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Nasopalatine canal morphology: CBCT review & nomenclature proposal

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REVIEW ARTICLE

Variations in nasopalatine canal morphology across populations: a cone-beam computed tomography systematic review and proposed nomenclature system

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ABSTRACT

Background: The nasopalatine canal (NPC), or incisive canal, is an interosseous conduit in the premaxilla, located just behind the maxillary central incisors. Its variations must be carefully considered in dental and oral surgical procedures, especially with the higher aesthetic considerations in the premaxilla. This study aims to assess the morphology of NPC and its variations across different populations while proposing a new classification system for naming and describing the NPC.

Materials and methods: Following the PRISMA guidelines, the Population, Intervention, Comparison, Outcome format was applied to formulate the intensive question. An electronic literature search was conducted in Google Scholar by using the subsequent databases: Clarivate Analytics' or ISI Web of Science, Elsevier's Scopus, and PubMed (MEDLINE). No restriction was placed on studies after the 2013 publication year. The keywords used were NPC morphology, incisive canal morphology, incisive foramen, NPC foramen, NPC shape, incisive canal shape, incisive canal, and NPC. Outstanding full-text studies were assessed according to inclusion and exclusion criteria, and appropriate reports were nominated. The collected data were analyzed and subjected to risk of bias and quality assessment.

Results: Ten full-length papers with a total of 1697 participants are included. Among them, the cylindrical shape, slant-straight course, and single canal are the most commonly observed in both sagittal and coronal views.

Conclusions: This review highlights the significant variability in the anatomical morphology of NPC across different populations, presenting challenges in establishing a standardized classification system. In order, the current study introduces a new, adaptable naming system to be utilized in education, research, and by clinicians during the description of the NPC anatomy.

Keywords: coronal plane, dental status, foramina of stenson, incisive foramen, nasopalatine canal shape, sagittal plane

INTRODUCTION

The anatomical landmarks of the pre-maxillary region and their relationships need to be considered when preparing for dental procedures. The potential risk of complications increases with variations in anatomical landmarks and increases in surgical interventions associated with this region [6, 18]. The nasopalatine canal (NPC) or incisive canal is described as an interosseous conduit in the premaxilla, just posterior to the maxillary central incisor teeth. It connects the nasal cavity to the oral cavity with two openings: the inferiorly located incisive foramen (IF) and the superiorly located foramina of Stenson (FS) [28]. The canal transmits the incisive nerve and the terminal branch of the descending sphenopalatine artery (nasopalatine artery), accompanied by fibrous connective tissue, minor salivary glands, and fat [29]. The NPC may also carry the branches of the trigeminal nerve and maxillary artery, providing sensory innervation and blood supply to the region of the anterior palate that includes the incisor and canine teeth [14, 34].

Knowing the anatomical variations of this canal (NPC) is essential in dental and oral surgical procedures, especially with the higher esthetic considerations in the premaxilla. Notably, implant placement is often required for rehabilitation of this region, with dental implants becoming the primary treatment option [2]. The evaluation of the NPC morphology and its anatomical variations is important to avoid complications during the insertion of dental implants, such as hemorrhage, sensory dysfunction, and non-osseointegration of the implant [35, 41]. Furthermore, preoperative evaluation of the NPC is necessary for the accurate diagnosis and effective treatment plan in local anesthesia, impacted-tooth extraction, enucleation of nasopalatine duct cyst, orthognathic surgery, and prosthetic dentistry. Variations in the morphology of the NPC must be evaluated during orthodontic movement of the maxillary incisor [3, 15, 27, 33, 39, 48, 50].

Since the discovery of X-rays over a century ago, few imaging techniques have influenced dental practice as much as cone-beam computed tomography (CBCT). According to the American Academy of Oral and Maxillofacial-Radiology, CBCT is the preferred imaging modality for obtaining information, and cross-sectional imaging should be utilized to evaluate dental-implant site insertion [55]. Many previous studies have shown that 3D CBCT imaging provides reliable and accurate measurements [10], and CBCT scans are considered the gold standard for dental and craniofacial imaging [56]. Therefore, these CBCT scans can reliably enable qualitative and quantitative assessments of the NPC morphological characteristics and surrounding structures [42], which has an advantage over limited morphometric information analysis of the NPC of 2D images. It also requires a lower radiation-dose and cost than CT scans [7, 37, 38, 44].

Variations in the NPC shape have been reported in numerous studies. In the Cypriot population [21]), the most common NPC shape in the sagittal is cylindrical, whereas in the Yemeni population, it is funnel-shaped [5]. Furthermore, in the German population [22], the dominant NPC shape in the coronal is Y-shaped, whereas in Brazilians [16], the single canal is the most frequent. Notably, other populations have shown variability across different studies. For example, in the Turkish-population, the dominant NPC shape in the sagittal is hourglass [8], cylindrical [17], and funnel [23]. In the Iranian population, the dominant NPC shape in the sagittal is cylindrical [40] and hourglass in another [53]. Additionally, in Saudi Arabia, the reported funnel shape is found to be the most frequent in sagittal [30], another identified the hourglass shape [49], and the cone shape is the most commonly found [4]. Similarly, some populations report different dominant shapes in the coronal plane, such as Iranian and Turkish populations [9, 19, 40, 46]. It may be explained by environmental and gene-related factors.

