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Original article

The nasopalatine canal, a limiting factor for temporary anchorage devices: a cone beam computed tomography data study

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Summary

Objectives: There is only little knowledge on topographical predispositions of the nasopalatine canal as a limiting factor for insertion of mid-palatal temporary anchorage devices (TAD). The purpose of the study was to assess the course of the nasopalatine canal, the adjacent vertical bone quantity, and whether it might differ among vertical facial types, using pre-existing cone beam computed tomography (CBCT) scans.

Material and Methods: Out of a consecutive sample collected from April 2008 to August 2012, only patient data depicting both upper and lower jaw completely were evaluated retrospectively. The linear measurements were taken on the respective midsagittal view perpendicular to the palate at the level of 1st molar/2nd premolar (5/6), 2nd premolar/1st premolar (4/5), and 1st premolar/canine (3/4). Screen-prints were used to measure the inclination of the nasopalatine canal in relation to the maxillary jaw base. Maxillary and mandibular divergence was assessed on rendered lateral cephalograms.

Results: Out of 3869 pre-existing consecutive CBCT scans, data from 398 patients met the inclusion criteria and could be extracted. The mean vertical bone was 4.09 mm at the 5/6 level, 5.22 mm at the 4/5 level, and 3.14 mm at the 3/4 level, respectively. A statistically significant negative correlation exists between jaw divergence and the canal angulation with regard to the maxillary base. A statistically significant negative correlation exists between the canal angulation and vertical bone measurements at the 4/5 and 3/4 levels.

Conclusions: Vertical bone volume is sufficient at 4/5 level for TAD placement, and bares only a small risk for neuro-sensory impairment. Therefore, only in rare cases a CBCT is justified for palatal implant placement. The course of the nasopalatine canal is negatively correlated with the vertical skeletal facial pattern pointing to the fact that in hypodivergent patients a TAD might be placed in a more distal or paramedian region.

Introduction

In orthodontics, anchorage is a prerequisite for the application of therapeutic forces, and can limit their successful use. Traditionally, orthodontic therapy used teeth, extraoral, and/or intermaxillary appliances for anchorage. Since patient compliance is not always optimal, and therefore absolute anchorage is not provided (1), temporary anchorage devices (TAD) (2) have been introduced. The simplicity in use, minimal stress during surgical implant installation and removal, as well as the reliable success rates of palatal implants (3–7) are prerequisites for the high acceptance of this treatment modality by the orthodontic patients.

Preoperative computed tomography (CT) has been suggested for planning and diagnosis by a number of authors to identify available vertical bone volume and the morphology of the nasopalatine canal, thus avoiding complications such as perforation of the nasal floor or damage to the neurovascular bundle of the nasopalatine nerve (8–15). Others have stated that lateral cephalograms provide sufficient information on bone availability for preoperative planning (14, 16, 17) and must be considered as the routine imaging procedure for palatal implant insertion planning. Adhering to the ALARA-principle, recommendation of 3-dimensional (3D) radiographic imaging such as CT or cone beam computed tomography (CBCT) over lateral cephalograms must be based on a concrete benefit for the patient, as it implies substantial additional radiation exposure. It has been shown that vertical bone height measured in lateral cephalograms showed 2 mm less bone height than actually found by probing in the mid-palatal middle and anterior region (16). It has been proposed that the vertical bone height represented on the lateral cephalogram represents rather the minimum quantity of the bone, and coincides with the vertical bone dimension of the parasagittal region. Therefore, an indication for 3D imaging using CBCT could be limited to only rare cases with marginal vertical bone quantity on the lateral cephalograms (14, 17).

