TURKISH JOURNAL of ORTHODONTICS

DOI: 10.4274/TurkJOrthod.2022.2021.0054

Systematic Review

Gingival Biotype and Its Relation with Malocclusion

Yousef Al-Thomali[1], Roshan Noor Mohamed[2], Sakeenabi Basha[3], Rekha Setty[4], Bheema Setty Manasali[5]

[1]Department of Orthodontics, Faculty of Dentistry, Taif University, Taif, Saudi Arabia
[2]Department of Pedodontics, Faculty of Dentistry, Taif University, Taif, Saudi Arabia
[3]Department of Preventive and Community Dentistry, Faculty of Dentistry, Taif University, Taif, Saudi Arabia
[4]Private Practitioner, Consultant Periodontist Taif, Saudi Arabia
[5]Department of Prosthodontics, Faculty of Dentistry, Taif University, Taif, Saudi Arabia

Cite this article as: Al-Thomali Y, Mohamed RN, Basha S, Setty R, Setty Manasali B. Gingival Biotype and Its Relation with Dental Malocclusion. *Turk J Orthod.* 2023; 36(1): 70-77

Main Points
- No relationship was observed between Angle's classification of malocclusion and the Gingival Biotype (GT)
- Keratinized gingival width was narrow among individuals with thin GT.
- Definitive relationship between GT among individuals with severe crowding cannot be established.
- Medium followed by thin GT was prevalent among individuals with pro-inclination of incisors.

ABSTRACT

Objective: To systematically review the relationship between gingival biotype (GT) and malocclusion.

Methods: The review followed PRISMA standards of quality for systematic reviews and meta-analyses reporting with PROSPERO registration number CRD42020126543. The systematic database search included MEDLINE, Scopus, Embase, PsychINFO, CINAHL, and other key journals; the article search was performed until February 2020. Cochrane's risk of bias in non-randomized studies-of interventions (ROBINS-I) was used to grade the methodological quality of the included studies.

Results: The systematic search identified 105 studies, six studies satisfied the inclusion criteria for eligibility. The study participants ranged from 26 to 200 (total n=812), with a mean of 135. Study participants were aged between 14 and 32 years. Five studies were graded as the moderate risk of bias and one study as low risk of bias. Two studies showed thin GT among individuals with severe crowding compared to mild crowding. Three studies showed a thin GT with a narrow zone of the keratinized gingival width compared to a thick GT. No relationship was found between GT and Angle's classification of malocclusion.

Conclusion: No relationship was observed between Angle's classification of malocclusion and GT. Thin GT was prevalent among individuals with pro-inclination of incisors. Keratinized gingival width was narrow among individuals with thin GT.

Keywords: Systematic review, Gingival biotype, malocclusion, width of keratinized gingiva

INTRODUCTION

Gingival biotype (GT) refers to different characteristics and thickness of gingiva in the buccolingual dimension.[1] They are categorized into different types depending upon their thickness as a thin, medium, thick, or very thick.[1,2] The quantitative differences in the gingival thickness are important because they respond differently to inflammation and surgical insult, which further influences the prognosis of the treatment.[1-3] In clinical practice, proper diagnosis of the GT is central to the decision making because it affects the outcome of periodontal therapy, orthodontic tooth movement, implant treatment, and root coverage procedures.[4,5] Many factors contribute to differences in GT like age, gender, tooth morphology, tooth position, growth type, and genetics.[3] GT plays a critical role during the orthodontic movement of the tooth because teeth with thin biotype are more prone to gingival recession and soft tissue defects compared to thick biotypes.[6,7] The literature suggests that the gingival recession

Corresponding author: Sakeenabi Basha, e-mail: sakeena@tudent.edu.sa

Received: May 19, 2021
Accepted: February 27, 2022
Epub: March 16, 2023
Publication Date: March 21, 2023

is a common anecdotal observation in periodontal - orthodontic interrelation.[6-8] Experimental evidence suggest that orthodontic tooth movement creates an environment favorable for plaque accumulation around the appliances leading to gingival inflammation and periodontal breakdown.[9,10] However, the root movement within the alveolar housing may lead to dehiscence, gingival recession, and root exposure.[9] Hence, the pre-treatment evaluation of the quantitative differences in the biotype should be considered as a factor that influences the successful outcome in root coverage procedures, implant restoration, and orthodontic treatment.[4,5,10] Previously authors have studied the correlation between GT and different types of malocclusion.[1,11-15] When the authors searched for the literature, could not find any systematic review, which assessed the relationship between GT and malocclusion. Therefore, the present systematic review was conducted with the aim of identifying the relationship between GT and malocclusion.

