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The significance of hard palate dimensions and sex differences in determining maxillary anterior teeth width

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SUMMARY

Background/Aim: *Selecting appropriately sized maxillary anterior teeth is of great importance for achieving satisfactory outcomes in complete denture therapy. When pre-extraction records are unavailable, clinicians use recommended anatomical landmarks for this purpose. Predictive value of these parameters in previous studies was inconsistent. The aim of this study was to assess sex-specific associations between selected hard palate measurements and the mesiodistal width of maxillary anterior teeth (ATW) in an adult Bosnian-Herzegovinian population.* ***Materials and Methods:*** *This retrospective cross-sectional study used 180 maxillary casts (114 women, 66 men). Recorded palatal dimensions included hamular distance, hard palate length, and distances from the incisive papilla to the right and left hamular notches. The mesiodistal width of the six maxillary anterior teeth was summed to obtain ATW. Sex differences were assessed using independent-samples and paired-samples t-tests. Associations between palatal measurements and ATW were evaluated using simple and multiple linear regression ($\alpha=0.05$).* ***Results:*** *Men had higher mean values for almost all palatal and dental variables, with no significant difference observed for the left lateral incisor ($p=0.155$). ATW was significantly greater in men compared with women ($t=3.96$, $p<0.001$). Papilla-hamular notch distances ($p=0.002$) were significantly associated with ATW in men, while all palatal measurements showed significant simple correlations ($p\leq0.002$) with ATW in women. In multiple regression, no palatal dimension remained independently predictive in men ($R^2=0.173$, $p=0.019$), while hamular distance was the only significant predictor in women ($\beta=0.219$, $p=0.020$; $R^2=0.169$, $p<0.001$).* ***Conclusions:*** *Hard palate measurements show sex-specific relationships with the width of maxillary anterior teeth. Although several dimensions have significant associations with ATW, their predictive value is modest. Therefore, these parameters may serve only as supportive guides when selecting artificial teeth.*

Key words: Palate, Hard; Sex Characteristics; Teeth Width; Dental Prosthesis Design; Artificial Teeth; Anthropometry

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Introduction

Prosthetic rehabilitation of edentulous patients is often very challenging because of severe functional and aesthetic alterations within the stomatognathic system. Although contemporary therapy options, such as restorations supported by dental implants, are being used, complete dentures remain the primary prosthetic solution in clinical cases of complete tooth loss.[1] When making complete dentures, occlusion and dentofacial harmony should be restored, and for these goals, appropriate denture teeth are necessary. Anterior teeth are particularly

important due to their central role in smile aesthetics[2] and patient satisfaction.[3] Patients, especially those wearing dentures for the first time, usually expect that artificial teeth and their lost natural teeth should be similar in size, shape, and color. In this regard, accurate determination of artificial tooth dimensions is of great importance.[4-6]

Pre-extraction records are useful in this process,[7] but if they are unavailable, correctly selecting the width of maxillary anterior teeth becomes difficult.[8] While tooth length is generally easier to estimate,[9] determining the appropriate width remains complex, even with some recommended anatomical guidelines[10].

Anatomical indicators of the maxillary anterior teeth width that were most extensively examined are related to certain facial dimensions. However, the inconsistent results of those studies did not fully clarify the association between the width of the maxillary anterior teeth and the examined facial dimensions, including intercommissural, interalar, intercanthal, interpupillary, and bizygomatic distances.[9,11-14]

Since facial dimensions can be influenced by soft-tissue mobility, aging,[15] body-weight changes,[16] and aesthetic procedures, it has been reported that only stable intraoral landmarks, such as the incisive papilla and hamular notches,[17,18] should be used to determine teeth width. However, there is no consensus on the relationship between intraoral indicators, such as various hard palate dimensions, and the width of anterior teeth, and a reliable universal indicator has not been found. The reported correlations vary across studies depending on the ethnicity[4] and sex of the subjects[10,19].