All surgical interventions, however, bare the risk of intraoperative or consecutive complications. Besides few studies focusing on specific aspects like pain and discomfort after palatal implantation (18), acceptance by patients (19) or the impossibility in post-orthodontic removal of the TAD (20), only one study assessed the spectrum of possible surgical complications or risks during palatal implant insertion or removal (21). Lack of primary stability or a small risk of a permanent sensory impairment in the region of the nasopalatine nerve might be a clinical consequence (21, 22). Finally, not only the total amount of the vertical bone height from the palatal cortical bone to the nasal floor might be a limiting insertion site factor, but also distance to the incisal nerve. The nasopalatine canal is localised close behind the incisors with apertures on the anterior palatal bone and nasal floor, forming a tube and a funnel-shaped opening to the oral cavity (23) and may exhibit important variations (24–30). So far, only the palatal bone quantity and quality have been assessed (14, 31–33). None of these respective studies have focused on topographical predispositions of the nasopalatine canal as a potential limiting factor for insertion of TADs in the mid-palatal area. Identifying the optimal region for TAD insertion is demanding, as the available bone quantity is not only restricted by the nasopalatine canal in the anterior direction, but is also limited by continuously decreasing bone availability in the posterior direction.

The aim of this study were, therefore, A. to assess the course of the nasopalatine canal, the adjacent vertical bone quantity at different antero-posterior locations and whether they might differ among vertical facial types by evaluating CBCT scans, and B. to investigate whether CBCT offers more diagnostic value in comparison to lateral cephalograms for TAD placement in the palate.

Materials and Methods

Study population

This retrospective study is based on data collected from cone beam computed tomography (CBCT) scans performed during examinations at Centre for Dental Medicine, University of Zurich, Switzerland, between April 2008 and August 2012. All CBCT existing images were reviewed (3869 patients), irrespective of the indication for performing the scan. Information about the referring department was available (Table 1), but no information about the original motives for taking the scans. Since the purpose of this investigation was to establish 'epidemiological' values, the intention was to use the large CBCT data bank in its entirety, unrelated to the reason the scans were taken for. Written informed consent for secondary use of the CBCT data was obtained by all patients (and their legal guardians) prior to scanning, according to the directives set by the National Federal Council. Irreversible anonymization was performed prior to the investigation in accordance with State and Federal Law, and adherence to ethical guidelines was confirmed by the local ethics committee (BASEC-Nr. Req. 2017-00016). Out of this consecutive sample, data from 398 patients met the following inclusion criteria:

- Both upper and lower jaw completely depicted in the respective field of view (FOV);
- Complete permanent dentition with no deciduous teeth in the buccal segments;
- Teeth in centric occlusion during CBCT scan;
- No history of maxillofacial injury or surgery;
- No extensive reconstruction of the dentition;
- No syndromes, nor mandibular hypo-/ or hyperdysplasia.

The CBCT images were obtained using the KaVo 3d eXam system (KaVo Dental GmbH, Biberach/Riß, Germany). The resolution of the study images varied from 0.25 mm to 0.4 mm isometric voxel sizes. KaVo eXam Vision Software Version 1.9.3.13 was used to visualize the data. Patients were seated in a standardized fashion: the chin stabilized with a chin-cup, the teeth in centric occlusion and the head parallel to the Frankfurt horizontal plane. Alignment lights were used to facilitate the positioning. The axial, coronal, and sagittal planes were manually adjusted as well and measurements were taken directly with the measuring tool included in the respective software. Contrast and brightness of the images were optimized manually for every image during the pre-measurement process.

For further image analysis, a coronal scan was used (Figure 1a) to select the sagittal plane (line D), which passes through the median suture of the hard palate, and the axial plane (line E) that runs through the tooth crowns, where the approximal contacts of the maxillary teeth are located. The selected axial scan was then used

Table 1. Distribution of CBCT assignment per referring department (in descending order).

