Relative Bone Width of the Edentulous Maxillary Ridge. Clinical Implications of Digital Assessment in Presurgical Implant Planning

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ABSTRACT

Background: Healthy, well-structured mucosa may clinically disguise atrophic jawbone in preimplant diagnosis.

Purpose: To analyze bone width in relation to the complete ridge thickness comparing the anterior with the posterior edentulous maxilla.

Materials and Methods: Data of 52 patients (mean age 62 ± 9 years) who were edentulous for at least 1 year and who received implant treatment were analyzed. Computed tomography (CT) scans were obtained and virtually analyzed in perpendicular sections of 12 maxillary positions (central and lateral incisors, canines, premolars, and first molars) using an implant planning software. Absolute thickness of complete jaw, bone, and mucosa were digitally measured at crestal and basal ridge levels allowing for relative bone width (B-rel) calculation.

Results: Mean B-rel at crestal levels was lower than at basal levels (38.6% vs 51.5%, $p < .001$). Bone width increased significantly ($p < .001$) in the posterior maxilla at both levels, whereas the thickness of palatal and buccal mucosa was considerably stable. Mean basal B-rel ranged from 49% (6.2 ± 2.0 mm) at incisors to 59% (9.0 ± 2.3 mm) at first molars ($p < .001$). Mean proportion of regions showing B-rel < 50% were 43% at basal and 80% at crestal levels.

Conclusions: The osseous volume of a large edentulous ridge might be clinically overestimated in preimplant diagnosis, as the relative bone width was generally lower than 50%. Clinicians can use the present results of the virtual bone and mucosa measurements to have a better first estimation of the osseous proportion depending on the maxillary area. However, up to date implant therapy for the edentulous maxilla requires CT-based prosthetically driven implant planning and preferably combination with guided implant placement by transferring planning information to a surgical template.

KEY WORDS: alveolar ridge, atrophic jaw, bone width, computed tomography, edentulous maxilla, implant planning

INTRODUCTION

Treatment strategies for rehabilitation of patients with an edentulous maxilla include removable dentures as well as fixed implant-supported restorations.[1] In both cases, healthy mucosal and bony tissues are required for a successful treatment and predictable outcome. The bone morphology of the ridge and the interjaw relation are of particular importance for either type of rehabilitation and should be well considered in the treatment plan.[2] The force impact of remaining teeth from the opposing mandible may lead to progressive bone resorption and localized or general atrophy of the edentulous maxilla. Particularly, the effect of remaining mandibular front teeth and missing or instable posterior occlusal support was described and termed as combination syndrome.[3] However, this syndrome is controversially discussed and not supported by evidence-based literature. The anterior maxillary resorption is combined with hypertrophy of mucosal tissues resulting in a

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flabby ridge and development of large tubera. Unstable ridge areas and painful sore spots under complete dentures further deteriorate the edentulous situation.[4,5] Altogether, specific conditions of the edentulous maxilla are challenging and require experience along with advanced prosthetic and surgical skills for rehabilitation.[6] Moreover, the maxillary anatomy is complex and the maxillary bone in general is of lower quality than the mandible,[7] but thick palatal mucosa may clinically compensate for unfavorable conditions. Thus, diligent analysis and planning is mandatory and straight-forward implant placement is not suggested. According to the classification of the Swiss Society of Implantology, a full-arch implant-supported removable denture or fixed denture prosthesis is surgically and prosthetically considered to be an advanced or complex procedure.[8]

In the context of preimplant diagnosis, a careful clinical examination is the first step. Healthy, well-structured mucosa may disguise the atrophic jawbone of the edentulous maxilla. Particularly, the thick palatal mucosa is well attached to the bone and the effective width of the maxillary bone is mostly overestimated (Figures 1 and 2). Clinical findings therefore must be validated by radiographic data in order to obtain proper information about the jawbone dimensions if implants are to be placed (Figure 3).

