The radioanatomization of the Nasopalatine canal on Cone Beam Computed Tomography – an eloquent study

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SUMMARY

The Nasopalatine Canal (NPC) was investigated using Cone Beam Computed Tomography (CBCT) to better comprehend its significance and semantic attributes in the diagnosis and treatment of pathologies and reconstructive surgeries involving the premaxilla, as it is more susceptible to progressive resorption and alterations in the morphometrics of the NPC, which increases its clinical significance. Axial, coronal, and sagittal CBCT sections were analysed in a sample of 60 individuals between the ages of 18 and 70. The chi-square test was used to examine differences between categorical variables, while the independent t test and the ANOVA test were used to examine differences between continuous variables.

A statistically significant adjudication vis-à-vis the transverse and longitudinal diameters of the Stensen foramen in the axial section, the transverse dimension of the NPC at Level C, and the labial bone length and labial bone width at Level 2 in the sagittal section bequeathed scientific acreage to this study. The Labial bone length and Labial bone width at Level 2, which were not contemplated in other researches, constitute this study as yardstick for imminent inquiries of NPC in these demeanours. This interpretation made an assay of various parameters of NPC, elaborated on the relevance of NPC in the anterior maxilla, and emphasised chartering a protocol to facilitate excellent surgical planning techniques in the placement of dental implants and surgical implants in the premaxillary region, admonishing maxillofacial trauma impacting the aesthetics, and ministration of the various pathologies.

Key words: Nasopalatine canal – Cone Beam Computed Tomography – Maxillae – Morphology – Analysis

INTRODUCTION

The Nasopalatine canal (NPC) is a paramount structure in the premaxilla that forms a conduit between the nasal and oral cavities (Lake et al., 2018). It is stationed posteriorly to the maxillary incisors, terminates beneath the incisive papilla, and unfurls into the external nasal cavity on each side as Stensen foramina, just 2 cm behind the posterior margin of the nostril. It transmits the anterior septal branch of the sphenopalatine

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artery, which forms a crucial part of the arterial plexus in the Littles area.

The maxilla, being more trabecular, is more susceptible to progressive resorption and alters the morphometrics of the NPC. Cysts very commonly occur in the canal from epithelial cell remnants secondary to trauma, infection, and constant irritation due to poorly fitting dentures, which enhances their clinical consideration.

The mid facial region is a housing of complex bony structures which are fragile and delicate and prone for fracture due to trauma. The sheer proficiency of the NPC's presentation is of enormous assistance in admonishing maxillofacial trauma affecting aesthetics and preventing post-surgical neurosensory afflictions. Dysesthesia and post-septal surgery complications can be avoided by a careful spurectomy in the antero-inferior part of the body of the nasal septum, owing to the conscientious knowledge of NPC.

Although the maxillary incisors form an indispensable implement for mastication and also contribute to high aesthetic merits for facial appearance due to their strategic location, they often need to be replaced due to their deficits secondary to trauma, caries, and infection. Careful consideration of the anatomy of the NPC and the labial cortical bone is essential in dental implant science. A better perspective on implant replacement is overtly achieved by thorough knowledge of the anatomy, thus avoiding oversized implants.

Cone Beam Computed Tomography (CBCT) is the image of choice in dentistry, otolaryngology, and interventional radiology diagnosis, planning, and treatment because it displays images in all three dimensions without superimposition in sparse sections.

Hence, this study was designed to review the NPC with CBCT with a view to understanding the primary importance of the architectural and semantic attributes of the NPC that are altered due to age, sex, ethnicity, tooth loss, and trauma (Lake at el., 2018), to aid in the diagnosis and treatment of pathologies and reconstructive surgeries involving the midface region, including dental implants.

MATERIALS AND METHODS

This inquiry was organised in the Department of Oral Medicine and Radiology, JSS Dental College and Hospital, India. Subjects between the ages of 18 and 70 who visited the outpatient clinic, met the inclusion criteria, and volunteered to participate in the study by providing written consent were chosen. The inquiry was executed in complete compliance with the Declaration of Helsinki. The inquiry was validated by the Institutional Ethical Committee, with research protocol number JSSDCH IEC 29/2020.

The sample size was estimated using SPSS software version 20 for hypothesis testing. The sample size derived was 54, with 27 males and 27 females, assuming a 97% confidence interval and 90% power by employing the credo

$$n = (z^2)\, P(1\text{-}P) / d^2,$$

in which n stands for sample size, z for the statistic indicating degree of confidence, P for the anticipated prevalence, and d for the permitted error. Despite the fact that this formula assumes P and d to be decimal numbers, it would be still accurate if they were percentages, with the exception that the phrase (1-P) in the numerator would change to (100-P). The sample size was then rounded to 60, with 30 males and 30 females, anticipating a 10% allowable error. A difference of 1.92 with pooled Standard Deviance was assumed.

Individuals between the age groups of 18 and 70 years without any morbidities, possessing both intact maxillary central incisors, and who are undergoing CBCT (PlanmecaPromexis 3D Mid, Planmeca Oy, Helsinki, Finland) evaluation for any mandibular arch pathologies, pre- and post-treatment assessment for the placement of mandibular implants, evaluation of TMJ disorders, and computation for orthognathic surgery on the mandible were encompassed in the study.

Subjects with a previous history or radiographic evidence of surgical implants of the maxilla, orthodontic treatment, dental implants, trauma and surgery, cysts, tumours, and central lesions in the premaxilla, peri-apical cysts, and maxillary cen-

tral incisor apicoectomies after root canal treatment were precluded from the study.

Diagnostic CBCT Axial, Coronal, and Sagittal Section Images of the Anterior Maxilla, Nasopalatine Canal, and Hard Palate without any artefacts related to inherent, subject, or exposure were designated for the study.

The corporeal characters of the NPC were appraised using the axial, coronal, and sagittal sections of CBCT independently by two experienced oral and maxillofacial radiologists twice, at an interval of 2 weeks to avoid inter- and intra-examiner variability, and the average was considered.

In the axial view, the Incisive Foramen (IF) and Stensen Foramen (SF) were located, and their longitudinal and transverse diameters were measured. The Labial Bone Thickness (LBT) of the maxillary bone antecedent to the NPC at both IF and SF levels was gauged with the transverse diameter as the yardstick. The end points of the transverse diameter line were designated as points A and C, whereas the midpoint of the diameter was designated as point B. LBT was calculated from points A, B, and C on the labial bone plate.

