Effect of lower incisors inclination on interproximal bone crest in orthodontically treated individuals

Carolina de Sá Werneck
Department of Orthodontics – Federal University of Juiz de Fora
✉ carol.werneck@yahoo.com.br

Fernanda Ramos de Faria
Department of Orthodontics – Federal University of Juiz de Fora

Cassiano Kuchenbecker Rösing
Department of Periodontology – Federal University of Rio Grande do Sul

Joana Godinho
Department of Orthodontics – University of Lisbon

Robert Willer Farinazzo Vitral
Department of Orthodontics – Federal University of Juiz de Fora

Marcio José da Silva Campos
Department of Orthodontics – Federal University of Juiz de Fora

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Abstract:
Introduction: Lower incisor inclinations can be orthodontically performed for better aesthetic results or to camouflage a skeletal problem. However, when buccolingual tooth movement occurs beyond the adaptive limits of the bone, it is associated with the onset of periodontal problems after treatment. **Objective:** This study aimed to evaluate the effects of natural and orthodontically induced buccolingual inclination of the lower incisors on the interproximal bone crest (IBC) at the end of orthodontic treatment. **Material and Methods:** A retrospective analysis of cephalometric and periapical radiographs obtained from the initial (T0) and final (T1) orthodontic documentation of 60 orthodontically treated individuals was performed. The lower incisor inclination in relation to the mandibular plane (IMPA), the thickness of the alveolar process and mandibular symphysis and the height of the IBC were measured. **Results:** There was no significant change in IMPA during treatment in the evaluated sample. Men had significantly thicker mandibular symphysis than women. A significant reduction was observed in alveolar process thickness and IBC height throughout the sample. Age showed a significant positive correlation with change in IBC height. Although IMPA was not directly correlated with IBC change during treatment, it was indirectly correlated when evaluated in conjunction with other variables. **Conclusion:** IMPA was not directly related to IBC height change. IMPA, alveolar process thickness and mandibular symphysis together were related to IBC height change.
Keywords: Incisor, orthodontics, periodontium, bone tissue.

Implementação e avaliação de protocolo de suplementação nutricional para idosos em um hospital privado

Resumo:
Introdução: As inclinações dos incisivos inferiores podem ser realizadas ortodonticamente para obter melhores resultados estéticos ou para camuflar um problema esquelético. Entretanto, quando o movimento dentário vestibulolingual ocorre além dos limites adaptativos do osso, pode ocorrer o aparecimento de problemas periodontais após o tratamento. **Objetivo:** Avaliar os efeitos da inclinação vestibulolingual dos incisivos inferiores, natural e induzida ortodonticamente, sobre a crista óssea interproximal (COI) ao final do tratamento ortodôntico. **Material e Métodos:** Foi realizada uma análise retrospetiva das radiografias cefalométricas e periapicais obtidas na documentação ortodôntica inicial (T0) e final (T1) de 60 indivíduos tratados ortodonticamente. Foram mensuradas a inclinação do incisivo inferior em relação ao plano mandibular (IMPA), a espessura do processo alveolar e da sínfise mandibular, e a altura da COI. **Resultados:** Não houve alteração significativa no IMPA durante o tratamento na amostra avaliada. Os homens apresentaram uma sínfise mandibular significativamente mais espessa do que as mulheres. Foi observada uma redução significativa na espessura do processo alveolar e na altura da COI em toda a amostra. A idade apresentou uma correlação positiva significativa com a alteração na altura da COI. Embora o IMPA não tenha sido diretamente correlacionado com a alteração da COI durante o tratamento, foi indiretamente correlacionado quando avaliado em conjunto com outras variáveis. **Conclusão:** O IMPA não foi diretamente relacionado com a alteração da altura da COI. O IMPA, a espessura do processo alveolar e a sínfise mandibular juntos foram relacionados com a alteração da altura da COI.
Palavras-chave: Incisor, orthodontics, periodontium, bone tissue.

