Effect of craniofacial morphology on gingival parameters of mandibular incisors

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ABSTRACT

Objectives: To investigate the association between the width of keratinized gingiva (WKG), gingival phenotype (GP), and gingival thickness (GT) with craniofacial morphology in sagittal and vertical dimensions.

Materials and Methods: WKG, GP, and GT of mandibular anterior teeth in 177 preorthodontic patients (mean age 18.38 $\pm$ 5.16 years) were assessed clinically using a periodontal probe, a Colorvue Biotype Probe, and ultrasound by a single examiner. Patients were grouped into skeletal Class I, II, and III and hyperdivergent, normodivergent, and hypodivergent based on ANB and SN-MP angles. Mandibular incisor inclination (L1-NB) was also measured. Clinical and cephalometric measurements were repeated to assess inter- and intraexaminer reproducibility.

Results: A significant association was found between thin GP and skeletal Classes I and III for the left mandibular central incisor (MCI; $P = .0183$). In skeletal Class III patients, L1-NB angle demonstrated a decreasing trend as phenotype thickness decreased. A significant association was found between thin phenotype and normodivergent and hypodivergent groups for MCIs (left: $P = .0009$, right: $P = .00253$). No significant association between WKG or GT and craniofacial morphology was found.

Conclusions: Thin GP is associated with skeletal Class I and III for the left MCI. Thin GP is associated with hypodivergent and normodivergent skeletal patterns for the MCIs. There was no association between WKG and GT and craniofacial morphology in both skeletal and vertical dimensions. Dental compensations that exist due to different craniofacial morphology may influence the GP. (*Angle Orthod.* 2023;93:545–551.)

KEY WORDS: Gingival phenotype; Skeletal pattern; Biotype

INTRODUCTION

Orthodontic tooth movement by means of proclination or expansion is traditionally considered a risk factor for development of bony dehiscence, fenestration, and gingival recession.[1–4] A hypothesis proposed by Wennström[5] suggested that mandibular incisors moved only within the limits of the alveolar process did

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not develop recession. Nonetheless, when moved beyond the anatomical limits of bone, dehiscence and fenestration developed. Thus, without proper alveolar bone support, the marginal gingiva may migrate apically and expose the root.[2–4]

Deformities of the jaw or mid-face result in disharmony in the positions of the dentition and overall occlusion. This is known as "dentoalveolar compensation," in which the dentition varies from a normal position to achieve a more functional occlusal contact, attempting to mask the underlying skeletal discrepancy.[6,7] Typically, compensatory or decompensatory labial-lingual movements of the incisors are required for either camouflage or surgical treatment, respectively.[8] Thus, understanding that different craniofacial morphologies may present with different periodontal soft and hard tissue parameters is beneficial in establishing anatomical limits prior to orthodontic or combined surgical treatment. This concept has been of interest in a small number of studies specific to Turkish, Korean, and Chinese populations.[9–11] However, due to differences in methodology and sampling, the conclusions were conflicting.

Thus, the aim of this study was to investigate the association between the width of the keratinized gingiva (WKG), gingival phenotype (GP), and gingival thickness (GT) with craniofacial morphology in both the sagittal and vertical dimensions. The null hypothesis was that there would be no association between the WKG, GP, or GT with skeletal class or vertical divergency.

MATERIALS AND METHODS

Ethics approval for this study was obtained from the Human Ethics Committee of University of Western Australia (RA/4/20/6339). A total of 177 preorthodontic patients at the Department of Orthodontics at the Oral Health Centre of Western Australia were recruited on a volunteer basis from June to November 2020.

Patients were included if they had good oral hygiene. The exclusion criteria were severe crowding ≥6 mm; decay, crowns, or fillings of maxillary and mandibular anterior teeth; gingivitis or periodontitis; pregnant or lactating; smoker; and currently taking or a history of taking any medications known to cause enlargement of the gingiva (calcium antagonists, cyclosporin A, phenytoin). Patients with severe crowding were excluded to remove the influence of tooth position and to focus on the impact of craniofacial morphology.