METHODS

The planning, conduct, and reporting of this systematic review follows PRISMA standards of quality for reporting systematic reviews and meta-analyses with register number CRD42020126543.[16] Approval from the Institutional Review Board was not required.

Questions

The area of focus was to examine the GTs in different dental malocclusion. The research question was defined according to the PICO format as follows:

P (Population/Patients): Original studies in human subjects with permanent teeth having skeletal or dental malocclusion.

I (Intervention): Subjects not undergoing any orthodontic treatment, only the descriptive studies with measurement of GTs among individuals with malocclusion.

C (comparison): GT in subjects with normal occlusion were compared with GTs in subjects with malocclusion.

O (Outcome): Measurement of GTs (thick, thin, mean thickness), the width of keratinized gingiva (WKG).

Study Eligibility

Research published in the English language that investigated the different types of GTs in permanent teeth among individuals with malocclusion were included in the study. The subjects were not undergoing any orthodontic intervention. The editorial letter, case reports, in vitro studies, and studies not investigating the types of GTs in permanent teeth were excluded at this stage.

Study Identification

The scientific database search included, Cochrane library (Cochrane review, Trails), Embase, MEDLINE (PubMed, OVID Medline, and Ebsco), Web of Knowledge (Social science, conference abstract), SCOPUS, CINAHL (Nursing and allied health), PsycInfo (Psychology and psychiatry), ERIC (Education) using key terms focused on the specific search strategy (malocclusion, skeletal, occlusion, Class I, Class II, Class III, gingival, biotypes, periodontal, morphotypes, thickness, associations, prevalence, dimensions, changes, evaluation). Besides, four key orthodontic journals (American Journal of Orthodontics and Dentofacial Orthopedics, Angle Orthodontics, European Journal of Orthodontics, and Journal of Clinical Orthodontics) and two periodontal journals (Journal of Periodontology and Journal of Clinical Periodontology) were searched for relevant articles. The research publications until February 2020 were searched. Any additional studies meeting the inclusion criteria were identified from the reference lists of all included articles.

Study Selection

The inclusion of studies was by screening all titles and abstracts independently and in duplicate. The intra-class correlation coefficient of 0.84 was achieved in inter-rater agreement for study inclusion. The Conflicts between the two reviewers were resolved through consensus discussion.

Risk of Bias Assessment

Cochrane's tool of risk of bias in non-randomized studies - of interventions (ROBINS-I)[17] was used to assess the risk of bias. Each domain is graded as a low risk of bias, moderate risk of bias, serious risk of bias, critical risk of bias, or no information.

Data Extraction and Data Synthesis

Two reviewers extracted the data independently using a data extraction sheet. Discrepancies between the reviewers were resolved by consensus through discussion. The following data were extracted from each included study: first author, year of publication, the type of study, study quality, sample size, inclusion criteria, treatment type, malocclusion type, measurement criteria, GTs, dimensions, statistical analysis used, and the conclusions by the authors.

RESULTS

Trail Flow

The search strategy identified 98 articles, with an additional seven identified from a review of references and screening of key journal indices. Of these, six articles were identified by the authors for inclusion in this systematic review (Figure 1).

Study Quality

Five studies were graded as a moderate risk of bias and one study as low risk of bias (Table 1). The data were available from 2012 to 2020.

Study characteristics in relation to age, gender, ethnicity, diagnostic criteria, and the type of malocclusion used.

The number of study participants ranged from 26 to 200 (total n=812, male=340, female=472), with a mean of 135. The study participants were aged 14 to 32 years. Two of the included studies were conducted in Saudi Arabia, two in Turkey, one in China, and one in Italy (Table 2). Three of the included studies

used trans-gingival probing to measure the GT and three studies used periodontal probing. Four studies (Matarese et al.[1], Alkan et al.[11], Kaya et al.[13], Zawawi et al.[14]) considered Angle's classification of malocclusion, Jing et al.[12] used skeletal malocclusion, and Zawawi and Al-Zahrani[15] measured GT in inclined or protruded incisors (Table 3).