Efecto de la inclinación de los incisivos inferiores sobre la cresta ósea interproximal en individuos tratados ortodóncicamente

Resumen:
Introducción: Las inclinaciones de los incisivos inferiores pueden realizarse ortodóncicamente para obtener mejores resultados estéticos o para camuflar un problema esquelético. Sin embargo, cuando el movimiento dental bucolingual se produce más allá de los límites adaptativos del hueso, se asocia a la aparición de problemas periodontales tras el tratamiento. **Objetivo:** Evaluar los efectos de la inclinación bucolingual natural e inducida ortodóncicamente de los incisivos inferiores sobre la cresta ósea interproximal (COI) al final del tratamiento ortodóncico. Material y métodos: Se realizó un análisis retrospectivo de las radiografías cefalométricas y periapicales obtenidas en la documentación ortodóncica inicial (T0) y final (T1) de 60 individuos tratados ortodóncicamente. Se midieron la inclinación del incisivo inferior en relación con el plano mandibular (IMPA), el grosor del proceso alveolar y de la sínfisis mandibular y la altura del COI. **Resultados:** No hubo cambios significativos en lo IMPA durante el tratamiento en la muestra evaluada. Los hombres presentaban una sínfisis mandibular significativamente más gruesa que las mujeres. Se observó una reducción significativa del grosor del proceso alveolar y de la altura del COI en toda la muestra. La edad mostró una correlación positiva significativa con el cambio en la altura del COI. Aunque lo IMPA no se correlacionó directamente con el cambio en la COI durante el tratamiento, sí se correlacionó indirectamente cuando se evaluó junto con otras variables. **Conclusión:** Lo IMPA no estaba directamente relacionado con el cambio en la altura del COI. El IMPA, el grosor del proceso alveolar y la sínfisis mandibular juntos estaban relacionados con el cambio en la altura del COI.
Palabras clave: Incisivos, ortodoncia, periodonto, tejido óseo.

INTRODUCTION

The dentofacial complex presents a compensatory mechanism if there is no functional balance, allowing it to achieve the best function, harmony, and facial proportions (GOLDSMAN, 1959; MOLINA-BERLANGA *et al.*, 2013). When there is a skeletal discrepancy in size, whether in a vertical, horizontal, or transverse dimension, the teeth and the alveolar bone tend to compensate to establish a better relationship with inadequate structure dimension, concealing the disproportion (GOLDSMAN, 1959). This mechanism allows, for example, the upper and lower incisors to be accommodated in a more or less harmonic relationship, regardless of the individual's skeletal pattern (BIBBY, 1980).

In the sagittal direction in patients with Class III malocclusions, there is commonly a lingual compensation of the lower incisors (PARK *et al.*, 2017; JING *et al.*, 2021). The disproportion in the vertical dimension commonly presents compensations by varying the lengthening of the mandibular symphysis and the incisor eruption (NIELSEN, 1991).

Changes in the inclination of the lower incisors can also be performed orthodontically (WEHRBEIN *et al.*, 1996) since anterior expansion is required for better aesthetic and occlusal results in many clinical situations (ÅRTUN AND GROBÉTY, 2001). Some studies have indicated that as long as the tooth movements occur within the limits of the alveolar bone, any damage to periodontal tissues is rare (ENGELKING and ZACHRISSON, 1982; WENNSTRÖM, 1987). However, the buccolingual tooth movement beyond the osseous envelope it be associated with some periodontal tissue problems after the orthodontic treatment (RENKEMA *et al.*, 2012 and 2013), such as bone fenestrations and dehiscences (BOLLEN *et al.*, 2008; LEUNG, 2010; CLOSS *et al.*, 2014; JOSS-VASSALLI *et al.*, 2010; JATI, FURQUIN and CONSOLARO, 2016; PARK *et al.*, 2017).

Some studies have investigated the relationship of periodontal tissues problems with orthodontic treatment (LO RUSSO, 2017; MORRIS, 2017; RENKEMA *et al.*, 2012; RENKEMA *et al.*, 2013; RENKEMA *et al.*, 2015; OLIVEIRA *et al.*, 2016; PERNET, 2019) and with the thickness of the mandibular symphysis (CLOSS *et al.*, 2014; MAZUROVA *et al.*, 2017), assessing the presence or absence of gingival recession. In some cases, periodontal tissue problems may be present but limited to bone tissue. In these cases, the gingiva is clinically normal besides the periodontal pocket, and it is clinical aspect does not show any changes in the level of the alveolar bone crest, at least in the short term (YAGSI, 2012; CASTRO, 2016). Surgical treatment is often

required if there is gingival recession, leading to an aesthetic improvement. However, once installed, bone dehiscence can no longer be repaired (MILLER, 1985 and 1993).