In the case of multiple foramina, the dominant foramen was used for study. If two or more foramina were present, then the average of their individual diameters was considered.

In the coronal section, variations in the canal morphology, such as single canals, two parallel canals, or Y-shaped canals with variants, were appreciated (Bornstein et al., 2011). Given the nature of bilateral superior terminations and the single end point at the Incisive Foramen, the canal has a characteristic Y or V shape (Lake et al., 2018).

In the sagittal view, the configuration of the NPC was assessed and segregated as Cylindrical (labial and palatal parts are parallel) or Funnel (increased anteroposterior dimension at one end), Hourglass (the antero-posterior dimension is the smallest near the centre) and Spindle (the antero-posterior dimension is the widest at the centre). The transverse dimensionality of the IF, SF, and midlevel of the NPC were calculated. (Etoz and Sisman, 2014; Safi et al., 2017).

The Labial Bone Width (LBW) from the Naso Palatine Canal to the Labial Cortical plate was measured at IF, midlevel, and SF level. This provides the dimension of the labial antecedent bone to the NPC. The Labial Bone Length (LBL) was calculated by tracing the corresponding lines from the NPC that estimated the LBW to the cortical bone at the IF and SF levels. The distance between the two foramina along a line originating from the midpoint of the transverse dimensionality of the Stensen foramen to the midpoint of the transverse dimensionality of the Incisive foramen gave the length of NPC. In the case of the curved NPC, the length was measured in two parts: from one end to the middle part and from there to the other end.

The angulation of the NPC to the horizontal palatine bone gave the inclination of the NPC and was measured in degrees.

RESULTS

The study sample comprised of 30 males and 30 females (Fig. 1), who were classified into 6 age groups (Fig. 2) (Table 1), and the CBCT images of NPC in Axial, Coronal, and Sagittal planes were analysed.

Table 1. Age wise distribution of the study sample.

Age group	Males	Females	Total
11-20	4(13.2%)	3(10%)	7(11.7%)
21-30	8(26.7%)	8(26.7%)	16(26.7%)
31-40	8(26.7%)	7(23.3%)	15(25%)
41-50	5(16.7%)	5(16.7%)	10(16.7%)
51-60	3(10%)	7(23.3%)	10(16.7%)
61-70	2(6.7%)	0	2(3.2%)

The IF and SF of the NPC were located in the Axial view and their longitudinal and transverse dimensions were appraised (Table 2) (Figs. 3, 4).

Table 2. Transverse and longitudinal dimensions of the IF and SF.

Dimensions	Males	Females
Transverse diameter IF	3.57+/-1.07 mm	3.17+/-0.8 mm
Longitudinal diameter IF	3.07+/-0.94 mm	2.97+/-0.8 mm
Transverse diameter SF	3.40 +/-1.27mm	3.33+/-1.24 mm
Longitudinal diameter SF	2.83 +/-0.93mm	2.63+/-0.76 mm

(IF = Incisive foramen, SF = Stensen foramen)

Fig. 1.- Study Sample Size (Blue= Males, Orange= Females).

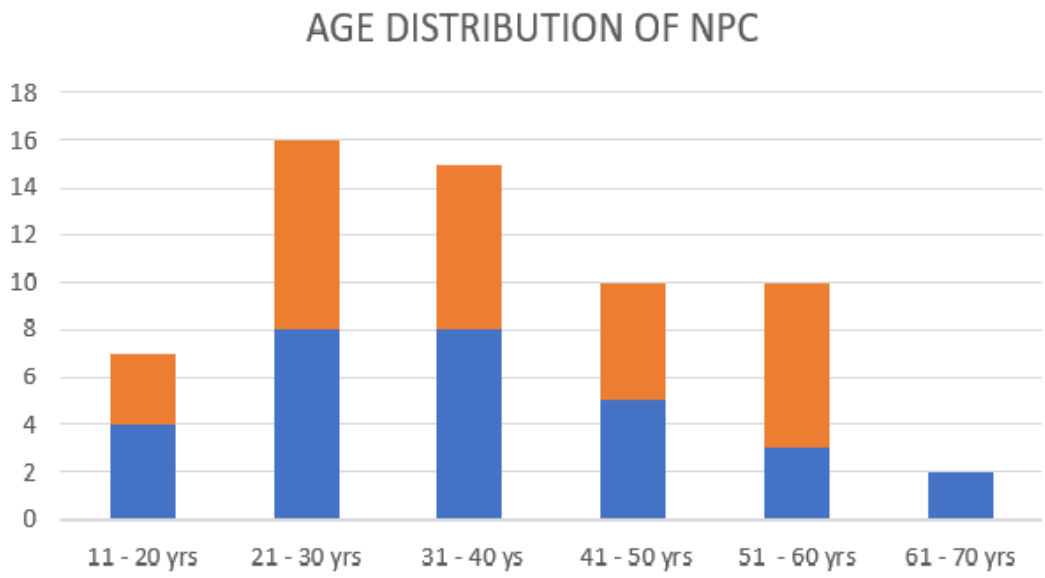

Fig. 2.- Age wise distribution of study sample.

The Labial Bone Thickness antecedent to the NPC at the IF level (Table 3) and at the SF level (Table 4) were tabulated.

In the Coronal section, the diverse morphological presentation of NPC as Single, Parallel, and Y-shaped canal was along these lines (Table 5) (Figs. 5, 6).

Table 3. Labial bone thickness in relation to IF in males and females.

LBT (IF)	Males	Females
Level A	8.00+/-1.46 mm	7.40+/-1.27 mm
Level B	8.30 +/-1.36mm	7.67 +/-1.21mm
Level C	8.07+/-1.48 mm	7.53 +/-1.43mm

(IF = Incisive foramen)

Fig. 3.- CBCT image of the Incisive foramen (**A** = Incisive foramen, **B** = Longitudinal and Transverse Diameters of IF, **C** = Labial Bone Thickness in relation to IF).