Three-dimensional radiographic diagnosis and virtual implant planning has become the gold standard for implant therapy in the edentulous maxilla.[9–12] The use of sophisticated computer software allows obtaining maximum information on the complex maxillary anatomy and the bone volume available for implant-supported reconstructions. The use of such digital tools for diagnostic measurements and detailed implant planning becomes more and more important particularly in guided surgery and immediate loading protocols.[13,14] Furthermore, esthetic aspects associated to soft and hard tissues can be easily evaluated.[15]

Little data are available in the literature on relative bone width and mucosal thickness of the edentulous maxillary ridge with regard to clinical diagnosis and presurgical implant planning.

Figure 1 Palpation of the edentulous maxillary ridge allows for a first clinical assessment of the ridge anatomy. No detailed implant planning is possible at this stage.

Figure 2 Measurement of clinical ridge thickness using a caliper. The relative bone proportion depends on the buccal and palatal mucosal thickness.

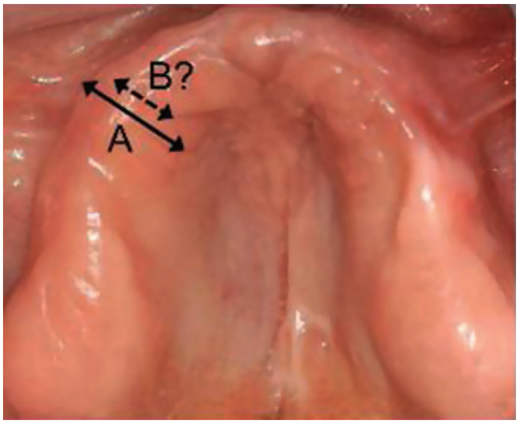

Figure 3 Healthy and well-structured mucosa may clinically disguise atrophic jawbone in preimplant diagnosis. Radiologic assessment is needed to measure absolute bone width (B) in relation to the complete ridge thickness (A).

Thus, the purpose of this study was to analyze bone width in relation to the complete ridge thickness and to compare anterior with posterior jaw areas in patients with an edentulous maxilla. For this purpose, a computed tomography (CT)-based software program was used.

The hypotheses were (1) that by clinical intraoral examination relative bone width is overestimated as it amounts less than 50% of the complete ridge thickness and (2) that relative bone width of the anterior and posterior maxillae does not differ significantly.

MATERIALS AND METHODS

Study Subjects

During a time period of 4 years, 52 patients, 30 female and 22 male patients with a mean age of 62 ± 9 years, were consecutively admitted for treatment and received implant-supported maxillary fixed and removable prostheses. All patients had an edentulous maxilla for at least 1 year when the radiographs were obtained for the planning procedure. Either multislice computed tomograms (Somatom, Siemens, Erlangen, Germany) or cone beam computed tomograms (CBCTs) (Accuitomo, Morita, Kyoto, Japan) were taken. The radiographic data were used for individual virtual implant placement by means of a specific planning software (Nobel Guide™ software, Nobel Biocare, Göteborg, Sweden). The entire treatment of all 52 patients was performed by trained prosthodontists in a university setting. In the context of the present study, the abstracted and anonymized radiographic three-dimensional data of these 52 patients were available for measurements of the maxillary ridge independently of the treatment they received. Patients with a history of palate or tuberosity surgery or presence of any stomatological disease that could affect soft and hard tissues, and patients taking medications (cyclosporin A, calcium channel blockers, and phenytoin) that have an influence on soft tissue quality (growth and hyperplasia) were excluded from the study. Eleven patients were smokers (>10 cigarettes per day), which was not an excluding factor.