Some studies have only considered the positioning of the lower incisors at the end of the orthodontic treatment, regardless of their initial inclination (RENKEMA *et al.*, 2012; RENKEMA *et al.*, 2013; RENKEMA *et al.*, 2015; OLIVEIRA *et al.*, 2016). Considering the adaptive process of the dentofacial complex regardless of the orthodontic treatment, we need to analyze whether the natural inclination of the lower incisors, along with the orthodontic movements, can change the periodontal tissues at the end of the orthodontic treatment.

The analyze thickness of the mandibular symphysis is also important in the beginning of the orthodontic treatment since this structure acts as a limiting factor for lower incisor movement (NAUERT and BERG, 1999; QU *et al.*, 2017). This might contribute to marginal gingival changes in lower incisors after orthodontic treatment (CLOSS *et al.*, 2014). Thus, the thickness of the mandibular symphysis may influence the final position of the lower incisors, which influences the orthodontic treatment plan (GRACCO *et al.*, 2010, QU *et al.*, 2017). Therefore, this study aimed to evaluate the effects of naturally occurring and orthodontically induced buccolingual inclination of the lower incisors on the interproximal bone crest (IBC) at the end of the orthodontic treatment. In addition, we analyzed the correlation between radiographic measurements and differences between male and female participants.

MATERIALS AND METHODS

The present study was approved by the Human Research Ethics Committee of the Federal University of Juiz de Fora (No. 2.771.641). All participants signed a written informed consent.

The sample size was determined based on a standard deviation of 0.2 mm and a difference of 0.15 mm between the mean values. A sample size of 30 individuals was obtained, considering a test power of 0.8 and a significance level of 0.05.

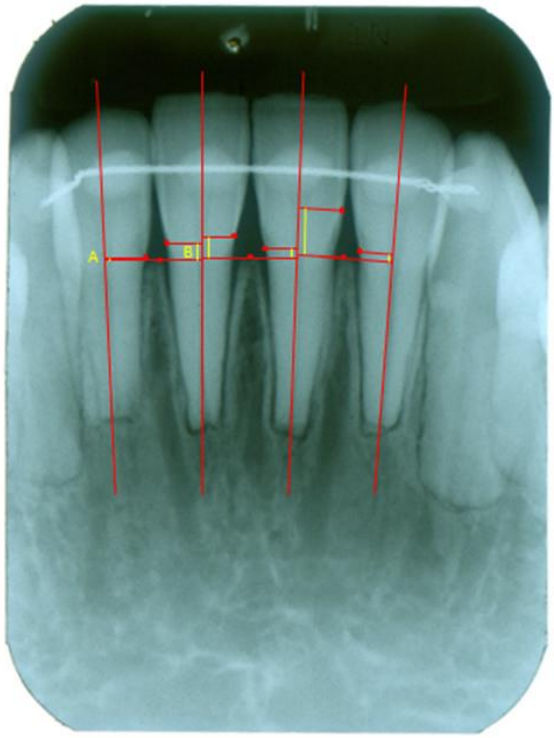
The cephalometric and periapical radiographs were collected before (T0) and after

(T1) orthodontic treatment of 60 individuals who were treated with an edgewise appliance (0.022"), regardless of the malocclusion type. The inclusion criteria were cervical vertebral maturation stage above CS5 (BACCETTI *et al.*, 2005) at T0; absence of extensive restorations in lower incisors; absence of a previous orthodontic treatment; absence of systemic diseases that affect the bone tissue; absence of smoking habits; absence of periodontal diseases at T0 and T1; mild or moderate dental mandibular anterior crowding at T0 (LITTLE, 1975).

The cephalometric and periapical radiographs of each individual were scanned at a resolution of 300 dpi using a HP G4050 scanner (Hewlett-Packard, Palo Alto, United States) and measured using ImageJ software (National Institute of Mental Health, Maryland, United States). The cephalometric and periapical radiographs were scanned using a millimeter ruler to correct the magnifications of the structures.