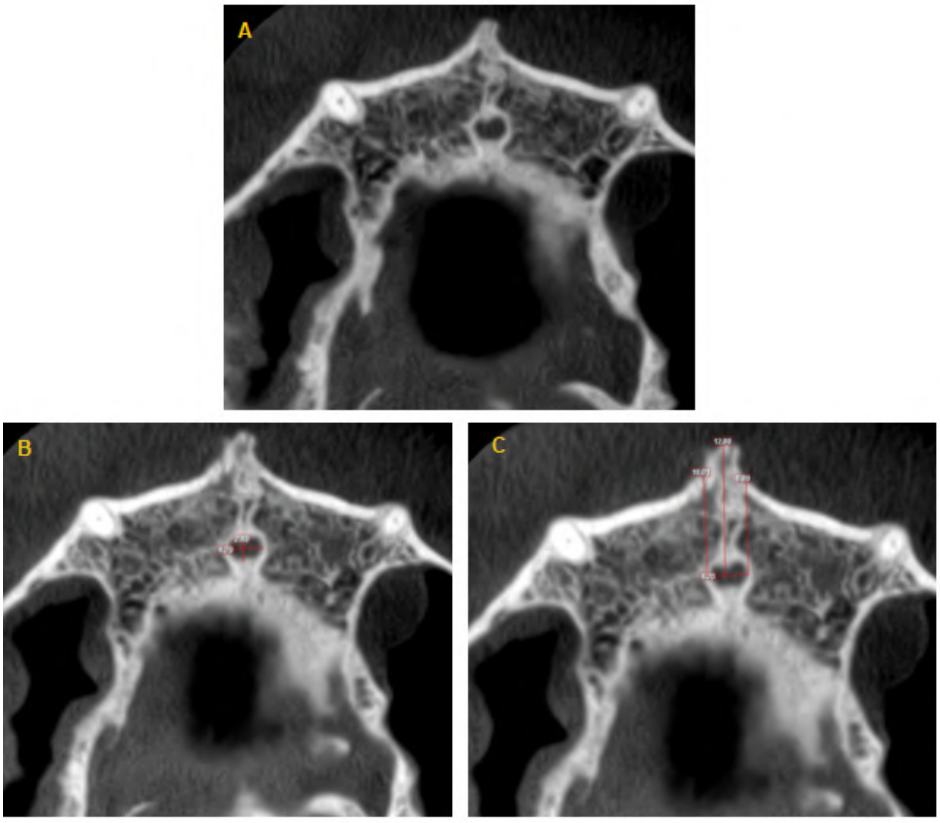

Fig. 4.- CBCT images of the Stensen foramen (**A** = Stensen foramen, **B** = Longitudinal and Transverse diameters of SF, **C** = Labial Bone Thickness in relation to SF).

Table 4. Labial Bone Thickness in relation to SF in males and females.

LBT (SF)	Males	Females
Level A	7.93+/-2.08 mm	7.07+/-1.81 mm
Level B	8.73 +/-1.63 mm	8.20 +/-1.91 mm
Level C	8.23+/-1.83 mm	7.63+/-1.92 mm

(SF = Stensen foramen)

Table 5. Morphology of NPC in coronal plane.

Morphology (Coronal)	Males	Females	Total
Parallel	2 (6.67%)	2 (6.67%)	4 (6.67%)
Single	25 (83.33%)	25 (83.33%)	50 (83.33%)
Y Type	3 (10%)	3 (10%)	6 (10%)

(NPC = Nasopalatine canal)

In the Sagittal plane, the variegated presentation of NPC was tabulated as Cylindrical, Funnel, Hour glass, and Spindle shaped. (Table 6) (Figs. 7, 8).

The Morphometric dimensions of NPC like Length, Transverse diameter at different strata, angulation of NPC to the palate, and the configuration of Labial bone width were systemized. (Table 7) (Fig. 9).

DISCUSSION

The motive of the current inquiry was primarily to analyse the anatomical constitution and the morphometric proportions of the NPC with the high-calibre imaging technique, CBCT, to contemplate the outcome of age and sexual role on the NPC. Excellent knowhow about the NPC is required to plan surgical techniques in the treatment of maxillofacial trauma for the therapeutics of various pathologies in order to avoid neural damage due to inadvertent administration of local anaesthetics, and to recognise neural damage that may occur as a sequel to maxillofacial trauma.

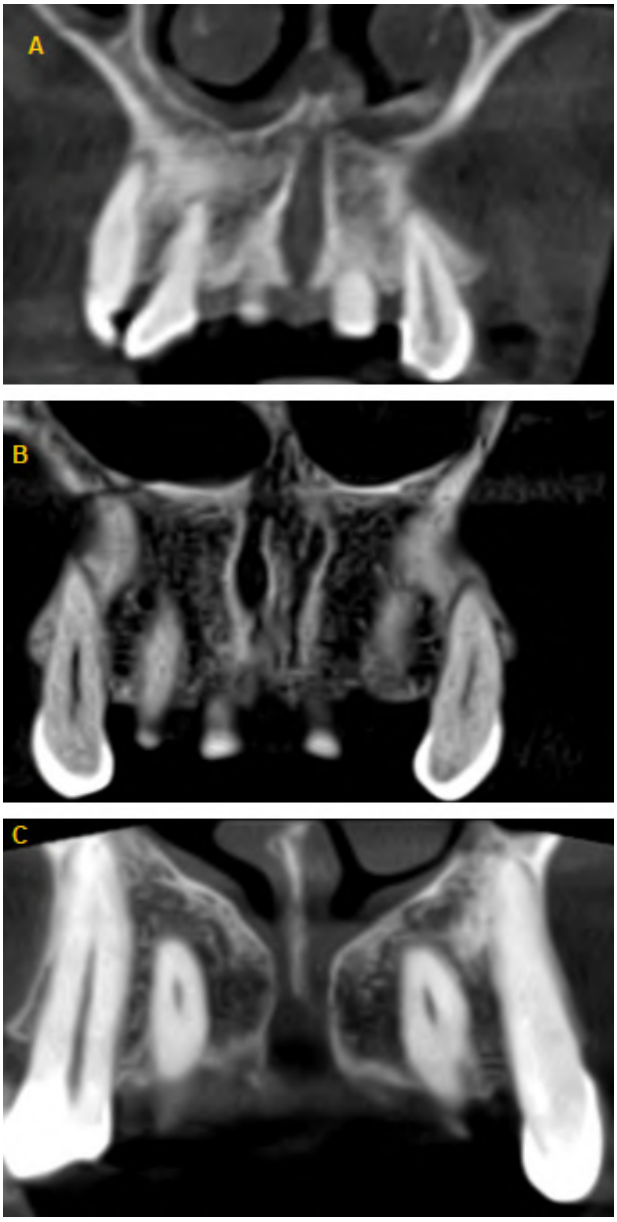

Fig. 5.- CBCT images of NPC in coronal section (**A** = Single canal, **B** = Parallel canals, **C** = Y shaped canal).