Patients were presented with information on the study, and written consent was obtained. Each patient had pretreatment lateral cephalograms taken with the head stabilized in the natural head position by positioning the ear rods of the machine in the external

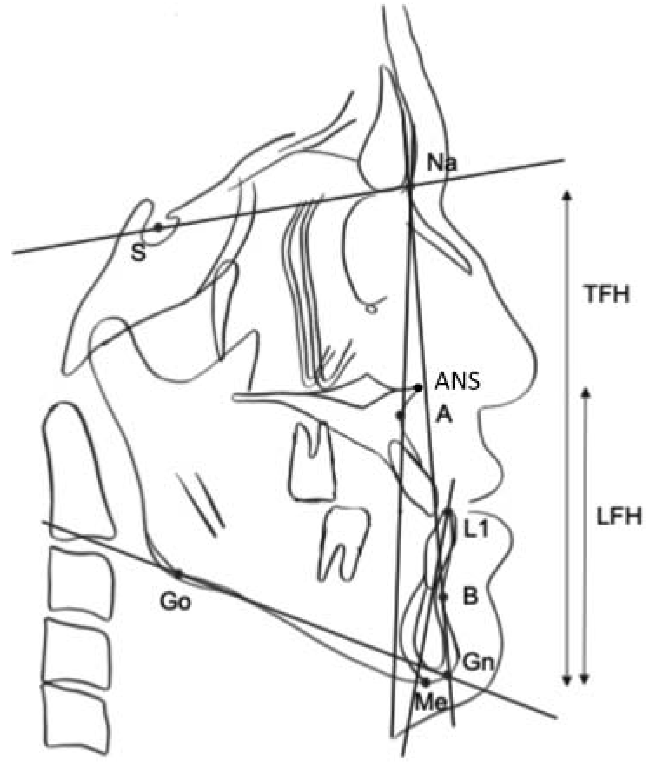

Figure 1. Cephalometric landmarks: sella (S), nasion (Na), anterior nasal spine (ANS), point A (A), point B (B), mandibular central incisor (L1), gnathion (Gn), menton (Me), gonion (Go), total facial height (TFH), lower facial height (LFH).

auditory meatus. An examiner (Dr Kong) traced the following skeletal landmarks (Figure 1):

- ANB: angle between point A, nasion (Na), and point B
- AB: linear distance between point A and B
- L1-NB distance: distance between the most labial point on the mandibular central incisor (MCI) to a line from Na to point B
- L1-NB angle: angle formed by the long axis of the MCI to a line from Na to point B
- L1-MP: long axis of the MCI measured to the mandibular plane and the most inward angle toward the body of the mandible
- SN-MP: angle between sella-nasion (SN) plane and mandibular plane (GoGn)
- Lower facial height to total facial height ratio: distance between anterior nasal spine and menton (Me) compared with the distance between Na and Me

Accepted values for L1-NB angle, distance, and L1-MP angle were as follows: 25°, 4 mm, and 92°. Patients were divided into groups based on ANB and SN-MP angles: skeletal Class I (0° ≤ ANB ≤ 4°), Class II (ANB >4°), Class III (ANB <0°), hyperdivergent (SN-MP >37°), normodivergent (30° ≤ SN-MP ≤ 37°), and hypodivergent (SN-MP <30°) skeletal patterns.

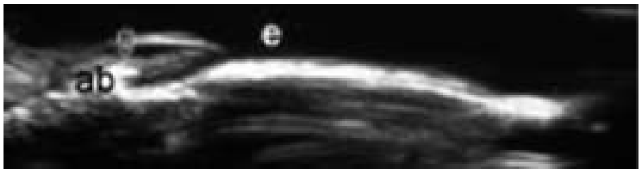

Figure 2. Buccolingual cross section of ultrasound (US) image showing enamel, gingival, and crest of alveolar bone.