The IBC height was assessed on the proximal surface of each lower incisor, except for the distal sides of the lateral incisors on periapical radiographs at T0 and T1. This variable is the shortest distance between two perpendicular lines along the axis of the evaluated incisor, one passing at the most cervical point of the IBC and the other at the cementum-enamel junction (CEJ) of the evaluated incisor. The values are considered positive if the CEJ is above the most cervical point of the IBC. For this study, we considered three interproximal regions: 1) right (42/41) - arithmetic mean between the IBC height of the mesial surface of the lower right lateral incisor and the distal surface of the lower right central incisor; 2) central (41/31) - arithmetic mean between the IBC height of the mesial surfaces of the lower right and left central incisors; 3) left (31/32) - arithmetic mean between the IBC height of the mesial surface of the lower left lateral incisor and the distal surface of the lower left central incisor (Figure 1).

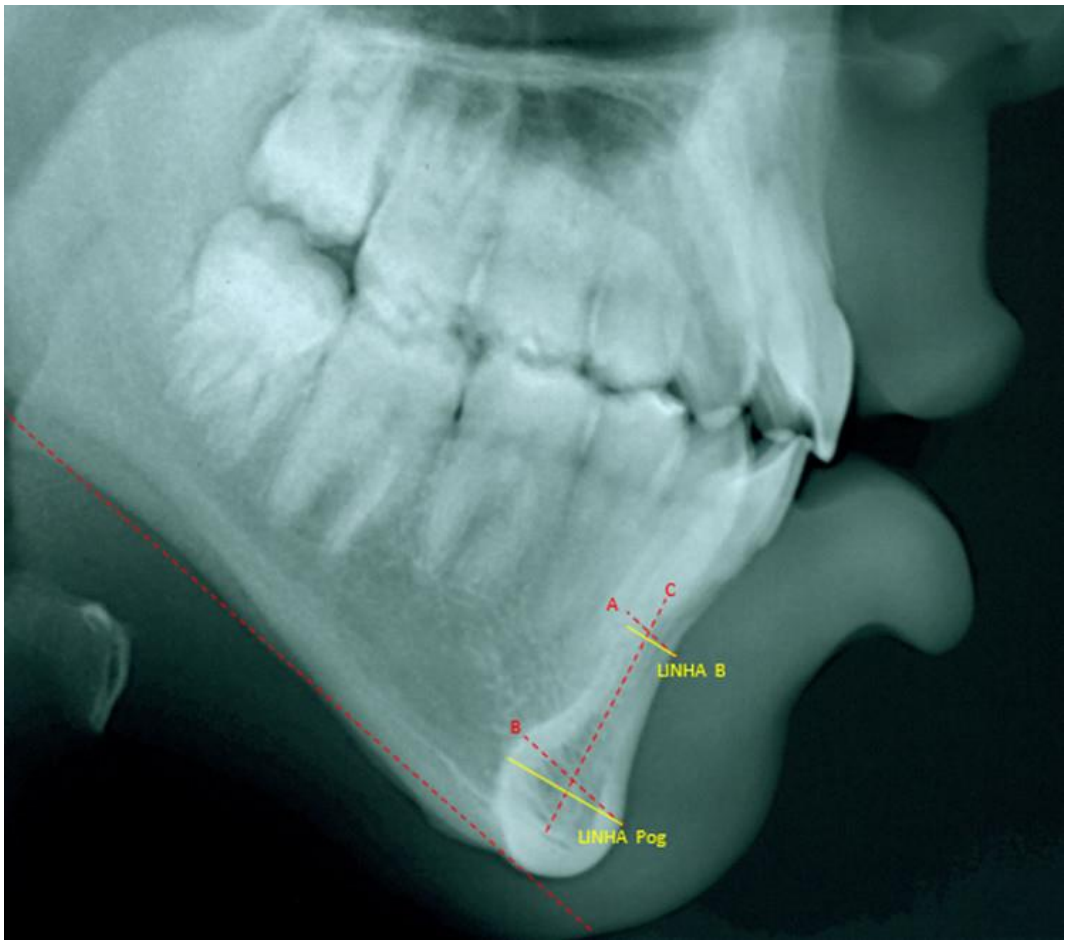
Figure 1. Measurement of interproximal bone height. Mean of segment A and B represent the height of the bone crest in the right interproximal region, between incisors 42 and 41.



Source: Authors.

In the cephalometric radiographs, the anteroposterior inclination of the lower incisors is the angle between the long axis of the most anterior lower incisor and the mandibular plane, and it is outlined by gonion and menton points in the cephalograms (TWEED, 1969). The thickness of the mandibular symphysis and alveolar process was measured according to Faria *et al.* (2023) (Figure 2).