The aim of the study is to provide the first sex-stratified evaluation of associations between selected hard palate dimensions and the mesiodistal width of maxillary anterior teeth in adults from Bosnia and Herzegovina. This study should provide more useful clinical guidelines because the same relationship was previously analysed in the same participants, but the results were reported exclusively for the combined sample.[20]

Materials and Methods

In this retrospective observational cross-sectional study, conducted at the Department of Prosthodontics, Faculty of Dentistry, University of Sarajevo, maxillary casts from 180 adults were evaluated, including 114 women and 66 men between 20 and 40 years of age. Ethical approval was obtained from the institutional committee, and written informed consent was provided by each participant. The study was carried out in accordance with the Declaration of Helsinki.

Casts were included in the study if they showed a complete maxillary dentition with well-aligned teeth. Minor variations in tooth position and the absence of third molars were accepted. Casts with restorations, untreated caries, visible tooth wear, spacing, or crowding on the maxillary anterior teeth were excluded from this study. Records from individuals with a history of orthodontic treatment, parafunctional habits, congenital or acquired maxillofacial conditions, or craniofacial trauma were also excluded.

All casts were made in type IV dental stone (Moldastone, Kulzer GmbH) by pouring alginate impressions (Xantalgin Select, Kulzer GmbH) that had been previously disinfected according to a clinical protocol (Aseptoprint Liquid, OCC Switzerland). After the gypsum had set, each cast was separated from the impression, inspected to confirm accurate reproduction of the teeth and anatomical landmarks, and then trimmed before measurement.

All measurements in this study were performed by a trained examiner using a digital calliper with a resolution of 0.01 mm (Emil Lux GmbH & Co. KG).

Palatal measurements included a) the hamular distance (HD), measured as the distance between the right and left hamular notches; b) the hard palate length (HPL), measured from the centre of the incisive papilla to the fovea palatine; c) the distance from the incisive papilla to the right hamular notch (RHN-IP); and d) the distance from the incisive papilla to the left hamular notch (LHN-IP). The mesiodistal widths of the maxillary anterior teeth were recorded on each cast for the right and left central incisors (WU1R, WU1L), lateral incisors (WU2R, WU2L), and canines (WU3R, WU3L). The individual widths of anterior teeth were measured at the level of the contact points.

Each tooth and palatal measurement was repeated three times on each cast, and the mean values were obtained and used for analysis. The combined mesiodistal width of the six maxillary anterior teeth (ATW) was then calculated for each subject.

Statistical analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (IBM SPSS Statistics, version 21, IBM Corp). Descriptive statistics were calculated for all variables. Differences by sex were assessed with an independent-samples t-test, and paired measurements from the same cast were compared with a paired-samples t-test. Associations between palatal measurements and anterior teeth width were evaluated using simple linear regression. In addition, multiple linear regression (enter method) was performed, which included all palatal predictors. Before regression analysis, data distributions, univariate outliers, and multicollinearity were assessed through the Variance Inflation Factor, and no violations of statistical assumptions were identified. The significance level in this study was set at 0.05.

Results

Total of 180 maxillary casts were analysed, including 66 men (36.7%) and 114 women (63.3%). Mean age did not differ significantly between sexes (women: 25.66±0.94 years; men: 25.14±1.08 years; p=0.494).

Men exhibited higher mean values for nearly all tooth and palatal measurements, except for the left lateral incisor (WU2L), which showed no significant sex difference (p=0.155). Detailed descriptive statistics and sex comparisons are presented in Table 1.

