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Ultrasonographic assessment of soft tissue thickness: Skeletal Class I and Class II orthodontic miniscrew placement sites

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Abstract:
Oral soft tissue thickness influences the primary stability and success of orthodontic miniscrew implants, particularly in non-keratinized mucosa. Therefore, it is of interest to evaluate the soft tissue thickness at orthodontic miniscrew placement sites in skeletal Class I and Class II patients using ultrasonography. One hundred participants (18-25 years) were equally allocated into four groups based on skeletal class and growth pattern and measurements were recorded at 19 maxillary and mandibular sites. Significant differences were observed at the mandibular central incisors and the left maxillary lateral incisor canine region, with the greatest buccal thickness between the lateral incisor and canine. Thus, palatal soft tissues were approximately 2.5-3 times thicker than buccal tissues, highlighting ultrasonography as a valuable tool for site-specific miniscrew placement planning.

Keywords: Oral soft tissue, ultrasonography, miniscrew implants, anchorage, growth pattern, skeletal malocclusion

Background:
Crowded, irregular and proclined teeth have been a problem for some individuals since antiquity and attempts to correct this disorder go back at least to 1000 BC. In 1728, the French pioneer Pierre Fauchard devised the first appliance, nothing that sufficient resistance must be exerted to produce mechanical pressure **[1].** Oral soft tissue plays an important role in the stability of miniscrew implants. As oral mucosa is the outermost lining of the oral cavity, it exists in two types: keratinized and non-keratinized. Gingiva is 75% parakeratinized, 15% keratinized and 10% non-keratinized. Orthodontic miniscrews surrounded by non-keratinized mucosa have a greater risk of failure than those surrounded by keratinized mucosa **[2].** For the soft-tissue component of stability, risk of failure for orthodontic miniscrews (OMS) surrounded by non-keratinized mucosa is higher than for OMS surrounded by keratinized mucosa **[3].** Therefore, in the buccal side of the alveolus, orthodontic miniscrews are usually placed in the interdental areas of the attached gingiva (AG), just adjacent to the mucogingival junction of the upper and lower arches. In the palate, the entire area of the palatal masticatory mucosa (PMM) is made up of keratinized tissue in which OMS can be reliably installed. However, the PMM is known to be at least two to three times thicker than the AG on the buccal side and different areas of the buccal AG have different soft-tissue thicknesses. Therefore, the soft tissue area for OMS installation is an important factor to consider **[4].** Temporary anchorage devices and extra dental anchorage devices have revolutionized clinical orthodontics by controlling anchorage and are designed specifically for orthodontic use **[5].** A new type of intraoral extradental anchorage, the titanium micro implant, has been developed as an alternative to conventional molar anchorage. The success rate of orthodontic miniscrews is between 80% and 95%**.** Researchers reported a miniscrew failure rate of 8.4%, authors reported a failure rate of less than 20%. The success rate for miniscrews placed in the palate is nearly 100%**.** The stability and success of orthodontic miniscrew implants depends on various factors including the thickness and mobility of soft tissue, the quality and quantity of cortical bone and the site of screw implantation **[6].** Recently, several kinds of implant anchors providing absolute anchorage have attracted the attention of orthodontists**.** Among them, titanium screws have advantages of minimal anatomic limitation for placement, lower medical cost, simpler placement surgery and less discomfort after implantation compared with dental implants **[7].** If orthodontic miniscrews with the same length are used in areas with different thicknesses of soft tissue, the length of OMS inserted in the bone will differ. So, the soft tissue thickness of the oral mucosa must be measured before OMS installation **[8].** Therefore, it is of interest to evaluate the soft tissue thickness at orthodontic miniscrew placement sites in skeletal Class I and Class II patients using ultrasonography.

Materials and Methods:
The present study was carried out in the Department of Orthodontics to clinically evaluate the soft tissue thickness at orthodontic miniscrew placement sites in skeletal class I and class II patients using ultrasonography. This study was divided into four groups. 100 patients aged 18-25 years were included based upon the inclusion and exclusion criteria **(Table 1)** and written informed consent was obtained from each individual at the beginning of the study.

Method of selection of study samples:
This study includes 100 patients (class I horizontal growth pattern - 25; class I vertical growth pattern - 25; class II horizontal growth pattern - 25; class II vertical growth pattern - 25; between the age groups 18 to 25 years) visiting the Department of Orthodontics and Dentofacial Orthopedics.