Bone Width Measurements

For the virtual prosthetically driven implant planning in the edentulous maxilla, a well-fitting properly designed complete denture was required. In the computer generated three-dimensional pictures, the tooth position of the denture, the denture base, and the jawbone were well distinguishable as the Nobel Guide™ software allowed for selective and well-defined superposition of the prosthetic planning. This allowed for measurements of bone height and width as well as thickness of the mucosa in all dimensions and positions of the jaw. The thickness of the mucosa covering the maxillary jawbone was expressed as the distance between the denture base and the bone surface. For data collection, the virtual analysis was performed in perpendicular cross sections. Twelve positions of the maxillary jaw were selected according to tooth position, indicating central incisors (CIs), lateral incisors (LIs), canines (Cs), premolars (PM1 and PM2), and first molars (Ms). These positions were precisely known as a result of the planning procedure based on the double scan method and the software application described. Digital caliper measurements were done by two calibrated investigators (98% interexaminer agreement). The absolute thickness of the complete jaw (A), the effective bone width (B), and palatal (mp) and buccal mucosa (mb) were measured at the crestal and at the basal level of the ridge. The crestal and basal levels were determined 3 and 8 mm, respectively, underneath the top of the ridge. The measurements were performed perpendicular to the axis of the ridge (Figure 4). This allowed for calculation of the bone width (B-rel) in relation to the complete ridge thickness (B-rel = B/A= B/[mp + B + mb]). For a certain amount of areas (CI = 5.9%, LI = 6.9%, C = 5.9%, PM1 = 7.8%, PM2 = 26.5%, M = 64.7%), the ridge height was less than 8 mm. Therefore, the width measurements were performed at a shorter distance from ridge top and at

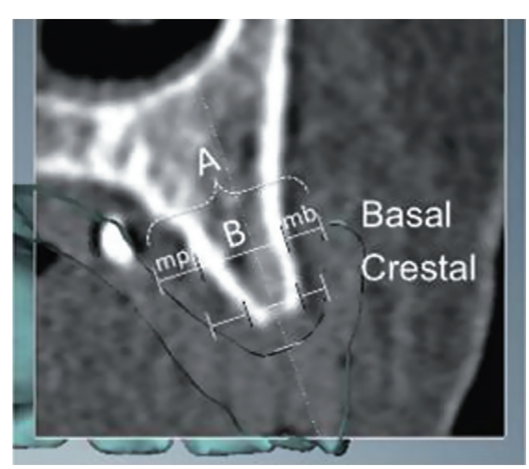

Figure 4 Measurements performed on a virtual computed tomography section using a digital caliper: absolute thickness of complete jaw (A), bone (B), palatal (mp), and buccal mucosa (mb).

areas of premolars and molars interfering with sinus cavity the antral distance was added to bone suggesting that an augmentation procedure (one- or two-stage sinus floor elevation) was required to fill this space.

Statistical Analysis

Descriptive statistics included mean values, standard deviation, and 95% confidence intervals, as well as minimum and maximum. The measurements were compared between male and female patients, tooth positions, and both levels of the ridge. Nonparametric testing was used to test for group differences. The significance level was set at $p < .05$. The SPSS software (SPSS 17.0, Chicago, IL, USA) was used for analysis.

RESULTS

Complete Ridge Thickness and Effective Bone Width

Measurements of related left and right jaw positions did not differ significantly ($p > .05$, Mann-Whitney *U* test). No differences were observed between female and male subjects ($p > .05$, Mann-Whitney *U* test). Mean complete ridge thickness and mean bone width increased significantly from anterior to posterior positions ($p < .001$, Kruskal-Wallis test) at both levels. The results of these measurements are represented in Tables 1 and 2. The average basal bone width was between 6.1 and 9.0 mm; the crestal width was between 3.6 and 5.5 mm. The proportion of areas allowing for the placement of a standard diameter implant showing a crestal bone width of at least 7 mm was lower in the anterior than in the posterior maxilla not exceeding 21.3% (Table 3).

The mucosal thickness mp (palatal) and mb (buccal) showed rather stable values as presented in Figures 5 and 6. The average thickness was lower at the buccal side and tended to decrease in the posterior area, while the palatal mucosa thickness increased slightly. At the buccal side, the average value was around 2 mm, while at the palatal side up to 5 mm was measured.

Calculation of Relative Bone Width (B-rel)

Relative bone width B-rel at crestal levels was generally lower (38.6% vs 51.5%, $p < .001$) than at basal levels (Figure 7). Mean basal bone proportions ranged from 49% at incisors to 59% at Ms ($p < .001$, Kruskal-Wallis test), with maximal values around 72 (CI) to 75% (M)