Figure 2. Measurement of the thickness of the alveolar process and mandibular symphysis. A - Line parallel to the mandibular plane passing through point B. B - Line parallel to the mandibular plane passing through Pog. C - Long axis of the mandibular symphysis. Line B - Distance between the most anterior and most posterior bone limits of the alveolar process, passing through point B and perpendicular to the long axis of the symphysis. Pog line - Distance between the most anterior and most posterior bone boundary of the mandibular symphysis, passing through point Pog and perpendicular to the long axis of the symphysis.



Source: Authors.

Two different investigators measured all variables of 10 individuals at T0 twice within a 20-day interval. Intra-and inter-examiner reliability was calculated using the intraclass correlation coefficient (ICC). Intra and inter-examiner reliability was considered excellent for each variable with an ICC ≥ 0.750.

Statistical analysis

The data distribution pattern was determined using the Kolmogorov-Smirnov test and adjusted with the Q-Q plot. Analysis of variance (ANOVA) was used to compare the mean value of incisor mandibular plane angle (IMPA), IBC height, alveolar process, and thickness of the mandibular symphysis at T0, T1, and T1-T0 among men, women, and the total sample. A multiple linear regression model was used to define the variables for the adjusted multivariable linear regression model, considering the associations between all variables measured in the previous phase. The multivariate linear regression model with the highest R-squared value and the best residual fit was selected. All tests were performed using Stata 15.0 statistical software (College Station, Texas, United States), with a 95% confidence interval and 5% significance level.

RESULTS

The sample consisted of 60 individuals, 35 women (58.3%) and 25 men (41.7%). Table 1 presents their initial and final ages and treatment duration.

Table 1 – Initial and final ages and treatment duration of the individuals.

	Women Mean (SD)	Men Mean (SD)	Total Mean (SD)
Initial age (years old)	17.6 (8.2)	17.4 (7.1)	17.5 (7.7)
Final age (years old)	22.3 (8.7)	21.5 (7.3)	22.0 (8.1)
Treatment duration (months)	57.5 (31.8)	44.6 (13.5)	52.2 (26.5)

SD - *Standard Deviation.*
Source: Authors.

The IBC height was more apically displaced at the end of the orthodontic treatment. The thickness of the alveolar process significantly reduced during orthodontic treatment throughout the sample, decreasing by almost 10% between T0 and T1. However, the incisor

inclination and the thickness of the mandibular symphysis did not significantly change. At T0, the thickness of the mandibular symphysis was significantly higher in men than in women (Table 2). During the orthodontic treatment, the inclination of the lower incisors increased among men compared to women and it increased by more than 2° in 42% of the sample (Table 3).

Table 2 – Mean for each variable adjusted by sex.

		T0 Mean (SD)	T1 Mean (SD)	T1-T0 Mean (SD)	*p-value***
IMPA	Women	92.77 (8.6)	93.0 (7.6)	0.27 (6.8)	
	Men	93.79 (6.0)	92.9 (6.1)	-0.79 (6.4)	
	Total	93.20 (7.6)	93.03 (7.0)	-0.17 (6.6)	0.843
IBC Height	Women	0.73 (0.6)	1.01 (0.5)	0.27 (0.5)	
	Men	0.95 (0.5)	1.28 (0.7)	0.35 (0.5)	
	Total	0.83 (0.6)	1.13 (0.6)	0.27 (0.5)	0.020
Alveolar Process	Women	6.74 (0.2)	6.,0 (1.2)	-0.63 (1.1)	
	Men	7.46 (0.3)	6.7 (1.7)	6.7 (1.7)	
	Total	7.05 (1.5)	6.36 (1.5)	-0.68 (1.1)	<0.0001
Thickness of the Mandibular Symphysis	Women	13.12 (2.0)*	13.2 (2.1)*	0.05 (1.0)	
	Men	15.13 (2.1)*	15.3 (2.0)*	0.18 (1.0)	
	Total	13.97 (2.3)	14.08 (2.3)	0.10 (1.0)	0.421

*Significant difference between men and women (p <0.05); **ANOVA; IMPA: incisor mandibular plane angle; IBC Height: interproximal bone crest.
Source: Authors.

Table 3 – Incisor mandibular plane angle (IMPA) changes during the orthodontic treatment.