The study group comprised 60 subjects aged between 10 and 70 years. The greater proportion of the subjects in the study were in their 2nd to 4th decades of life, owing to increased awareness of dental health, access to the modern amenities of dental practice, increased ventures into appre-

Table 6. Morphology of NPC in sagittal plane.

Morphology (Sagittal)	Males	Females	Total
Cylindrical	8 (26.67%)	11(36.67%)	19 (31.67%)
Funnel	14 (46.67%)	9 (30%)	23 (38.33%)
Hour glass	6 (20%)	6 (20%)	12 (20%)
Spindle	2 (6.67%)	4 (13.33%)	6 (10%)

(NPC = Nasopalatine canal)

Table 7. Dimensions of different parameters of NPC in Sagittal sections in males and females.

Morphology Sagittal	Males	Females
Labial Bone WidthL1	6.7 mm	6.27 mm
Labial Bone Width L2	6.93 mm	6.03 mm
Labial Bone Width L3	7.80 mm	6.93 mm
Labial Bone Length	10.57+/-2.7 mm	8.57+/-2.73 mm
NPC Length	13.87+/-6.5 mm	9.5+/-2.1 mm
Transverse Diameter Level A	3.27+/-0.94 mm	2.67+/-0.82 mm
Transverse Diameter Level B	2.67+/-1.02 mm	2.50+/-0.77 mm
Transverse Diameter Level C	2.93+/-1.08 mm	2.50+/-0.9 mm
Angulation of NPC	119+/-9°	154.43+/-21.3°

(NPC = Nasopalatine canal)

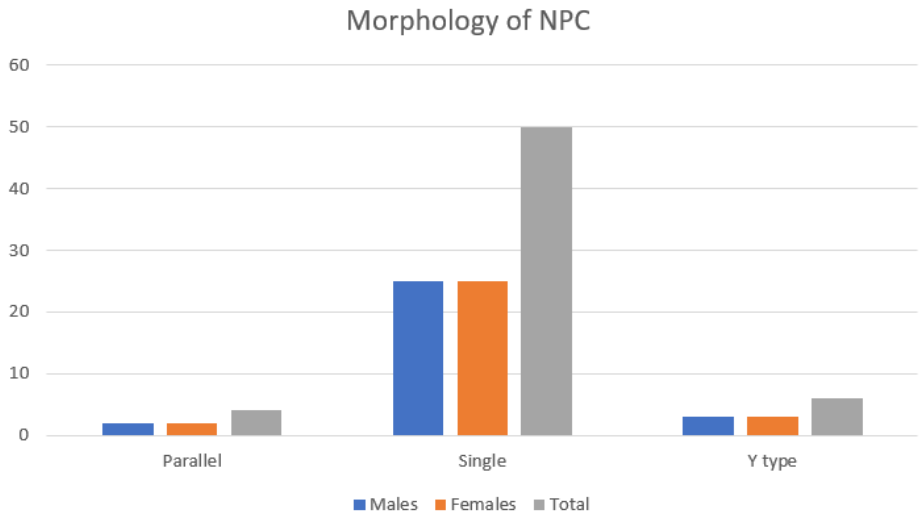

Fig. 6.- Morphology of NPC in Coronal plane.

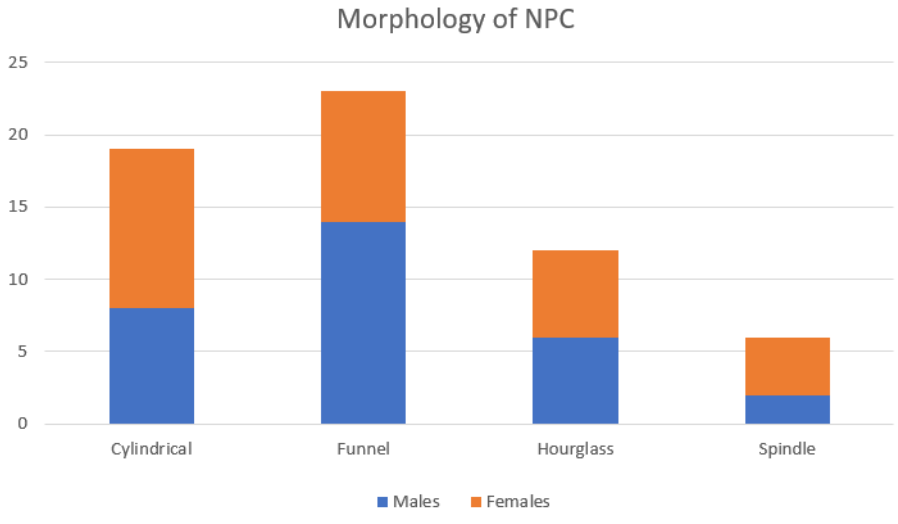

Fig. 7.- Morphology of NPC in Sagittal plane.