GP was assessed using a Colorvue Phenotype Probe. This probe features different colors, white, green, and blue, representing thin, medium, and thick GP, respectively. It was inserted into the gingival sulcus at the mid-labial aspect of each mandibular anterior tooth with minimal pressure. Depending on the visibility of the colors through the labial gingiva, a GP classification for each tooth was made. WKG was measured with a periodontal probe from the crest of the gingiva to the mucogingival line. Measurements were performed by an examiner (Dr Kong) who had been calibrated against a periodontist (Dr Miranda).

Ultrasound (US; Philips Affiniti 70G Pure Wave) was carried out by a dentomaxillofacial radiologist (Dr Aps) using a hockey stick–shaped transducer (10 $\times$ 30 mm) with a frequency of 7–15 MHz to measure the GT of the mandibular anterior teeth of each patient. A gel pad (Aquaflex) was used as the medium, covering the labial surface of the teeth and gingiva. Prior to this study, validation of this machine against another direct method (transgingival probing) was performed. The US images captured at each tooth show a buccolingual cross section of the enamel, gingiva, and crest of the alveolar bone (Figure 2). A total of 1062 images were taken. GT was measured on a perpendicular line, drawn from the mucogingival surface to the summit of the alveolar bone crest, corresponding to the gingival sulcus. Measurements were performed by an examiner (Dr Kong), who had been calibrated against the radiologist to the nearest 0.01 mm.

Table 1. Overall Counts and Mean Md1-NB Angle for Each Group and ANB and SN-Md Angles for Skeletal Class and Divergency Groups, Respectively[a]

	Class I	Class II	Class III
Count, n (%)	60 (33.9)	86 (48.6)	31 (17.5)
Mean ANB angle, °	2.6	6.3	−2.3
Mean Md1-NB angle, °	24.6	27	22.4
	Hyperdivergent	Normodivergent	Hypodivergent
Count	77 (43.5)	88 (49.7)	12 (6.8)
Mean SN-Md angle, °	41.9	34.7	27
Mean Md1-NB angle, °	27.1	23.9	25.3

For intra- and interexaminer reproducibility, 10 random patients were selected for repeat probing by examiners (Dr Kong and Dr Miranda) and remeasuring of their US images by examiners Dr Kong and Dr Aps, 1 week later. Also, 20 random lateral cephalograms were retraced and remeasured to assess intraexaminer reproducibility of an examiner (Dr Kong).

Statistical Analysis

The data were analyzed using the R environment, JMP Pro, and SPSS for statistical computing. Sample size was calculated considering an alpha level of .05, a power of .80, and 95% confidence interval.[12] One hundred thirty-one participants were necessary to confirm agreement. Mean, median, and frequency distributions were calculated for continuous and categorical variables. To explore the association between gingival parameters (phenotype, thickness, and WKG) and craniofacial morphology (skeletal class and divergency), a multilevel logistic regression was performed.

RESULTS

Of the 177 preorthodontic patients, 86 were male (48.6%) and 91 were female (51.4%). The mean age was 18.38 $\pm$ 5.16 years, with a range of 13–58 years. Most patients were Caucasian (79.7%), followed by Asian (13.6%) and Central African (6.7%). The counts and percentages of skeletal class and divergency groups as well as their mean ANB angle for the skeletal class, SN-Md angle for divergency and Md1-NB angles for both groups are summarized in Table 1.

The intrarater reliability of the examiner (Dr Kong) using US and probing methods showed excellent agreement (intraclass correlation coefficient [ICC] = .98, ICC = .97). Interrater reliability between the radiologist (Dr Aps) and examiner (Dr Kong) and between the periodontist (Dr Miranda) and examiner (Dr Kong) indicated excellent agreement (ICC = .98, k = .95).

Overall, the mean WKG, mean GT, and median GP were 2.63 mm, 0.84 mm, and 1.67 for the mandibular incisors and 1.94 mm, 0.77 mm, and 1 for the mandibular canines, respectively. Table 2 shows mean WKG, mean GT, and median GP of the mandibular canines and incisors for each skeletal class and divergency group. No significant association was found between WKG or GT and skeletal class for MCIs (left: $P = .88$, right: $P = .94$). No significant association was found between WKG or GT and divergency for MCIs (left: $P = .26$, right: $P = .27$).

