THE ROLE OF MORPHOMETRIC CHARACTERISTICS OF ANTERIOR MAXILLA IN PLANNING THE INTERVENTIONS ACCOMPANIED BY ORTHODONTIC TEETH MOVEMENT – AN OVERVIEW

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ULOGA MORFOMETRIJSKIH KARAKTERISTIKA PREDNJE MAKSILE U PLANIRANJU INTERVENCIJA U OKVIRU ORTODONTSKOG POMERANJA ZUBA - PREGLEDNI RAD

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Received/Priljen: 10.12.2021.

Accepted/Prihvaćen: 14.12.2021.

ABSTRACT

The anterior maxilla or premaxilla is part of the upper jaw and the most significant content of this region, from the aspect of orthodontic therapy, are the incisor teeth. The frequency of complications during orthodontic movement of the upper incisors refers to a more detailed evaluation of the anatomical structures of the premaxilla. The aim of this study was to investigate morphological and morphometric characteristics of the anterior maxilla by cone beam computed tomography, which could be of interest for planning orthodontic teeth movement. By reviewing the available literature, we compared the values of the alveolar bone height, the distance between the alveolar crest and enamel – cement boundary, total alveolar bone width, the thickness of the buccal, and palatal plate, nasopalatine canal, and accessory canals of the anterior maxilla. The results of our study show changes in the labial and palatal aspects of the alveolar bone height during orthodontic interventions. Different results of the alveolar bone width are in correlation with gender, age, and type of orthodontic tooth movement. Distance between the nasopalatine canal and maxillary central incisors was estimated at the value from 4 to 6 mm, which is below the recommended value for maximum incisal retraction by Proffit. Research results show variations in shape, length, and diameter of the nasopalatine canal, which indicates individual varieties detected on cone beam computed tomography. Other anatomical structures and measures show an insignificant correlation with orthodontic teeth movement. According to the contradictory results of the available articles, it is required to achieve an individual approach to orthodontic interventions in the area of the anterior maxilla.

Keywords: anterior maxilla, morphometric characteristics, orthodontic teeth movement, cone beam computed tomography - CBCT, nasopalatine canal - NPC, accessory canals - ACs.

SAŽETAK

Prednja maksila ili premaksila je deo gornje vilice, a najznačajniji segment ove regije, sa aspekta ortodontske terapije, su sekutići. Učestalost komplikacija tokom ortodontskog pomeranja gornjih sekutića upućuje na potrebu za detaljnijom evaluacijom anatomskih struktura premaksile. Cilj ovog istraživanja je bio da ispita morfološke i morfometrijske karakteristike prednje maksile pomoću kompjuterizovane tomografije konusnog snopa, koje mogu biti od interesa prilikom planiranja ortodontskog pomeranja zuba. Pretragom dostupne literature, upoređivali smo vrednosti visine alveolarne kosti, distance između alveolarne kreste i gledno - cementne granice, totalnu širinu alveolarne kosti, debljinu bukalne i palatinalne ploče, nazopalatinalni kanal i akcesorne kanale prednje maksile. Rezultati studija ukazuju na promene labijalnog i palatinalnog aspekta visine alveolarne kosti tokom ortodontskih intervencija. Različiti rezultati širine alveolarne kosti su u korelaciji sa polom, starosti i vrstom ortodontskog pomeranja zuba. Distanca između nazopalatinalnog kanala i maksilarnih centralnih sekutića je procenjena na vrednost od 4 do 6 mm, što je ispod preporučene vrednosti za maksimalnu retruziju sekutića od strane Proffita. Rezultati istraživanja pokazuju varijacije u obliku, dužini i dijimetru nazopalatinalnog kanala, što upućuje na individualne varijetete koji se mogu otkriti pomoću kompjuterizovane tomografije konusnog snopa. Ostale anatomske strukture i mere ne pokazuju značajnu korelaciju sa ortodontskim pomeranjem zuba. Shodno oprečnim rezultatima dostupne literature, neophodno je ostvariti individualni pristup tokom ortodontskih intervencija u predelu prednje maksile.