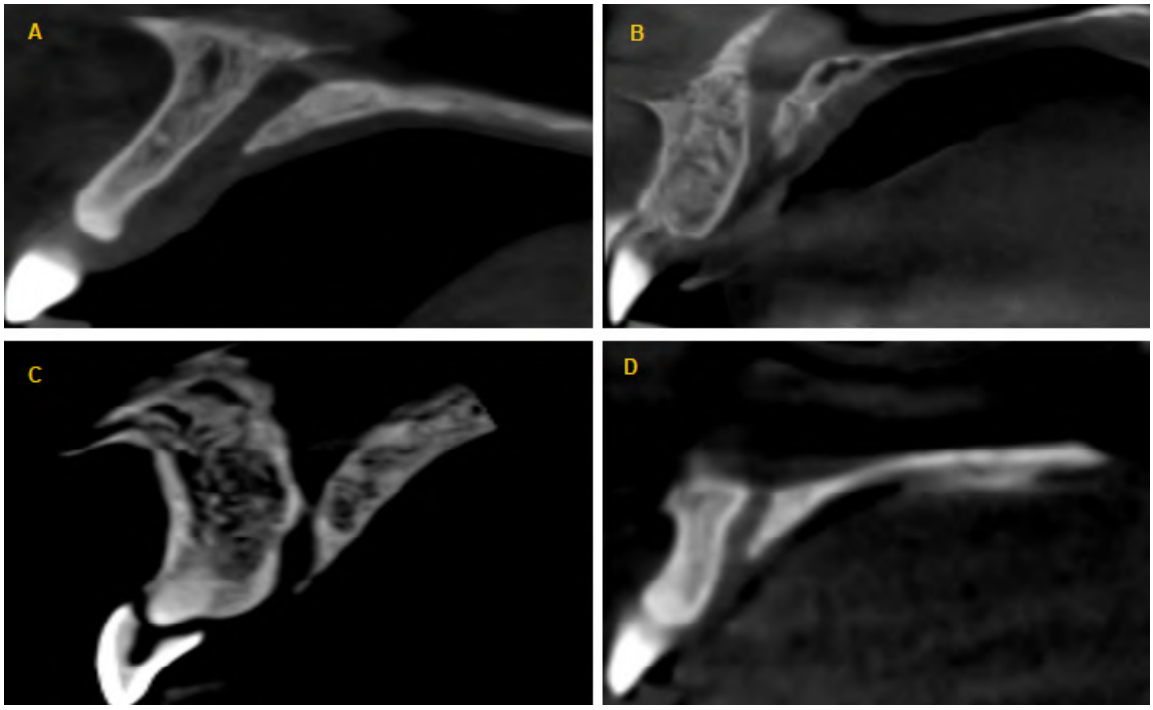

Fig. 8.- CBCT Images of NPC configuration in Sagittal section. (**A** = Cylindrical canal, **B** = Funnel canal, **C** = Hour glass canal, **D** = Spindle canal).

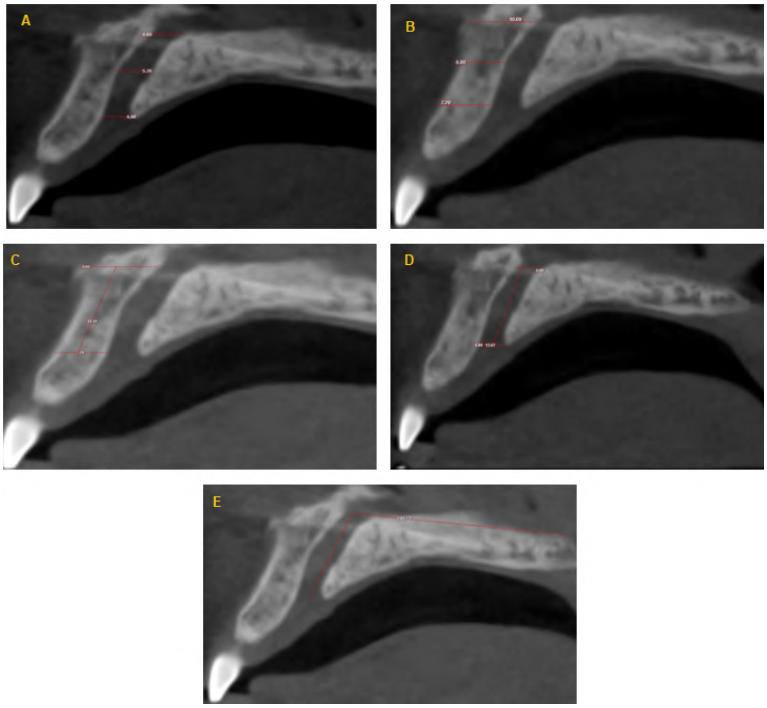

Fig. 9.- CBCT Images of NPC dimensionality in Sagittal section (**A** = Transverse diameter at 3 levels, **B** = Labial Bone Width, **C** = Labial Bone Length, **D** = NPC length, **E** = Angulation of NPC to the hard palate).

ciable aesthetics, phonetics, and functional demands, and an increased willingness to voluntarily participate in the study. This was analogous to the survey performed by Rai et al. (2021), where most of the participants were in the age category of 11 to 30 years, and in the research of Friedreich et al. (2015), where the age demographic of most of the participants was 20 to 29 years old.

The corporeal attributes of the NPC were then contrived on the diagnostic Axial, Coronal, and Sagittal slices of the CBCT images, and were subjected to the following arbitrations:

Axial Section

IF & SF dimension

Males had a transverse IF diameter of 3.57 +/- 1.07 mm, whereas females had a transverse IF diameter of 3.17 +/-1.87 mm in the axial pictures. Males had an IF longitudinal dimension of 3.07 +/- 0.94 mm, while females had a dimension of 2.97 +/- 0.80 mm. Males transverse SF diameters were 3.33+/-1.24 mm and female were 3.40+/-1.27 mm. Male longitudinal SF diameters were 2.83 +/- 0.91 mm, and female were 2.63 +/- 0.76 mm. Comparable values were obtained by Rai et al. (2021), where the mean transverse diameter of IF in males was 3.24 +/-1.03 mm and in females 3.22 +/-0.97 mm. The average longitudinal dimension of IF in males was 3.21 +/- 1.03 mm and 2.83 +/- 0.85 mm in females.

In a discrete analysis by Milanovic et al., (2021), it was noticed that the mean transverse diameter of IF was 3.53 +/- 0.11 mm. In an analysis by Soumya et al. (2019) , the measured transverse diameter of IF in males was 3.25 +/-1.05 mm and in females 3.21 +/-0.92 mm. The longitudinal dimension of IF and both the transverse and longitudinal dimensions of SF were not estimated in these studies.

Apart from the transverse and longitudinal dimensions of the Stensen foramen, there was no statistically significant distinction between the genders and age groups in this study in accordance with the one-way ANOVA test.