Patient records:
After selection of individuals, a detailed case history was taken. Informed consent and radiograph (lateral cephalogram) were taken in natural head position (NHP) in the Oral Radiology department using standard conditions for each individual participating in the study.

Armamentarium:
[1] 0.5 mm lead pencil
[2] Metallic scale
[3] 0.003-inch acetate paper
[4] Transparent plastic protractor
[5] Cheek retractor
[6] Cotton pellets
[7] Lateral cephalogram

Ultrasonography device components:
[1] SW - 1000 Ultrasound measure instrument (Main unit)
[2] A-scan ultrasonography probe
[3] Foot pedal
[4] Touch pen
[5] Printer paper roll

Method of the study:
Ethical clearance for the study was obtained from the Institutional Ethics Committee. Case history and lateral cephalogram were taken in natural head position in the Oral Radiology department using a standardized technique. Informed consent from each patient or guardian was obtained. On the lateral cephalogram, ANB angle and mandibular plane angle were measured. An ANB angle of 2° was classified as skeletal class I and an ANB angle >2° as skeletal class II. A mandibular plane angle (Sn-Go-Gn) <32° was grouped as horizontal growth pattern and Sn-Go-Gn >32° as vertical growth pattern. Based on these Cephalometric measurements, 100 patients were divided into 4 groups:

[1] Group A - Skeletal class I with horizontal growth pattern (25 patients)
[2] Group B - Skeletal class I with vertical growth pattern (25 patients)
[3] Group C - Skeletal class II with horizontal growth pattern (25 patients)
[4] Group D - Skeletal class II with vertical growth pattern (25 patients)

Soft-tissue thickness was measured in the interdental areas of buccal attached gingiva in the maxilla and mandible using an ultrasonography probe. A total of 12 sites in the maxilla (**Table 2**) and 7 sites in the mandible (**Table 3**) were selected for soft tissue thickness measurement. The A-scan SW-1000 is composed of a main unit, A-scan compact and inner-illuminated ultrasonography transducer probe, a built-in printer and a foot switch (AKAS MEDICAL, Bangalore, India). The frequency was 10 MHz. Before soft tissue thickness measurement, the gingiva was dried with cotton rolls. Measuring sites in the maxilla and mandible were marked with an indelible pencil. The thickness of the soft tissue on the palatal side was measured 6 mm below the gingival crest, slightly apical to the trifurcation area of the right and left permanent first molars. The ultrasonic measurements were made with the A-scan ultrasonography transducer probe using the pulse-echo principle, with the transducer adapted perpendicular to the most gingival surface. Five readings were recorded and the average was computed. By using the printout of this graph and with the help of an optical projector, the thickness of soft tissue was determined.

Statistical analysis:
Data were entered in MS Excel and analysed using SPSS version 24.0 (IBM, USA). Quantitative data were expressed as mean and standard deviation. Comparison of means within the same groups was done using paired t-test. Comparison of means between two groups was done using unpaired t-test. Comparison among four groups was performed using ANOVA and Post Hoc Tukey's HSD test was applied to assess significance between individual groups. A p-value <0.05 was considered statistically significant, while $p<0.001$ was considered highly significant.

Results:
A total of 100 patients were included, of whom 36 were male and 64 were female. The mean age was 19.93 ± 1.93 years. Significant differences were seen in the thickness of the buccal attached gingiva between mandibular central incisors across all four groups. Post Hoc Tukey's HSD test was used to assess whether the mean difference between individual groups was significant. When comparing buccal attached gingiva thickness across all four groups, significant differences were found between maxillary and mandibular central incisors (CICI) and highly significant differences were found in the left maxillary lateral incisor-canine (LT. LIC) region. No significant differences were seen at the remaining sites in the maxillary and mandibular arches. When comparing male and female groups, significant differences in the thickness of buccal attached gingiva were seen between canines and first premolars (CP1), wherein men showed thicker attached gingiva in the mandible and women showed thicker attached gingiva in the maxilla for this region. No significant differences were seen between buccal attached gingiva in skeletal class I and class II jaw bases, or between right and left sides in any of the four groups **(Table 4).**

Table 1: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
All patients selected should be physically and periodontally healthy.	History of previous orthodontic treatment.
Age - 18 to 25 years.	History of prosthodontic treatment (any fixed or removable prosthesis).
Skeletal class I and class II jaw base.	History of tooth extractions (except for the third molars).
Horizontal and vertical growth pattern.	Extensive restorations.

