 | 0.715    |
| 16-25              | 3.34±1.23 |          |
| 26-35              | 3.12±1.18 |          |
| 36-45              | 3.09±1.00 |          |
| 46-55              | 3.09±1.00 |          |
| 56-65              | 3.09±1.00 |          |
| Total              | 3.27±1.09 |          |
| Incisive foramen (L-P) diameter | 3.79±0.87 | 0.255    |
| 16-25              | 3.68±0.77 |          |
| 26-35              | 3.55±0.74 |          |
| 36-45              | 3.64±0.92 |          |
| 46-55              | 3.41±0.62 |          |
| 56-65              | 3.61±0.80 |          |
| Total              | 3.61±0.80 |          |
| Incisive foramen (M-D) diameter | 3.34±1.39 | 0.083    |
| 16-25              | 3.18±1.12 |          |
| 26-35              | 3.92±0.85 |          |
| 36-45              | 3.73±0.84 |          |
| 46-55              | 3.89±0.76 |          |
| 56-65              | 3.61±1.05 |          |
| Total              | 3.61±1.05 |          |
| Canal diameter     | 2.43±0.89 | 0.242    |
| 16-25              | 2.12±0.77 |          |
| 26-35              | 1.97±0.79 |          |
| 36-45              | 1.98±0.73 |          |
| 46-55              | 2.09±0.73 |          |
| 56-65              | 2.12±0.80 |          |
| Total              | 2.12±0.80 |          |
| Incisive canal length | 10.19±2.20 | 0.089    |
| 16-25              | 11.08±2.66 |          |
| 26-35              | 10.53±2.71 |          |
| 36-45              | 10.04±2.07 |          |
| 46-55              | 10.76±2.84 |          |
| 56-65              | 10.66±2.52 |          |
| Total              | 10.66±2.52 |          |
| Incisive foramen location | 14.62±2.75 | 0.026    |
| 16-25              | 13.81±1.14 |          |
| 26-35              | 13.54±1.04 |          |
| 36-45              | 14.06±1.74 |          |
| 46-55              | 13.04±1.97 |          |
| 56-65              | 13.81±2.05 |          |
| Total              | 13.81±2.05 |          |
| L1                 | 11.08±2.89 | 0.026    |
| 16-25              | 11.13±2.47 |          |
| 26-35              | 10.46±2.32 |          |
| 36-45              | 10.98±2.11 |          |
| 46-55              | 11.04±2.63 |          |
| 56-65              | 10.94±2.49 |          |
| Total              | 10.94±2.49 |          |
| L2                 | 6.82±1.56 | 0.010    |
| 16-25              | 7.04±1.54 |          |
| 26-35              | 7.13±1.65 |          |
| 36-45              | 7.22±1.90 |          |
| 46-55              | 6.80±1.63 |          |
| 56-65              | 7.00±1.66 |          |
| Total              | 7.00±1.66 |          |
| L3                 | 6.89±1.37 | 0.392    |
| 16-25              | 7.13±1.49 |          |
| 26-35              | 7.63±1.91 |          |
| 36-45              | 7.02±1.39 |          |
| 46-55              | 7.15±1.42 |          |
| 56-65              | 7.16±1.54 |          |
| Total              | 7.16±1.54 |          |

Table 2: Contd....

| Age group          | Mean±SD   | P        |
|--------------------|-----------|----------|
| Incisive foramen location | 11.04±2.63 |          |
| 16-25              | 10.94±2.49 |          |
| 26-35              | 10.46±2.32 |          |
| 36-45              | 10.98±2.11 |          |
| 56-65              | 10.94±2.49 |          |
| Total              | 10.94±2.49 |          |

SD: Standard deviation

The mean length of IC ranges between 8.1 mm and 11.96 mm in Caucasians[4,10,12,14,18] 12.0 mm–15.87 mm in Koreans[19] The diameter of NPF is greater compared to IF. The values obtained for the diameters of the IC at three different points implied presence of funnel contoured pathway amidst superior (broader NF orifice), midway (intermediary IC diameter) and inferior (narrower IF orifice) points, akin to that illustrated by Mraiwa et al.[2] and Kim et al.[11] which is in opposition to that noted by Asaumi et al.[13] who interpreted the orifice to be wider at the oral cavity side. Mardinger et al.[18] and Tözüm et al.[10] found the middle part of the canal to be the narrowest.

When data for IF and NF are cumulated with IC length, it appears that Mongoloids[15] have a longer IC with narrower IF compared to Caucasians[4,12] having relatively shorter canal with broader IF. With increase in age, the NP canal diameter increases and the IC length decreases due to the bone resorption.[12,14,15,18,20] However, the present study did not detect any significant difference in canal dimensions in subjects of various age groups probably because edentulous patients were excluded; Mardinger et al.[18] suggested presence of teeth assure stability in dimensions of IC in dentate subjects.

- Incisive foramen location – In the present study, average distance equals to 13.81 ± 2.05 mm, with males and females exhibiting 14.09 ± 2.01 mm and 13.54 ± 2.07 mm showing statistical difference in gender as well as in relation to age groups. Liang et al. reported average of 10.6 mm in dentate group,[14] while Al-Amery et al.[13] reported mean distance of 12.05 mm. The difference might be due to geographical, race and ethnicity variation among population groups.