Interestingly, these NPC shape variations have not yet been supported by a systematic review, especially in subjects with maxillary anterior teeth. After tooth extraction, maxillary atrophy may cause the NPC to enlarge by up to 32%, occupying approximately 58% of the width of the maxillary alveolar ridge [44]. It is worth noting that previous classification systems lack a unified coding system, fails to represent unclassified variations and canal levels, and may oversimplify NPC morphology. Accordingly, the present study aims to assess and compare published literature on NPC morphology and its variations across different populations in terms of subjects with maxillary anterior teeth, alongside proposing a new classification system for naming and describing the NPC that can be utilized in education, research, and clinical practice.

MATERIALS AND METHODS

Protocol, registry, and PICO question

This systematic review was performed following the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [6, 43], and the protocol was registered to PROSPERO (reg. no. CRD42024590108). The Population-Intervention-Comparison-Outcome (PICO) format was applied to formulate the following intensive question: “What are the shapes of the NPC at different views (Intervention) relative to the interpretation/assessment of CBCT in patients with maxillary anterior teeth among different countries/ethnicities/populations (Population) to exhibit the variations in NPC morphology or shape in all screened participants (Outcome) and compare the results among participants from different countries (Comparison)”.

Inclusion and exclusion criteria

The inclusion and eligibility criteria were as follows: clear CBCT for in vivo clinical investigations evaluating the NPC shapes at different views, participants 17 years and older, and papers that were published in English between 2013 and 2024. Studies involving patients without maxillary anterior teeth and patients with premaxillary pathology were excluded. Systematic reviews, case reports, case series, pilot studies, and studies published in languages other than English were also excluded.

Literature search

Two independent reviewers (AMA and MMA) carried out a systematic literature search using mixtures of Medical Subject Headings (MeSH) terms and free keywords together with Boolean operators (i.e., AND, OR, and NOT) with respect to the PICO question. An electronic literature search was performed in Google Scholar and achieved between September and October 2024, using the subsequent databases: Clarivate Analytics' or ISI Web of Science, PubMed (MEDLINE), and Elsevier's Scopus without a restriction to research after the 2013 publication year. A manual search was then directed by examining the bibliographies of all initially selected papers to identify published research that may have been unexploited throughout the electronic exploration. The keywords utilized were nasopalatine canal morphology, incisive canal morphology, incisive foramen, nasopalatine canal foramen, nasopalatine canal shape, incisive canal shape, incisive canal, and nasopalatine canal.

Two independent reviewers (AMA and MMA) performed a systematic literature search using mixtures of Medical Subject Headings terms and free keywords together with Boolean operators (i.e., AND, OR, and NOT) with respect to the PICO question. An electronic literature search was conducted in Google Scholar between September and October 2024 using the subsequent databases: Clarivate Analytics' or ISI Web of Science, Elsevier's Scopus, and PubMed (MEDLINE), without a restriction to studies after the 2013 publication year. A manual search was then directed by examining the bibliographies of all initially selected papers to identify published research that may have been unexploited throughout the electronic exploration. The keywords used were NPC morphology, incisive canal morphology, IF, NPC foramen, NPC shape, incisive canal shape, incisive canal, and NPC.

Study selection

After removing duplicate studies, two independent reviewers (FA and BM) checked the heading and abstract of papers in relation to the eligibility criteria. Outstanding full-text studies were assessed according to inclusion and exclusion criteria, and appropriate reports were nominated. The published papers and articles selected, as well as the confirmation procedures, went through three phases: 1) choice created on title and its relevance to NPC assessment shape in different views, 2) assortment created on abstract significance, and 3) full-text research screening. Any disagreements about the research saved by electronic and manual searches between two reviewers were settled by a third reviewer (AMH).

Data extraction and analysis

A uniform worksheet (Excel software from the Microsoft Office package) was utilized to extract data of interest from the involved papers, which were published between 2013 and 2024. The collected data were categorized into three parts and represented in two tables as follows:

The first table or part was related to the classifications of the NPC-shape at the sagittal plane. It comprised CBCT studies, which included researcher(s) name, population, publication years, and country in which the study is conducted, age of participants, sample size of CBCTs involved, shape of the NPC at this plane (sagittal) that was divided into funnel, cylindrical, hourglass, banana, cone, spindle, tree, and other (Fig. 1).

The second table was related to the classifications of the NPC direction course at the sagittal, and NPC shape at the coronal plane. It contained CBCT studies with researcher(s) name, population, publication years, study country, sample size of CBCTs recruited, direction course of the NPC at the sagittal, and NPC shape at coronal view (categorized as slant-straight, vertical-straight, slant-curved, or vertical-curve at the sagittal and single-canal, two parallel, or Y-type at the coronal Figure 2.

