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Evaluations and Measurements of the Occurrence of Maxilla and Palatine Bone Asymmetry Based on 3D Printed Stereolithographic Models in Elderly Edentulous People

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Abstract: This study aimed to evaluate and measure the occurrence of jaw and palate asymmetry based on 3D-printed stereolithographic models of edentulous elderly people. The analyses were performed on 3D models of the jaws, which were printed using the data (CT) obtained from the CBCT center. The control group consisted of 10 modern adult skulls (7 male and 3 female skulls) owned by the Department of Anthropology of the Wrocław University of Environmental and Life Sciences. The small size of the studied groups did not allow for the performance of the analysis indicating the form of the observed morphological asymmetry—it was impossible to differentiate to indicate whether the examined features showed directional or fluctuating asymmetry. However, it was possible to determine the direction of the morphological asymmetry of the analyzed features. Both in the test group and the control group, it was a right-sided asymmetry. The analysis of the significance of differences in mean values of the asymmetry index showed that the intensity of asymmetry of the anterior part of the superior alveolar arch was significantly greater in the test group. The severity of the asymmetry of the lateral part of the alveolar arch in the tested groups did not differ significantly. The authors concluded that adequate maxillary height does not only influence proper dental prosthesis adhesion but also corresponds with a potential source for correct dental implant placement. We also concluded that the vertical height of the edentulous alveolar process of the mandible is important for adequate prosthesis fixing. In some cases, the bone atrophy and the bone itself are asymmetrical, so planning a prosthesis might be challenging. The adequate placement of implants should include the symmetry of jaw bones because of future masticatory force impact on the bone and the entire masticatory system, including the temporomandibular joint.

Keywords: maxilla; palatine bone; 3D printed models; cranium; craniometric measurements; asymmetry; edentulous

1. Introduction

The hard palate as an element of the craniofacial skeleton is comprised of two facial bone structures: the palatine process of the maxilla and the paired palatine bones [1]. The maxilla is made up of two maxillary bones linked together by an intermaxillary suture.

Maxillary bones are composed of the body, frontal process, zygomatic process, palatine process, and alveolar process. The anterior part of the hard palate (the palatine process of the maxilla) covers the area between the two sides of the maxillary dental arch until it meets the two horizontal palatine processes posteriorly [1]. The alveolar process supports all of the maxillary teeth and is resorbed when the teeth are lost [1]. The morphogenesis of the maxilla and teeth is closely related to the embryological development of the individual, in direct correlation with the formation of the cephalic extremity [2,3]. The width of the dental arch increases progressively and proportionately in size by continued bone deposition along the buccal surface of the maxillary tuberosity in the molar area posterior to the zygomatic process [4]. This surface contour is so oriented that it faces two general directions [4]. The contours and shape of the palate bone and maxillary bone change with age [5–8]. Research by Johnson et al., 1986, which was conducted on complete denture patients, revealed that 93% showed some variation of a U-shaped palatal form [5]. Moreover, other factors influencing the structure of the jaw bones and their possible asymmetry are influenced by individual and/or genetically derived factors such as oral respiration, skeletal malocclusion, and various types of traumatic, inflammatory, or cleft conditions. All these factors, while modeling the shape of the palate and jaws, also contribute to its asymmetry [7,9–11]. Human antimeres are naturally asymmetrical, and the mentioned small difference provides an individual with a unique appearance [10], which also has reference to the shape of the alveolar arch.