Table 1. Comparison of maxillary anterior teeth and hard palate measurements between men and women

Dimensions	Sex									
	Men (n=66)				Women (n=114)					
	Min	Max	95% CI Mean	SD	Min	Max	95% CI Mean	SD	t	p
WU1R	7.30	10.25	8.74±0.15	0.61	7.40	10.37	8.52±0.11	0.60	2.37	0.019
WU2R	5.46	8.69	6.89±0.14	0.57	5.37	8.90	6.68±0.10	0.53	2.53	0.012
WU3R	6.75	9.20	8.09±0.14	0.59	6.80	8.83	7.70±0.08	0.45	5.02	<0.001
WU1L	7.30	10.17	8.80±0.15	0.60	5.40	9.93	8.54±0.12	0.63	2.74	0.007
WU2L	5.90	8.70	6.84±0.13	0.54	5.50	8.56	6.72±0.10	0.56	1.43	0.155
WU3L	6.60	9.50	8.05±0.13	0.53	6.60	8.73	7.72±0.08	0.42	4.48	<0.001
ATW	40.40	52.90	47.41±0.65	2.68	40.40	51.59	45.88±0.44	2.40	3.96	<0.001
HD	37.32	49.82	44.50±0.72	2.99	32.00	49.93	41.76±0.61	3.30	5.55	<0.001
HPL	40.70	52.75	46.71±0.65	2.69	40.09	51.27	45.47±0.48	2.64	3.00	0.003
RHN-IP	42.80	57.16	50.61±0.69	2.85	41.60	56.75	49.04±0.55	2.98	3.47	0.001
LHN-IP	42.80	57.71	50.43±0.78	3.22	41.00	57.70	48.95±0.60	3.29	2.94	0.004

Legend: WU1R, WU1L - widths of the right and left maxillary central incisors; WU2R, WU2L - widths of the right and left maxillary lateral incisors; WU3R, WU3L - widths of the right and left maxillary canines; ATW - combined mesiodistal width of the six maxillary anterior teeth; HD - hamular distance; HPL - hard palate length; RHN-IP - distance from the right hamular notch to the incisive papilla; LHN-IP - distance from the left hamular notch to the incisive papilla.

Table 2. Comparison of right-left maxillary measurements in men

Compared dimensions	Paired Differences				
	n	95% CI Mean	SD	t	p
WU1R - WU1L	66	-0.06±0.10	0.40	-1.192	0.237
WU2R - WU2L	66	0.05±0.13	0.52	0.719	0.475
WU3R - WU3L	66	0.05±0.08	0.34	1.146	0.256
RHN-IP - LHN-IP	66	0.18±0.37	1.55	0.937	0.352

Legend: WU1R, WU1L - widths of the right and left maxillary central incisors; WU2R, WU2L - widths of the right and left maxillary lateral incisors; WU3R, WU3L - widths of the right and left maxillary canines; RHN-IP - distance from the right hamular notch to the incisive papilla; LHN-IP - distance from the left hamular notch to the incisive papilla.

Table 3. Comparison of right-left maxillary measurements in women

Compared dimensions	Paired Differences				
	n	95% CI Mean	SD	t	p
WU1R - WU1L	114	-0.02±0.09	0.47	-0.368	0.713
WU2R - WU2L	114	-0.04±0.09	0.50	-0.924	0.357
WU3R - WU3L	114	-0.02±0.07	0.37	-0.566	0.572
RHN-IP - LHN-IP	114	0.09±0.36	1.95	0.497	0.620

Legend: WU1R, WU1L - widths of the right and left maxillary central incisors; WU2R, WU2L - widths of the right and left maxillary lateral incisors; WU3R, WU3L - widths of the right and left maxillary canines; RHN-IP - distance from the right hamular notch to the incisive papilla; LHN-IP - distance from the left hamular notch to the incisive papilla.

Within each sex, no significant right-left differences were observed for maxillary anterior tooth widths or for distance from the right hamular notch to the incisive papilla (RHN-IP) versus distance from the left hamular notch to the incisive papilla (LHN-IP) as shown in Tables 2 and 3.

In both sexes, the combined mesiodistal width of six maxillary anterior teeth (ATW) differed significantly from hamular distance (HD), RHN-IP, and LHN-IP. Comparisons between ATW and hard palate length (HPL) were not statistically significant (Tables 4 and 5).