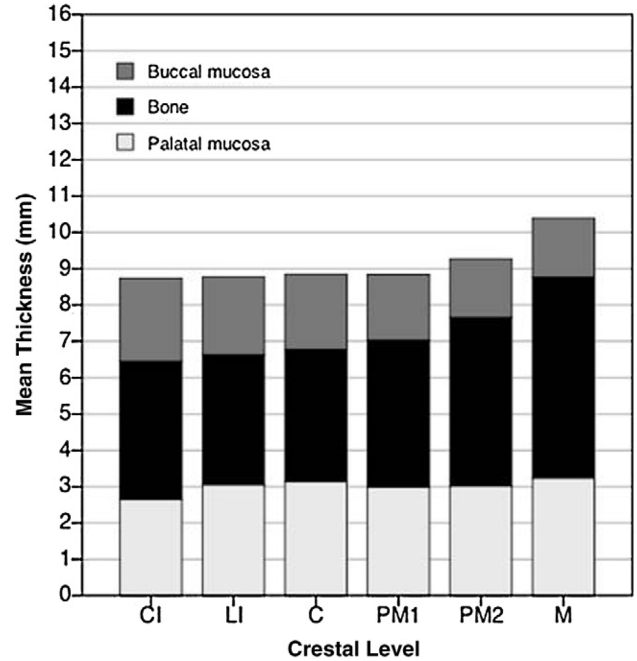

Figure 5 Basal level: bar chart showing mean thickness of the bone, mucosa, and complete ridge for the different regions. C = canine; CI = central incisor; LI = lateral incisor; M = first molar; PM1 = first premolar; PM2 = second premolar.

(Table 4). Mean crestal B-rel was significantly higher at molars (43.7%) compared with incisors, Cs, and premolars ($p = .001$, Kruskal-Wallis test). Maximal B-rel values at crestal level reached 66 (M) to 69% (CI).

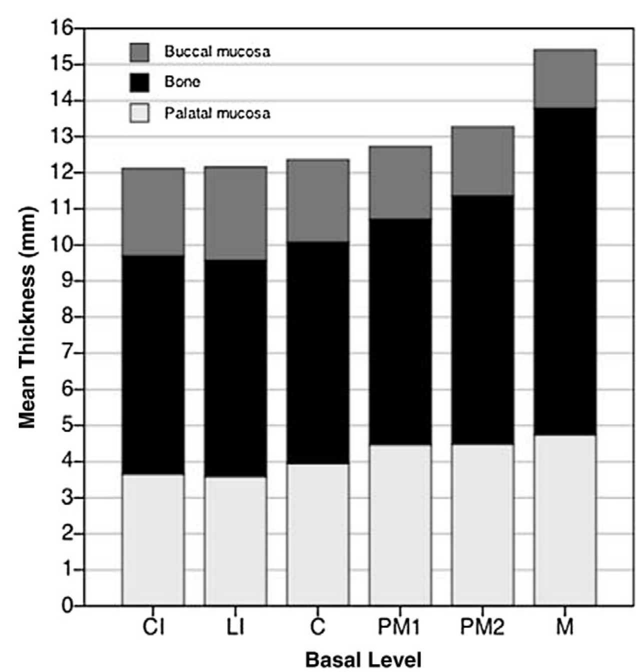

Figure 6 Crestal level: bar chart showing mean thickness of the bone, mucosa, and complete ridge for the different regions. C = canine; CI = central incisor; LI = lateral incisor; M = first molar; PM1 = first premolar; PM2 = second premolar.