Cranio-facial skeleton asymmetries are a well-known problem and can be caused by various factors, mostly craniofacial deformities, trauma, or other acquired factors, especially the too early loss of molar/premolar teeth for various reasons, such as caries or periodontal diseases. Since asymmetry in older people also influences proper prosthesis position, and mastication force distribution when wearing dentures, every clinician should remember about adequate planning for future denture position in the edentulous maxillary and mandibular bones. The aging process has a strong influence on the edentulous bone, which results in different volumes of the maxillary alveolar process. Detailed research by Suresh et al. [12] on 100 dry specimens of the skull showed the role of aging/edema in the maxillary arch, the size of the alveolar process, and the shape and thickness of the hard palate in the studied patients and explained how to adjust the appropriate treatment of elderly edentulous patients [12]. According to the research by Kazanje, et al. a lack of proper facial vertical height related to edentulous patients and inadequate dental treatment or a lack of dental prosthesis increase poor facial appearance [13]. In patients with permanent dentition, many studies have been known to compare the shape/size and position of teeth in different bone relationships in comparison with angular and skeletal malocclusion. However, most of them relieve the position of the 16/26 upper molars as a good symmetry position [14].

The present study aimed to evaluate and measure the occurrence of jaw and palate asymmetry based on 3D-printed stereolithographic models of edentulous elderly people. The issue of the probability that the *in vivo* loss of the dentition increases the morphological asymmetry of the anterior part of the upper alveolar arch due to the different dynamics of the resorption processes of the alveolar structures has been clarified. Moreover, the analyzed aspect was to obtain an answer to the question: does the loss of jawbones progress asymmetrically with age, and is symmetry/asymmetry related to one another in older edentulous people?

Presented herein is perhaps the first attempt in known literature to measure and study a detailed asymmetry on 3D stereolithographic models as a preliminary study to evaluate any anatomical asymmetry that might influence on future surgical and prosthodontic planning for each patient treatment. The degree of bone atrophy, bone shape, and size along with detailed anatomical landmarks presented in the following paper are important for any clinician. A small number of study groups are related to the availability of material and study participants' willingness to perform a full CBCT evaluation and later on conduct the necessary studies. Since this paper uses a novel approach and study methodology, it

might be a quite important background for any further studies conducting similar results on 3D models and prosthodontic/surgical treatment planning.

2. Materials and Methods

2.1. Test Group and Printed Models of Maxilla (CT)

For the analysis, 3D models of the jaws were used, which were printed thanks to the (CT) data obtained from the CBCT center. We did not influence the conduct of CT. From the “cohort” of cases (57) with complete data, 15 (6 women and 9 men) were randomly selected. The age range ranged from 49 to 71 (mean 60.7 years, SD = 5.8). The age range of women ranged from 58 to 71 years (mean age 64, SD = 4.7). The age range of men ranged from 49 to 67 years (mean 58.6, SD = 5.6).

The control group consisted of 10 modern adult skulls (adults and mature age). A total of 7 male and 3 female skulls were in the collection of the Department of Anthropology of the Wrocław University of Environmental and Life Sciences. The skulls were selected randomly. The only selection criterion was complete dentition in both jaws.

2.2. Measurements

For the study, 15 randomly selected models of jaws were used together with the adjacent pterygoid process of the sphenoid bone. The only condition for inclusion in the analysis was toothlessness in the jaws. All CT examinations were performed during regular medical visits. The data for each case was anonymized. Only age and gender were determined for each case, and CT examinations were performed independently of this study. Therefore, the consent of the Bioethics Committee was not required. CT was collected from the same center, so the research group was a cohort including one recording session. Printing was carried out using an Inspire A370 (Tiertime, Beijing, China) printing device with a high degree of printing precision (construction volume $320 \times 330 \times 370$ mm with $12.6 \times 13.0 \times 14.6$ inches and with minimal layer thickness of 0.18 mm, while build speed was 5–60 cc/h. 3).

There were 6 points in the alveolar processes of the jaws (3 in each jaw). The first point, A and B (Figure 1), was located on the outer edge of the alveolar process, at the height of the intersection by a line running perpendicularly from the greater palatal opening. The second point (C and D) was placed at the height of PM2, in the axis of intersection by the line running from the infraorbital foramen (Figure 1). The third point (E and F) is marked on the outer edge of the C1 alveolar arch (Figure 1). Then, measurements of the smallest distances between the bilateral points A–D, A–F, B–C, and B–E were performed to determine the asymmetry of the alveolar processes in the research and control groups. Craniometric measurements were made using an electronic caliper (GEODORE No. 711 with an accuracy of 0.03 mm–0.001 inch).