Department	*N*	%
Clinic of Cranio-Maxillofacial-Surgery	227	57
Clinic of Oral Surgery	95	23.9
Clinic of Masticatory Disorders, Removable Prosthodontics, Geriatric and Special Care Dentistry	30	7.5
External referrals	21	5.3
Department of Otorhinolaryngology, Head and Neck Surgery	10	2.5
Clinic of Fixed and Removable Prosthodontics and Dental Material Science	8	2
Clinic of Orthodontics and Pediatric Dentistry	4	1
Clinic of Preventive Dentistry, Periodontology and Cariology	3	0.8
Total	398	100

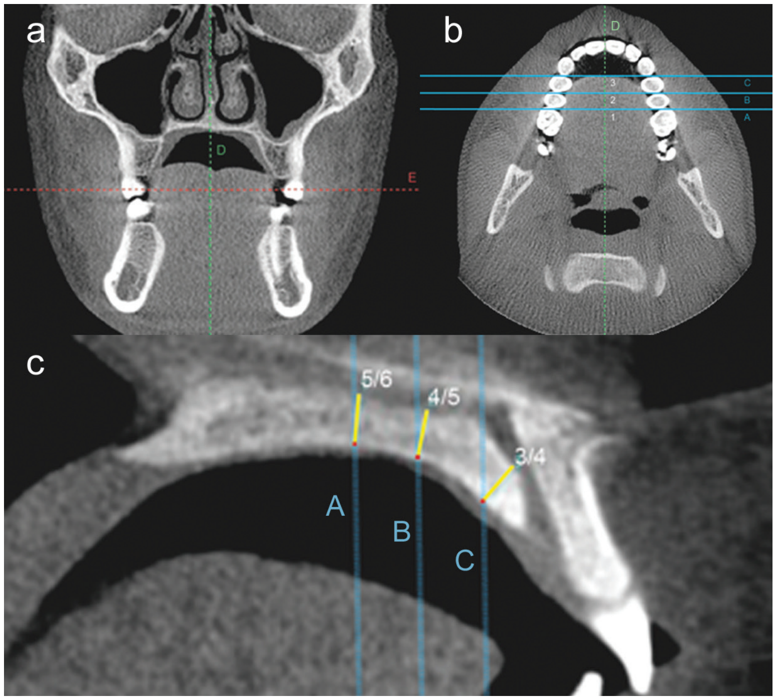

Figure 1. (a) Coronal scan of a CBCT from a patient included in the study. Line D (green) represents the selected sagittal plane. Line E (red) represents the axial plane. (b) Axial view exhibiting the selection of the respective coronal planes: coronal plane between first molar and second premolar (line A), between first and second premolar (line B), between canine and first premolar (line C). Measurement points in the median (sagittal plane) identified by the crossings of the coronal planes A, B, and C (points 1, 2, and 3). (c) Sagittal view of the hard palate with the three measurement points (ContPnt 5/6, 4/5, 4/3) as identified by the crossings of the coronal planes (A, B, and C), respectively.

to adjust the coronal planes (line A, B, C) to get the three points of measurement, where they cross the sagittal plane (line D) (Figure 1b). If necessary, the images were rotated so that the sagittal planes pass between the central incisors and through the middle of the spine.

In the sagittal plane as determined in Figure 1a, the first measurement of the hard palate (point 1) was taken between the first molar and second premolar. The second measurement of the hard palate (point 2) was taken between the second premolar and the first premolar. And the third measurement (point 3) was taken between the first premolar and canine (Figure 1c). If the proximal contacts of the contralateral sides did not correspond to each other on the coronal plane, the proximal contacts of the left side were chosen to determine the measurement points.

The linear measurements were taken on the respective sagittal view (Figure 1c). The measurements were taken using the included measuring tool for distances provided by the software (eXam Vision). The crossings of the coronal planes A, B, and C through the hard palate on the axial scans determined the measurement points. The distances in mm were taken perpendicular from the oral surface of the cortical bone to the nasal surface or nasopalatine canal critical surface of the hard palate, respectively.