Quality assessment

The quality of the involved research was assessed using the Risk of Bias in Non-randomized Studies (ROBINS-I) tool, following the guidelines in the Cochrane Handbook for Systematic Reviews [51]. The overall risk of bias outcome can be categorized as low, moderate, serious, and critical risks. The same two reviewers (KM and ST) independently evaluated the quality of studies using the ROBINS-I quality assessment tools for non-randomized studies. After completing the five main domains for each study, an overall assessment of the risk of bias was determined.

CBCT setting in nomenclature

In the current study. CBCT records were conducted by two experienced technicians using a Vatech Co. PaX-i3D green device (model-PHT 60 CFO, KR). Using a 15 × 15 cm field-view, a tube voltage of 50–99 kV, and a voxel size of 0.2–0.3 mm, with a fifteen-second scanning time. Then, data was exported in (DICOM format) and analyzed using Ez3D-i software on a Dell 7720-UHD 17-inch screen. Ethical approval was obtained by the Medical Ethics Committee of Ibn-Alnafis University (19/Feb 12/2024). These records included male and female participants aged 18 to 68.

RESULTS

PRISMA study selection process

The primary search keywords yielded 1672 studies and published articles. After removing 1450 unrelated and duplicate studies and articles, the independent reviewers (AMA and MMA) read the abstracts of 222 studies to exclude ineligible studies. A total of 169 studies were excluded, and 53 studies were screened. Then, 15 studies were excluded owing to full text not retrieved (12), and 3 were systematic reviews. The remaining 38 studies were selected for full text retrieval. Further 28 studies were excluded owing to the absence of maxillary anterior teeth. Finally, 10 full length papers were included in the current review and divided into the following: 7 studies described the classification of the NPC shape at the sagittal view [16, 21, 30, 32, 36, 54, 57], 5 represented the prevalence of the NPC shape at the coronal view, [16, 26, 30, 31, 45], and 2 described the NPC shape by direction course at sagittal view [21, 54]. These studies measured the NPC parameters in relation to nations ethnics from different countries and populations. The flowchart of the literature-exploration method is shown in Figure 3.

Selected studies and their baseline characteristics

All selected studies are retrospective, cross-sectional, and analyze a CBCT of participants from different countries. The highest number of CBCT assessed in this review is 460 for a study conducted among the Indian population, [45], whereas the lowest number of examined CBCT is 90 in a study conducted in Pakistan [26]. The lowest age of the participants is 17 years for a study among the Turkish population [32], whereas the highest age is 86 years for a study conducted among Indians [54].

Prevalence of NPC morphologies

Sagittal shape

As shown in Table 1, the first part is related to the classifications of the NPC shape at the sagittal plane. It comprises CBCT studies including researcher(s) name, country, publication years, in which the study is conducted, age of participants, sample size of CBCTs involved, the shape of the NPC at this plane (sagittal) which is divided into funnel, cylindrical, hourglass, banana, cone, spindle, tree, and other as a reverse cone or reverse funnel. Cylindrical-shaped is reported as the most prevalent and recorded in five studies, ranging from 29.4% to 56.4%. For the cylindrical shape, over half of the screened CBCT for Cyprus and Brazilian populations 56.4% and 50.9% [16, 21], whereas the lowest is found among the Turkish population 29.4% [32]. Funnel-shaped is the second most common and is recorded among Saudis and Serbians, followed by Indians at 36% and 35.4% [30, 36, 54], whereas the lowest percentage is documented among Brazilians at 14.3% [16].

The hourglass and banana NPC shapes are less recorded, and the banana shape is the least common [16, 21, 30, 36]. The least prevalent NPC shape is documented as a spindle (11%), and it is found among Indians [54]. Almost similar percentages (5% and 4.5%) are recorded for a tree NPC shape among the Turkish population [32, 57].

Sagittal direction course

Table 2 represents the relation between the shape of the NPC at a sagittal direction course and coronal view. Data on the sagittal direction course are more limited and inconsistent across studies. Only two published studies document the percentage of the shape of the NPC first conducted in Cyprus, the highest at slant-straight (67.6%), followed by 19.6% at vertical-straight, whereas the lowest is 6.1% at the slant-carved [21]. Meanwhile, the second study was performed among participants from India and counted the highest percentage the slant-straight and slant-curved (51% and 45%), whereas the lowest was 1% for the vertical-curved shape [54].

Coronal shape

At the coronal view, studies indicate that a single-canal is the most common, although findings vary across regions. The percentage of a single-canal is recorded in five studies and counted as 87.8%, 72.8%, 71%, 43.04%, and 39.34% among populations from Pakistan, Brazil, Saudi Arabia, India, and Spain, respectively [16, 26, 30, 31, 45]. The two parallel shapes are recorded in four studies and are highest among Indians, but the lowest is among Saudis with 10.86% and 2% [30, 45], whereas the Y-type is documented in five studies with 52.45%, 46,08%, 27%, 19.7%, and 12.2% for Spanish, Indian, Saudis, Brazilian, and Pakistanis, respectively [16, 26, 30, 31, 45] Table 2.