2.3. Statistical Analysis

The direction of the morphological asymmetry of the alveolar structures of the maxillary bones was determined based on the difference between the corresponding right and left measurements: [A–D]–[B–C] and [A–F]–[B–E] (Figure 1). A positive value of the difference indicated right-hand asymmetry and a negative value of left-handed asymmetry.

The severity of morphological asymmetry was determined based on the value of the indicator recommended in the literature [15–18], which allows estimating the asymmetry of the analyzed features at the individual level. The indicated formula is used to calculate the value of the morphological asymmetry index:

$$FA1 = \text{mean} \times \left[\frac{|P - L|}{(P + L)0.5} \right]$$

where P and L are the values of bilateral measurements. $FA1$ —asymmetry index value; P —measurement of the feature on the right side; L —measurement of the feature on the left side.

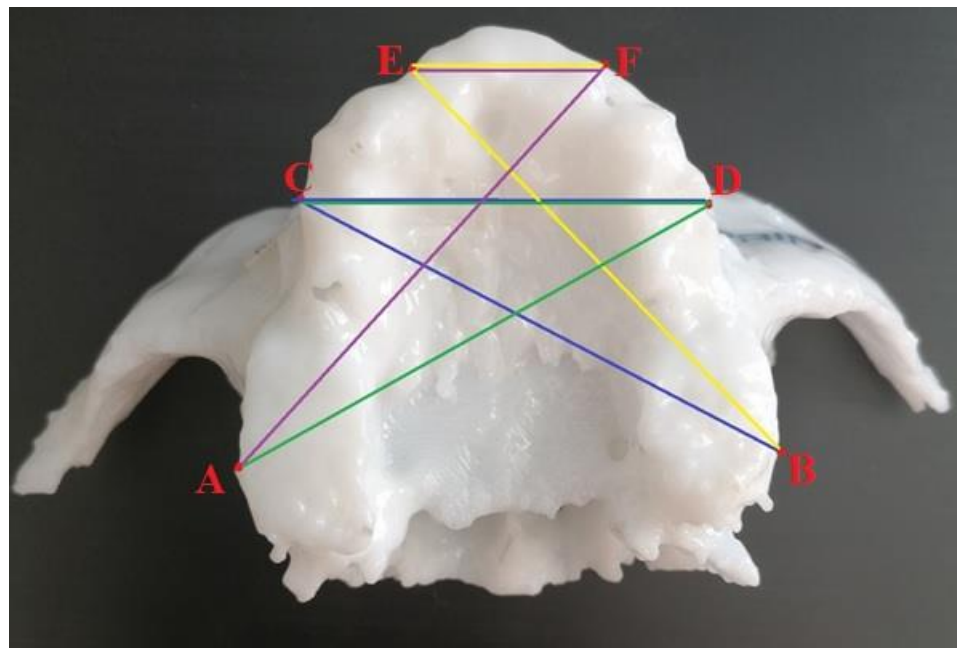


Figure 1. Points for craniometric measurements on the maxillary alveolar processes (A–F).

For the values of direct measurements of bone structures, the difference between bilateral measurements, and the morphological asymmetry severity index, basic statistics were calculated, i.e., mean, min and max values, standard deviation, skewness, and kurtosis (Tables 1–6). The W Shapiro–Wilk test was used to analyze the distribution of differences between bilateral measurements and the values of the asymmetry index for compliance with the model’s normal distribution. As the distributions of the values of the asymmetry index turned out to be skewed, the significance of differences in mean indexes between the test and control group was assessed using the Mann–Whitney U test. To estimate the significance of differences in the mean values of the asymmetry indices of both traits in the control group, the Wilcoxon order of pairs test was used.

Table 1. Basic statistics of the measurement features of the maxillary ridge structures—test group.