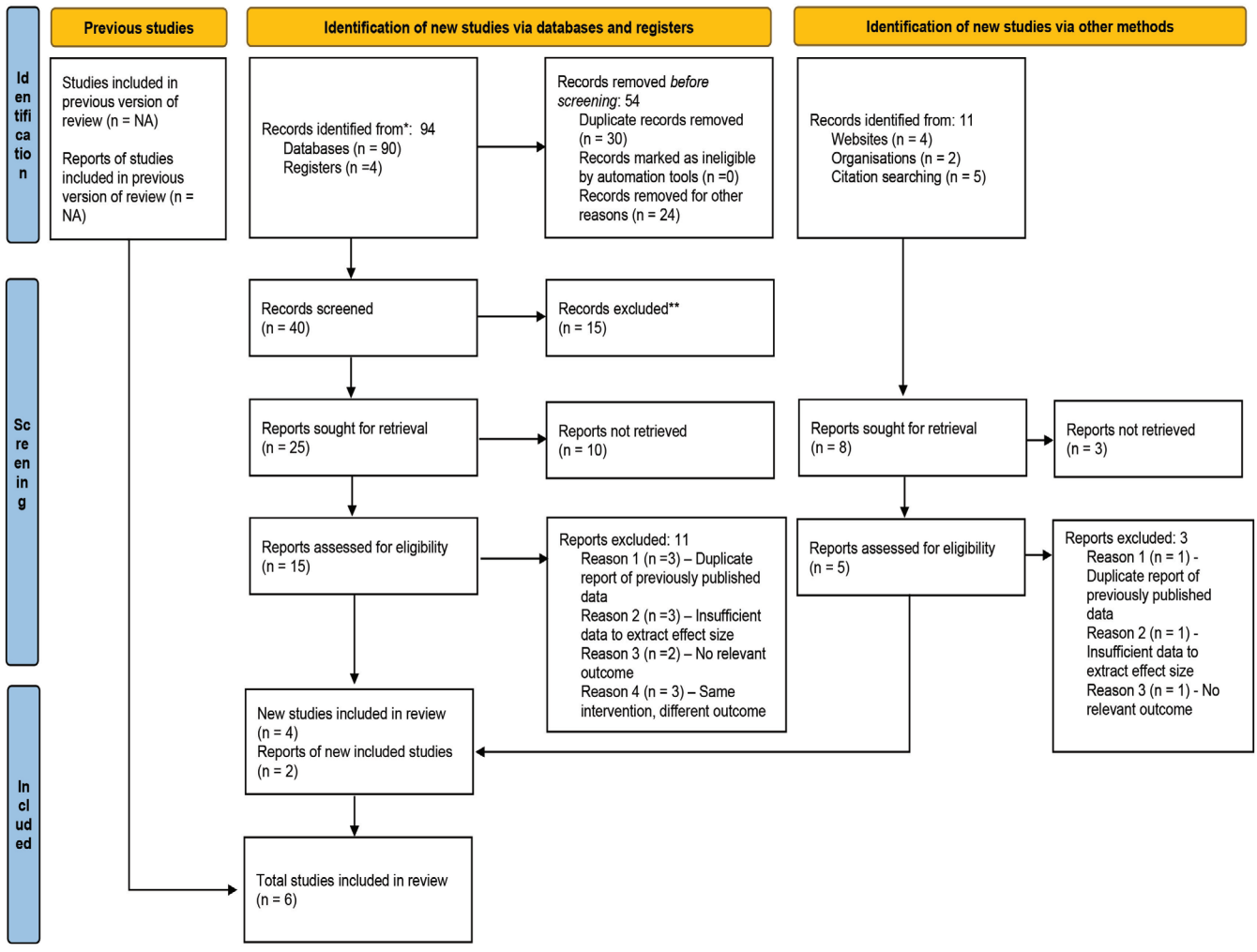

Figure 1. Study selection flow diagram of systematic review

Table 1. Risk of bias assessment of included studies using Cochrane's risk of bias in non-randomized studies - of interventions (ROBINS-I)