A significant association was found between thin GP and skeletal Classes I and III for the left MCI ($P = .0183$). The counts and percentages of the number of

Table 2. Mean WKG and GT and Median GP for Mandibular Anterior Teeth for Each Skeletal Class and Divergency Group[a]

	Mean WKG, mm	Mean GT, mm	Median GP
Mandibular canines			
Class I	1.98	0.76	1
Class II	1.85	0.77	1
Class III	2.08	0.78	1
Hyperdivergent	1.95	0.77	1
Normodivergent	1.95	0.76	1
Hypodivergent	1.88	0.8	1
Mandibular incisors			
Class I	2.54	0.80	1.5
Class II	2.71	0.88	1.75
Class III	2.5	0.81	1.5
Hyperdivergent	2.76	0.87	1.75
Normodivergent	2.54	0.83	1.5
Hypodivergent	2.54	0.84	1.625

[a] GP indicates gingival phenotype; GT, gingival thickness; WKG, width of keratinized gingiva.

thin, medium, and thick phenotypes in each skeletal class for the left MCI are summarized in Table 3.

For the left MCI, in Class III patients, the mean L1-NB angle was higher in thick GP (25.5°) compared with medium (23.5°) and thin (21.8°) GP. An opposite trend was found for skeletal Class II patients, in which a lower mean L1-NB angle was found in thick GP (12.3°) compared with medium (26°) and thin (28.1°) GP (Figure 3A–C).

A significant association was found between thin GP and hypodivergent and normodivergent groups for MCIs (left: $P = .0009$, right: $P = .0253$). The counts and percentages of the number of thin, medium, and thick GP in each divergency group for MCIs are summarized in Tables 4 and 5.

In hypodivergent patients, for the MCIs, the mean L1-NB angle was 26° for thin GP compared with thick GP (right: 19°, left: 11°). For the right MCI in normodivergent patients, the mean L1-NB angle for thin GP was 22.1° and was 27° for medium and thick GP (Figure 4A–C).

Table 3. Proportion and Counts of Thin, Medium, and Thick Phenotype in Skeletal Class I, II, and III Groups[a]

Mandibular Left Central Incisor	Thin GP	Medium GP	Thick GP
Class I, n (%)	38 (72)	12 (23)	3 (6)
Class II, n (%)	33 (50)	30 (45)	2 (3)
Class III, n (%)	19 (68)	7 (25)	2 (7)

[a] GP indicates gingival phenotype.

DISCUSSION

Camouflaging severe skeletal discrepancies in which teeth are repositioned at their anatomic limits may enhance the occurrence and severity of iatrogenic sequelae.[13–15] This is concerning when incisor protrusion is planned in the presence of thin labial bone, gingival phenotype, and thickness.[1,3,13,16–19]

A significant association between thin GP with skeletal Classes I and III for the left MCI ($P = .0183$) was found but not for the right MCI. This may have been due to the left MCI being more proclined than the right in both skeletal class groups. Although a larger proportion of Class I and III groups displayed a thinner phenotype than medium or thick phenotype, 50% of skeletal Class II patients still displayed a thin phenotype, which was almost equal in proportion to medium phenotype. Thus, the results do not discount the existence of a thin phenotype in skeletal Class II patients but rather show that a higher proportion of skeletal Class I and III patients exhibited this phenotype in comparison with the other groups. Nevertheless, the results were consistent with studies that found significantly higher proportions of teeth in the mandible with a thin phenotype in Class III skeletal patients due to lingually compensated incisors.[10,20]

Interestingly, a smaller mean L1-NB angle was found in skeletal Class III patients with a thin phenotype compared with those with medium and thick phenotypes. In skeletal Class II patients, the inverse was observed, in which phenotype was thinner as the mandibular incisors were further proclined. Although