	Taking medications that affect the periodontal tissues (*e.g.* cyclosporine-A, calcium channel blockers, or phenytoin).

Table 2: Total 12 sites in maxilla

Sr No.	12 Sites in Maxilla
1	Between central incisors (CICI)
2	Between right lateral incisor and canine (LIC)
3	Between right canine and 1st premolar (CP1)
4	Between right 2nd premolar and 1st molar (P2M1)
5	Between right 1st and 2nd molar (M1M2)
6	Right palatal attached gingiva between 2nd premolar and 1st molar (P2M1)
7	Midpalatine raphe area between 1st and 2nd molar
8	Between left lateral incisor and canine (LIC)
9	Between left canine and 1st premolar (CP1)
10	Between left 2nd premolar and 1st molar (P2M1)
11	Between left 1st and 2nd molar (M1M2)
12	Left palatal attached gingiva between 2nd premolar and 1st molar (P2M1)

Table 3: Total 7 sites in mandible

Sr No.	7 Sites In Mandible
1	Between central incisors (CICI)
2	Between right canine and 1st premolar (CP1)
3	Between right 2nd premolar and 1st molar (P2M1)
4	Between right 1st and 2nd molar (M1M2)
5	Between left canine and 1st premolar (CP1)
6	Between left 2nd premolar and 1st molar (P2M1)
7	Between left 1st and 2nd molar (M1M2)

Table 4: Comparison of Buccal Attached Gingival Thickness between Skeletal Class I and Class II Subjects in Horizontal and Vertical Growth Patterns (Maxillary and Mandibular Arches)

Site	Arch	Growth Pattern	Class I Mean±SD	Class II Mean±SD	t-value	p-value	Inference NS=Not Significant (p>0.05); HS=Highly Significant (p≤0.001)
CICI	Maxillary	Horizontal	1.37±0.04	1.41±0.10	-1.879	0.066	NS
RT. LIC	Maxillary	Horizontal	1.97±0.22	1.94±0.07	0.68	0.5	NS
RT. CP1	Maxillary	Horizontal	1.66±0.17	1.62±0.16	0.874	0.387	NS
RT. P2M1	Maxillary	Horizontal	1.27±0.05	1.26±0.06	0.483	0.632	NS
RT. M1M2	Maxillary	Horizontal	1.39±0.07	1.40±0.07	-0.6	0.551	NS
RT. PALATAL P2M1	Maxillary	Horizontal	3.16±0.24	3.16±0.21	0	1	NS
MID PALATAL M1M2	Maxillary	Horizontal	0.83±0.10	0.80±0.05	1.592	0.118	NS
LT. LIC	Maxillary	Horizontal	1.93±0.06	1.94±0.07	-0.501	0.619	NS
LT. CP1	Maxillary	Horizontal	1.67±0.17	1.64±0.15	0.699	0.488	NS
LT. P2M1	Maxillary	Horizontal	1.30±0.07	1.27±0.06	1.518	0.136	NS
LT. M1M2	Maxillary	Horizontal	1.40±0.07	1.41±0.07	-0.46	0.647	NS
LT. PALATAL P2M1	Maxillary	Horizontal	3.13±0.20	3.17±0.17	-0.7	0.487	NS
CICI	Mandibular	Horizontal	0.77±0.03	0.78±0.02	-0.86	0.394	NS
RT. CP1	Mandibular	Horizontal	1.12±0.06	1.14±0.07	-0.911	0.367	NS
RT. P2M1	Mandibular	Horizontal	1.16±0.03	1.15±0.02	1.516	0.136	NS
RT. M1M2	Mandibular	Horizontal	1.61±0.09	1.58±0.07	1.286	0.205	NS
LT. CP1	Mandibular	Horizontal	1.12±0.05	1.13±0.05	-0.199	0.843	NS
LT. P2M1	Mandibular	Horizontal	1.17±0.04	1.16±0.03	0.861	0.394	NS
LT. M1M2	Mandibular	Horizontal	1.60±0.09	1.57±0.07	1.206	0.234	NS
CICI	Maxillary	Vertical	1.48±0.17	1.48±0.13	-0.074	0.942	NS
RT. LIC	Maxillary	Vertical	1.93±0.05	1.96±0.09	-1.656	0.104	NS
RT. CP1	Maxillary	Vertical	1.66±0.15	1.69±0.13	-0.588	0.559	NS
RT. P2M1	Maxillary	Vertical	1.29±0.07	1.26±0.05	1.732	0.09	NS
RT. M1M2	Maxillary	Vertical	1.38±0.06	1.37±0.08	0.533	0.597	NS
RT. PALATAL P2M1	Maxillary	Vertical	3.09±0.18	3.07±0.25	0.418	0.678	NS
MID PALATAL M1M2	Maxillary	Vertical	0.82±0.06	0.81±0.04	0.602	0.55	NS
LT. LIC	Maxillary	Vertical	1.94±0.05	2.01±0.08	-3.494	0.001	HS
LT. CP1	Maxillary	Vertical	1.69±0.15	1.71±0.12	-0.53	0.598	NS
LT. P2M1	Maxillary	Vertical	1.29±0.06	1.28±0.04	1.107	0.274	NS
LT. M1M2	Maxillary	Vertical	1.39±0.06	1.38±0.08	0.509	0.613	NS
LT. PALATAL P2M1	Maxillary	Vertical	3.10±0.14	3.04±0.19	1.171	0.247	NS
CICI	Mandibular	Vertical	0.79±0.03	0.79±0.02	0.521	0.605	NS