ROBINS-I criteria	Author/Year					
	Jing et al.[12] (2019)	Alkan et al.[11] (2018)	Kaya et al.[13] (2017)	Matarese et al.[1] (2016)	Zawawi and Al-Zahrani[15] (2014)	Zawawi et al.[14] (2012)
BC	L	L	L	L	L	L
BSP	L	L	L	L	L	L
BCI	S	L	M	L	S	L
BDI	M	M	L	M	M	M
BMD	M	M	L	L	M	M
BMO	M	L	L	M	M	L
BSR	L	L	L	M	L	L
Overall score	M	M	L	M	M	M

BC, Bias due to confounding; BSP, Bias in selection; BCI, Bias in classification of interventions; BDI, Bias due to deviations from intended interventions; BMD, Bias due to missing data; BMO, Bias in measurement of the outcomes; BSR, Bias in selection of the reported result; L, Low risk of bias; M, Moderate risk of bias; S, Serious risk of bias.

Table 2. Descriptive data of the included studies

Author/Year	Study type	Inclusion criteria	Population studied	Sample size (Male/ Female), mean age (range) in years	Statistical analysis used	Authors conclusion
Jing et al.[12] (2019)	Cross-sectional	Periodontally (PD ≥5 mm) and systemically healthy subjects with skeletal Class III malocclusion	China	26 (9/17) 23.29 ± 3.71 years	Analysis of variance (ANOVA) and chi-square test	Significant correlation between WKG and GT. Higher prevalence of thick GT in maxillary anterior teeth compared to mandibular teeth
Alkan et al.[11] (2018)	Cross-sectional	Periodontally (PD ≥4 mm) and systemically healthy subjects	Turkey	181 (63/118) Male 15.8 ± 2.6 years Females 17.3 ± 3.9 years	Factorial variance analysis and chi-square test	No significant relationship of WKG and the mean GT according to the Angle classification
Kaya et al.[13] (2017)	Cross-sectional	Systemically and periodontally healthy subjects (Free from attachment loss and PD <4 mm) with complete permanent dentition	Turkey	187 (66/121) Less than 29 years	Factorial variance analysis and chi-square test	No significant relationship of WKG and the mean GT according to the Angle classification
Matarese et al.[1] (2016)	Cross-sectional	Systemically and periodontally healthy	Italy	76 (38/38) Age-14.7 years	Student's t-test and the chi-square test	Prevalence of thick gingival biotype in patient with Class II malocclusion and a slight prevalence of thin gingival biotype in patient with Class I malocclusion. Difference not statistically significant
Zawawi and Al-Zahrani[15] (2014)	Cross-sectional	Systemically and Periodontally healthy subjects with age more than 18 years	Saudi Arabia	142 (64/78) 26.56 ± 2.55	Student's t-test and chi-square test	A high prevalence of thin GT in proclined and protrused mandibular anterior teeth
Zawawi et al.[14] (2012)	Cross-sectional	Systemically and Periodontally healthy subjects with age more than 18 years	Saudi Arabia	200 (100/100) Male -32.4 ± 11.0 years Female- 31.7 ± 11.1 years	Student's t-test and chi-square test	A high prevalence of thin GT among females and smokers had thicker GT. No relationship was found between GT and Angle's classification of malocclusion.

WKG, Width of keratinized gingiva; MGJ, Muco gingival junction; GT, Gingival biotype; PD, Probing depth.

The type of GT according to malocclusion type and WKG: Jing et al.[12] showed 72.5% to 96.2% thick GT in maxillary teeth and 44.2% to 47.1% thick GT in mandibular teeth (p=0.001). The WKG was 4.88 mm to 5.59 mm in maxillary teeth and 3.02 mm to 3.68 mm in mandibular teeth. Alkan et al.[11] showed 11.6% of thin GT in subjects with Class II malocclusion, 12.7% in Class I, and 5.5% in Class III malocclusion (p=0.895). Subjects with severe crowding presented with 12.7% thin GT (p=0.794). Kaya et al.[13] showed a mean GT of 0.73 ± 0.17 mm in Class I occlusion and 0.66 ± 0.7 mm in Class III occlusion (p=0.140). Severe crowding subjects presented with a mean GT of 0.71 ± 0.16 mm (p=0.321). Matarese et al.[1] showed 34.9% prevalence of thick GT in Class I occlusions and 32.6% thick GT in Class II and Class III occlusions (p=0.143). Zawawi et al.[14] showed 57.1% prevalence of thick GT in Class I occlusion, 55.9% thick GT in Class II, and 46.2% thick GT in Class III occlusion (p=0.6) (Table 4).