Table 4. Comparison of ATW with palatal dimensions in men

Compared dimensions	n	Paired Differences 95% CI Mean	SD	t	p
ATW - HD	66	2.91±1.00	4.13	5.715	<0.001
ATW - HPL	66	0.70±0.80	3.31	1.718	0.091
ATW - RHN-IP	66	-3.20±0.74	3.11	-8.371	<0.001
ATW - LHN-IP	66	-3.03±0.80	3.31	-7.419	<0.001

Legend: ATW - combined mesiodistal width of the six maxillary anterior teeth; HD - hamular distance; HPL - hard palate length; RHN-IP - distance from the right hamular notch to the incisive papilla; LHN-IP - distance from the left hamular notch to the incisive papilla.

Table 5. Comparison of ATW with palatal dimensions in women

Compared dimensions	n	Paired Differences 95% CI Mean	SD	t	p
ATW - HD	114	4.12±0.65	3.49	12.588	<0.001
ATW - HPL	114	0.40±0.55	2.97	1.441	0.152
ATW - RHN-IP	114	-3.16±0.59	3.16	-10.669	<0.001
ATW - LHN-IP	114	-3.07±0.61	3.34	-9.832	<0.001

Legend: ATW - combined mesiodistal width of the six maxillary anterior teeth; HD - hamular distance; HPL - hard palate length; RHN-IP - distance from the right hamular notch to the incisive papilla; LHN-IP - distance from the left hamular notch to the incisive papilla.

Among men, ATW showed significant associations with RHN-IP and LHN-IP, while HD and HPL were not significant predictors (Table 6).

Among women, all assessed palatal variables demonstrated significant associations with ATW, with LHN-IP showing the strongest correlation, as presented in Table 7.

Table 6. Simple linear regression models evaluating associations between palatal measurements and anterior teeth width (ATW) in men

Regression model	Mean X	Mean Y	X/Y	Regression parameters r	a	b	p
HD -> ATW	44.50	47.41	0.94	0.061	49.85	-0.06	0.626
HPL -> ATW	46.71	47.41	0.99	0.239	36.61	0.24	0.053
RHN-IP -> ATW	50.61	47.41	1.07	0.369	29.85	0.35	0.002
LHN-IP -> ATW	50.43	47.41	1.06	0.381	31.43	0.32	0.002

Legend: HD - hamular distance; HPL - hard palate length; RHN-IP - distance from the right hamular notch to the incisive papilla; LHN-IP - distance from the left hamular notch to the incisive papilla; ATW - combined mesiodistal width of the six maxillary anterior teeth.

Table 7. Simple linear regression models evaluating associations between palatal measurements and anterior teeth width (ATW) in women

Regression model	Mean X	Mean Y	X/Y	Regression parameters r	a	b	p
HD -> ATW	41.76	45.88	0.91	0.283	37.29	0.21	0.002
HPL -> ATW	45.47	45.88	0.99	0.306	33.20	0.28	0.001
RHN-IP -> ATW	49.04	45.88	1.07	0.324	33.08	0.26	<0.001
LHN-IP -> ATW	48.95	45.88	1.07	0.347	33.50	0.25	<0.001

Legend: HD - hamular distance; HPL - hard palate length; RHN-IP - distance from the right hamular notch to the incisive papilla; LHN-IP - distance from the left hamular notch to the incisive papilla; ATW - combined mesiodistal width of the six maxillary anterior teeth.

The multiple regression models explained approximately 17% of the variance in ATW for both sexes. Among men, no palatal variable remained a significant independent predictor, whereas among women, hamular distance was the only variable that remained significant (Tables 8–11).

