Palatal Soft Tissue Thickness at Different Ages Using an Ultrasonic Device

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Objective: *To evaluate the palatal soft tissue thickness among placement sites of temporary anchorage devices (TADs) in late mixed, early permanent and permanent dentition.* ***Materials and Method:*** *The sample consisted of three groups; 42 late mixed dentition (mean age = 11.0 years), 41 early permanent dentition (mean age = 13.8 years), and 38 permanent dentition (mean age = 23.1 years). Soft tissue thickness was measured intraorally with an ultrasonic device using a grid of 27, 4x4 mm² squares to delineate the measurement points. Repeated measures analysis of variance was performed to analyze the data.* ***Results:*** *There was a significant difference in soft tissue thickness among dentition groups with the permanent dentition group showing the highest values ($P < 0.001$). In each group, the thickness significantly increased from median to lateral and from anterior to posterior sites. Furthermore, the thickness showed a significant difference according to the arch form and gender ($P < 0.05$). However, there were no significant differences according to irregularity index and Angle classification.* ***Conclusions:*** *The soft tissue thickness of the palate increases from the late mixed to permanent dentition. These findings may be helpful for clinicians to enhance their successful application of TADs in the palate.*

Keywords: *Palatal soft tissue thickness measurement, Ultrasonic device, Dentition, TADs*
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INTRODUCTION

Temporary anchorage devices (TADs) are an efficient alternative to the extraoral ones with several advantages. They provide an absolute anchorage without patient compliance, and a more convenient and simple force system for various tooth movements.[1]

TADs are frequently placed in the palate due to the good bone quantity, accessibility, and lower susceptibility to inflammation. In particular, the paramedian area is ideal in adolescents when a midpalatal suture may present a risk.[2,3]

It might be important to evaluate the soft tissue thickness of the palate before the installation of TADs, since thick soft tissue will lead to a shorter length of miniscrew in the bone. Currently, three methods are used to measure soft tissue thickness. One is direct measurement using a needle or periodontal probe under local anesthesia.[4,5] The second is indirect measurement using cone-beam computed tomography (CBCT).[6-9] This method has radiation exposure problem and limited resolution due to slice thickness. Finally, there is direct measurement using an ultrasonic device which has convenience and shows repeatability, reliability, and accuracy.[10-17]

Recently, the application of palatal plates to the paramedian area of adolescent patients in a mixed dentition stage was reported as an anchorage for full arch distalization.[18] However, the association between the placement site of the TADs and the various soft tissue thickness of the palate has not been evaluated.

There are studies about soft tissue measurements at the buccal attached gingiva, palatal slope,[19] and midpalatal suture in cadavers.[20] However, no studies have been conducted to evaluate soft tissue thickness of the paramedian area of palate in different growth stages.

Therefore, the purpose of this study was to measure the

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soft tissue thickness on the palate and analyze the differences according to different dentition for the placement of TADs.

MATERIALS AND METHOD

A randomly selected sample (n = 121) consisted of 3 groups; 42 late mixed dentition (LMD, 22 males and 20 females; mean age = 11.0 years), 41 early permanent dentition (EPD, 19 males and 22 females; mean age = 13.8 years), and 38 permanent dentition (PD, 18 males and 20 females; mean age = 23.1 years). The Institutional Review Board of the Catholic University of Korea had reviewed and approved the study.

Subjects were excluded from the study if they had ectopically positioned teeth or had taken any medication, such as cyclosporin A, a calcium channel blocker, or phenytoin that would affect periodontal tissue or had a high vault and extremely narrow palate or accentuated rugae.

The soft tissue thickness of the palate was measured in 27 square 4x4 mm² areas using an ultrasonic gingival thickness meter (SDM, KRUPP Corporation, Essen, Germany), (range of measurement 0.3 to 8.0 mm; resolution 0.1 mm; ultrasonic frequency 5 MHz; sensor diameter 3.0 mm) (Figure 1). To delineate these areas, a grid was marked with an indelible pencil (Albrecht Durer, Faber-Castell, Nurnberg, Germany) intraorally on the palate. Anteroposterior lines were drawn at 4, 8 and 12 mm proximal to the midpalatal line. And then, 10 perpendicular lines were made at 4 mm intervals starting from 10 mm apical to the gingival crest of the interdental papilla between central incisors (Measured values were sorted and grouped into 9 cells formed by 3 mediolateral columns (medial, middle and lateral) and 3 anteroposterior rows (anterior, middle and posterior) each row is spanning 3 successive areas (Figure 2). Soft tissue thickness was averaged for each cell. All measurements were made by one investigator (S.M.L.) in a wet environment with minimal pressure on the soft tissue.