Table 3. Data regarding the gingival biotypes, method of assessment, dimensions

Author	Tooth type/ number of teeth examined	Criteria's assessed	Definitions of assessment method for WKG	Gingival biotype measurement	Malocclusion type	Tooth dimensions analysis
Jing et al.[12]	Maxillary and mandibular anterior teeth	PI, GR, WKG, GT, BI, PD	WKG from MGJ to the FGM at the mid buccal aspect of the tooth and dental arch	Periodontal probing. Transparency of FGM while probing the sulcus at the mid facial aspect of tooth. Thin GT when the underlying periodontal probe can be seen through the gingiva; otherwise, it was considered thick.	Skeletal Class III malocclusion with ANB ≤-5 degrees	NA
Alkan et al.[11]	Maxillary anterior teeth	GI, PI, PD, WKG, GT	WKG from MGJ to the FGM	TGP using digital caliper with a sensitivity of 0.01 mm. Apical to the FGM and coronal to the MGJ. Mean of GT less than 1 mm=Thin biotype. More than 1 mm=Thick biotype	Angles Class I, Class II and Class III	Space analysis for crowding: mild (0-3 mm), moderate (4-6 mm), and severe (>6 mm).
Kaya et al.[13]	Mandibular anterior teeth	GI, PI, PD, WKG, Crowding	WKG from MGJ to the FGM at the buccal area of the mandibular anterior teeth	TGP using digital caliper with a sensitivity of 0.01 mm. Apical to the FGM and coronal to the MGJ. Mean of GT less than 1 mm=Thin biotype. More than 1 mm=Thick biotype	Angles Class I, Class II and Class III	Space analysis for crowding: mild (0-3 mm), moderate (4-6 mm), and severe (>6 mm).
Matarese et al.[1]	Mandibular anterior teeth	NA	NA	TGP using translucence of a periodontal probe UNC 15. Thin GT when the underlying periodontal probe can be seen through the gingiva; otherwise, it was considered thick.	Angles Class I, Class II and Class III	NA
Zawawi and Al-Zahrani[15]	Maxillary and mandibular incisor teeth	GT	NA	Periodontal probing. Transparency of FGM while probing the sulcus at the mid facial aspect of incisors. Thin GT when the underlying periodontal probe can be seen through the gingiva; otherwise, it was considered thick.	Inclined or protrude incisors	Inclination (proclination/ retroclination) and position (protrusion/retrosion) of the maxillary and mandibular incisors were assessed on lateral cephalometric radiographs
Zawawi et al.[14]	Maxillary anterior teeth	GT	NA	Periodontal probing. Transparency of FGM while probing the sulcus at the mid facial aspect of both maxillary central incisors. Thin GT when the underlying periodontal probe can be seen through the gingiva; otherwise, it was considered thick.	Angles Class I, Class II and Class III	NA

GI, Gingival index; PI, Plaque index; BI, Bleeding index; PD, Probing depth of periodontal pockets; WKG, Width of keratinized gingiva; MGJ, Muco gingival junction; FGM, Free gingival margin; GT, Gingival biotype; TGP, Trans gingival probing; NA, Not available.