TABLE 1 Basal Level: Measurements (mm) of Ridge Width for the Individual Regions

Tissue	Region	Mean	SD	95% CIn	Min	Max
A (complete ridge)	Total	13.0	2.4	12.8–13.2	7.6	21.6
	CI	12.1	1.8	11.7–12.5	8.5	17.3
	LI	12.2	2.0	11.7–12.6	8.6	19.3
	C	12.4	2.0	11.9–12.8	8.2	18.6
	PM1	12.7	2.0	12.3–13.1	9.0	19.3
	PM2	13.3	2.2	12.8–13.7	9.5	19.5
	M	15.4	2.6	14.8–16.0	7.6	21.6
		$p < .001$				
B (bone)	Total	6.7	2.2	6.6–6.9	0.2	14.9
	CI	6.2	2.0	5.8–6.7	0.2	12.0
	LI	6.1	1.9	5.7–6.5	1.8	12.5
	C	6.2	1.9	5.8–6.6	2.4	12.5
	PM1	6.2	1.6	5.9–6.5	2.7	10.4
	PM2	6.9	1.9	6.5–7.3	2.4	12.0
	M	9.0	2.3	8.5–9.5	0.2	14.9
		$p < .001$				
mp (palatal mucosa)	Total	4.1	1.2	4.0–4.2	1.2	8.3
	CI	3.5	1.3	3.3–3.8	1.2	7.3
	LI	3.6	1.2	3.4–3.8	1.2	8.3
	C	4.0	1.1	3.8–4.2	1.6	6.8
	PM1	4.5	1.1	4.3–4.7	2.3	8.0
	PM2	4.5	1.1	4.3–4.7	1.8	7.7
	M	4.7	1.2	4.4–5.0	1.3	7.6
		$p < .001$				
mb (buccal mucosa)	Total	2.1	0.8	2.1–2.2	0.7	6.8
	CI	2.4	1.0	2.2–2.6	1.2	6.8
	LI	2.6	0.8	2.4–2.7	1.2	5.2
	C	2.3	0.7	2.1–2.4	1.0	4.5
	PM1	2.0	0.7	1.9–2.2	1.0	5.7
	PM2	1.9	0.7	1.8–2.1	0.7	3.9
	M	1.6	0.5	1.5–1.7	0.7	3.6
		$p < .001$				

C = canine; CI = central incisor; CIn = confidence interval; LI = lateral incisor; M = first molar; PM1 = first premolar; PM2 = second premolar.

The percentage of areas with a B-rel less than 50% was generally high (Table 5), showing crestal values of 65.5 to 87.6% and basal values of 16.0 to 54.4%.

DISCUSSION

The purpose of the present study was to investigate the effective bone width of the edentulous maxillary ridge based on radiographic data in relation to the complete ridge thickness as it presents in the clinical intraoral examination. The first hypothesis that the relative bone width can be overestimated up to 50% was accepted for the majority of the areas in particular at crestal level of the premaxilla. The second hypothesis was rejected as the relative bone width differed significantly between anterior and posterior maxillary areas.

The results of the relative bone calculation based on the digital measurements on CT cross sections can provide reliable width estimation prior to radiologic examination. This is advantageous for the first planning steps during clinical examination; it enhances quality of the information given to the patient and may facilitate its decision making.

TABLE 2 Crestal Level: Measurements (mm) of Ridge Width for the Individual Regions

Tissue	Region	Mean	SD	95% CIn	Min	Max
A (complete ridge)	Total	9.1	2.1	9.0–9.3	4.0	17.8
	CI	8.7	1.9	8.4–9.1	5.4	14.2
	LI	8.8	2.0	8.4–9.2	5.0	15.0
	C	8.8	2.0	8.5–9.2	5.6	16.0
	PM1	8.8	1.9	8.5–9.2	4.8	14.1
	PM2	9.3	2.4	8.8–9.7	4.0	17.5
	M	10.4	2.4	9.9–10.9	5.9	17.8
		$p < .001$				
B (bone)	Total	4.2	1.8	4.0–4.3	0.0	11.5
	CI	3.8	1.5	3.5–4.1	0.0	8.2
	LI	3.6	1.5	3.3–3.9	0.5	7.8
	C	3.7	1.6	3.4–4.0	0.8	8.0
	PM1	4.1	1.6	3.7–4.4	1.0	9.2
	PM2	4.7	2.1	4.2–5.1	0.8	9.9
	M	5.5	2.1	5.1–6.0	1.3	11.5
		$p < .001$				
mp (palatal mucosa)	Total	3.0	1.0	3.0–3.1	1.0	7.2
	CI	2.6	0.7	2.5–2.8	1.0	5.9
	LI	3.0	1.0	2.8–3.3	1.2	6.0
	C	3.2	1.0	3.0–3.4	1.0	6.1
	PM1	3.0	1.0	2.8–3.2	1.0	6.3
	PM2	3.1	1.1	2.8–3.3	1.0	7.2
	M	3.3	1.2	3.1–3.6	1.1	6.9
		$p = .001$				
mb (buccal mucosa)	Total	1.9	0.9	1.9–2.0	0.7	8.1
	CI	2.3	1.1	2.1–2.5	0.8	8.1
	LI	2.1	1.0	1.9–2.3	0.7	6.9
	C	2.1	1.0	1.9–2.3	0.8	7.1
	PM1	1.8	0.8	1.7–2.0	0.7	5.6
	PM2	1.6	0.6	1.5–1.7	0.7	4.0
	M	1.6	0.5	1.5–1.8	0.7	5.1
		$p < .001$				

C = canine; CI = central incisor; CIn = confidence interval; LI = lateral incisor; M = first molar; PM1 = first premolar; PM2 = second premolar; SD = standard deviation.