Ključne reči: prednja maksila, morfometrijske karakteristike, ortodontsko pomeranje zuba, kompjuterizovana tomografija konusnog snopa - CBCT, nazopalatinalni kanal - NPC, akcesorni kanali - ACs.

MORPHOLOGICAL AND MORPHOMETRIC CHARACTERISTICS OF THE ANTERIOR MAXILLA

The premaxilla, also known as the incisive bone (lat. *os incisivum*, *os intermaxillare*), is part of the maxilla bone that bears the incisor teeth (1). This anatomical structure is associated with Goethe; thus it has also been named *os Goethei* (2). The beginning of calcification of the premaxillary bone is noted in the 7th month of pregnancy (3). During the growth period, the premaxilla passes through the stages from completely independent bone to totally integrated bone to other facial structures (4). The premaxillary bone connects with the secondary palate, maxillary, nasal, and frontal bones by sutures (2). Abrecht (1882) named the anterior part of the premaxillary suture *endognathion*, as well as the posterior part *mesognathion*. The posterior end of the premaxillary suture forms the anterior and lateral walls of the incisive foramen, whereas the palatine process of the maxilla forms the posterior wall (1). *Os intermaxillare* represents the basis of apertura piriformis (2). The region of the premaxilla consists of the alveolar process with the facial processes, incisor teeth, the palatal plate of the premaxilla bone, and the prevomerine, known as processus Stenoianus (5). From the dental aspect, incisor teeth are the most important part of the anterior maxilla, which has various functions, like phonetics, mastication, and esthetic. Therefore, irregularities in those teeth are the most common reason for orthodontic treatment (6, 7, 8).

The concept of “envelope of discrepancy”, which is presented by Ackerman et al., describes the limits of central incisors movement (9 - 14). Possible types of orthodontic tooth movement in the region of the anterior maxilla are protrusion, retraction, intrusion, extrusion, tipping, torquing, rotation, and combined movements (15, 16). The clinical guidelines advise that maximum intrusion of the maxillary central incisor is 2 mm, the same as protrusion. Recommended retraction by orthodontic alone is 7 mm. The maximum amount of extrusion, during orthodontic movement, is limited to 4 mm (13, 14). In setting goals for treatment, the three-dimensional (3D) position of the maxillary central incisors is regarded as a relevant role (17 - 21). Maxillary incisors play an essential role in physiological functions like pronunciation and mastication. Maxillofacial function and facial aesthetics are determined by the position of the central incisors (22). A successful treatment outcome with long-term stability can be achieved during incisor movement within the biologic limitations, which are based on several hard and soft tissue criteria (23). The orthodontic movement without describing boundary leads to the possibility of contact with the hard tissue by surrounding anatomical structures (24 - 27). However, excessive tooth movement could cause side effects, such as root deviation from the alveolar housing of dentition giving rise to dehiscence and fenestration (28 - 33). The most common complication of orthodontic treatment is upper incisors root resorption (34, 35). Other disadvantages of uncontrolled movement can be observed as alveolar bone loss, gingival recession, etc (8, 28, 29, 36).

One of the most common orthodontic irregularities in the area of the anterior maxilla is the protrusion of incisors, which, among other things, could be an independent irregularity, but also within other malocclusions, such as bimaxillary or bialveolar protrusion and class II division 1. Therefore, orthodontic treatment of these irregularities involves retrusion and intrusion of those teeth (36). The hard tissue like a maxillary cortical plate and the cortical plate of the incisive canal are the determining factors for teeth movement (6, 7, 22).