These observations are ornately expounded in this study. Despite a vast expanse of literature about CBCT studies on NPC, only this study made a forthright attempt at an appraisal of SF and IF dimensions other than the survey by Rai et al., (2021) where only IF was considered.

Labial Bone Thickness (LBT)

The Labial Bone Thickness was calculated with respect to IF at these 3 points, and the observed values were: 8.0+/-1.46 mm and 7.4+/-1.47 mm at Point A; 8.3+/-1.36 mm and 7.67+/-1.21 mm at Point B; and 8.07+/-1.48 mm and 7.53+/-1.43 mm at Point C in males and females, respectively.

Males and females had labial bone thicknesses of 7.93+/-2.08 mm and 7.07+/-1.81 mm at Point A, 8.73+/-1.63 mm and 8.20+/-1.91 mm at Point B, and 8.23+/-1.83 mm and 7.63+/-1.92 mm at Point C.

These various parameters, which have been appraised in this study, could not be compared with other studies, as none of them are as exhaustive as this study. This study brings to the fore the need for more detailed studies regarding the varying parameters of this one.

Coronal Section

Morphology

The morphology of the NPC was studied and categorised based on Bornstein et al. (2011) who classified them as type A, which has a single canal; type B, which has two parallel canals; and type C, which has variations of the Y type of canal with one oral opening (the Incisive foramen) and two or more nasal openings (the Stensen foramina).

In this study, a single canal of NPC (type A) was widely noted in 50 (83.33%) subjects, followed by a Y-shaped type (type C) in 6 (10%) and a parallel canal (type B) in 4 (6.67%). The most common were a single Stensen foramen and an incisive foramen, followed by two Stensen foramina and one incisive foramen. The parallel type with two Stensen foramina and incisive foramina was the least common finding.

In an analysis guided by Rai et al. (2021), single canals were common (83.2%), followed by parallel (16.4%) and Y-shaped (0.4%). In analogy, the NPC study by Kajan et al. (2015) opined that single-canal (81.8%) was more common than parallel (9.1%) and Y-shaped (9.1%). In the study by Thakur et al. (2013), a single canal was seen in 94.3% of the subjects, followed by a parallel canal in 4.9% and a Y-shaped canal in 0.8%. In a separate survey conducted by Jayasinghe et al. (2020), mainly patients had single canal (48%) or parallel canal (46%), whereas only a small percentage of patients (6%) had Y-shaped canal.

The current study aligns with the above-stated studies in apropos of the presentation of the NPC type in the coronal section.

Interestingly, the analysis by Bahsi et al. (2019) revealed that 63.3% had Y-shaped canals, 39.34% had single canals, and 8.19% had parallel canals. In the study conducted by Khojastepour et al. (2017), Y-shaped canals were marginally more common (47.9%) when compared to single canals (45%), and the least common type were parallel canals (7.1%) in males. Similarly, in females, the most common type of NPC in coronal section was Y-shaped (45.3%), followed by single canal (42.2%) and parallel canal (12.4%). Rao et al. (2018) in their research opined that Y-shaped was the most common (46%), ensued by single (43%) and parallel (11%). According to Jain et al. (2017), the predominant variant was the Y-shaped canal (49.38%).

It can be circumspectly concluded that the morphological characteristics are multifactorial, the result of inter-racial and socio-economic status, and also due to effective methodology.

Sagittal Section

Morphology

The sagittal slices were used to study the morphometrics of the NPC. In 2014, Falci et al. (2013) divided NPC morphologies into six categories: tree branch, cylindrical, banana-like, funnel-like, cone-like, and hourglass-shaped shapes.

The current study found that the most prevalent kind of NPC was funnel-shaped, with 23 (38.33%), followed by cylindrical 19 (31.67%), then hourglass 12 (20%), and spindle 6 (10%).

The outcomes of this study corresponded with the investigation by Rai et al. (2021), which found that NPC with a funnel shape predominated (38.4%), followed by cylinder (38%), hourglass (19.6%), and spindle (4%). This study is also in accordance with other studies: in Milanovic et al. (2021) it was revealed that the funnel shape (35.4%) was the most prevalent forms of NPC, followed by cylindrical (31.0%), hourglass (24.8%), and banana (8.8%) shapes; and in the analysis by Arnaut et al., (2021) the NPC form with the highest representation was the funnel (34.59%), followed by the cylinder (28.57%) and hourglass (24.81%), with only 12.03% of respondents belonged to the banana type; and also in the study done by Thakur et al. (2013) funnel-shaped (38.4%) NPC was most common followed by cylindrical (38.0%) hourglass (19.6%) followed by spindle shaped.

The present study is in fragmentary concord with the analysis done by Jayasinghe et al. (2020): funnel-shaped NPC (38%) were more common, followed by hourglass (26%), spindle (20%), and cylindrical (18%) variants of NPC.

On the contrary, Bahsi et al. (2019) concluded that the cylindrical shape of NPC was more common (26.7%), followed by the hourglass (26.7%), banana (16%), cone-shaped (14.7%), funnel (13.3%), and reverse cone (0.7%). In the survey conducted by Soumya et al. (2019), cylindrical canals were most prevalent, followed by hourglass-, funnel-, and banana-shaped canals. On CBCT pictures of 230 patients, Fernandez-Alonso et al. (2015) identified NPC as 48.2% cylindrical, 30.9% hourglass, 20.5% funnel, and 0.4% banana-like.

Utilizing the Chi square test, it was found that there was no statistically significant difference between the various morphological types in sagittal view among the various age groups, as well as between the sexes with a P value > 0.05. Similarly, Rai et al. (2021) and Jayasinghe et al. (2020) showed no statistical difference with respect to the configuration between different age groups and genders.

The present study is comparable to the preponderance of the studies, except for the studies done by Soumya et al. (2019), Bahsi et al. (2019) and Fernandez-Alonso et al. (2015), which were conducted on Asian, Turkish, and Hispanic populations. Across the literature, evidence both supports and refutes sex differences in the morphometry of NPC (Lake et al., 2018). This disparity warrants for further in-depth research and the systematisation of methodology and protocol in the interpretation of NPC.