To evaluate the difference in soft tissue thickness in the arch form, the sample was classified into 3 groups of 31 tapered, 50 ovoid, and 40 square arch forms through matching the dentition to custom-made disposable arch form templates (OrthoForm, 3M Unitek, Monrovia, Calif).

Likewise, to assess the differences according to the severity of irregularity, the samples were classified according to irregularity index[21] as follows: 1. Mild (n= 78) irregularity up to 4 mm (spacing was also included), 2. Moderate (n= 31): irregularity between 4 and 8 mm, and 3. Severe (n= 12): irregularity more than 8 mm.

In addition, the samples were divided into Class I (74), II (37), and III (10) according to Angle's classification.

To test the intra-examiner reliability, 10 randomly selected cases from each age group were measured 2 weeks later by the same person (S.M.L.).

Statistical analysis

Data were analyzed using SPSS 16.0.2.1 (SPSS Inc., Chicago, Ill). Intra-class correlation coefficient (ICC) test

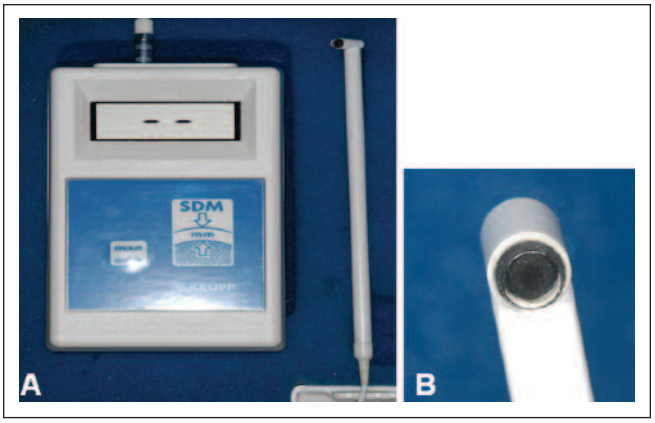

Figure 1. (A) SDM ultrasonic gingival thickness meter (KRUPP Corporation, Essen, Germany). (B) SDM's tip having 3 mm diameter.

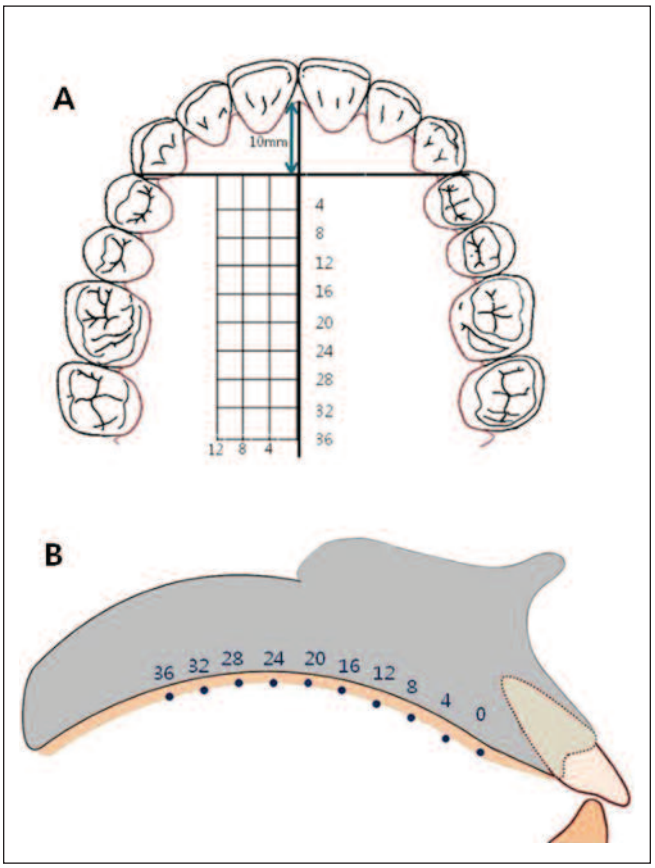

Figure 2. Location of measurement areas on the maxilla. (A) occulsal view. (B) sagittal view sectioned at the midpalatal suture.

revealed high reliability between the two assessments (ICC = 0.97). Repeated measures analysis of variance (RM ANOVA) was used to test inter- and intra-group differences of palatal soft tissue thickness according to the late mixed, early permanent and adult groups, as well as arch form, irregularity index, Angle classification, and gender. Statistical significance was determined at $P < 0.05$.