TABLE 3 Percentages of Areas Showing a Crestal Bone Width of Less Respectively More Than 7 mm for the Individual Regions

Bone Width (Crestal Level)	CI	LI	C	PM1	PM2	M
<7 mm	97.0	98.1	98.0	95.2	88.2	78.7
≥7 mm	3.0	1.9	2.0	4.8	11.8	21.3
Total	100.0	100.0	100.0	100.0	100.0	100.0

C = canine; CI = central incisor; LI = lateral incisor; M = first molar; PM1 = first premolar; PM2 = second premolar.

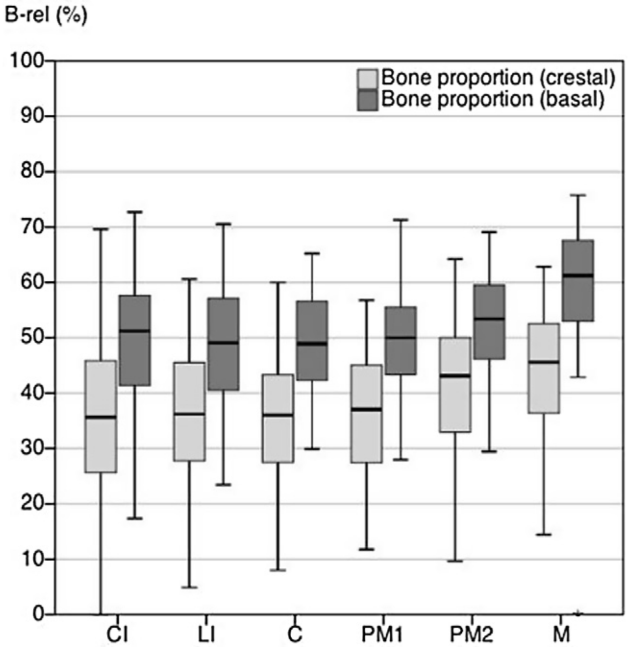

Figure 7 Box plot showing relative bone width (B-rel) at crestal and basal levels for the different regions. C = canine; CI = central incisor; LI = lateral incisor; M = first molar; PM1 = first premolar; PM2 = second premolar.

There are other types of width measurements that do not require radiographs such as model-based mapping method using needles or endodontic probes.[16,17] The oral mucosa is subject of different studies using ultrasonic devices for the mucosal width measurements, too.[18,19] However, these methods take clinically more time and are invasive, and their accuracy is controversially discussed. Measurements of the alveolar bone dimensions by ridge mapping were different from CT-based measurements, showing a mean variability of about 0.4 mm.[20] However, one study provided ridge mapping measurements of the buccolingual ridge width consistent with those measurements obtained by direct caliper measurements during surgical exposure of the bone.[21] By means of the CT-based analysis, the jaw morphology can be assessed in cross sections as well as in three-dimensional reconstructions including the virtual implant planning and placement; without destruction of any model, the analysis can be interrupted, continued, and repeated any time. Furthermore, the analysis can be performed within a reasonable period of time much shorter than a model analysis. Thus, this method seems to be much more clinically accurate than a model-based one.

Marked resorption of the alveolar ridge is a major factor limiting implant treatment.