	N	Mean	Min	Max	SD	Skewness	Kurtosis
A–D	15	55.44	47.60	63.70	5.096	0.037	−1.04
B–C	15	55.31	47.50	64.40	5.660	0.077	−1.30
A–F	15	53.95	48.00	59.40	3.835	0.126	−1.42
B–E	15	52.05	45.00	60.10	4.086	0.313	−0.42

Table 2. Basic statistics of the measurement features of the maxillary ridge structures—control group.

	N	Mean	Min	Max	SD	Skewness	Kurtosis
A–D	10	60.08	57.30	67.40	3.030	1.695	3.49
B–C	10	59.72	57.20	65.20	2.416	1.552	2.21
A–F	10	55.24	52.00	58.60	2.228	0.173	−1.38
B–E	10	54.46	51.10	58.00	2.944	0.075	−2.08

Table 3. Basic statistics of the difference in bilateral measurements of the maxillary alveolar process—test group.

	N	Mean	Min	Max	SD	Skewness	Kurtosis
(A–D)–(B–C)	15	0.13	−3.60	3.50	2.019	−0.199	−0.634
(A–F)–(B–E)	15	1.91	−5.40	5.70	2.620	−1.497	3.662

Table 4. Basic statistics of the difference in bilateral measurements of the maxillary alveolar process—control group.

	N	Mean	Min	Max	SD	Skewness	Kurtosis
(A–D)–(B–C)	10	0.36	−1.60	2.20	1.184	0.024	−0.454
(A–F)–(B–E)	10	0.78	−0.40	3.40	1.309	1.352	0.739

Table 5. Basic statistics of the asymmetry index of bilateral measurements of the maxillary alveolar process—test group.

	N	Mean	Min	Max	SD	Skewness	Kurtosis
FA1–(A–D)–(B–C)	15	0.029	0.002	0.070	0.020	0.511	−0.366
FA1–(A–F)–(B–E)	15	0.051	0.008	0.104	0.031	0.148	−0.893

FA1–(A–D)–(B–C) is the determination of the value of the morphological asymmetry index of the A–D and B–C measurements; FA1–(A–F)–(B–E) is the determination of the value of the morphological asymmetry index of the A–F and B–E measurements.

Table 6. Basic statistics of the asymmetry index of bilateral measurements of the maxillary alveolar process—control group.

	N	Mean	Min	Max	SD	Skewness	Kurtosis
FA1–(A–D)–(B–C)	10	0.015	0.000	0.033	0.012	0.377	−1.238
FA1–(A–F)–(B–E)	10	0.018	0.002	0.064	0.022	1.613	1.334

FA1–(A–D)–(B–C) is the determination of the value of the morphological asymmetry index of the A–D and B–C measurements; FA1–(A–F)–(B–E) is the determination of the value of the morphological asymmetry index of the A–F and B–E measurements.

3. Results

3.1. Bilateral Measurements of the Structures of the Alveolar Process

The values of the arithmetic means of the performed measurements differ, in each case, between the test group and the control group. For all traits, higher mean values were found in individuals from the control group (Tables 1 and 2). Due to the specific structure of the test group, which mainly consists of its small size, the need to jointly include people of both sexes, and the fact that there are evident resorptive changes within the appendage resulting from the natural loss of dentition, the significance of differences in the mean values of the measurements was no longer tested in the analyzed groups.

3.2. Difference of Examined Features—Direction of Morphological Asymmetry

In both tested groups, the obtained values of the arithmetic mean of differences in bilateral measurements are positive, which means that both in the test group and in the control group, the morphological asymmetry is right-handed (Tables 3 and 4). The analysis of the structure of the distribution of differences in bilateral measurements also allows the identification of the form of morphological asymmetry (directional asymmetry, fluctuation, and antisymmetry); however, due to the features of the research group indicated in the previous section, this type of differentiation was not possible.

3.3. Index of Morphological Asymmetry of the Examined Features

In both studied groups, the asymmetry of the traits (A–F)–(B–E) (Figure 1) is described by higher values of the morphological asymmetry index (Tables 5 and 6).