RESULTS

In comparison of the soft tissue thickness according to dentition, a significant difference was found among groups ($P <$

0.001). The thickness in the PD group ranged between 1.8 to 3.9 mm, the EPD group ranged between 1.8 and 3.2 mm, and the LMD group ranged between 1.8 to 3.0 mm. In each group, the palatal soft tissue thickness had significantly increased from median to lateral and from anterior to posterior sites ($P < 0.001$) with a significant interaction between both directions ($P < 0.001$) (Table 1). In addition, there was a significant interaction between dentition group and the site of measurement ($P = 0.016$).

In comparison of thickness according to gender, females displayed a significantly thicker soft tissue than males ($P = 0.023$) (Table 2). Also, there was a significant interaction between the gender and the site of measurement ($P = 0.018$).

Also, the soft tissue thickness showed a significant difference according to the arch form ($P = 0.036$). The tapered group displayed a thicker soft tissue (range: 2.05 to 3.34 mm) than that of the ovoid (range: 1.77 to 3.54 mm) and square groups (range: 1.70 to 3.17 mm) (Table 3). However, there was no significant interaction between the arch form and the site of measurement ($P = 0.230$).

There were no significant differences in soft tissue thickness according to irregularity index ($P = 0.193$) and Angle classification ($P = 0.131$) (Tables 4 and 5).

Table 1. Comparison of Palatal Soft Tissue Thickness among Late Mixed, Early Permanent and Permanent Dentitions (unit: mm)

	Late Mixed Dentitionv (n = 42)							Early Permanent Dentition (n = 41)							Permanent Dentition (n = 38)							p-value§
	Median		Middle		Lateral		p-value‡	Median		Middle		Lateral		p-value‡	Median		Middle		Lateral		p-value‡	
	Mean	SE	Mean	SE	Mean	SE		Mean	SE	Mean	SE	Mean	SE		Mean	SE	Mean	SE	Mean	SE		
Anterior	1.79	0.41	2.05	0.40	2.39	0.39		1.94	0.42	2.25	0.46	2.49	0.54		2.21	0.56	2.50	0.42	2.93	0.51		< 0.001
Middle	1.83	0.69	2.04	0.66	2.38	0.61	< 0.0001	1.83	0.70	2.20	0.72	2.47	0.67	< 0.0001	1.80	0.69	2.70	0.84	3.19	0.75	< 0.0001	
Posterior	2.32	0.99	2.95	1.09	3.04	1.20		2.08	0.96	2.97	0.98	3.18	1.16		t2.15	0.93	3.18	1.04	3.92	1.21		
p-value†	< 0.0001							< 0.0001							< 0.0001							

Repeated measures ANOVA

Median represents the area between lines 0 and 4 mm lateral to the midpalatal suture; middle, between lines 4 and 8 mm; lateral, between lines 8 and 12 mm.

Anterior represents the areas between lines 0-4, 4-8, and 8-12 mm posterior to lingual interdental papilla of incisors.

Middle represents the areas between lines 12-16, 16-20, and 20-24 mm posterior to lingual interdental papilla of incisors.

Posterior represents the areas between lines 24-28, 28-32, and 32-36 mm posterior to lingual interdental papilla of incisors.

SE, standard error

† The significance level of the effect of the anteroposterior position in late mixed, early permanent and permanent dentition groups.

‡ The significance level of the effect of the mediolateral position in late mixed, early permanent and permanent dentition groups.

§ The significance level of the comparison of the 3 groups.

Table 2. Comparison of Palatal Soft Tissue Thickness According to Gender (unit: mm)

	Male (n = 59)							Female (n = 62)							p-value§
	Median		Middle		Lateral		p-value‡	Median		Middle		Lateral		p-value‡	
	Mean	SE	Mean	SE	Mean	SE		Mean	SE	Mean	SE	Mean	SE		
Anterior	1.96	0.53	2.16	0.46	2.49	0.55		1.98	0.47	2.36	0.45	2.69	0.50		0.023
Middle	1.68	0.59	2.14	0.68	2.56	0.67	< 0.0001	1.95	0.75	2.46	0.85	2.77	0.84	< 0.0001	
Posterior	1.98	0.92	2.84	1.00	3.43	1.29		2.39	0.95	3.21	1.04	3.30	1.20		
p-value†	< 0.0001							< 0.0001							

Repeated measures ANOVA

† The significance level of the effect of the anteroposterior position in male and female subjects.