Generally, orthodontic teeth movement causes alveolar bone remodeling. Remodeling of the alveolar bone involves two opposite processes - resorption and apposition. If those processes are coordinated, tooth movement is named “with the bone”. Likewise, disharmony between resorption and apposition is referred to as “through the bone” (28). Extensive root movement, accompanied with predominant resorption, poses a risk of external apical root resorption (EARR). The most common complication of orthodontic treatment is EARR. It is considered to be a multifactorial impact problem, with a high prevalence of occurrence in cases treated orthodontically. The literature suggests that extensive orthodontic tooth movement and incisor intrusion with an increase in lingual root torque enhances the risk of EARR (37 - 40). Otherwise, lingual crown tipping, distal bodily retraction, or extrusion had no noticeable influence (16). Orthodontic movements can expose upper incisor teeth to proximity or contact with the labial and palatal cortical plates, nasopalatine canal (NPC) and accessory canals of the anterior maxilla (11, 12) and thus cause side effects.

In the last few decades, an important place in planning orthodontic therapy has been cone beam computed tomography (CBCT). Accurate visualization and precise representation of morphology are enabled by using CBCT. Standard 2D images such as lateral cephalometric radiographs cannot afford proper spatial visualization of the premaxilla, hence CBCT represents an essential procedure for planning and follow-up orthodontic treatment (41). However, the availability of CBCT has allowed observation of the diametrical relationship of the incisors and surrounding structures. Morphological measurements of the alveolar bone refer to height and thickness, both in buccal and palatal plates and total alveolar width (42). Measuring the alveolar bone width and height is the most commonly performed by CBCT scans (43). Alveolar bone total height is measured from the alveolar crest to the floor of the nasal cavity. The change of the vertical dimension bone is measured by the distance from the alveolar crest to the enamel-cement boundary (42). Total alveolar bone width is measured from the buccal to the palatal plate at three levels of the teeth root area (44). Fuentes et al. analyzed buccal bone width in a sagittal view of CBCT scan in five different levels from A to E. Levels B, C, D were arranged equidistantly in the space among levels A to E. Level A consists of the line A1-A2 located in the apical tooth part. Level E consists of the line E1-E2 located on the alveolar crest. Point A1 marks the vestibular side of the labial bone, whereas point A2 notes the root apex (43). Palatal bone thickness was

measured in three levels - cervical, middle and apical. The first level implies a distance of 1 mm from the top of the palatal ridge. The second level was measured at the middle of the palatal root length. Finally, the third level refers to the root apex (45). Those alveolar bone diameters are measures of interest for orthodontic movements. Characteristics of this study including author/year, origin, sample size, patient age, and type of research about morphological measurements of alveolar bone, as shown in Table 1.

In the cross-section of the premaxillary suture and medial line, CBCT provides an exact spatial morphology of the NPC, like shape, diameter, and length (24, 46). NPC is located behind the upper central incisors (25). This structure contains the salivary glands, nasopalatine nerve, an offshoot of the nasopalatine artery (47). Using sagittal cross-section slices at CBCT, the most commonly described division of the NPC shape is at four types (banana-, hourglass-, cylindrical- and funnel-shaped) (48 - 50). Milanovic and collaborators presented that the most frequent NPC type in females is a cylindrical shape, such as funnel in males, while the banana type is least represented. Anteroposterior (A-P) diameter of the nasal and incisal foramen and length of the NPC are observed on sagittal CBCT slice, while the mediolateral (M-L) dimension of NPC is evaluated at the axial slice of CBCT. Milanovic and co-workers indicate the canal length as a measure which is significantly increased in males until the A-P dimension of the nasal foramen, A-P and M-L dimension of the incisive foramen had no significant gender impact (51). Gull and co-workers defined three vertical levels of the NPC. Level 1-palatal opening level, midlevel (L2), and root apex level (L3). On the axial cross-section, they marked the most medial point of the maxillary central incisors roots (Im), the most posterior point of MCIs roots (Ip), and the most lateral point of the NPC (Ci) (22). A good evaluation of the canal diameter and NPC shape could be a limiting factor in planning orthodontic therapy because the contact of the central incisive root with a compact of incisive canal causes EARR with no canal remodeling (52). The most critical root area for touching NPC during retraction of central incisors is the interspace between the NPC and mediopalatal surface of maxillary central incisor roots (23). Therefore, Uesugi et al. recommended simulation movement of central incisor teeth during orthodontic treatment (26). Characteristics of this study including author/year, origin, sample size, patient age, type of research about morphological measurements of the nasopalatine canal, as shown in Table 2.