For the measurement of the inclination of the nasopalatine canal (Figure 2) with regard to the maxillary jaw base as determined by the anterior and the posterior nasal spine, a line F was manually drawn on a screen-print (HP Laser Jet 500 Color M551) using a sharp pencil connecting the respective landmarks. A second line F' was drawn parallel to line F at the opening of the nasopalatine canal, where the incisive nerve emerges from the nasopalatine canal. Where line F crosses the nasopalatine canal, the posterior and the anterior bony aspect of the canal were registered and half of the distance was marked. This was done similarly at the oral opening of the canal. Through these two points, a line G was drawn. The intersection of line F and line G was taken for the measurement of angle (α) representing the angulation of the nasopalatine canal with regards to the maxillary jaw base (Figure 2).

Lateral cephalograms, as commonly used for orthodontic treatment planning, were calculated by the eXam Vision software using the data from the CBCT scans (Figure 3), and then printed. The jaw divergence (β) was obtained by the intersection of maxillary base line, determined by landmarks of anterior and posterior nasal spine and mandibular base line represented by the landmarks Gonion (Go) and Menton (Me). The first (Go) is derived by bisecting the angle formed by the junction of the ramal and mandibular planes (34), the latter (Me) is defined as the lowermost point on the symphysis in the median plane (35). All drawings were done by an experienced senior specialist in orthodontics. In order to assess the intra-observer reliability (repeatability), all measurements of 20 existing randomly chosen data sets were repeated 2 months apart.

Statistical analysis

A commercially available software package (IBM SPSS version 20, Armonk, New York, USA) was used for all statistical analyses. To determine intra-observer reliability (repeatability), the intraclass correlation coefficient (ICC) for absolute agreement based on a one-way random effects analysis of variance (ANOVA) was calculated, which was done for each variable separately. The variables were descriptively evaluated, box-and-whisker plots were generated for the distances and normal distribution was tested with a Kolmogorov–Smirnov test. None of the variables followed normal distribution ($P < 0.05$), except angle α ($P = 0.066$), hence non-parametric statistical testing was performed, using a two-sided Spearmen's rho for continuous data and a Mann–Whitney *U*-test for categorical data

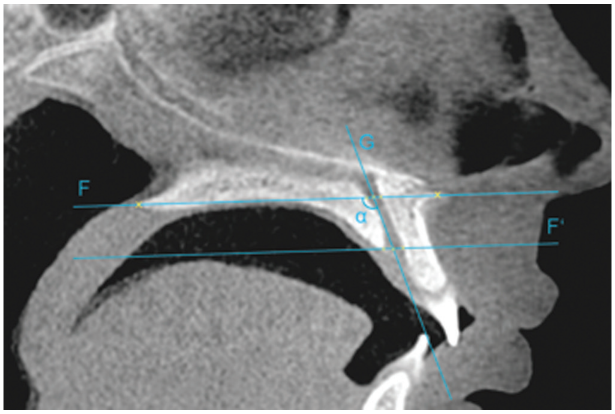

Figure 2. Representative illustration of the measured angle (α) representing the angulation of the nasopalatine canal (line G) compared to the base of the upper jaw. Line F is drawn through the anterior and posterior spine of the palate.

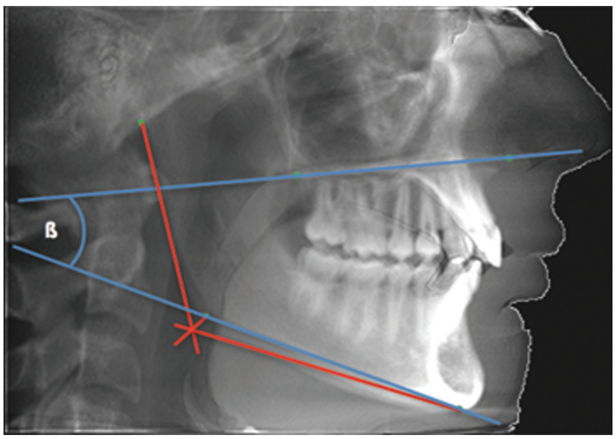

Figure 3. Lateral cephalogram calculated by the eXam Vision software illustrating the jaw base divergence.

to measure the statistical dependence between the variables. Scatterplots between the variables were generated with linear best fit lines to illustrate the association between the variables. *P* values smaller than 0.05 were considered statistically significant.