The analysis of the significance of differences in the mean values of the asymmetry index of the examined features showed that the intensity of the asymmetry of the structures of the anterior part of the superior alveolar arch [FA1–(A–F)–(B–E)] is significantly greater in the test group. The severity of the asymmetry of the lateral part of the alveolar arch [FA1–(A–D)–(B–C)] did not differ significantly in the tested groups (Table 7). The obtained result allows us to assume that there is a loss of in vivo dentition that increases the mor-

phological asymmetry of the anterior part of the upper alveolar arch due to the increased dynamics of bone tissue resorption processes in these structures.

Table 7. The difference in the severity of morphological asymmetry of the examined features between the test group and the control group—the Mann–Whitney U test.

	Sum.Rang Test	Sum.Rang Control	U	Z	p Level	N Test	N Control	2 * 1str.
FA1–(A–D)–(B–C)	229.00	96.00	41.00	1.886	0.059	15	10	0.062
FA1–(A–F)–(B–E)	248.00	77.00	22.00	2.940	0.003 **	15	10	0.002 **

FA1–(A–D)–(B–C) is the determination of the value of the morphological asymmetry index of the A–D and B–C measurements; FA1–(A–F)–(B–E) is the determination of the value of the morphological asymmetry index of the A–F and B–E measurements. * $p < 0.05$; ** $p < 0.01$.

The analysis of the severity of the morphological asymmetry of the examined features within the distinguished groups showed that the mean values of the indicators of the asymmetry of bilateral features do not differ significantly from each other (Table 8).

Table 8. The difference in the severity of morphological asymmetry of the studied features within groups—Wilcoxon’s pair order test.

	N	T	Z	p
FA1–(A–D)–(B–C) & FA1–(A–F)–(B–E) test group	15	26.0	1.931	0.053
FA1–(A–D)–(B–C) & FA1–(A–F)–(B–E) control group	10	26.0	0.153	0.878

FA1–(A–D)–(B–C) is the determination of the value of the morphological asymmetry index of the A–D and B–C measurements; FA1–(A–F)–(B–E) is the determination of the value of the morphological asymmetry index of the A–F and B–E measurements.

4. Discussion

Surgical treatment in orthognathic surgery of such asymmetrical discrepancies requires detailed measurements and evaluation of bone height, shape, and position to plan a good adequate surgical approach. Nowadays, bone asymmetries can also be caused by other factors, such as individual and genetically derived factors, and even asymmetrical teeth loss and bone formation within the remaining teeth in older people. Since asymmetry in older people also influences proper prosthesis position, and mastication force distribution when wearing dentures, every clinician should remember to plan adequately for future denture position in the edentulous maxillary and mandibular bones. A lack of lateral molars not only influences prosthesis adherence but also, according to the study, underlines the value of symmetry of the anterior and posterior parts of the maxillary bones. Because no adequate data on edentulous maxillary bone symmetry and asymmetry are known, the presented study evaluated and compared maxillary symmetry in edentulous patients on 3D stereolithography to find the potential correlation and usage of such 3D models in treatment planning.

Palate and maxillary bone contour and shape change at various ages [5]. The degree of midline anterior inclines, curved midpalatal regions, and flat anterior/posterior midpalate sections varied greatly, which might also correspond to the authors’ findings that the bone maxillary steep could be related to the relapse from teeth loss in edentulous patients and total maxillary bone remodeling. In our opinion, since anterior teeth are mostly present in older people, the molar/premolar area is already missing some valuable teeth, which form and shape the proper bone position and height. The authors concluded that adequate maxillary height does not only influence proper dental prosthesis adhesion but also corresponds with a potential source for good dental implant placement.