A large number of studies pay more attention to the morphology of the nasopalatine canal, as the most prominent anatomical structure in the anterior maxilla, while the existence of accessory canals is often neglected or misdiagnosed (53). Accessory canals (ACs) showed commonly bilaterally and in a curved shape. Olivera-Santos and co-workers presented seven groups of localization of additional foramina - central incisors region between central and lateral incisors, lateral incisor region, canine region, first premolar region, and adjacent to the incisive foramen, anterior, posterior or lateral (54). Complicated with ACs examination could be the result of the

pore cortical layer, diameter smaller than 1 mm, and variable course (55). Vasiljevic and colleagues showed that the anatomical characteristics of ACs were determined by the type of NPC. However, the distance between ACs and central incisor teeth was not coordinated by NPC type in the lower region of the anterior maxilla. Patients with the cylindrical shape of NPC, at the upper part, expressed increscent distance from AC to the central incisors compared with the banana type (27). Although, those anatomical structures have been noted a long time ago (56), the influence of ACs on orthodontic tooth movement and possible complications have not yet been evaluated in the literature. Characteristics of this study including author/year, origin, sample size, patient age, type of research about morphological measurements of accessory canals of the anterior maxilla, as shown in Table 3.

The objectives of this study were to measure the morphology of the premaxillary alveolar bone, the nasopalatine canal (NPC), accessory canals of the anterior maxilla (ACs), and evaluate the differences in this structure between gender and age, especially during orthodontic treatment of retraction and intrusion of upper incisors.

PLANNING OF ORTHODONTIC THERAPY ACCORDING TO MORPHOMETRIC CHARACTERISTICS OF THE ANTERIOR MAXILLA

The prevalence of malocclusion among the world population is 56% (57). Due to a large number of orthodontic interventions, the possibility of various complications is increased. Therefore, knowledge of the anterior maxilla morphology is crucial for planning orthodontic therapy, to prevent the possibility of side effects. Thus, we analyzed morphological and morphometric characteristics of the anterior maxilla that could be of clinical importance.

In the region of the anterior maxilla CBCTs compared with other diagnostic methods showed a vertical ridge loss 3.5 times greater (58). According to Sheerah and co-workers, the mean alveolar bone height of the upper central incisor and the upper lateral incisor is 2.40 ± 0.77 and 2.38 ± 0.64 , respectively (42). The results of the Sheerah and co-workers (42) study showed significant gender differences in bone ridge height, with males exhibiting greater facial bone heights than those of females according to the distance between the alveolar bone crest and enamel - cement boundary. This is in line with the study by Chhatwani and co-workers who also reported lower vertical bone height to the women than men (59). Sheerah et al. also showed a correlation between age and facial plate height, according to which older people are more likely to have a greater alveolar bone height than younger people (42). Similarly, Chhatwani and co-workers reported a significant association between the height of the palatal bone and age. They reported a well-defined decrease of the palatal bone during aging (59). Fuentes et al. reported only two cases of 50 CBCT scans by gender and tooth showed a greater palatal wall value when compared to the buccal plate of central incisors in both cases of the male

gender. Also, they reported that the buccal wall was the highest at three scans in the 15- to 30-year and one in the 46- to 60-age range. The palatal wall was highest for both central and lateral incisors in all age ranges, except in 46- to 60- age range for lateral incisor (43). From the aspect of orthodontic therapy, anterior maxilla teeth retraction leads to a significant increase of alveolar bone height on the labial side and its decrease on the palatal side. The possible reason for the labial side changes is extrusion of the upper incisors during retraction (60). Similarly, Lund and co-workers reported a decrease in alveolar bone height in premolar extraction cases, which was found on the palatal side (61). In contrast, Maspero et al reported a loss of the labial vertical bone in upper central incisors and no significant changes of the lingual vertical bone (62). Additionally, Castro and co-workers described irrelevant changes of labial and lingual alveolar bone height in the region of upper incisors (63). Chaimongkol et al. represented no difference between labial and palatal bone height changes (64). Further, Papadopoulou et al. showed a significant decrease in the buccal alveolar height (1.95 ± 1.83 mm) and a significant increase in the palatal alveolar bone height (1.31 ± 2.41 mm) caused by orthodontic force eruption (45). Ma et al. reported about skeletal Class II and Class III malocclusions and showed the labial alveolar bone height was higher in the patients in the skeletal Class II group than those in skeletal Class III (14).