‡ The significance level of the effect of the mediolateral position in male and female subjects.

§ The significance level of the comparison of the 2 groups.

Table 3. Comparison of Palatal Soft Tissue Thickness According to Arch Form (unit: mm)

	Tapered (n = 31)							Ovoid (n = 50)							Square (n = 40)							p-value§
	Median		Middle		Lateral		p-value‡	Median		Middle		Lateral		p-value‡	Median		Middle		Lateral		p-value‡	
	Mean	SE	Mean	SE	Mean	SE		Mean	SE	Mean	SE	Mean	SE		Mean	SE	Mean	SE	Mean	SE		
Anterior	2.12	0.57	2.22	0.47	2.59	0.57		1.90	0.51	2.33	0.47	2.60	0.50		1.95	0.39	2.21	0.45	2.59	0.55		0.036
Middle	2.05	0.83	2.51	0.94	2.75	0.99	< 0.0001	1.77	0.61	2.21	0.72	2.67	0.69	< 0.0001	1.70	0.64	2.250	0.71	2.60	0.66	< 0.0032	
Posterior	2.55	0.81	3.47	1.28	3.34	1.24		2.30	1.02	3.12	0.83	3.54	1.21		1.77	0.84	2.58	0.88	3.17	1.29		
p-value†	< 0.0001							< 0.0001							< 0.0001							

Repeated measures ANOVA

† The significance level of the effect of the anteroposterior position in tapered, ovoid and square arch form groups.

‡ The significance level of the effect of the mediolateral position in tapered, ovoid and square arch form groups.

§ The significance level of the comparison of the 3 groups.

Table 4. Comparison of Palatal Soft Tissue Thickness According to Irregularity Index (unit: mm)

	Mild (n = 78)						p-value‡	Moderate (n = 31)						p-value‡	Severe (n = 12)						p-value‡	p-value§
	Median		Middle		Lateral			Median		Middle		Lateral			Median		Middle		Lateral			
	Mean	SE	Mean	SE	Mean	SE		Mean	SE	Mean	SE	Mean	SE		Mean	SE	Mean	SE	Mean	SE		
Anterior	1.90	0.49	2.24	0.46	2.61	0.55		2.07	0.42	2.23	0.46	2.53	0.50		2.19	0.62	2.49	0.51	2.66	0.52		0.193
Middle	1.77	0.68	2.28	0.77	2.69	0.74	< 0.0001	1.79	0.57	2.17	0.74	2.52	0.61	< 0.0001	2.25	0.94	2.75	0.92	2.88	1.16	< 0.029	
Posterior	2.14	0.91	2.97	1.04	3.40	1.27		2.24	1.03	2.94	0.79	3.32	1.03		2.40	1.08	3.65	1.38	3.21	1.64		
p-value†	<0.0001							<0.0001							<0.001							

Repeated measures ANOVA

† The significance level of the effect of the anteroposterior position in the irregularity groups.

‡ The significance level of the effect of the mediolateral position in irregularity groups.

§ The significance level of the comparison of the 3 groups.

Table 5. Comparison of Palatal Soft Tissue Thickness According to Angle Classification (unit: mm)

	Class I (n = 74)						Class II (n = 37)						Class III (n = 10)						p-value
	Median		Middle		Lateral		Median		Middle		Lateral		Median		Middle		Lateral		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Anterior	1.87	0.44	2.19	0.44	2.51	0.45	2.18	0.58	2.38	0.52	2.72	0.66	1.98	0.35	2.42	0.30	2.77	0.51	0.131
Middle	1.85	0.67	2.21	0.71	2.54	0.68	1.82	0.74	2.42	0.93	2.90	0.88	1.63	0.69	2.50	0.68	2.72	0.73	
Posterior	2.31	0.99	2.92	0.95	3.16	1.12	2.01	0.91	3.25	1.22	3.71	1.33	1.92	0.79	3.03	0.85	3.60	1.52	

Repeated measures ANOVA

Significance level of the comparison of the 3 groups.