In patients with permanent dentition, many studies comparing teeth shape/size and position in various bone relations compared to angle malocclusion and skeletal malocclu-

sion are known. Most of the relief on the position of the first upper maxillary molars 16/26 is a good symmetry position [14]. In the authors' study, because of 3D stereolithographic evaluation, the authors used six independent maxillary points (Figure 1) to establish any connection with possible asymmetry within edentulous maxillary processes. Since all 3D models had been toothless, no adequate data following possible malocclusion or jawbones disproportions had been found. On the other hand, horizontal asymmetry towards the midline should be used to establish any possible asymmetry, which might influence dental planning, especially if there is any residual dentition in the mandible and the patient has any dentoalveolar discrepancies. Other authors used permanent dentition as reference points. Al Shahrani et al.'s [14] studies on 3D models for malocclusion evaluation suggest that there is variability in maxillary arch variations among different malocclusion groups. The authors used the values from the ICD-intercanine distance and IM-intermolar distances, and for the measurements of palatal height, they used the length of the perpendicular line from the deepest point on the palate on the mid palatal raphe joining a straight line from the deepest portion of gingival contours of teeth 16 and 26 in Al Shahrani et al. study [14]. Last but not least, Al Shahrani et al.'s 2019 study compared dental malocclusion and palatal dimensions in correlation with fingerprint dermatoglyphics [14]. On the other hand, upper incisors and upper anterior teeth also are valuable for study purposes [19,20]. Ahmad's [19] study indicated that the angle of circumferences of upper anterior teeth of the narrow, short, and deep palates will be more tapered than that of the wide, long, and shallow palates. With this conclusion from the study, it seems that vertical and horizontal dimensions, along with palate depth, are essential for teeth's position in the bone. On the other hand, Nasiri et al.'s [20] study estimated that the height and shape of central maxillary incisors vary in men and women along with occlusion type and are greatly related to anterior facial height. Similar results had been seen in the authors' study; however, the data on gender and palatal dimensions on stereolithographic models were not conclusive enough. Since the shape and volume in all stereolithographic models vary in statistical analysis, it seems that anterior maxillary dimensions are more asymmetrical than posterior ones, which might correspond with the time of teeth loss and therefore bone remodeling. Therefore, 3D stereolithographic models should be used for planning and evaluation purposes rather than gender classification. However, if a bigger test group would be evaluated, perhaps then a statistically significant result on palatal: gender values can be concluded.

Patients undergoing orthodontics treatment also require 3D jaw evaluation, mostly to establish the type of malocclusion. In edentulous patients, the shape and size of alveolar bone are shaped by the movement of teeth during orthodontic treatment. A significant correlation between torque variations and bone thickness changes was observed for the apical buccal level of the anterior side [21] ($p < 0.05$). According to Maspero et al., limited and not significant alveolar bone resorption for the apical thickness of anterior teeth occurred at ± 5 degrees of torque variation, while for tooth inclination exceeding $+5$ or -5 degrees, the bone remodeling was more evident [21]. This result was more visible in the anterior region, which had been the most affected area by bone remodeling and that torque variation was highly related to apical bone thickness adaptation for maxillary and mandibular incisors and maxillary canines [22]. Also, orthognathic surgery and surgically assisted maxillary surgery SARME impact palatal dimensions. In this study, three-dimensional palatal measurements, including depth, length, and width, were measured in an attempt to discover their correlation with each maxillary arch form and perimeter based on six measurement proportions, which in theory should be more asymmetrical in the anterior region due to the SARME procedure surgically enhancing bone formation between anterior incisors. It seems that measurements of inter-molar width, inter-canine width, and arch perimeter are evaluated quite a lot [21,22]. The mentioned authors concluded, that about two-thirds of those seeking orthodontic treatment were females. Nearly 80% of the tested sample had a narrow palate, followed by 15 and 5% with an intermediate palate and broad palate, respectively. Males had increased dimensions compared [21,22] to females, with significant differences, except in palatal depth in the molar area and palatine

height index, in which females showed more increased dimensions than males, but the differences were statistically non-significant. In our study, the depth of palate, both in the canine and molar, based on the 3D stereolithographic model was inconclusive, but it should be deeper in the posterior area, which corresponds with early teeth loss and more asymmetrical results in the presented study authors.