Results

The results of the repeatability analysis are given in Table 2. All intraclass correlation coefficients are above 0.9, demonstrating very satisfactory results for all variables. The demographic descriptive values of the evaluated sample are summarized in Table 3, establishing that no apparent gender-related differences exist concerning age distribution.

Table 4 visualizes the measured variables including testing for normal distribution. Due to a lack of normal distribution, further analyses were done using non-parametric testing. As some of the patients had extractions, not all premolars were present and therefore the numbers of ContPnt 5/6, 4/5, and 3/4 are not consistent. The respective measured vertical bone distances listed in the table are also given as box-and-whisker plots in Figure 4. The mean value for the first measurement of the hard palate (point 1) between the first molar and second premolar is 4.09 mm. The mean vertical bone available between the second premolar and the first premolar (point 2) is 5.22 mm, and the measurement between the first premolar and canine (point 3) exhibits a mean value of 2.88 mm. In the majority of the cases (56.1 per cent), vertical bone volume >4 mm in the region 5/6 (first molar and second premolar; Figure 5) was found. In Table 5, the measured bone variables are categorized according to gender. A distinctive and statistical significant difference can be observed, as males exhibit on average more bone quantity than females.

Table 2. Values of the Intraclass Correlation Coefficients (ICC) to determine repeatability of the measurements.

ICC	*N*	ICC	95% CI
Jaw divergence β (°)	20	0.991	0.977–0.996
Nasopalatine canal angulation α (°)	20	0.995	0.988–0.998
ContPnt 5/6 (mm)	20	0.985	0.963–0.994
ContPnt 4/5 (mm)	18*	0.982	0.952–0.993*
ContPnt 3/4 (mm)	9*	0.907	0.620–0.979*

*Contact Point 4/5 is missing in 2 cases, due to extracted premolars during orthodontic treatment. In 11 cases, measurement could not be taken due to direct insertion into the incisive foramen at contact point 3/4.

Table 3. Descriptives of the sample regarding gender and age distribution.

	Overall *N* = 398	Females *N* = 197	Males *N* = 201
Mean age (y)	26.6	26.7	26.5
Min (y)	9.4	9.4	10.7
Max (y)	63.0	49.7	63.0
SD (y)	9.1	8.7	9.5

In order to assess different associations between the measured variables, correlation analyses were performed. In a first step, the correlation was sought between age and the bony measurements, and the jaw divergence with the other variables (Table 6); subsequently a correlation analysis was done to establish potential association between the angulation of the canal and the bony measurements (Table 5). It is apparent that a statistically significant, but weak negative correlation exists between both angle measurements (Table 7), indicating that the greater the divergence between the jaws, the steeper the canal angulation will be. In order to illustrate the weak association between the two angulations, α was plotted against β, and a regression line was drawn (Figure 6). Furthermore, statistically significant negative correlations were established between the canal angulation and bone measurements 4/5 and 3/4, respectively, demonstrating that the more obtuse the angle, the shorter these distances. It is noteworthy to pinpoint the lack of this association with measurement 5/6.

Discussion

There is only little knowledge on topographical predispositions regarding the nasopalatine canal as a potential limiting factor for insertion of mid-palatal temporary anchorage devices (TAD). The purpose of the study was to assess the course of the nasopalatine canal, the adjacent vertical bone quantity, and whether it might differ among vertical facial types, using a large pre-existing cone beam computed tomography (CBCT) data bank. Ultimately, the findings were to be used to elucidate whether a CBCT scan offers substantial new information not available on lateral cephalograms relevant for TAD placement. An improved understanding of nerve and bone

Table 4. Descriptives of the variables; normal distribution tested with Kolmogorov–Smirnov test at significance level $P = 0.05$.