Dimension of facial bone wall in the anterior maxilla of dentate subjects was investigated by different researchers using CBCT. In the crestal area, the facial bone wall was either missing or less than 1 mm thick in the majority of the patients.[22–24] The results indicated

TABLE 4 Relative Bone Width (B-rel) in Percentages at Basal and Crestal Ridge Levels for the Individual Regions

Basal Level	CI	LI	C	PM1	PM2	M	Mean	*p*-Value
Mean	49.0	48.4	48.8	49.6	52.4	59.5	51.5	<.001
Median	51.7	49.1	48.9	50.0	53.4	61.2	51.8	
SD	14.0	11.6	9.3	8.6	9.7	10.7	11.3	
95% CIn	45.6–52.3	45.3–50.9	46.7–50.9	47.7–51.4	50.3–54.4	57.0–61.9	50.5–52.5	
Minimum	0.0	13.6	29.9	27.9	26.1	14.4	0.0	
Maximum	72.7	70.5	65.2	71.3	69.1	75.8	75.8	
Crestal level	**CI**	**LI**	**C**	**PM1**	**PM2**	**M**	**Mean**	***p*-Value**
Mean	35.3	35.6	34.4	36.4	40.6	43.7	38.6	.001
Median	35.6	36.2	36.0	37.0	43.1	45.6	39.3	
SD	14.0	12.2	12.6	11.5	12.2	10.9	12.6	
95% CIn	32.0–38.7	32.9–38.3	31.5–37.3	34.0–38.9	38.1–43.2	41.3–46.2	37.5–39.6	
Minimum	0.0	4.9	8.0	11.8	9.6	14.4	0.0	
Maximum	69.6	60.6	60.0	56.8	64.2	62.8	69.6	

C = canine; CI = central incisor; CIn = confidence interval; LI = lateral incisor; M = first molar; PM1 = first premolar; PM2 = second premolar; SD = standard deviation.

TABLE 5 Percentages of Areas with Less Than 50% of Relative Bone Thickness (B-rel) at Basal and Crestal Ridge Levels for the Individual Regions

B-rel < 50%	CI	LI	C	PM1	PM2	M	Mean
Basal level	45.1	54.7	54.4	50.0	38.0	16.0	43.1
Crestal level	78.3	83.5	86.5	87.6	75.0	65.5	79.6

C = canine; CI = central incisor; LI = lateral incisor; M = first molar;.PM1 = first premolar; PM2 = second premolar.

that such a thin bone wall will most probably undergo marked dimensional diminution following tooth extraction. From previous studies, it is known that the healing process after tooth extraction may reach 50% of bone width reduction within the first 12 months.[25] It was also reported that after 12 months the resorption of the residual ridge may progress further with a variable rate.[26,27] A long-term study of edentulous individuals covering 25 years of complete denture wearing revealed a continued but slow reduction of the residual ridges throughout the observation period.[28] However, in the long-term perspective, it is difficult to estimate additional factors such as chronic diseases and systemic health conditions affecting the bone metabolism. Furthermore, the local impact on the ridge by ill-fitting dentures and occlusal load from opposing dentition may contribute to the atrophy. This is particularly the case in elder patients who lost their teeth many years ago. In the present study, the patient's mean age was 62 years, suggesting that these factors may have played a role for the degree of jaw atrophy. Some patients whose data were used in the present study lost their teeth due to different reasons, often not really known (periodontal infection, deep caries, and endodontic problems) and at different time points in the past. From all patients of the present investigation, it was known that the minimum time of being edentulous and wearing a complete maxillary lasted for more than 1 year.

Animal studies have indicated that bone resorption is a pressure-regulated phenomenon with a lower threshold for continuous than for intermittent pressure.[29] Clinical studies support the opinion that denture-wearing jaws lose more bone than those without dentures.[30] However, the results of leaving out dentures at night are not conclusive, nor does the literature offer any strong evidence for the combination syndrome, which has been described as a result of unfavorable loading.[3,31,32] Furthermore, the tissue composition of postextraction sites of subjects with an edentulous maxilla was demonstrated not to be different between those having a periodontitis history and those with nonperiodontitis tooth loss and between premolar and molar sites.[33]