Most authors worldwide focus on anterior maxillary teeth dimensions [23]. In many studies describing the anterior incisor dimensions, Sayed et al. describe the anterior teeth dimensions in edentulous patients [23]. Sayed et al. evaluated combined anterior teeth width (CATW) and inter alar width (IAW), intercommunal width (ICoW), and inter hamular notch distance (IHND) plus 10 mm [23]. The evaluation of the linear relationship between central incisor length (CIL) with facial height (FH) and CIW with bizygomatic width (BZW) was also performed. Those measurements are quite reasonable and interesting when full-patient follow-up can be a performer. In the authors' study, data are quite limited to 3D stereolithographic models. Furthermore, the authors indicate that palatal dimensions are important to estimate the dimensions of anterior teeth, which are known world studies that seem to be the last teeth present in most studied material. It seems that palatal dimensions not only correspond with the anterior maxillary width but also with the shape and size of anterior nares, the volume of the opening of the piriform aperture, and posterior choanae. The volume of the upper part of the airways is related to tonsil size, retroposition of the soft palate, and other factors [24,25]. In some procedures, like SARPE (surgically assisted rapid palatal expansion), the volume of upper airways is increasing which helps greatly improve the quality of breathing. The intercanine, IC, and intermolar IM distances remain the most used and the most reliable measurements for a variety of purposes. Another quite important factor is the measurement of superior airway relations in the Kecik et al. study [24]. OSA (obstructive sleep apnea) patients are greatly dependent on the relations between the oropharyngeal volume, upper airway, vertical palatal dimensions, the degree of maxillary narrowing, and intermolar and intercanine widths. In the authors' study, edentulous bone height and symmetry might correspond with proper nasal breathing and adequate base width on anterior nares and posterior choanae, but it still requires some additional studies. So far, no studies on nares/choanae volumes and nasal cavity structures anatomy have evaluated elderly edentulous patients with OSA, which might be an interesting topic if comparing those findings with polysomnography and detailed bone anatomy. That is why PNS-posterior nasal spine dimensions towards the posterior pharyngeal wall are important. The correlation between anterior-posterior nasal spines and molar distance is important not only for breathing but also for distance in the posterior palatal distance, especially concerning the posterior palatal suitable situation and voice pronunciation. Also, other studies seem to investigate the superior and middle respiratory tract with CBCT [25]. Studies on edentulous maxillas and transverse palato-maxillary dimensions are limited. Avci et al. studied [26] the palatal height ratio, defined as the ratio of the width of the edentulous maxillary arch to the height of the palate. The authors categorized the height, width, and anteroposterior dimensions of the edentulous maxillae. Perhaps the presented authors' study on 3D stereolithographic could improve this evaluation, based on more 3D virtual measurements.

Furthermore, we conclude that the vertical height of the edentulous alveolar process of the mandible is important for adequate prosthesis fixing. In some cases, the bone atrophy and the bone itself are asymmetrical, so planning a prosthesis might be challenging. Then, a careful patient evaluation, both on CBCT scans and plaster models is required. The volume of bone and any asymmetry are also related to the residual dentition. It seems that in the authors' work, stereolithographic models based on patients' 3D CBCT scans are accurate enough to plan any prosthodontic treatment; however, the presented study on maxillary asymmetry revealed that even if asymmetry is present, its degree should influence any treatment at all, while teeth loss during time teeth volume and shape might vary. Important bone volume is necessary to maintain the proper stable position for denture fixtures and dental implants. It seems that, most commonly, bone needs special regenerative techniques

to improve its volume and shape for any dental implant placement. In Fiorellini et al.'s study, the individualism of all bone resorption and its volume indicated that the majority of 56.5% needed additional guided bone regeneration procedures, and 43.5% required sinus augmentation procedures [27]. Similar findings related to bone loss and jaw atrophy are important in cases of implant planning then the limited amount of bone is troublesome for denture fixation. Similar to the bone height and proper value, proximity also affects important structures, such as the nasopalatine canal or inferior border of the nasal cavity, and can be troublesome for proper dental implant placement. Anatomical studies indicate that multiple variations of the nasopalatine canal regarding the buccal bone wall and shape/size towards the anterior maxillary plate also influence proper dental implant placement. Furthermore, in edentulous patients, the position of the nasopalatine canal might vary.