	N	Median	IQR	Min	Max	Normal distribution
Jaw Divergence β (°)	398	27.0	8.0	13	45	No
Nasopalatine Canal Angulation α (°)	398	103.0	10.0	79	131	Yes
ContPnt 5/6 (mm)	398	4.0	2.35	0.80	8.94	No
ContPnt 4/5 (mm)	378	5.20	2.13	1.79	10.25	No
ContPnt 3/4 (mm)	226	2.88	2.00	0.57	7.38	No

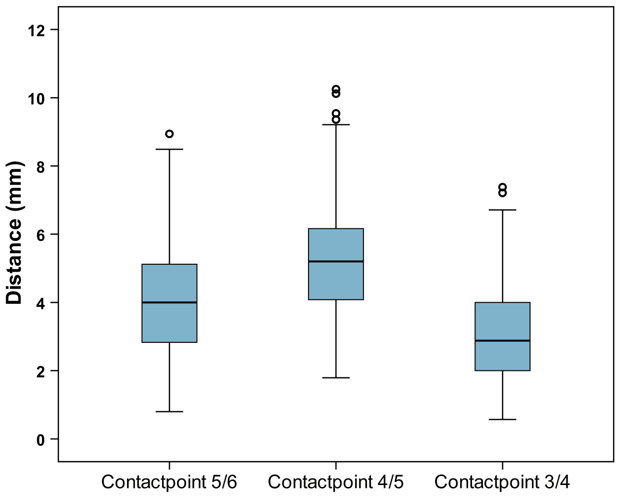

Figure 4. Box-and-whisker plots for the measured distances (vertical bone available).

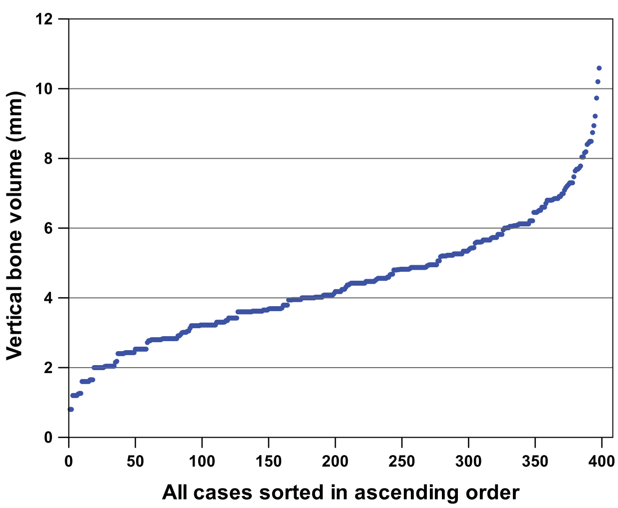

Figure 5 All measurements for vertical bone volume in the region 5/6 (first molar and second premolar; $n = 398$).

morphology and the influencing vertical factors might be helpful to reduce respective nasopalatine canal and neurovascular tissue injury or compression while the TAD insertion process causing sensory dysfunction (36, 37). Lack of primary stability with subsequent loss of TAD (21, 22) and permanent sensory impairment might be important subsequent clinical consequences.

As dental computed tomography (CT) or cone beam computed tomography (CBCT) of the alveolar process are well established for the evaluation of the alveolar bone volume before implant placement (38, 39), some have argued that they might be used to assess the vertical bone volume of the hard palate prior to TAD placement. This present study cannot substantiate this approach, and rather confirms that for the majority of the cases lateral cephalograms provide sufficient information on bone availability for preoperative planning (14, 16, 17) and must be used as routine imaging procedure for palatal implant insertion planning.