Quality assessment (risk of bias)

Table 3 shows the ROBINS-I of the included studies. Seven studies revealed an overall moderate risk of bias [16, 26, 31, 32, 36, 54, 57], whereas three exhibit a serious risk [21, 30, 45]. The main shortcomings identified across studies include insufficient details on the examiner's qualifications, the lack of blinding in measurement processes, and incomplete reporting of reliability analyses. Regarding reliability analysis, seven included studies that report conducting intra- or inter-examiner reliability analysis. It is frequently displayed as a single value, range, or overall rate [16, 30–32, 36, 57]. Only one study reported the conduct of inter-rater reliability but without reliability-analysis value [26], whereas the remaining three studies did not report reliability analyses [21, 45, 54].

DISCUSSION

The present study was the first systematic review to assess the shape of NPC and its variations among different populations in terms of subjects with the presence of the maxillary anterior teeth. In the current review, the age of the participants in the selected studies is 17 years and older, as mentioned earlier the majority of skull growth and facial structure development in humans occurs by ages 15 to 16 years [11, 52]. The edentulous premaxilla is commonly selected as the optimal location for maxillary rehabilitation with dental implants, and it has become one of the most preferred restorative dentistry procedures. However, as dental implant procedures have become more common as it was reported to be associated with some dental complications, thus, clinicians must consider both the morphology of the NPC and the available bone amount when establishing a personalized treatment plan. These parameters can be addressed by using CBCT images. After tooth extractions, trauma, periodontal issues, or cyst and tumor pathology, the buccal alveolar plate in the anterior-maxilla often undergoes resorption [20]. Those lost structures may affect the success of implant placement in this region.

The size, location, and NPC contents such as the nasopalatine nerve and artery are at risk for injury during anterior maxillary surgical procedures or if a dental implant penetrates the NPC [35, 41]. Damage to the nasopalatine nerve can lead to postoperative paresthesia or pain in the palate, nasal floor mucosa, and the region of the maxillary anterior teeth [39, 58]. Furthermore, injury to the nasopalatine artery may cause intraoperative bleeding, potentially resulting in a hematoma that compresses the nasopalatine nerve, leading to further complications [39]. High rates of bone resorption in the premaxilla buccally to the NPC are frequently observed in clinical practice. Therefore, this resorption complicates optimal implant placement and can result in both functional and esthetic concerns [13]. Moreover, an enlarged NPC adds difficulty to osteotomy procedures during implant surgery. Bone ridge resorption and NPC morphology assessments are essential for successful treatment planning in dental implant procedures [20].

In the sagittal plane, studies categorize the shape into four types among populations from Cyprus, ,Serbia, and Saudi Arabia [21, 30, 36], whereas another study in India classifies the examined NPC shape into four other types at the same plane [54]. However, in a Brazilian population, they record five different shapes [16], and two studies conducted on Turkish-populations document five types or shapes of the NPC at the same plane [32, 57]. This can be explained by the different populations. Notably, this anatomical variation prevents the assumption of a standard classification of this canal in to certain types. Thus, the presence of different classifications without standardization may impact the prevalence percentage.

According to the study by Firincioglulari and Orhan [21], whose findings are similar to those of [16, 32, 54, 57], the cylindrical shape is identified as the most common morphology, with prevalence rates ranging from 29.4% to 56.4%. For the cylindrical shape, over half of the screened CBCT for Cyprus and Brazilian populations [16, 21]. The funnel shape is the second most prevalent, with the highest rates recorded among Saudi and Serbian populations with 36% and 35.4%, respectively, followed by India with 31% [30, 36, 54]. Meanwhile, the lowest percentage is documented among Brazilians (14.3%) [16]. Some studies indicate that the banana shape is the least common [16, 21, 30, 36], whereas others reported the tree [32, 57] or spindle [54] shapes as the least prevalent. These inconsistent findings may be owing to variations in classifications and diversity of ethnicity. Moreover, this finding agrees with the recent systematic review, indicating that NPC dimensions also vary among individuals from different populations [6]. Although data on sagittal direction courses are more limited, slant-straight direction courses in the sagittal plane appear more common in this review. However, a study conducted in Cyprus by Firincioglulari and Orhan [21] reports a prevalence of 6.1% for slant-curved courses, whereas Thakur et al. [54] found a much higher prevalence of 45% for slant-curved courses in India.

In the coronal plane, Khan et al. [26] reported that the single-canal is the most common anatomic variation type, with 87.8% recorded in Pakistan. The prevalence is 71% in Saudi Arabia Linjawi et al. [30] and 72.8% in Brazil de Costa et al. [16]. Conversely, studies by Rao et al. [45] in India and López Jornet. et al. [31] in Spain report the Y-type as a more common shape, with prevalence rates of 46.08% and 52.45%, respectively. Fernández-Alonso et al. [20] demonstrated that the canal shape can change owing to the divisions in the anteroposterior direction along the coronal sections. Additionally, there is the possibility of the absence of NPC and nasopalatine foramina [24]. For this reason, we recommend examining the division levels in the canal in coronal slices.