At first, the degree of the bone condition is related to the presence of teeth. Over time, bone can change and be atrophic. Therefore, the anterior maxillary dimension made by the authors indicates that more anterior palatal depth CBCT remains the diagnostic tool of choice for proper dental planning. So far, no adequate studies on the comparison of CBCT 3D and in vivo specimens of 3D stereolithographic models have been published. Even though anterior and posterior maxillary symmetry is derived not only from the presence of teeth but also from individual bone architecture. CBCT is an accurate tool to investigate the residual bone ridge in the edentulous maxilla for dental implant therapy. The bucco-palatal crest width and coronal bone height in a CBCT measurable study by Padhye and Bhatavadekar [28] estimated that many of the dimensions were too narrow and required additional bone-guided surgery [28,29]. So far, many studies discuss adequate bone volume for dental implant rehabilitation in edentulous patients [29].

The aging process greatly influences edentulous bone, which results in different maxillary alveolar process volumes. A detailed study by Suresh et al. [12] on 100 dry skull specimens described the role of aging/edentulousness on the maxillary arch, the size of the alveolar process, and the shape and thickness of the hard palate in South Indians and explained and customized a more appropriate treatment of elderly edentulous patients. The authors concluded that bone resorption results in a reduction of the width and depth of the alveolar arch concomitant with the alteration of the hard palate. A lack of proper facial vertical height related to edentulous patients and adequate dental treatment or lack of dental prosthesis increases poor facial appearance. Other studies seem to confirm this [13]. It seems that palatal depth and accurate bone dimensions influence denture position. This topic was frequently evaluated world-wide to establish the type of ideal edentulous patient profile for those who require additional bone regenerative procedures or others, to improve their prosthetic rehabilitation. Palatal shape, size, and proportions are also used in other branches of medicine. Morphometry studies are also used in forensic medicine [29]. Mustafa et al.'s study evaluated only dentate patients, both young and adult, based on dental casts after silicone impressions had been taken [30]. Forensic medicine also greatly depends on the shape of palatal folds, the incisive papilla position, and its relation to central maxillary incisors. For example, it was reported by a study performed on South Indian dry skulls that palatal dimensions were significantly higher in males and were hence sexually dimorphic [31]. Bigoni et al., who noted significant sex differences in the palatal dimensions in a European sample, reported comparable results [32]. Moreover, Sumati and Phatak [33] also found that the size of the palate, among five hard palate variables, was the best determinant of sex in a sample from the North Indian population. It shows that the dental casts of the upper jaw reflect the anatomy of the palate as accurately as making direct measurements on dry skulls. Gender evaluation and others based on palatal and bone dimensions are well known [7,8,34,35]. In the end, the two most important things are known. Proper bone condition and its volume enables accurate implant placement, which helps in good masticatory, speech, and appearance in edentulous patients. Studies by Sakae et al. [36] and Candel-Martí et al. [37] seem to confirm it. Phonetics and speech in patients with full dentures are better than in those without any dental appliances. In some

cases in which dental implants can be used, better functional, aesthetic, and behavioral results can be achieved.

5. Conclusions

Severe atrophic maxilla might require different placement of implants, such as more palatally or with the usage of zygomatic implants. At this point, the adequate placement of implants should include the symmetry of jawbones because of future masticatory force impact on the bone and the entire masticatory system with the temporomandibular joint as well. Since the paper used a novel approach and study methodology, it might be a quite important background for any further studies conducting similar results on 3D models and prosthodontic/surgical treatment planning.

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