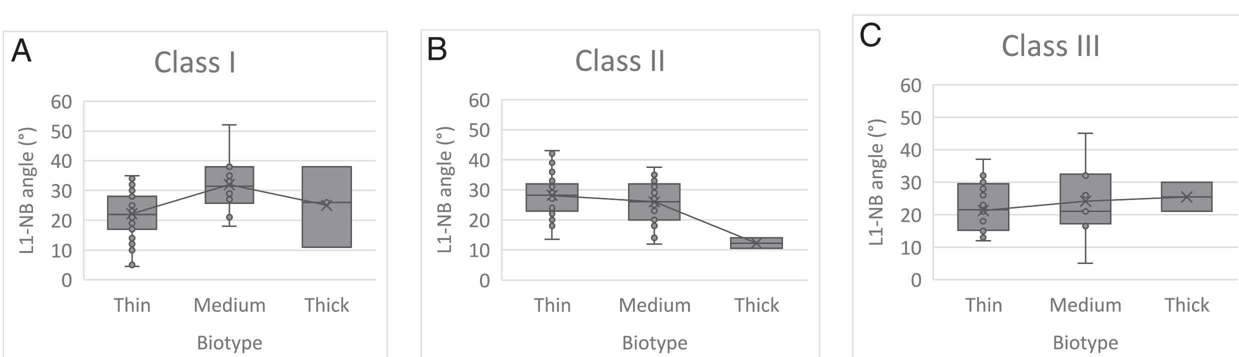

Figure 3. Mandibular left central incisor: mean L1-NB angle for each GP type for skeletal classes: (A) Class I, (B) Class II, and (C) Class III. GP indicates gingival phenotype.

Table 4. Proportion and counts of Thin, Medium, and Thick Phenotype in Different Divergency Groups for the Mandibular Left Central Incisor[a]

Mandibular Left Central Incisor	Thin GP	Medium GP	Thick GP
Hyperdivergent, n (%)	25 (45)	26 (46)	4 (7)
Normodivergent, n (%)	58 (73)	19 (24)	2 (2.5)
Hypodivergent, n (%)	7 (58)	4 (33)	1 (8)

[a] GP indicates gingival phenotype.

Table 5. Proportion and Counts of Thin, Medium, and Thick Phenotype in Different Divergency Groups for the Mandibular Right Central Incisor

Mandibular Right Central Incisor	Thin GP	Medium GP	Thick GP
Hyperdivergent, n (%)	25 (44)	26 (46)	5 (9)
Normodivergent, n (%)	49 (63)	25 (32)	4 (5)
Hypodivergent, n (%)	7 (58)	4 (33)	1 (8)

[a] GP indicates gingival phenotype.

this relationship was not significant, previous studies have found GP and GT to be dependent on the degree of dental compensation of the mandibular incisors, which might explain these results, especially in skeletal Class III groups.[11,21]

With regard to divergency, a thin GP was significantly associated with hypodivergent and normodivergent groups for MCIs (left: $P = .0009$, right: $P = .0253$); this was in contrast to previous studies.[22,23] However, Björk[24] proposed that the inclination of teeth was greatly influenced by mandibular rotation. In forward rotators, mandibular incisors are guided forward during eruption, and in backward rotators, the incisors become retroclined. In addition, studies have shown that mandibular incisor proclination and protrusion are significantly associated with thin GP.[11,21] In the current study, a trend was found in which the right MCI for the hypodivergent group was more proclined in those with a thin phenotype (L1-NB = 26°) than in those with a thick phenotype (L1-NB = 19°). The opposite trend was found in the normodivergent group, in which the right MCI was less proclined in those with a thin GP. An insignificant difference of 3° was found in the L1-NB angle of the hyperdivergent group between thick and thin GP.

These results were in contrast to a recent study that found no statistically significant relationship between GT and craniofacial morphology.[22] This may have been due to differences in methodology and sampling. As GT of the mandibular anterior teeth was averaged into a single value, it is conceivable that GT was overestimated since it can vary in different sites of the mouth.[25–27] This study assessed the gingival parameters of the mandibular anterior teeth individually and as two groups: incisors and canines. Kaya's study[22] was also limited to a Turkish population. In addition, the mean ANB angle for skeletal Class III patients in their sample was –0.87° compared with –2.3° in this study, indicating a possible difference in severity of dental compensation of the mandibular incisors and therefore less influence on gingival architecture than this study.