The mean of total alveolar bone width, according to Zhang and co-workers, in the coronal, middle, and apical third for maxillary central and lateral incisors was 9.55 ± 1.45 , 8.30 ± 1.10 , respectively. They reported significantly larger ridge width in males compared with females for both central and lateral incisors (44). Similarly, Cassetta and collaborators introduced higher values of total alveolar bone thickness in males compared with females (65). These results are inconsistent with the results of other authors who found no sex differences (66, 67). Also, Cassetta et al. showed a statistically significant difference between adolescents and adults in alveolar bone thickness in favor of adults (65). Likewise, Zhang et al. showed the alveolar bone width increased from the coronal to the apical direction (44). From the aspect of orthodontic therapy, Yodthong et al. reported total bone thickness at the apical level significantly increased during incisor retraction (68). Chaimongkol et al. described total alveolar bone width at the midroot and apical levels were notably decreased in the tipping group (64). Observing incisor proclination and extrusion, Thongudomporn and co-workers showed a statistically significant, but clinically irrelevant decrease in total bone thickness at midroot and apical levels, ranging from 0.34 to 0.59 mm (69). Lim et al. reported the thinnest cortical bone in the interradicular area of the central/central incisor and central/lateral incisor, observing the rest interradicular sites of the maxilla bone (67).

According to AlTarawneh et al., the mean value of the labial bone width at coronal, middle, and apical thirds for central and lateral incisors were respectively: 0.73, 0.69, 0.60, and 0.70, 0.61, 0.49 mm (70). However, Papadopoulou et al. reported the thickness of the alveolar buccal bone was 1.06 ± 0.58 mm, 1.24 ± 0.85 mm, and 1.34 ± 0.60 mm (45), which is in accordance with Cassetta and co-workers (65). Yodthong et al. showed the labial bone thickness at the crestal level significantly increased during upper incisor retraction (68). Contrary, Chaimongkol et al. introduced a significant decrease of the labial bone thickness at the middle and apical root levels in the bodily movement group (64). Further, Thongudomporn and co-workers reported non - significant changes in the buccal alveolar bone width at all levels (69). Similarly, Nayak Krishna and collaborators showed insignificant changes in the labial alveolar bone thickness, except to the maxillary left lateral incisor whose labial bone thickness decreases significantly at the midroot level (71).

The study by Papadopoulou et al. declared the thickness of the alveolar palatal bone was 1.61 ± 0.56 mm, 3.50 ± 1.44 mm, and 6.15 ± 2.72 mm. According to their results, the palatal alveolar bone thickness was notably greater than the buccal at all levels (45). The study by Yodthong et al. (68) declared a non - statistically significant decrease in palatal bone width after retraction of maxillary incisor teeth, which is in contrast with the results of Sarikaya et al. (72) and Vardimon et al. (73). Nayak Krishna and colleagues showed the maxillary lingual bone thickness to the right central incisor decreased at the cervical and apical root levels, to the left central incisor decreased at all three levels, to the right lateral incisor decreased at the apical root level, and finally, to the left lateral incisor at cervical and apical root levels. They represented that the thickness of the lingual alveolar bone to upper lateral incisors decreased more than that of central incisors. It is assumed that the reason is a weaker periodontal ligament area of maxillary lateral incisors compared to that of central incisors (71). Also, the studies of the thickness of the labial and palatal alveolar bone after incisor retraction reported significant changes on the palatal than labial bone (28, 72). Further, Chaimongkol and co-workers reported a significant decrease of the palatal bone width in the tipping group compared with the control and bodily movement group (64). Thongudomporn et al represented a decrease of the palatal alveolar plate thickness at the middle and apical root levels during incisor protraction and extrusion (69).