Table 4. Outcomes of the included studies

Author			GT (mean or % prevalence)	WKG (mean or % prevalence)	p value
Jing et al.[12]	Maxillary teeth		Thick GT- 72.5% to 96.2%	4.88 mm to 5.59 mm	0.001
	Mandibular teeth		Thick GT- 44.2% to 47.1%	3.02 mm to 3.68 mm	
Alkan et al.[11]	Class I		Thin - 21 (11.6%) Thick - 50 (27.6%)	4.9 ± 1.7 to 7.3 ± 2.1 mm	
	Class II		Thin - 23 (12.7%) Thick - 57 (31.5%)	4.02 ± 2.2 to 7.2 ± 1.9 mm	0.895
	Class III		Thin - 10 (5.5%) Thick - 20 (11%)	4.7 ± 1.6 to 6.4 ± 2.5 mm	
	Mild crowding		Thin - 18 (9.9%) Thick- 39 (21.5%)	3.1 ± 1.5 to 7.4 ± 2.6 mm	
	Moderate crowding		Thin - 13 (7.2%) Thick - 27 (14.9%)	4.2 ± 2.2 to 7.8 ± 1.8 mm	0.794
	Severe crowding		Thin - 23 (12.7%) Thick - 61 (33.7%)	2.7 ± 1.5 to 7.3 ± 2.02 mm	
Kaya et al.[13]	Class I		0.73 ± 0.17 mm (0.299-1.388)	2.13 ± 1.27 to 3.97 ± 1.43 mm	
	Class II		0.72 ± 0.16 mm (0.333-1.182)	1.94 ± 1.48 to 3.99 ± 1.73 mm	0.140
	Class III		0.66 ± 0.17 mm (0.275-0.961)	1.90 ± 1.08 to 3.58 ± 1.93 mm	
	Mild crowding		0.71 ± 0.16 mm (0.324-1.218)	2.46 ± 1.29 to 3.8 ± 1.24 mm	
	Moderate crowding		0.69 ± 0.21 mm (0.275-1.388)	2.44 ± 1.39 to 3.84 ± 1.45 mm	0.321
	Severe crowding		0.75 ± 0.14 mm (0.448-1.056)	2.15 ± 1.08 to 2.73 ± 1.48 mm	
Matarese et al.[1]	Class I		Thin -19 (57.6%), Thick- 15 (34.9%)	NA	
	Class II		Thin - 7 (21.2%), Thick- 14 (32.6%)	NA	0.143
	Class III		Thin - 7 (21.2%), Thick- 14 (32.6%)	NA	
	Pro-inclination		Medium, followed by thin biotype more prevalent	4.08 ± 0.78 mm at baseline 3.42 ± 0.78 mm at 9 month of treatment	NA
	Retro-inclination		Thick biotype more prevalent	4.50 ± 0.85 mm at baseline 4.97 ± 0.87 mm at 9 month of treatment	NA
Zawawi and Al-Zahrani[15]	Maxillary incisor	Inclination in mm	Thin GT - 25.5 ± 3.4	NA	0.89
			Thick GT - 25.4 ± 3.3	NA	
		Position in mm	Thin GT - 6.3 ± 2.1	NA	0.87
			Thick GT - 6.3 ± 2.2	NA	
		Crowding in mm	Thin GT - 2.07 ± 1.7	NA	0.85
			Thick GT - 2.01 ± 1.8	NA	
	Mandibular incisor	Inclination in mm	Thin GT - 97.05 ± 6.3	NA	0.02
			Thick GT - 94.6 ± 5.9	NA	
		Position in mm	Thin GT - 5.7 ± 2.8	NA	0.02
			Thick GT - 4.7 ± 2.7	NA	
		Crowding in mm	Thin GT - 3.2 ± 2.4	NA	0.52
			Thick GT - 3.5 ± 2.3	NA	
Zawawi et al.[14]	Class I		Thin - 60 (42.9%) Thick - 80 (57.1%)	NA	
	Class II		Thin - 15 (44.1%) Thick - 19 (55.9%)	NA	0.6
	Class III		Thin - 14 (53.8%) Thick - 12 (46.2%)	NA	

NA, Not available; GT, Gingival biotype; WKG, Width of keratinized gingiva

DISCUSSION

Various risk factors are associated with gingival recession, particularly in the mandibular anterior region in orthodontic patients. These risk factors include: age of the patient, periodontal health status, tobacco smoking, duration of orthodontic treatment, amount of force applied, the amount and type of tooth movement, GTs, and WKG.[4,5,6-9] GT is central to maintaining the periodontal health by determining the periodontium behavior to various bacterial, chemical and physical insults. Individuals with a thin GT are more prone to gingival recession following orthodontic treatment.[7,12] This systematic review was conducted to check the relationship between GT and malocclusion. The review included six cross-sectional studies.[1,11-15]