The greatest mean thickness was identified to be about 6–9 mm posterior to the incisal foramen in the mid-sagittal plane (8). If the necessary bone volume for an orthodontic implant installation is defined as 4 mm or more, 95 per cent of the patients investigated had sufficient vertical bone volume for accommodating palatal implants with a length of 4 mm (8, 40). The present patient cohort, in contrast, showed a great range of variation of vertical bone volume posterior to the incisal foramen (ranging from 0.57 to 10.25 mm, Table 3), rendering a detailed preoperative diagnostic process necessary in order to avoid potential perforation of the floor of the nose. Yet, in the majority of the cases (56.1 per cent), vertical bone volume was sufficient (>4 mm) in the region 5/6 (first molar and second premolar) to warrant the safe placement of TADs (see also Figure 5).

In an attempt to quantify the potential effect of gender and age on the available palatal bone height, the results of this present study indicate that the performed measurements are not influenced by age, but by gender. Males had statistically significant more bone vertical bone height. Caution must however be exercised when interpreting the clinical relevance of this finding, since on average the difference between males and females varied between 0.5 mm and 0.8 mm (Table 4).

The results of the present study demonstrate that routine use of CBCT for palatal TAD placement cannot be encouraged. This judgment has already been shared by Wehrbein and colleagues (16) who stated that using lateral cephalograms rather than CT examination is sufficient for obtaining precise information for the intended implant sites before placing palatal implants. Since the former are used for orthodontic diagnosis and treatment planning, this would avoid unnecessary radiation exposure to the patient (ALARA-principle). It was suggested that the vertical bone heights in the anterior and middle thirds of the hard palate were at least 2 mm greater than identified on lateral cephalograms. A safety level of at least 2 mm is therefore recommended when planning treatment on the basis of lateral cephalograms (16). The vertical dimension on lateral cephalometry reflects rather the minimum quantity of bone, which is usually seen in the parasagittal plane, and not the maximum quantity of vertical bone in the median plane. Therefore, preoperative CT or cone-beam computed tomography (CBCT) is only indicated in very rare cases revealing a marginal bone quantity on the respective lateral cephalogram (14, 17).

To date, there is no data available about the course of the nasopalatine canal and adjacent vertical bone height in the anterior maxilla, and its possibly underlying relation to the skeletal pattern. In a retrospective study assessing complications associated with the surgical insertion and removal of palatal implants, one patient suffered from a prolonged hypoaesthesia of the anterior palate (21). This may have been due to a direct injury of the incisive nerve. The difficulties

Table 5. Descriptives of the bone variables according to gender.

		ContPnt 5/6 Median (IQR)	ContPnt 4/5 Median (IQR)	ContPnt 3/4 Median (IQR)
Gender	All	4.0 (1.55)	5.2 (2.13)	2.9 (2.00)
	Females	3.6 (1.93)	4.7 (2.02)	2.6 (1.96)
	Males	4.3 (2.13)	5.5 (2.41)	3.1 (2.29)
Mann–Whitney *U*-test	*P* value	**<0.001**	**<0.001**	**0.035**

Mann–Whitney *U*-test evaluating the influence of gender on the variables (bold lettering marks statistically significant findings).

Table 6. Correlations between age, α, β, and the bone measurements (bold lettering marks statistically significant findings).

		ContPnt 5/6	ContPnt 4/5	ContPnt 3/4
	N	398	378	226
Age	Corr. coefficient	0.043	−0.026	0.002
	P value	0.396	0.618	0.978
α	Corr. coefficient	−0.061	−0.176	−0.262
	P value	0.228	**0.001**	**<0.001**
β	Corr. coefficient	0.013	0.008	0.024
	P value	0.793	0.880	0.715

Table 7. Correlations between β and α (bold lettering marks statistically significant findings).