RT. CP1	Mandibular	Vertical	1.13±0.06	1.11±0.06	1.192	0.239	NS
RT. P2M1	Mandibular	Vertical	1.15±0.03	1.15±0.03	0.761	0.45	NS
RT. M1M2	Mandibular	Vertical	1.58±0.07	1.62±0.06	-1.955	0.056	NS
LT. CP1	Mandibular	Vertical	1.13±0.05	1.11±0.05	1.282	0.206	NS
LT. P2M1	Mandibular	Vertical	1.16±0.03	1.15±0.03	0.498	0.621	NS
LT. M1M2	Mandibular	Vertical	1.59±0.07	1.62±0.05	-1.626	0.111	NS

Table 5: Comparative statistics between buccal attached gingival thickness of right and left sides in maxillary and mandibular arches

Arch	Site	N	Right Side Mean±SD	Left Side Mean±SD	t-value	p-value	Inference
Maxillary	LIC	100	1.95±0.12	1.95±0.07	-0.247	0.805	Not significant (>0.05)
	CP1	100	1.66±0.15	1.68±0.15	-7.174	0.0001	Highly significant (<0.001)
	P2M1	100	1.27±0.06	1.29±0.06	-5.641	0.0001	Highly significant (<0.001)
	M1M2	100	1.39±0.07	1.40±0.07	-3.685	0.0001	Highly significant (<0.001)
	Palatal P2M1	100	3.12±0.22	3.11±0.18	1.051	0.296	Not significant (>0.05)
Mandibular	CP1	100	1.95±0.06	1.95±0.05	-0.411	0.682	Not significant (>0.05)
	P2M1	100	1.66±0.03	1.68±0.03	-2.37	0.02	Significant (<0.05)
	M1M2	100	1.27±0.07	1.29±0.07	-0.241	0.81	Not significant (>0.05)

Table 6: Proposed miniscrew selection and stocking chart

	Area of miniscrew implantation	Transmucosal collar length (mm)	Screw length (mm)
Anterior maxilla	CICI, LIC, CP1	2	6
Anterior mandible	CP1	1.5	6
Posterior maxilla	P2M1, M1M2	1.5	7-Jun
Posterior mandible	P2M1, M1M2	1.5	7-Jun
Palate	P2M1	4	7-Jun
Midpalate	Midpalatine raphe between first molars	1	6

Discussion:

It was Eger *et al.* **[9]** who first used an ultrasonic device with a 5-MHz transducer probe to assess gingival thickness, reporting excellent reliability for measurement of gingival thickness (GTH) in relation to tooth type and age. The ultrasound probe works similarly to a sonogram: the probe is pressed against the tissue, the beam penetrates the mucosa and echoes that return are recorded and displayed, enabling software to image the periodontal structures automatically. This study was restricted to young adults aged 18-25 years to exclude age-related effects on soft tissue thickness, although no differences in means and standard deviations between different age groups. Intragroup variations in the thickness of buccal attached gingiva of the maxilla and mandible were also studied and the results were similar to those of Schwarz *et al.* **[10].** In the maxilla, the buccal attached gingiva between the lateral incisor and the canine (LIC) was thickest, followed by that between the canine and first premolar (CP1) and then between the first and second molars (M1M2). The palatal masticatory mucosa was nearly 2.5 to 3 times as thick as the buccal attached gingiva. In the maxillary arch, the buccal attached gingiva between the canine and first premolar was thicker in women than in men; this was statistically significant. This finding did not agree with previous studies **[11].** Although statistically significant, the difference was not clinically striking enough to affect orthodontic miniscrew selection between sexes. This study has proposed a range of Tran's mucosal collar lengths for orthodontic miniscrew selection based on the thickness of soft tissues in different areas. For the buccal aspects of the canine and first premolar in both sexes, a screw with a 6-mm length and a Tran's mucosal collar of 2 mm would be a fair choice for the maxilla. The thicknesses of the buccal attached gingiva between the second premolar and first molar and between the first and second molars were significantly greater in men than in women. The thickness of the palatal masticatory mucosa between the second premolar and first molar, 6 mm below the gingival crest was significantly greater in men than in women. The thickness of the palatal mucosa in this study was 2.5 to 3 times more than the corresponding buccal areas, coincident with the findings of Cha *et al.* **[12].** In the mandibular arch, the buccal attached gingiva between the canine and first premolar was thicker in men than in women. For the mandibular canine and first premolar region, a screw 6 mm long with a Tran's mucosal collar of 1.5 mm would be a good preference in both sexes. When comparing buccal attached gingival thicknesses between the maxillary and mandibular arches, the areas between the anterior teeth and the premolars in the maxillary arch and between the molars in the mandibular arch, showed thicker soft tissues than corresponding areas in the opposite arch **(Table 5).** These findings are significant because they can explain the different rates of failure of orthodontic miniscrews in the maxillary and mandibular arches. In both men and women, the thicknesses of the buccal attached gingiva were greater in the maxilla than in the mandible **(Table 5).** Burak *et al.* **[13]** reported similar variations in mucosal thickness in men and women, related to sex and periodontal phenotype variations. Orthodontic miniscrews can be placed with equivalent bone-to-screw contact anywhere in the zone of buccal attached gingiva up to 6 mm apical to the alveolar crest with adequate interradicular space. The range of thickness of the buccal attached gingiva is nearly 1 to 2.5 mm in the maxilla and the mandible; therefore, for buccal interdental sites, clinicians are advised to stock 2 types of miniscrews: one with a trans gingival collar of 1.5 mm and a screw length of 6 mm and another with a smooth trans gingival collar of 2 mm and a length of 6 mm. If screws without a Tran's mucosal collar are used, a screw length of 7 to 8 mm should meet the demands of all buccal interdental areas **(Table 6).** In the midpalatal region, the soft tissue thickness was in the range of 0.7 to 1 mm. Nucera *et al.*

[14] stated that bone around the midpalatal area is 2 mm thicker than its image on lateral Cephalometric radiographs; supporting the concept that adequate cortical bone in the midpalatal area is suitable for screw implantation. A radiologic evaluation is recommended before placement of orthodontic miniscrews to prevent damage to the nasal mucosa or penetration of the maxillary sinus. A miniscrew 6 to 7 mm long is suggested for the midpalate region, with a smooth 1-mm Tran's mucosal collar and 6-mm length being most ideal. Del Rosso *et al.* **[15]** recommended miniscrew of 2 mm in diameter with a 6-mm length and a 1-mm Tran's gingival collar for the midpalatal region.

Conclusion:

Soft tissue thickness varies across the maxillary and mandibular arches, influencing orthodontic miniscrew placement and stability. Palatal tissues were 2.5-3 times thicker than buccal tissues, while midpalatal thickness remained approximately 1 mm. Assessing site-specific soft tissue thickness before miniscrew placement may improve bone engagement and clinical stability.

Conflict of interest: The authors declare no conflicts of interest.

Clinical trial number: Not applicable.

Limitations:

This study was limited to young adults aged 18-25 years, excluding skeletal Class III patients and lacking long-term clinical correlation with miniscrew success. It did not assess underlying bone quality or tissue mobility. Being a single-center, cross-sectional study with gender imbalance, results may not be fully generalizable. Ultrasonography, though non-invasive, remains operator-dependent.

Future scope:

Future studies should include a broader age range and skeletal Class III patients to improve generalizability. Longitudinal research correlating soft tissue thickness with actual miniscrew success rates is recommended. Incorporating bone density assessment and evaluating soft tissue mobility can provide a more comprehensive protocol for site-specific miniscrew placement. Multi-center trials with standardized ultrasonography techniques may enhance reproducibility and clinical applicability.

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