DISCUSSION

The aim of this study was to compare the palatal soft tissue thickness among late mixed, early permanent and permanent dentitions for placement of temporary anchorage devices. Also, the effects of the arch form, gender, irregularity index, and Angle classification on the thickness were evaluated.

Melsen *et al*[22] proposed several factors contributing to the success and failure of skeletal anchorage. Beside the experience of the operator, cortical bone thickness and quality, insertion technique, and treatment planning, type and thickness of soft tissue was suggested as one of the main reasons. Therefore, in our study the palatal soft tissue thickness was measured to present a map that aids the decision of site selection for miniscrews or a palatal plate.

Previous studies on soft tissue thickness were limited to buccal and palatal slope, and moreover those were held on periodontal perspectives for guiding periodontal therapies.[12,13,15,16] Recently, the soft tissue thickness has been measured for more stable placement of TADs.[19] However, the paramedian area of the palate was not included. In addition, a previous study has evaluated the palatal soft tissue thickness on a sectioned cadaver specimen, but it was only limited to the midpalatal area.[20]

Most researches have evaluated the palatal bone and soft tissue using reference lines through the incisive foramen and posterior nasal spine or perpendicular to the occlusal plane. These methods were possible using 3D CBCT and cadavers.[20,23,24] However, in our *in vivo* study, the transverse reference lines were drawn directly on the palatal soft tissue.

A previous study has reported the high reliability of SDM in measurement of soft tissue thickness.[25] Also, Müller *et al*[14-16] assessed the reliability and validity of ultrasonic measurements of soft tissue thickness in different parts of the oral cavity. They reported that the palatal mucosa, which includes the rugae, presented some difficulties, yet the results were reliable. However, Lowson and Jones[26] reported that the ultrasound technique underestimated mucosal thickness by 0.6 mm on average at sites where mucosal thickness was less than 6 mm.

Cha *et al*[19] were unable to measure the midpalatal area due to limited accessibility to the sensor, so subjects with a high vault and an extremely narrow palate were excluded from the evaluation of the paramedial area in our study. If the study is repeated, this measurement is possible if a special tip is used. Subjects with accentuated rugae were also excluded from this study because their condition complicates the measurement procedure.

Recently, Kim *et al*[20] evaluated the soft tissue thickness of midpalatal suture, but only in cadavers. Palatal mucosa was thickest at a point 4 mm posterior from the incisive papilla (mean 2.93 mm), and showed lesser value in more posterior areas, ranging from 1.01-0.90 mm. Our data showed thicker soft tissue thickness medially (1.80 to 2.21 mm) than that of Kim *et al,*[20] in the midpalatal region of the permanent dentition group. This difference may be due to shrinkage during the processing of the specimens.[27,28]

For application of TADs, several studies showed that the palatal bone thickness and density increased anteriorly and medially.[23,24] Interestingly, in our study, the thickness of soft tissue showed an opposite tendency to the bone, the thickness decreasing anteriorly and medially. These results synergistically support the suggestion that the anterior medial area of the palate is more suitable as a skeletal anchorage.

Considering the different age groups, Eger *et al*[12] reported

no differences in means and standard deviations of gingival thickness between different age groups (20-25, 40-45, 55-60 years). In our study of the palatal tissue thickness, the samples were divided by the types of dentition; late mixed, early permanent, and permanent dentition groups, the mean age being 11.0, 13.8, and 23.1 years respectively. Interestingly, our results showed significant differences between each of the groups where the older group showed thicker mucosa. Wara-aswapati *et al*[4] reported significantly thicker palatal mucosa in older groups. Also, they showed no significant difference between genders within each group. However, our results demonstrated thicker palatal soft tissue in females. This might be due to the difference in the method and the region of interest during measurements.

Finally, from our study, different measurement values were obtained according to the arch form of the palate; the tapered arch form showing the greatest thickness. We did not evaluate the deep palate cases so this creates an opportunity for future research to assess the soft tissue of the palate according to palatal depth.

CONCLUSIONS

From this study, the following findings may be helpful for the clinicians to enhance their successful application of TADs in the palate.

There was a significant difference in soft tissue thickness among different dentition groups. The soft tissue thickness of the palate increased from the late mixed to permanent dentition.

The palatal soft tissue thickness is significantly increased from median to lateral and from anterior to posterior sites.

The thickness of the palatal tissue showed significant differences depending on the arch form and gender, but not on the irregularity index and Angle classification.

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