Table 1. Characteristics of included studies about morphological measurements of alveolar bone of the anterior maxilla

Author / Year	Origin	Sample size	Average age	Type of research
Sheerah et al. 2019	Almadinah, Saudi Arabia	186 (109 males and 77 females)	34.65 ± 11.57	Facial bone thickness and height of the alveolar bone crest
Fuentes et al. 2015	Temuco, Chile	50	15 - 60 y	Buccal bone thickness
Zhang et al. 2015	Houston, Texas, USA	51 (20 males and 31 females)	16 - 80 y (45.25 ± 17.72)	Alveolar bone height and width
Sun et al. 2021	Beijing, China	308 (101 males and 207 females)	11 - 17 y (12.79)	Alveolar bone width and height
Lund et al. 2012	Gothenburg, Sweden	171	10 - 19 y	Bone - height
Ma et al. 2019	Beijing, China	Skeletal Class II - 31 Skeletal Class III - 31	Group A: 22.8 ± 4.2 y Group B: 21.1 ± 4.9 y	Vertical bone level and alveolar bone thickness
Yodthong et al. 2012	Songkhla, Thailand	23 (2 males and 21 females)	18 - 27 y (20.4 ± 2.7)	Labial, palatal, and total bone thickness
Papadopoulou et al. 2020	/	7 (1 male and 6 females)	43.14 ± 16.23	Alveolar bone height and thickness
Sarikaya et al. 2002	Ankara, Turkey	19	14.1 ± 2.3 y	Labial and lingual (palatal) bone thickness
Vardimon et al. 1998	Tel Aviv and Jerusalem, Israel	40 (31 treated (14 males and 17 females) and 9 untreated)	Treated group: 12 y 3 m	Cortical bone remodeling
Maspero et al. 2019	Goiania, Goias, Brazil	22	11 - 16 y (13)	Vestibular - palatal inclination and alveolar bone remodeling
Castro et al. 2016	Goiania, Goias, Brazil	30	Adults	Distance from cementoenamel junction to alveolar crest
Chaimongkol et al. 2018	Songkhla, Thailand	43	9.49 ± 1.56 y	Alveolar bone thickness and height
Thongudomporn et al. 2015	Songkhla, Thailand	15 (4 males and 11 females)	9.9 ± 1.0 y	Alveolar bone thickness
Cassetta et al. 2013	Rome, Italy	48	Adolescent: 12 - 18 y Adults: 19 - 50 y	Alveolar cortical bone thickness and density
Nayak Krishna et al. 2013	Mangalore, India	10	15 ± 3 y	Alveolar bone thickness
Lim et al. 2009	Seoul, South Korea	28 (14 males and 14 females)	23 - 35 y (27.3)	Cortical bone thickness

Morphological and morphometric characteristics of NPC are determining factors for planning orthodontic treatment. Possible iatrogenic trauma, such as EARR, can be the result of contact or invasion of the maxillary central incisor with the NPC (22).

Using sagittal cross-section, Mardinger and collaborators indicate that the most represented NPC was funnel (34,6%), onwards cylindrical (28,6%), hourglass (24,8%), and banana shape which was found in just 12% of participants (49). Lake and co-workers (74) and Fukuda and colleagues (75) mark funnel shape as the most frequent. The study by Gill-Marques and colleagues indicates a frequent occurrence of banana type (76). Thakur and co-workers (77) and Milanovic and colleagues (51) showed no significant gender difference in NPC type.