The method of assessment of GT: Different methods are used for assessing the GT like invasive and non-invasive. The noninvasive methods include visual assessment, probe transparency, ultrasonic devices, and cone-beam computed tomography. However, they have limitations like lack of reliability, need of repeatable measurements, and potential side effects of radiation exposure in routine clinical practice.[18-20] Invasive methods include trans-gingival probing, parallel profile radiography technique, and histological section. In this review, three studies[12,14,15] used periodontal probing, three studies[1,11,13] used trans gingival probing. The most frequently used techniques in modern orthodontic practice for GT measurements are periodontal probing and transgingival probing because it is easy to perform, reproducible, reliable, objective centered and less expensive.[7,11,14]

Tooth position, and GTs: GTs change with the position of the teeth during the eruption period. With the increasing age, these changes will reduce because the connective tissue becomes denser, the epithelium becomes thinner, the cell count decreases, and keratinization increases.[6,7] GT varies with tooth position in the arch. In this review, four studies showed medium to thin GT among individuals with pro-inclination of incisors.[7,11,13,15] Gingival thickness varies according to arch type and in the present review Jing et al.[12] showed a significantly higher prevalence of thin GT in mandibular teeth compared to maxillary teeth among subjects with skeletal Class III malocclusion.

GT and malocclusion type: GT changes with facial characteristics, facial profile, and tooth position.[6] In this review, four studies compared GT among subjects with Angle's classification of malocclusion.[1,11,13,14] No relationship was observed between Angle's classification of malocclusion and GT.

Relationship between GT and the WKG: The adequate WKG is an essential component in maintaining periodontal health.[21] Keratinized gingiva provides a firm and stable basis for maintaining good oral hygiene and during restorative and esthetic procedures. Studies have reported contradictory results regarding the WKG that would maintain periodontal health during orthodontic treatment.[11,13,20] In this review, three studies assessed the WKG and the results showed thin GT with a narrow zone of the WKG compared to thick GT.[11-13]

The limitation of the present systematic review is, the meta-analysis cannot be performed due to heterogeneity of data among included study. A future research based on homogeneous data derived from valid randomized control trials would help to substantiate the finding of this review.

CONCLUSION

In conclusion, the present systematic review cannot show a definite association between thin GT among individuals with severe crowding compared to mild crowding. Thin GT presented with a narrow zone of the WKG compared to a thick GT. No relationship was observed between the Angle's classification of malocclusion and GT. Further, future studies with the inclusion of vertical and sagittal skeletal relationship, tooth position, and overjet/overbite are needed to arrive at the conclusive evidence in this field of research.

Ethics

Ethics Committee Approval: Approval from the Institutional Review Board was not required.

Informed Consent: N/A.

Peer-review: Internally peer-reviewed.

Author Contributions: Concept - Y.A.T., R.N.M., S.B., R.S., B.S.M.; Design - Y.A.T., R.N.M., S.B., R.S., B.S.M.; Data Collection and/or Processing - Y.A.T., R.N.M., S.B., R.S., B.S.M.; Analysis and/or Interpretation - Y.A.T., R.N.M., S.B., R.S., B.S.M.; Literature Review - Y.A.T., R.N.M., S.B., R.S., B.S.M.; Writing - Y.A.T., R.N.M., S.B., R.S., B.S.M.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

REFERENCES

1. Matarese G, Isola G, Ramaglia L, et al. Periodontal biotype: characteristic, prevalence and dimensions related to dental malocclusion. *Minerva Stomatol.* 2016;65(4):231-238. [CrossRef]
2. Fischer KR, Künzlberger A, Donos N, Fickl S, Friedmann A. Gingival biotype revisited-novel classification and assessment tool. *Clin Oral Investig.* 2018;22(1):443-448. [CrossRef]
3. Zweers J, Thomas RZ, Slot DE, Weisgold AS, Van der Weijden FG. Characteristics of periodontal biotype, its dimensions, associations and prevalence: a systematic review. *J Clin Periodontol.* 2014;41(10):958-971. [CrossRef]
4. Fu JH, Yeh CY, Chan HL, Tatarakis N, Leong DJ, Wang HL. Tissue biotype and its relation to the underlying bone morphology. *J Periodontol.* 2010;81(4):569-574. [CrossRef]
5. Cook DR, Mealey BL, Verrett RG, et al. Relationship between clinical periodontal biotype and labial plate thickness: an in vivo study. *Int J Periodontics Restorative Dent.* 2011;31(4):345-354. [CrossRef]