The hypothesis that the bone width may be clinically overestimated by 50% was confirmed by the measurements performed on the CT cross sections showing a mean bone proportion of 34 to 36% in the anterior maxilla at the crestal ridge level while bone width of 52 to 59% in the posterior maxilla at a basal levels was still present. Relative and absolute bone width increased significantly from the anterior to the posterior maxilla with a peak at the M regions. The results of the present study showed no significant difference between the left and ride sides, suggesting a symmetrical jaw shape and resorption process on the long term. Furthermore, the results demonstrated that gender was not an important factor as there were no significant differences between female and male subjects. Altogether, this means that during the clinical examination, the maxillary ridge might be misinterpreted. Additionally, in the area of the premolars and molars, the bone volume was compromised by the extension of the sinus. A sinus floor elevation is often indicated to provide the required bone height for stable implant placement. Bone augmentation may be indicated when the distance from the sinus floor to the top of the alveolar ridge is less than 8 to 10 mm.[34,35] Two main techniques of sinus floor elevation for dental implant placement are in use: a two-stage technique with a lateral window approach, followed by implant placement after a healing period, and a one-stage technique using either a lateral or transalveolar approach. The decision to apply the one- or the two-stage techniques is based on the amount of residual bone available and the possibility of achieving primary stability for the inserted implants.[36] The remaining bone height is claimed to be at least 5 to 6 mm for the one-stage approach.[37,38] Based on this information of the consensus articles, the indication for a staged approach is given if less than 3 mm bone height is left. In the present study, the remaining bone height was measured with respect to the basal and crestal width measurements. For most areas, the ridge height was more than 8 mm and therefore sufficient for crestal and basal measurements (CI = 94.1%, LI = 93.1%, C = 94.1%, PM1 = 92.2%, PM2 = 73.5%, M = 35.3%). In the rare cases with a remaining bone height of less than 3 mm, the two measurements were performed at crestal and basal limits (CI = 1.0%, LI = 1.0%, C = 1.0%, PM1 = 2.0%, PM2 = 3.9%, M = 15.7%). These data were included in the analysis suggesting the necessity of a staged sinus grafting procedure for areas interfering with the sinus cavity. A simultaneous sinus grafting approach (one stage) would be necessary in 5.8 (PM1), 22.6 (PM2), and 49% (M position) for the placement of an 8-mm-long implant after slight flattening of the ridge top with a remaining bone height of 3 to 8 mm. This should be taken in consideration for the interpretation of the present data.

The measured absolute basal bone width of the CIs was on average 6.1 mm. At crestal level, however, the minority of the measurements in the selected cross sections showed values of more than 7 mm. This would not allow for the placement of a standard diameter implant that is usually between 4.0 and 4.3 mm without additional augmentation procedures.[39–41] Similar findings were reported by other recent studies investigating anatomical morphology of the nasopalatine canal.[42] In the posterior maxilla, the bone width values reported in the present study were slightly lower to other recent studies.[43,44] This group of authors measured the ridge width in different levels of CT cross sections as well showing 1- to 2-mm higher values at premolar and M sites. The patients in this study were in contrast to the subjects of the present study partially edentate and not completely edentulous suggesting that the ridge might have gone through less resorption.

In the context of the present study, it was the intention to give a practical guideline for the first estimation of the osseous proportion in the edentulous jaw. Therefore, the bone width was calculated in relation to the complete ridge thickness. For the individual patient, no final conclusion can be drawn from the relative bone width itself on whether an implant can locally be inserted with or without additional surgical procedures. The individual three-dimensional diagnostics and implant planning must still be performed before surgery considering prosthodontic, surgical, and financial aspects.[9] However, with the help of the present results, a first estimation can be drawn already in clinical examination and the patient can be informed earlier in the treatment and with more accurate information. Moreover, the surgical procedure can be planned specifically, the approach modified[45–47] and performed with high accuracy transferring the presurgical implant planning (three-dimensional positions, axes, and arrangement) to the clinical situation.[13,14,48,49]

CONCLUSIONS

The osseous volume of a large edentulous ridge might be overestimated clinically, as the relative bone width was on the average lower than 50% particularly in the premaxilla. Absolute and relative bone width is increasing in the posterior jawbone, whereas the thickness of palatal and buccal mucosa was considerably stable. The data show that the average bone width is insufficient for the placement of implants with standard diameter (around 4 mm) in many areas. Clinicians can use the present results of the virtual bone and mucosa measurements to have a better first estimation of the osseous proportion depending on the maxillary area.

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