Rationale for proposing a new coding system

The introduction of a new coding system is necessary because there is currently no single NPC code that represents different levels. While previous classifications have focused on grouping NPC canals based on the type or number [12, 20], these approaches have deficiencies in describing unclassified configurations [20, 24, 47]. Additionally, studies have revealed significant morphological variations in the NPC, including an uncategorized number of canals through-canal levels [9, 22, 47, 50]. So, classification into certain types or groups may be insufficient and inaccurate.

The goals of the new naming system

To create a single code for different planes and levels that is clear, easy to understand, and accurate to be utilized in education, research, and clinical practice during a description of the NPC. It can also express the discovered and undiscovered number of foramina/canals, in addition to the shape or direction course of the canal.

Terminology

(1) The nasopalatine canal (NPC), or incisive canal, is described as an interosseous conduit in the premaxilla, just posterior to the maxillary central incisor teeth. It connects the nasal cavity to the oral cavity with two openings: (2) the inferiorly sloped incisive foramen (IF) and (3) the superiorly located Nasopalatine foramen (NF) /Foramina of Stenson (FS), which are found on both sides of the septo-premaxillary crest.

The new naming system code

Main rule → $\mathbf{S/D}^{\mathbf{I\text{–}C\text{–}N}}$

- **S**/**D** = **S**hape OR **D**irection-course of Nasopalatine canal at sagittal plane.
- **I** = Number of **I**ncisive foramina (IF).
- **C** = Number of **C**anals between IF and NF.

- **N** = Number of **N**asopalatine foramina (NF).

Examples of the new naming system

In the first example (Fig. 4), CBCT radiographs show the following: sagittal (A) and axial (B, C) views, funnel shape (A), single incisive foramen (B), and two nasopalatine foramina (C).

Naming with the new single-code system ⇨ *Funnel*$^{1-2}$

The sagittal and axial planes are expressed with a single code *funnel* $^{1-2}$, where “Funnel” represents the shape of the NPC in the sagittal plane, the first digit indicates the number of incisive foramina, and the second digit represents the number of the nasopalatine foramina.

Figure 5 shows the 2nd example, CBCT radiographs with the following; Sagittal (A) and axial (B–D) views. Cylindrical shape (A), single incisive foramen (B), three nasopalatine canals at the mid-level (C), and two nasopalatine foramina (D);

Naming with the new single-code system ⇨ *Cylindrical* $^{1-3-2}$

Based on the coronal cross-section, Bornstein et al. [12] classified the NPC into three types: (1) Single canal: characterized by one incisive foramen and one foramen of Stenson, it can be presented as *S/D*^{1} in the new system. (2) Two parallel canals: involving two incisive foramina and two foramina of Stenson, presented as *S/D*$^{2-2}$ in the new system. (3) Y-type canal: defined by one incisive foramen and two or more foramina of Stenson (e.g., 1 incisive foramen and 2 foramina of Stenson presented as *S/D*$^{1\text{-}2}$ in the new system). Nevertheless, Görürgöz C, Öztaş [23] demonstrated that 0.3% of cases exhibited three IF openings and two NF, represented as a 3–2 configuration (S/D3-2 in the new system). Also, Nikkerdar et al. [40] revealed that 2% of cases had three IF openings. In addition, Jain et al. [25] found that 6.2% of cases resulted from the 3-(1 and 3) configuration. According to the study by Fernández-Alonso et al. [20], this same configuration represented 1.8% of cases with three IF openings and one or more NFs. Other studies, conducted by Bahşi et al. [9] and Al-Amery et al. [1], identified cases where two or more openings were located in the middle of the canal.

It is worth noting that the introduction of new naming systems remains a challenge, because researchers and clinicians may face difficulties when comparing their findings with previous studies that used existing systems. However, for example, in the sagittal plane, the same descriptive terminology for canal shapes can be utilized, with a flexible naming system designed to encompass the complexity of the NPC. Additionally, the numerical representation of the foramina has been made more comprehensive and flexible to describe the NPC and the anatomy of NPC between the IF and NF. The new naming system provides a simple and more accurate method in education and teaching during the description of the NPC. It also allows the classification of previously unclassified canal configurations by requiring only the number of canals to be reported. Unlike previous classifications that categorize canals into limited types, the current new approach is more adaptable to the complex anatomy of NPC. Moreover, the single code includes multiple views that eliminate the need to describe every plane separately and without connections. Recommend future studies to validate the system using a large, diverse dataset.

Limitations

Based on findings related to variations in NPC, the present review highlights the importance of utilizing CBCT imaging for accurate diagnosis and surgical planning. However, certain limitations of the review should be noted. The included articles were written in English, which may increase the risk of language bias. Moreover, the risk of bias was moderate to high in most of the studies; therefore, the results should be interpreted with caution. The number of studies examining the current topic is limited, so the review did not include the axial view of the NPC. Unstandardized classifications across studies can prevent comparisons, and the inability to assess the heterogeneity of studies prevents the possibility of conducting a meta-analysis.