Labial Bone Width (LBW)

In this study, mean Labial Bone Width at Level 1 (L1) was **6.70 mm** and **6.27 mm, 6.93 mm** and **6.03 mm** at Level 2 (L2), and at Level 3 (L3) it was **7.80 mm** and **6.93 mm** in males and females, respectively. The labial bone width is a cardinal determining factor in the successful restoration

of the osseous integrity of the maxilla (Lake et al., 2018). The elaborate scrutiny of this study in this aspect at different levels revealed increased width in males as compared with females. In terms of statistics, males had labial bone widths (L2) that were substantially higher than those of females.

In similarity, the study by Bornstein et al. (2011) revealed labial bone width at L1 was **7.12 mm** and **6.01 mm**, **7.26 mm** and **6.05 mm** at L2, and at L3 it was **8.09 mm** and **7.21 mm** in males and females, respectively. The parameter of LBW at L2, which was statistically significant in this study, was in line with the statistically significant parameter of LBW at L2 in the scrutiny conducted by Bornstein et al. (2011), who also had a statistically significant parameter of LBW at the L1 level.

In comparison, a study done by Milanovic et al. (2021) assessed the labial bone width as **7.11 +/- 0.03 mm, 7.52 +/- 0.17 mm,** and **9.22 +/- 0.25 mm** at L1, L2, and L3, respectively. According to Kajan et al. (2015) the average labial bone width was **5.96 +/- 1.5 mm** at Level 1**, 6.82 +/- 1.6 mm** at Level 2, and **6.23 +/- 2.1 mm** at Level 3.

In consensus with this study, the evaluation of NPC conducted by Acar et al. (2015) the LBW was **6.74 mm** and **6.24 mm** at L1; **6.57 mm** and **6.04 mm** at L2; and, **7.21 mm** and **6.53 mm** at L3 level in males and females, respectively.

Khojastepour et al. (2017) measured only the labial bone width in males and females at (L1) 7.36 +/- 1.45 mm and 6.78 +/-1.27 mm, and at (L3) 8.45 +/-2.24 mm and 8.52 +/-2.03 mm, respectively. Albeit, L2 bone width was not prepended, their assessment at L1 and L3 level was analogous to this study.

Only LBW at L2 was measured by Jain et al. (2017) and found to be 5.71 +/- 1.29 mm. LBW at the other two levels was not measured in that study, but nonetheless it was comparable to the L2 dimension of this study. The labial bone width at the level of L1 was only determined to be 6.50 +/-1.52 mm by Soumya et al. (2019) and was comparable with this study. This assessment was done irrespective of the gender of the subjects, and a mean value was expressed.

Dissimilitude in the LBW at different strata can be ascribed to diversification in the shape of the NPC amid different studies. The decorous study of the NPC and its relevance to labial bone width is of utmost importance at Level 2, as any deficit of the bone at that level may hamper the surgical planning and surgical intervention of implant placement. Additional scientific analysis is asked for in this aspect at all three levels, explicitly at the L2 level.

Labial Bone Length (LBL)

In this study, the average labial bone length was 10.57 +/- 2.7 mm in males and 8.57 +/- 2.73 mm in females. The difference was statistically significant ($p < 0.05$), despite certitude that males have structurally longer labial bone length than females.

This parameter was not considered in other studies except by Jain et al. (2017), where it was **17.72 mm** in males and **16.68 mm** in females. The difference in labial bone length for males and females, which is considerably greater compared to this study, can be ascribed to gender specific disparities in facial architecture. The length is salient in apposition to implant emplacement. Exemplary scientific viewpoint regarding the measurement in this aspect of study is preordained.

NPC Length

The average length of the NPC in males was **13.87+/-6.5 mm** and **9.5+/-2.1 mm** in females in this study. There was no statistically significant distinction between the length of the canal in males and females, even though the mean length of the NPC was longer in males.

This was akin to the study done by Rai et al. (2021), where the average linear measure of NPC was in males: **13.60 +/- 2.62 mm** and in females: **11.69 +/- 2.41 mm**. This was closer to the analyses by Jayasinghe et al. (2020), where the average length in males was **13.49 mm** and in females, **10.98 mm,** and by Bahsi et al. (2019), where the average linear measure of NPC noted in men was **12.96 +/- 2.57 mm** and **12.16 +/- 2.45 mm** in women. It was Acar et al. (2015) who, on measuring the length of NPC, found it in males to be **10.20 mm** and in females to be **9.04 mm** on average. In

the Khojastepour et al. (2017) study of NPC, the length in males was higher **(11.46 +/- 2.86 mm)** than in females **(9.37 +/- 2.24 mm)**.

Just a modest body of research, regardless of gender differences, has measured the overall length of NPC. The average NPC length, irrespective of gender difference, in this study was **11.68 +/- 4.30 mm,** which corresponds to hereunder studies. NPC research by Fernandez-Alonso et al. (2015) derived an average length of NPC of **12.28 +/- 2.98 mm**; in the study by Thakur et al. (2013), the average linear measure of NPC was found to be **10.08 +/- 2.25 mm**; and in the scrutiny of NPC by Milanovic et al. (2021), **10.26 mm** was the average length of NPC. Similarly, the average length of NPC in the study by Rao et al. (2018) was 10.32 +/- 2.70 mm, compared to 11.13 +/-3.23 mm in the study by Jain et al. (2017) and 9.9 +/- 2.6 mm in the study by Liang et al. (2009). The study by Arnaut et al. (2021) showed a mean length of **10 mm** with a wide scope of **8-16 mm,** and it was **16.33 mm** in the study by Almery et al. (2015), with the right canal being somewhat longer than the left canal. Additionally, the length of the NPC also varies based on the height of the maxillary bone (Lake et al., 2018).

The results of this study are consistent with the majority of earlier investigations. Despite racial disparities and tooth presence or absence, the measurement method may have a substantial role in the variability in canal length among studies.

Transverse Diameter of NPC

Depending upon the NPC morphology in the sagittal slices, this study implied that there were notable variations in the size of NPC at IF, SF, and mid-level. The mean transverse diameter of NPC at IF level (Level A) was **3.27+/-0.94 mm** and **2.67+/-0.82 mm**; at mid-level (Level B) was **2.67+/-1.02 mm** and **2.5+/-0.77 mm;** and at SF level (Level C) was **2.93+/-1.08 mm** and **2.5+/-0.9 mm** in men and women, respectively. Using the one-way ANOVA test, all metrics with p values > 0.05 showed no evidence of a significant difference between age and gender groups, with the exception of level C diameter in sagittal view.