Observed in sagittal CBCT cross-section, Bornstein et al.⁷⁸ presented the average length of NPC slightly above 10,99 mm and it was in the range between 8 mm (79) and 10 mm (80). Kim and co-workers (81) describe the anteroposterior dimension of the incisal foramen (AP-IF) and the study results indicate the value above $4,79 \pm 1,26$, but those measures were above the values by Khojastepour et al. (82). On the other end of NPC, Zhou, and colleagues (83) indicate the measure of AP diameter nasal foramen, which was twice less than AP-IF. Obtained on the axial CBCT cross-section, Kajan (84) and Thakur and colleagues (77) analyses showed the mean value of the mediolateral dimension of the incisal foramen (3,5 mm and 3,62 mm). Otherwise, Mraiwa and colleagues (79) represent that the average ML-IF measure was 4.6 mm. Various data of the channel dimension suggest that the NPC morphology could be depended on more samples as shape, age, gender, etc.

Milanovic et al. estimated the correlation between NPC shape and predefined dimension. The results of the study indicate a relationship between funnel NPC shape and significantly lower AP - IF value, regarding the hourglass and cylindrical type. In comparison with a cylindrical shape, funnel NPC type showed diameter augmentation of A-P IF. On the other hand, an important reduction of the M-L IF dimension was recorded in cylindrical type. The same parameter had the opposite result in banana shape (24). Khurana (85) and Chung (86) and colleagues drew attention to the correlation

between the increase of the NPC with high prevalence of possible contact, during maximal central incisors retraction. A large value of ML IF dimension is classified as a cause of potential complication during orthodontic tooth movement (26).

Retraction of the central incisor teeth more than 4 - 6 mm leads to the approximation or contact roots of these teeth and the incisive canal (23, 87). Similarly, Gull et al. represented that the results of the distance between the MCIs roots and the NPC were approximately among 5 mm and 6 mm, a bit less than the retraction recommended by Proffit (13). Furthermore, this dimension does not necessarily represent the "safety zone" for retraction, because large variations of morphological and morphometric characteristics of the incisive canal require three-dimensional evaluation (22). Matsumura and co-workers reported that the closest relation between the central incisors and the canal was at the level of the oral opening (3.1 mm), while an enlarged measure was noted at the root apex level of central maxillary incisors (4.5mm) (88). Opposite results were represented by Cho (89) and Gull (22) who reported increased distance from upper to lower levels. Many studies showed the proximity of the NPC and the right central incisor (90, 91). On the axial CBCT slice, Gull and colleagues measured that the mean width of the incisive canal, at the apex root level, was about 3mm to 5mm, with also large variation noted in the literature from 1.1 to 6.7mm (22). Otherwise, Matsumura et al. described the cross-sectional area of the incisive canal (CSA) at three vertical levels and marked the apex root area of the NPC (81.4 mm²) as significantly greater than two other levels (88). Due to conflicting study results, it is crucial to evaluate the morphometric characteristic of anatomical details, and the relationship between MCIs and surrounding structures.

Observing the incisive canal height, Pan and colleagues found no difference between adults and teenagers. Still, in the case of contact of the upper central incisors with NPC, they reported the lower height of the NPC in the contact group (2.86 mm) compared with the noncontact group (4.07 mm). Also, no difference was found in the width of the incisive canal between various ages and comparing contact and non-contact group (87). Gull et al. showed the distance between upper central incisor roots and the NPC was approximately 5 mm and 6 mm (22).

Table 2. Characteristics of included studies about the incisive canal

Author / Year	Origin	Sample size	Average age	Type of research
Pan et al. 2018	Beijing, China	33 (20 males and 13 females)	Teenagers: 12.76 ± 1.09 y Adults: 25.38 ± 5.09	Contact of the IC and MCIs
Chung et al. 2015	Seoul, South Korea	2 (2 females)	19 y and 46 y	Approximation and contact of the IC and MCIs