No significant association between WKG or GT of the mandibular incisors and skeletal class or divergency was found. The latter was in agreement with a 2018 study.[22] However, the same authors in 2017 found GT of the right mandibular incisors to be statistically significantly lower in Angle Class III malocclusions, although the skeletal relationship was not taken into account.[9] In the present study, the differences in GT between the hyperdivergent and hypodivergent groups were 0.03 mm and 0.07 mm between skeletal Class III and II, which were statistically and clinically not significant. Similarly, there was a nonsignificant difference in WKG among all skeletal classes as well as between hypodivergent and hyperdivergent groups. The severity of crowding and WKG have been significantly associated, such that, as crowding increases, there is a corresponding increase in WKG of the mandibular incisors and decrease at the canines.[9]

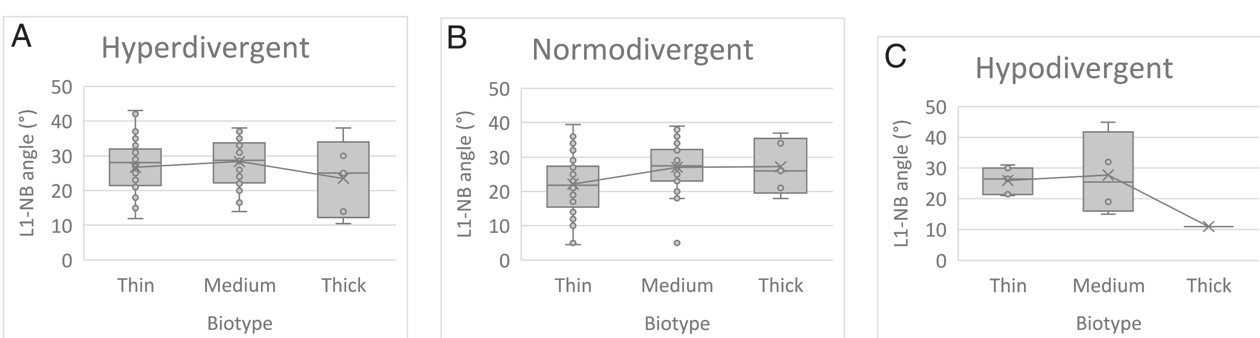

Figure 4. Mandibular right central incisor: mean L1-NB angle for each GP type for groups: (A) hyperdivergent, (B) normodivergent, and (C) hypodivergent. GP indicates gingival phenotype.

Limitations

Although there is no clear-cut difference in skeletal morphology, a limitation of this study was the inclusion of both Angle Class II, division 1 and 2 malocclusions.[28] Proclination of the incisors is typical of Class II, division 1, and retroclination is typical of Class II, division 2. There is no doubt that mandibular incisor inclination is also affected. This may explain why an insignificant association between GP and skeletal Class II types was found. These results must also be interpreted bearing in mind its academic setting, where the severity of the craniofacial discrepancy of the subjects included is generally larger and may not be indicative of the general population. Ideally, the sample of skeletal Class patients could have been divided into hypodivergent, normodivergent, and hyperdivergent groups. However, although 177 patients comprises a relatively large sample, the number of hypodivergent and skeletal Class III patients was small compared with other groups within the sample, which might have affected the overall power of the study. In addition, this study was also confounded by the variation in ethnicities with associated gingival colors and the possible differences in transparency reflected as inaccuracies in the interpretation of direct measures.

Further studies to evaluate the impact of orthodontic treatment in specific craniofacial types are recommended.

CONCLUSIONS

- Thin GP is associated with skeletal Class I and III for the left MCI.
- Thin GP is associated with hypodivergent and normodivergent skeletal patterns for the MCIs.
- There was no association between WKG and GT and craniofacial morphology in both skeletal and vertical dimensions.
- The amount of proclination of the mandibular incisors due to different craniofacial morphology may influence the GP.

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