Similitude was noted in the analysis by Thakur et al. (2013), where the average transverse diameters at Level A, Level B, and Level C were **3.15 mm, 2.32 mm,** and **2.86 mm,** respectively, and by Jayasinghe et al. (2020) the mean transverse diameter of NPC at Level A was **3.03 mm**, at Level B **2.37 mm,** and at Level C **2.85 mm**, respectively.

Analogous results were obtained in an analysis by Rai et al. (2021), where the transverse diameter at Level A was **3.61+/-1.17 mm** and **3.31+/-1.06 mm**, **2.34+/-1.04 mm** and **2.12+/-0.99 mm** at Level B, and at Level C it was **3.35+/-1.86 mm** and **3.18+/-1.62 mm** in males and females, respectively.

Kajan et al. (2015) computed the NPC at all three levels and proffer the results as **3.53 +/- 1.1 mm**, **2.35 +/- 1.1 mm**, and **3.8 +/- 2.3 mm,** respectively.

A plethora of studies have estimated the dimensions only at Level A and C, and the measurements are akin to the dimensions **3.27 +/- 94 mm** and **2.67 +/- 0.82 mm** for males and **2.93 +/-1.08 mm** and **2.5 +/- 0.9 mm** for females, respectively, estimated in this study.

A study by Khojastepour et al. (2017) revealed that the mean diameter of NPC was 3.40 +/-1.08 **mm** and **2.97 +/- 0.91 mm** at Level A and **3.39 +/- 1.55 mm** and **2.98 +/- 1.45 mm** at Level C in males and females, respectively. In an analysis by Acar et al. (2015), it was found that the average diameter at Level A was **4.14 mm** in men and **3.72 mm** in women. The average diameter at Level C in men was **3.12 mm** and **3.03 mm** in women. Bornstein et al. (2011) also determined that the mean transverse dimension of NPC at Level A was **4.45 mm** and **4.38 mm** and **3.65 mm** and **3.37 mm** at Level C in males and females, respectively. Jain et al. (2017) enunciated the average transverse diameter of NPC at Level A and Level C to be **4.53 mm** and **3.98 mm;** also **3.63 mm** and **3.19 mm** in men and women, respectively.

In the scrutiny by Milanovic et al. (2021), the average transverse diameter of the NPC at Level A was **5.04 +/- 0.12 mm** and at Level C, **2.93 +/- 0.01 mm,** and in the Bahsi et al. (2019) study, the transverse diameter of the NPC at Level A was **6.71 +/- 1.50 mm** in men and **6.23 +/-1.28 mm** in women, and at Level C, **4.25 +/-1.15 mm** in men and **4.01 +/-0.99 mm** in women. The transverse dimension of the NPC at level B was not contemplated in some of these studies.

Soumya et al. (2019), with their scrutiny of the transverse dimension of NPC only at Level A, inferred the computation as **3.23 +/- 0.89 mm** in men and **2.99 +/- 1.0 mm** in women. This finding is in accordance with the measurements of this study.

Morphological differences in NPC and racial differences in facial structure are important factors contributing to measurement variation between males and females at different levels. However, these measurements obtained in this study match the preponderance of other studies. However, the disparity with other studies may be epithetical to the morphological disparity in NPC along with the genealogical contrast in facial architecture amid different genders at different strata. It also appears that the diameter increases in pathologies that results in structural deficits of the maxilla such as, trauma, cyst formation and tooth loss (Lake et al., 2018).

Angulation of NPC to hard palate

The average angulation of NPC with respect to the hard palate noted in this study was **119+/-9.0 degrees** in males and **154.43+/-21.3 degrees** in females. The average orientation in females is greater than the average inclination in males, so statistically there is absolutely no dissimilarity between men and women.

This was in comparison to the study done by Jayasinghe et al. (2020), where the mean inclination of the NPC was **115.69 degrees,** and women had a greater mean inclination **(117.43 degrees)** than men (**113.67 degrees),** but it was not statistically significant.

Similarly, in the syudy by Bahsi et al. (2019), the NPC angle in males was 105.45 +/- 7.72 degrees and in females it was 105.98 +/- 7.77 degrees, with no statistically significant difference.

Similarly, in the study done by Rai et al. (2021), the inclination was **77.04 +/- 44.05 degrees** in males and **87.15 +/- 39.67 degrees** in females.

In the study done by Thakur et al. (2013), the incline angle was **63 +/-8.03 degrees** with respect to the horizontal flush hard palate plane, heedless of the gender of the sample subjects.

The NPC angulation noted in the study by Jain et al. (2017) was **67.98 degrees** in females and **73.45 degrees** in males, with an average of **69.32 +/- 7.70 degrees.**

Various researchers have employed different anatomical landmarks to arrive at the angulation of the NPC with respect to the hard palate. Complementary values of angular measurements were noticed when the anterior nasal spine or posterior nasal spine were used by the researchers. The contradictory findings pertaining to the angulation of NPC in the studies emphasise the requirement of a standard protocol for the adoption of a particular anatomical landmark (the anterior or posterior nasal spine) as a basis for measuring the angulation.

This study made an attempt at sequencing the definition of the various parameters in the analysis of NPC, elaborated on the importance of NPC and its complex anatomy in the anterior maxilla, and emphasised the chartering a protocol for the same.

In tour d'horizon, the study's findings suggest that the investigation of topographic details, obtained with a precise approach, offers useful insight into the different relationships between the NPC and the anterior maxilla structures. The consistency of the observed interpretations of labial bone width, labial bone length, transverse diameter of the NPC, and angulation of the NPC might be appropriate as a preliminary evaluation to understand the primary importance of the architectural and semantic attributes of the Nasopalatine canal to aid in the diagnosis and treatment of pathologies and reconstructive surgeries involving the midfacial region, including dental implants, particularly for surgeons using an expeditious approach. This three-dimensional surveillance of NPC for its anatomical interpretation and acreage facilitates the discernment while planning complex surgeries in the anterior maxilla and hence circumvents untoward complications and necessitate for impending explicit scientific analysis of NPC with respect to genealogical, racial, dentate status, and age transition.

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