	α
N	398
Corr. coefficient	−0.219
P value	**<0.001**

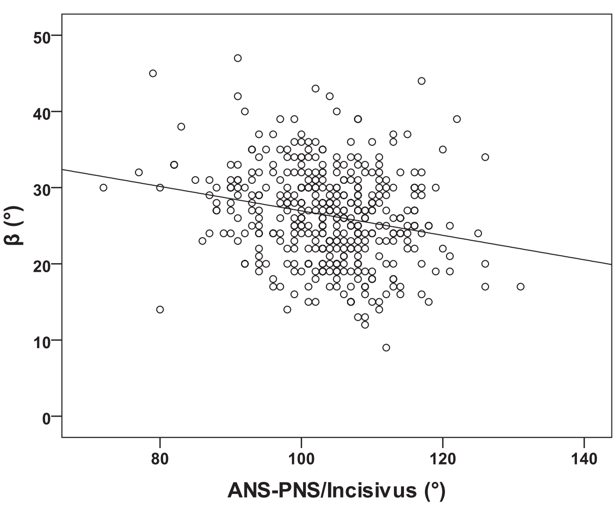

Figure 6. Scatter plot including regression line exhibiting the weak association between the two angles (α and β).

for implant placement in the anterior maxilla in context with the nasopalatine canal are known to oral surgeons and different studies have already investigated the anatomical morphologies of the nasopalatine canal (29, 41, 42). Mraiwa concluded that the nasopalatine canal may show important anatomical variations, and therefore a careful pre-operative observation is required prior to dental implant in the incisor region. Variable procedures have been presented to deal with the nasopalatine canal and its nerve when inserting dental implants in the respective region ranging from enucleation, application of autogenous cancellous bone harvested from the chin, and subsequent implant insertion (43) to more conservative approaches trying to spare the neurovascular structure of the nasopalatine canal by combining horizontal and vertical bone grafting with a lateralization of the vital structures in the region of the incisive foramen only (44). But all dental implants are inserted anterior to the incisal foramen, in contrast to orthodontic TADs.

It is interesting to note that based on the findings of the present study, the morphology of the nasopalatine canal varies in the canine and premolar region in relation to the vertical skeletal pattern. Patients with a hypodivergent skeletal pattern showed a significantly shallower inclination than patients with a hyperdivergent skeletal pattern. This points to the fact that the vertical bone volume is reduced in patients with a hypodivergent skeletal pattern. Despite the statistical significance, the correlation coefficient remained moderately low, indicating a questionable clinical significance. Nevertheless, some tendencies can be discerned. The area of the first and second maxillary premolar appears to be the most favourable overall anatomic area for palatal TAD placement. However, with placement at the canine and first premolar region, it is important to consider the potential proximity to the nasopalatine canal. Although the incisive foramen is topographically closely related to the incisive papilla, the actual canal extends superiorly and posteriorly with a negative correlation to the vertical facial skeletal pattern. If clinically or radiographically indicated, paramedian implant insertion in this anterior region might be recommended.

CBCT should not be used routinely to evaluate the available vertical bone for palatal TAD placement, lateral cephalograms provide enough information for respective insertion planning. While in full agreement with this recommendation, the present study also identifies some of the subjects who might benefit from a CBCT scan. In selected, but rare cases, an improved understanding of the subject's anatomical predisposition may help to reduce or even prevent nerve injury and subsequent lack of primary stability leading to an early loss of the implant.

In conclusion, orthodontic palatal temporary anchorage devices with a length of 4 mm might be inserted at the level of the contact point of the first and second premolar or more distally and bares only a small risk for neuro-sensory impairment. The course of the nasopalatine canal is negatively correlated with the vertical skeletal facial pattern, and in hypodivergent patients a TAD might be placed even in a more distal or paramedian region. The results of this study make it evident that a CBCT scan is not necessary for safe palatal TAD placement in the majority of the cases. A CBCT is only justified in very rare cases in which bone quantity on lateral cephalogram appears critical.

Conflict of interest

None to declare.

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