While a standard classification of the NPC into certain groups or types cannot be assumed, we suggest a more flexible NPC naming system that can include multiple planes and can also express the discovered and undiscovered classifications. However, the current system does not address certain parameters, such as the axial shape of the NPC (e.g., heart-shaped, triangular, or oval) or its dimensions. Although adding this information might provide useful insight, it will increase the complexity and the risk of misinterpretation. Nevertheless, we can use supplementary descriptions, such as words, numbers, or phrases, to provide additional details when necessary. For example, a code like “6 *Funnel* $^{1\text{-}2}$”, with “6” representing the diameter of the IF in mm.

CONCLUSIONS

From this systematic review of the NPC morphology, a notable variation exists across the different populations. The cylindrical shape, slant-straight course, and single canal are the most commonly observed in both sagittal and coronal views. The current findings underscore the need for future studies with a clearly defined methodology for higher-quality analyses and more reliable findings. While a standard classification of the NPC into certain groups or types cannot be assumed, the new NPC naming system can create a single code for different planes, more flexible and accurate to be utilized in education, research, and clinical practice during the description of the NPC anatomy. A personalized treatment plan using CBCT imaging is essential for the accurate diagnosis of nasopalatine canal morphology.

ARTICLE INFORMATION AND DECLARATIONS

Ethics statement

Ethical approval was obtained from the University of Ibn al-Nafis for Medical Sciences (Re # MDEC/Ref-19/2023–24). All participants provided their informed consent for participation in the present study.

Author contributions

A.M.A. contributed to the data collection, data analysis, and manuscript writing. M.M.A. contributed to the data collection, data analysis, and manuscript editing. T.S.G. contributed to the project development, data collection and management, data analysis, and manuscript writing. N.M.A. contributed to the data analysis and manuscript editing. B.M.A. contributed to the data analysis and manuscript editing. K.M. contributed to the data analysis and manuscript editing. H.E.H. contributed to the assistant data analysis and manuscript editing. All authors have read and approved the manuscript.

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Conflict of interest

The authors declare no competing interests.

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Table 1. Studies included in the % of classifications of NPC at sagittal according to the shape.

Author (S), Year/ Country	**Age (Years)**	**Samples Number**	**Funnel**	**Cylindrical**	**Hourglass**	**Banana**	**Cone**	**Spindle**	**Tree**	**Other**
Firincioglulari and Orhan 2024/Cyprus [21]	≥ 18	150	18.8%	56.4%	20.8%	4%	NM	NM	NM	NM
Yülek et al., 2024/Türkiye [57]	18–65	100	18%	32%	22%	17%	6%	NM	5%	NM
Magat and Akyuz., 2023/ Türkiye [32]	17–82	330	15.5%	29.4%	13.9%	9.4%	27.3 %	NM	4.5 %	NM
Linjawi et al., 2021/Saudi Arabia [30]	≥ 20 – ≥ 60	100	36%	30%	28%	6%	NM	NM	NM	NM
Milanovic et al., 2021/Serbia [36]	≥ 18	113	35.4%	31.0%	24.8%	8.8%	NM	NM	NM	NM
de Costa et al.,	21–60	132	14.3%	50.9%	15.1%	7.5%	NM	NM	NM	12.1 %

2019/Brazil [16]										
Thakur et al., 2013/India [54]	20–86	100	31%	39%	19%	NM	NM	11%	NM	NM

Table 2. Studies included in the % of the classification of NPC by sagittal direction course and coronal view.

Author (S), Year/country	Age (Years)	CBCT Number	Sagittal				Coronal		
			Slant-straight	Vertical-straight	Slant-curved	Vertical-curved	Single	Two parallel	Y-type
Firincioglulari and Orhan 2024/Cyprus [21]	≥ 18	150	67.6%	19.6%	6.1%	6.8%	NM	NM	NM
Khan et al., 2023/Pakistan [26]	18–60	90	NM	NM	NM	NM	87.8%	NM	12.2%
Linjawi et al., 2021/Saudi Arabia [30]	≥ 20 – ≥ 60	100	NM	NM	NM	NM	71%	2%	27%
de Costa et al., 2019/Brazil [16]	21–60	132	NM	NM	NM	NM	72.8%	7.5%	19.7%
Rao et al., 2018/India [45]	> 18	460	NM	NM	NM	NM	43.04 %	10.86 %	46.08 %
López Jornet et al., 2015/Spain [31]	> 18	122	NM	NM	NM	NM	39.34 %	8.19%	52.45 %
Thakur et	20–86	100	51%	3%	45%	1%	NM	NM	NM

al., 2013/India [54]									

Table 2. Risk of bias ROBINS-I of the included studies.