The current study affirmed effect of aging on position of IF indicating that implant surgery may become more complicated for elderly patients. Surgical intervention might be required where the canal contents are pushed back and IF obturated by bone graft[20‑22] or IC used as anatomic buttress.[22]
Anterior maxillary bone thickness

Anterior maxillary bone was broadest at level of nasal spine (10.94 mm), and was thinnest at lower labial alveolus (7.16 mm), presenting a tapered contour superio-inferiorly. Configuration of the labial bone anterior to IC reveals equitable distribution between straight and concave category, none being convex in shape. Ethnicity and gender has not affected the shape of this bone. The mean anterior maxillary bone thickness was found to be 8.36 mm, in males and females was 8.54 mm and 8.18 mm, respectively, 

\[ P < 0.05 \text{ at all levels of assessment.} \]

Age influenced mean bone thickness of anterior maxilla significantly, it was recorded to be thicker in younger subjects, 11.08 mm in 16–25 years, but reduced to 9.06 mm in subjects >45 years.

Zhang et al. reported alveolar width increased from coronal to apical region in anterior maxilla, larger ridge width in males compared to females.

Nowzari et al. reported that mean bone thickness in anterior maxilla was 1.05 mm with presence of ≥2 mm thickness bone apically. No significant differences in bone thickness were found between ethnic, gender, age groups.

Vera et al. in their study related to anterior maxilla, concluded that median buccal alveolar bone thickness 1 mm apical to the tooth was 0.83 mm and the mid-root level was 0.70 mm.

Guncu et al., Nahass and Naiem, López Jornet et al. stated greater alveolar bone thickness anterior to the nasal canal zone in males compared to females.

Zekry et al. reported absence of significant difference between values of right and left sides as well as between genders with regard to the anterior maxillary bone thickness; however statistically significant differences were observed between age groups.

Al-Amery et al. reported that bone at anterior maxilla was thickest at level of nasal spine and was thinnest at lower labial alveolus resulting in a tapering appearance superio-inferiorly. Labial mean bone thickness in males was significantly more compared to that in females. Mean bone thickness of anterior maxilla was significantly affected by age factor, thicker in young patients compared to older age groups.

Significant correlation has been observed between overall position of IF with anterior maxillary bone thickness. Labial bone thickness is essential for longstanding stability of mucosa surrounding dental implants. Occluso-gingival position of implant is determined by extent of alveolar crest while convexity of alveolar process at the emerging crown is affected by thickness of maxillary labial bone.

The purpose of measuring thickness of labial osseous wall at three different levels was to evaluate labial bone thickness at diverse apico-occlusal references, that might influence placement of immediate implants, thus analyzing if further apical positioning of an implant would contribute to suitable bony thickness. Therefore, it is important to examine maxillary labial bone proportion for teeth scheduled for extraction and to be restored immediately with an implant.

The results of the current study regarding the anterior maxillary bone thickness is comparable to that noted by Asaumi et al., Bornstein et al., Guncu et al., Tözüm et al. demonstrating increasing bone thickness from crest to apex. According to Cheng et al., there is no significant change in the shape of basal bone and the present study coincides with this data, bone thickness of anterior maxilla at anterior nasal spine level did not vary significantly between the younger (11.08 mm) and the older (11.04 mm) subjects. However, this parametric value is marginally less as compared to the mean of 12–15 mm recorded in Caucasians, but is greater than that noted for Japanese. The average thickness of 8.37 mm as accessed by computing the data at three levels was bordering on to the mean values declared by Mraiwa et al. and Asaumi et al. but lower to that noted for Chinese. The range of 3.92–12.18 mm was also not much disparate from that noted by Mraiwa et al., and therefore, the considerate advice on the need for careful preoperative examination should be pursued for Asian subjects also.

The present study reports that bone thickness of anterior maxilla in males is greater than that of females indicating more precautions for females during surgical procedures. Furthermore, researches by Mardinger et al., Artzi et al., Tözüm et al. proclaimed that anterior maxillary bone thickness decreases with advancing age which might be related to anterior teeth loss with aging. This study came up with an unexpected conclusion that even in entirely dentulous subjects, labial bone thickness showed 26% reduction with increasing age, correlating bone remodeling and anatomical loss with progressing age. Regarding the anterior maxillary bone thickness, the conclusion of present study exhibits that labial bone width is adequate with an average value ranging from 6.34 mm to 7.15 mm which is considered adequate for immediate implant surgery. The average thickness at Level L1 presented a significantly greater bone width than at Level L3 recommending more apical positioning of implants taking advantage of increased bone thickness.
Limitations of the study
Although the variables were minimized, there are still some limitations in the study. The current study was done in dentate population wherein subjects having any sort of pathology in the anterior maxilla, fracture of anterior maxilla, missing central incisors, subjects undergoing orthodontic treatment were not included in the study. The sample size was relatively small. Future investigations with larger sample size would help to further validate current findings. A longitudinal study can provide with more accurate details for age-related changes of important anatomical landmarks.

CONCLUSION
The buccal alveolar bone in anterior tooth positions being thin and fragile is prone to resorptive processes following tooth extraction that may interfere with the osseointegration of an immediately placed implant. Presence of considerable inconsistency in the dimensions of NPF, IC and foramen, and anterior maxillary bone width, even within subjects of the same race indicates the influence of age and gender rather than ethnicity. This study contributes a comprehensive anatomical position of the IC and dimensions of adjoining structures that can serve as a helpful reference. Use of CBCT is recommended during treatment planning for implant surgery.

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Conflicts of interest
There are no conflicts of interest.

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