6. Wennström JL. The significance of the width and thickness of the gingiva in orthodontic treatment. *Dtsch Zahnarztl Z.* 1990;45(3):136-141. [CrossRef]
7. Rasperini G, Acunzo R, Cannalire P, Farronato G. Influence of Periodontal Biotype on Root Surface Exposure During Orthodontic Treatment: A Preliminary Study. *Int J Periodontics Restorative Dent.* 2015;35(5):665-675. [CrossRef]
8. Melsen B, Allais D. Factors of importance for the development of dehiscences during labial movement of mandibular incisors: a retrospective study of adult orthodontic patients. *Am J Orthod Dentofacial Orthop.* 2005;127(5):552-561; quiz 625. [CrossRef]
9. Aziz T, Flores-Mir C. A systematic review of the association between appliance-induced labial movement of mandibular incisors and gingival recession. *Aust Orthod J.* 2011;27(1):33-39. [CrossRef]
10. Vasconcelos G, Kjellsen K, Preus H, Vandevska-Radunovic V, Hansen BF. Prevalence and severity of vestibular recession in mandibular incisors after orthodontic treatment. *Angle Orthod.* 2012;82(1):42-47. [CrossRef]
11. Alkan Ö, Kaya Y, Alkan EA, Keskin S, Cochran DL. Assessment of Gingival Biotype and Keratinized Gingival Width of Maxillary Anterior Region in Individuals with Different Types of Malocclusion. *Turk J Orthod.* 2018;31(1):13-20. [CrossRef]
12. Jing WD, Xu L, Xu X, Hou JX, Li XT. Association between Periodontal Biotype and Clinical Parameters: A Cross-sectional Study in Patients with Skeletal Class III Malocclusion. *Chin J Dent Res.* 2019;22(1):9-19. [CrossRef]
13. Kaya Y, Alkan Ö, Keskin S. An evaluation of the gingival biotype and the width of keratinized gingiva in the mandibular anterior region of individuals with different dental malocclusion groups and levels of crowding. *Korean J Orthod.* 2017;47(3):176-185. [CrossRef]
14. Zawawi KH, Al-Harthi SM, Al-Zahrani MS. Prevalence of gingival biotype and its relationship to dental malocclusion. *Saudi Med J.* 2012;33(6):671-675. [CrossRef]
15. Zawawi KH, Al-Zahrani MS. Gingival biotype in relation to incisors' inclination and position. *Saudi Med J.* 2014;35(11):1378-1383. [CrossRef]
16. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *J Clin Epidemiol.* 2009;62(10):1006-1012. [CrossRef]
17. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ.* 2016;355:i4919. [CrossRef]
18. Eghbali A, De Rouck T, De Bruyn H, Cosyn J. The gingival biotype assessed by experienced and inexperienced clinicians. *J Clin Periodontol.* 2009;36(11):958-963. [CrossRef]
19. Slak B, Daabous A, Bednarz W, Strumban E, Maev RG. Assessment of gingival thickness using an ultrasonic dental system prototype: A comparison to traditional methods. *Ann Anat.* 2015;199:98-103. [CrossRef]
20. Shao Y, Yin L, Gu J, Wang D, Lu W, Sun Y. Assessment of Periodontal Biotype in a Young Chinese Population using Different Measurement Methods. *Sci Rep.* 2018;8(1):11212. [CrossRef]
21. Singh J, Rathod VJ, Rao PR, Patil AA, Langade DG, Singh RK. Correlation of gingival thickness with gingival width, probing depth, and papillary fill in maxillary anterior teeth in students of a dental college in Navi Mumbai. *Contemp Clin Dent.* 2016;7(4):535-538. [CrossRef]