Study	Confounding	Participant selection	Missing data	Measurements	Selection of the reported result	Overall
Firinciogluari and Orhan 2024/Cyprus [21]	□	□	□	□	□	□
Yülek et al., 2024/Türkiye [57]	□	□	□	□	□	□
Khan et al., 2023/Pakistan [26]	□	□	□	□	□	□
Magat and Akyuz, 2022/Türkiye [32]	□	□	□	□	□	□
Linjawi et al., 2021/Saudi Arabia [30]	□	□	□	□	□	□
Milanovic et al., 2021/Serbia [36]	□	□	□	□	□	□
de Costa et al., 2018/Brazil [16]	□	□	□	□	□	□
Rao et al., 2018/India [45]	□	□	□	□	□	□
López Jornet et al., 2014/Spain [31]	□	□	□	□	□	□
Thakur et al., 2013/India [54]	□	□	□	□	□	□

□ **Critical** □ **Serious** □ **Moderate** □ **Low**

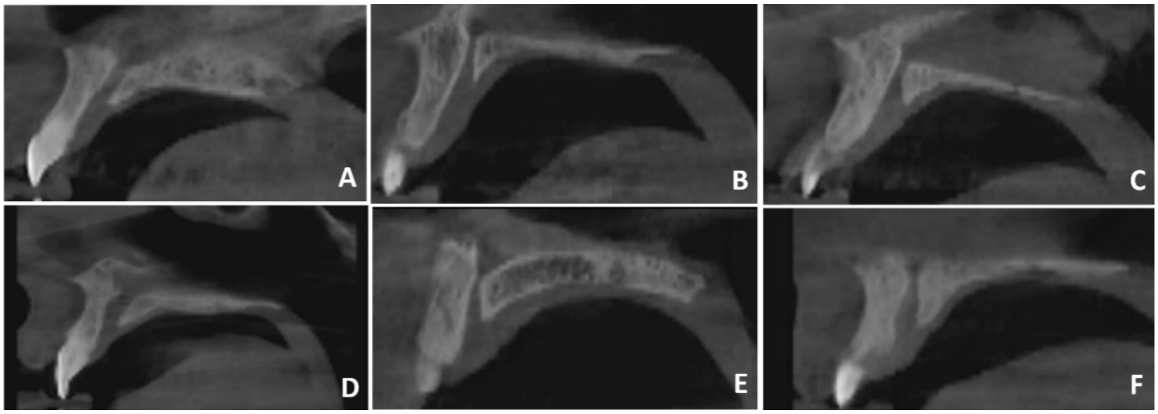

Figure 1. Cone-beam computed tomography images show the nasopalatine canal morphology in the sagittal plane. A. Cylindrical shape. **B.** Cone shape. **C.** Funnel shape. **D.** Banana shape. **E.** Hourglass shape. **F.** Spindle shape.

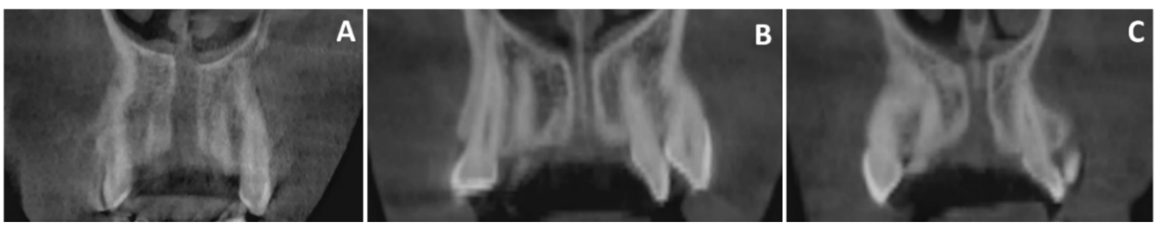

Figure 2. Cone-beam computed tomography images show the nasopalatine canal morphology in the coronal plane. **A.** Single-canal. **B.** Two parallel canals. **C.** Y-type.