Table 8. Model fit statistics for the multiple regression model predicting anterior teeth width (ATW) in men

R	R^2	Adjusted R^2	Standard Error	F	p
0.416	0.173	0.119	2.51	3.186	0.019

Table 9. Regression coefficients for the multiple regression model predicting anterior teeth width (ATW) in men

	Unstandardized Coefficients		Standardized Coefficients			95% CI for B	
Predictor	B	Standard Error	Beta	t	p	Lower Bound	Upper Bound
Intercept	36.175	8.105		4.463	<0.001	19.968	52.382
X_1 HD	-0.090	0.113	-0.100	-0.795	0.430	-0.315	0.136
X_2 HPL	-0.246	0.204	-0.248	-1.210	0.231	-0.653	0.161
X_3 RHN-IP	0.255	0.243	0.271	1.047	0.299	-0.232	0.741
X_4 LHN-IP	0.274	0.216	0.330	1.269	0.209	-0.158	0.707

Legend: ATW - combined mesiodistal width of the six maxillary anterior teeth; HD - hamular distance; HPL - hard palate length; RHN-IP - distance from the right hamular notch to the incisive papilla; LHN-IP - distance from the left hamular notch to the incisive papilla.

Table 10. Model fit statistics for the multiple regression model predicting anterior teeth width (ATW) in women

R	R^2	Adjusted R^2	Standard Error	F	p
0.411	0.169	0.139	2.23	5.54	<0.001

Table 11. Regression coefficients for the multiple regression model predicting anterior teeth width (ATW) in women

	Unstandardized Coefficients		Standardized Coefficients			95% CI for B	
Predictor	B	Standard Error	Beta	t	p	Lower Bound	Upper Bound
Intercept	26.766	4.314		6.204	<0.001	18.215	35.316
X_1 HD	0.159	0.067	0.219	2.369	0.020	0.026	0.292
X_2 HPL	0.108	0.148	0.118	0.725	0.470	-0.187	0.402
X_3 RHN-IP	0.039	0.135	0.048	0.286	0.776	-0.229	0.306
X_4 LHN-IP	0.116	0.122	0.159	0.955	0.342	-0.125	0.357

Legend: ATW - combined mesiodistal width of the six maxillary anterior teeth; HD - hamular distance; HPL - hard palate length; RHN-IP - distance from the right hamular notch to the incisive papilla; LHN-IP - distance from the left hamular notch to the incisive papilla.

In men, the regression equation incorporating the estimated coefficients was expressed as: $ATW = 36.175 - 0.090X_1 - 0.246X_2 + 0.255X_3 + 0.274X_4$.

In women, the regression equation incorporating the estimated coefficients was expressed as: $ATW = 26.766 + 0.159X_1 + 0.108X_2 + 0.039X_3 + 0.116X_4$.

Discussion

This study provides the first sex-stratified analysis of the relationship between selected hard palate dimensions and the mesiodistal width of the maxillary anterior teeth (ATW) in an adult Bosnian-Herzegovinian population. The study parameters were assessed using cast measurements, a method supported by previous research[21,22], as it has been reported that the same accuracy can be achieved with cast measurements or direct intraoral measurements[23].

As reported in numerous craniofacial studies, men exhibited higher mean values for nearly all dental and palatal measurements, reflecting the well-established sexual dimorphism in tooth size and maxillary morphology[24-27]. The only exception in the present sample was the left lateral incisor. The mean widths recorded in this study are comparable to those reported for the European population, where no sex-related difference in the width of this tooth has also been observed.[28] Lateral incisors have the most variable dimensions among the anterior teeth, and this variability can differ between the right and left sides.[29,30] This variability may help explain why the left lateral incisor did not show a measurable sex difference in this sample.

The consistently symmetrical right-left values for both tooth dimensions and palatal distances in each sex are in agreement with previous reports.[19,31-34] Such symmetry is clinically relevant because it can minimize the influence of unilateral morphological variations when these measurements are used to estimate anterior teeth width.