Author / Year	Origin	Sample size	Average age	Type of research
Gull et al. 2018	Srinagar, India	32 (13 males and 19 females)	22.3 ± 4.5 y	Morphologic features and proximity of the IC and MCIs
Mardinger et al. 2008	Tel Aviv, Israel	207 (92 males and 115 females)	16 - 86 y (58.12)	Morphological changes of the NPC related to dental implantation
Thakur et al. 2013	New Delhi, India	100 (50 males and 50 females)	20 - 86 y	Anatomy and morphology of the NPC
Milanovic and Vasiljevic 2021	Kragujevac, Serbia	113 (63 males and 50 females)	M: 45.20 ± 2.14 y F: 41.06 ± 1.96 y	Gender differences in the morphological characteristics of the NPC
Bornstein et al. 2011	Bern, Switzerland	100 (44 males and 56 females)	43.09 y	Dimensions and anatomic characteristics of the NPC
Mraiwa et al. 2004	Leuven, Belgium	34 (17 males and 17 females)	26 - 68 y	Location, morphology, and dimensions of the NPC
Al - Amery et al. 2015	Kuala Lumpur, Malaysia	90 (46 males and 44 females)	15 - 75 y	Anatomical variations of the NPC
Kim et al. 2020	Daejeon, South Korea	167 (99 males and 68 females)	20 - 84 y (54.66)	Morphology of the incisive foramen
Khojastepour et al. 2017	Shiraz, Iran	301 (140 males and 161 females)	34.56 ± 11.87 y	Morphology and dimensions of the NPC
Zhou et al. 2014	Nanjing, China	80 (33 males and 47 females)	18 - 42 y (23.08 ± 6.30)	Morphology of the NPC
Kajan et al. 2015	Rasht, Iran	198 (98 males and 100 females)	46.5 ± 13.8 y	Anatomical variations of the NPC
Milanovic and Selakovic et al. 2021	Kragujevac, Serbia	113 (63 males and 50 females)	M: 45.20 ± 2.14 y F: 41.06 ± 1.96 y	Morphological characteristics of the NPC
Chung et al. 2021	Seoul, South Korea	34	18 - 47 y	Incisive canal remodeling
Matsumura et al. 2017	Tokyo, Japan	93 (31 males and 62 females)	18 - 39 y (24.3 ± 5.6)	Relationship between MCIs and NPC
Cho et al. 2016	Seoul, South Korea	38 (21 males and 17 females)	21.2 ± 3.17 y	Morphologic features and relative position of the NPC
Liang et al. 2009	Leuven, Belgium	120 (55 males and 65 females)	16 - 73 y	Anatomic variability of the NPC

By searching the literature, we realized that accessory canals of the anterior maxilla, especially canalis sinuosus, are little-known structures (92). As canalis sinuosus contains nerve and blood vessels (93), it is very important to know its morphometric characteristics. Otherwise, performing the interventions in the region of the anterior maxilla like orthognathic surgery, placement of dental implants, periodontal surgery, etc. (94) can cause irreversible damage (95). However, asdasfas

there are no articles that confirm the relationship between ACs and orthodontic tooth movement.

Multiple differences in morphological and morphometric characteristics of the anterior maxilla indicate an individual approach in planning orthodontic teeth movement, to minimize the side effects.

Table 3. Characteristics of included studies about accessory canals of the anterior maxilla

Author / Year	Origin	Sample size	Average age	Type of research
Orhan et al. 2017	Ankara, Turkey	1046 (788 males and 672 females)	M: 43 y F: 45.5 y	Anatomical variation of canalis sinuosus
Shelley et al. 1998	Manchester, England, Great Britain	1 male	35 y	Canalis sinuosus imitating periapical inflammatory lesion
Aoki et al. 2020	Itajai, Santa Catarina, Brazil	200 (93 males and 107 females)	18 - 85 y	Anatomical variation of canalis sinuosus
Salli et al. 2021	Istanbul, Turkey	673 (351 males and 322 females)	14 - 82 y	Location of canalis sinuosus
Vasiljevic et al. 2021	Kragujevac, Serbia	130 (69 males and 61 females)	M: 45.1 ± 1.98 y F: 41.25 ± 1.72 y	Morphological and morphometric characteristics of accessory canals

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