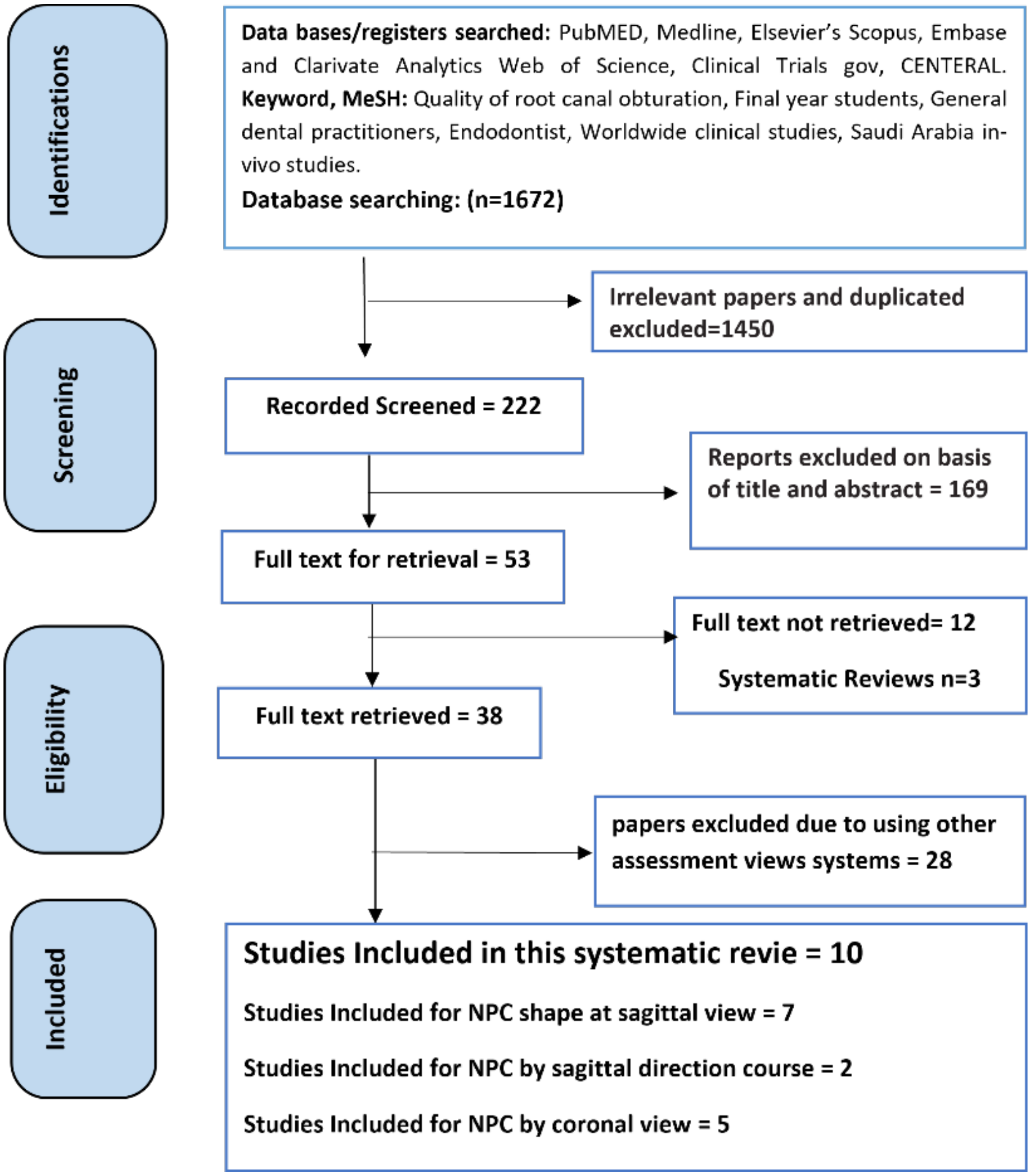

Figure 3. PRISMA flowchart of the study selection procedure.

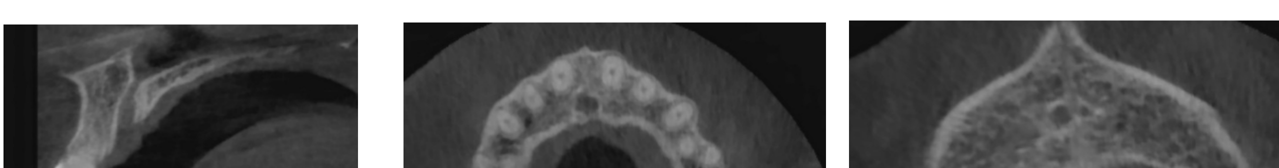

Figure 4. Example 1 for naming a cone-beam computed tomography (CBCT) radiograph using the proposed system. CBCT radiographs show the following: sagittal (**A**) and axial (**B, C**) views, funnel shape (**A**), single incisive foramen (**B**), and two nasopalatine foramina (**C**).

Naming with the new single-code system → *Funnel* $^{1-2}$

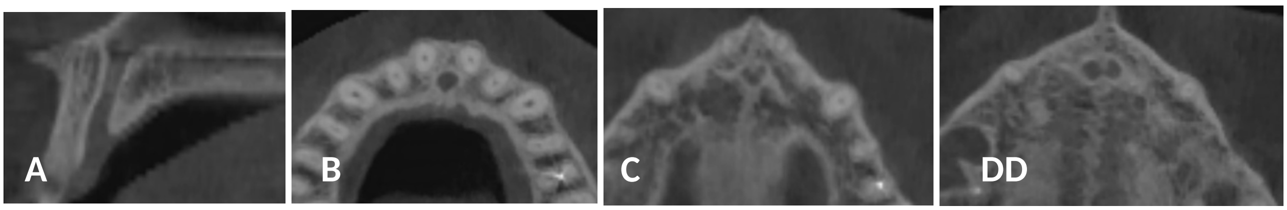

Figure 5. Example 2 for naming a cone-beam computed tomography (CBCT) radiograph using the proposed system. CBCT radiographs with the following; sagittal (**A**) and axial (**B–D**) views. Cylindrical shape (**A**), single incisive foramen (**B**), three nasopalatine canals at the mid-level (**C**), and two nasopalatine foramina (**D**).

Naming with the new single-code system → *Cylindrical* $^{1-3-2}$