In contrast to previous findings based on a combined sample[20], the present results showed that ATW did not differ significantly from hard palate length (HPL) in either sex. In this study, the differences between ATW and hamular distance (HD), as well as between ATW and the papilla-hamular notch distances (RHN-IP and LHN-IP), were statistically significant in both sexes. Previous

studies examining the relationship between anterior teeth width and palatal measurements were conducted on combined samples without sex-specific analyses, as shown by Baker et al[34], Shivaji et al[35], and Sayed et al[36], and therefore their results are not directly comparable to the present findings. Although similarity in mean values alone cannot be taken as evidence of predictive validity, the close correspondence between HPL and ATW indicates that this dimension lies within an anatomical range comparable to the width of the anterior maxillary teeth. Because the sagittal dimensions of the hard palate show relative constancy over time, largely due to the limited influence of alveolar remodelling on this maxillary region[18], HPL could be useful for estimating anterior teeth width in clinical situations where pre-extraction records are unavailable, provided that its correlation with anterior teeth width is sufficiently strong.

Regression analyses in this study further clarified these relationships, revealing sex-specific patterns. Among men, only the distances from the incisive papilla to the hamular notches showed significant individual associations with ATW. Neither HD nor HPL demonstrated predictive value in simple regression. In women, all palatal dimensions were significantly associated with ATW, with the strongest correlations observed for the papilla-hamular notch distances. Several studies have also reported significant simple correlations between palatal dimensions and anterior teeth width, although all analyses were performed on combined samples rather than stratified by sex.[20,35] By contrast, the study by Larasati et al found no significant simple associations between ATW and any of the corresponding palatal measurements in either men or women, including the papilla to hamular distances and the hamular distance.[19] Those results did not reveal sex-specific predictive relationships. Differences in sample structure and variability can explain the opposite results between the studies. Larasati et al included fewer male participants and reported a narrower range of palatal measurements[19], which reduced the detection of significant simple associations with ATW. In contrast, the present study involved a larger and more balanced sample with greater variation in palatal dimensions, making relationships easier to identify. Population differences in palatal and dental morphology may also have contributed to the different regression outcomes.

When the variables were analysed together, the pattern of predictors in this study changed. In men, none of the palatal measurements remained significant in the multivariable model, suggesting that the overlap among these dimensions may reduce the effect of any single variable. In women, HD was the only variable that retained an independent contribution. These results confirm the diagnostic value of HD reported in previous studies.[17,35,37] Also, they suggest that the proportional relationship between the hard palate and the anterior teeth is more stable in women. In contrast, greater anatomical variability in men can reduce the predictive strength of individual palatal variables. Larasati et al reported no independent predictors in either sex.[19] Different results in women may reflect differences in sample size, measurement range, and population morphology. No other study has evaluated multivariable predictors of maxillary anterior teeth width separately in men and women, which restricts further direct comparisons. The present findings also indicate that palatal measurements, although limited in predictive strength, may offer practical value as initial reference points when estimating maxillary anterior teeth width. Their usefulness appears to be greatest when considered together with additional anatomical parameters rather than applied independently. A better understanding of sex-specific morphological variation may further enhance the clinical relevance of these measurements, and future research could help clarify which combinations of indicators provide the most reliable guidance when selecting artificial teeth.

Within the limits of the study design, these findings help clarify how palatal morphology relates to anterior teeth dimensions. The unequal number of men and women may have influenced the stability of some estimates, especially in the smaller group, where weaker associations are more difficult to detect. This does not alter the observed sex-specific patterns but suggests that future studies with more balanced groups could refine these comparisons. Broader samples and more detailed anatomical assessments may further improve understanding of which palatal characteristics most accurately reflect maxillary anterior teeth width.

Conclusions

According to the results of this study, hard palate measurements show sex-specific relationships with the mesiodistal width of maxillary anterior teeth. In men, the distance between the incisive papilla and the hamular notch, and in women, the hamular distance, may serve as supportive guides when selecting artificial teeth.

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