IMPA	Women n (%)	Men n (%)	Total n (%)
Maintenance (±2°)	8 (23)	7 (28)	15 (25)
Reduction of more than 2°	12 (34)	8 (32)	20 (33)
Increase of more than 2°	15 (43)	10 (40)	25 (42)

IMPA: incisor mandibular plane angle.
Source: Authors.

Significant correlations are observed between the IBC height and the initial and final ages, indicating a more apical position of the IBC height before and after treatment analyses. The IBC height after treatment (T1) also showed a correlation with sex, as it was more apically positioned in men (Table 4).

Table 4 – Correlation between interproximal bone crest height and the other variables analyzed.

	Interproximal Bone Crest		
	T0 (%)	T1 (%)	T1-T0 (%)
Initial age	57.8*	54.1*	7.0
Final age	49.8*	42.7*	10.0
Sex	24.4	-32.5*	6.0
Treatment duration	-24.2	16.7	3.7
IMPA at T0	-5.7	10.0	-15.4
IMPA at T1	-4.2	6.5	-9.5
IMPA at T1-T0	1.5	-5.2	7.9
Alveolar process at T0	5.0	1.1	-2.2
Alveolar process at T1	17.8	10.2	12.5
Alveolar process at T1-T0	26.4	10.5	17.9
Thickness of the mandibular symphysis at T0	18.5	18.5	25.0
Thickness of the mandibular symphysis at T1	18.2	18.2	24.0
Thickness of the mandibular symphysis at T1-T0	2.0	2.0	1.0

*p<0.05; IMPA: incisor mandibular plane angle.
Source: Authors.

The multivariable linear regression showed that IBC height was influenced by 46% and was significantly associated with sex, initial age, IMPA, and thickness of the mandibular symphysis at T0. For each additional degree of buccal inclination before treatment, the IBC was apically displaced by 0.02 mm. The increase of 1 mm in the thickness of the mandibular symphysis was correlated with the positioning of the 0.08 mm incisal crest. For each additional year in the initial age, the IBC was positioned 0.05 mm more apically. Sex also significantly influenced the IBC height, with 0.33 mm more apically poisoned in men (Table 5).

Table 5 – Correlation between interproximal bone crest height at T0 and the other variables analyzed using multivariable linear regression.

	Correlation coefficient	*p-value*
Initial age	0.0526105	<0.001
Sex	0.3278086	0.058
IMPA at T0	0.0218436	0.057
Alveolar process at T0	0.0252969	0.670
Thickness of the mandibular symphysis at T0	-0.0857117	0.047
R-squared = 0.4623		

IMPA: incisor mandibular plane angle.
Source: Authors.

At T1, the IBC height was influenced by 36% and significantly affected by treatment duration and final age. Each additional month in the final age was correlated with the positioning of a 0.008 mm incisal crest. For each additional year in the final age, the IBC height was 0.05 mm more apically positioned (Table 6). For changes in IBC height during orthodontic treatment (T1-T0), the initial IMPA had a significant influence of 19%. For each 1° reduction in buccal inclination at T0, the IBC height decreased by 0.02 mm during orthodontic treatment (Table 7).

Table 6 – Correlation of interproximal bone crest at T1 with the other variables analyzed using multivariable linear regression.

	Correlation coefficient	*p-value*
Treatment duration	-0.0081864	0.017
Final age	0.0530525	0.000
R-squared = 0.3665		

Source: Authors.

Table 7 – Correlation of interproximal bone crest difference (T1-T0) with the other variables analyzed using multivariable linear regression.

	Correlation coefficient	*p-value*
IMPA at T0	-0.026632	0.045
Alveolar process at T1	0.0859119	0.220
Thickness of the mandibular symphysis at T0	0.0782769	0.079
Treatment duration	0.0031641	0.362
R-squared = 0.1923		

IMPA: incisor mandibular plane angle.
Source: Authors.

DISCUSSION

In this study, IBC height, alveolar process, and thickness of the mandibular symphysis variables showed differences between men and women, but only the thickness of the mandibular symphysis was statistically significant. Other studies have found similar differences in which men had a thicker mandibular symphysis than women (AKI *et al.*, 1994; NANDA and GHOSH, 1995; MAZUROVA *et al.*, 2017; FARIA *et al.*, 2023) and the IBC height was more apically positioned at the end of orthodontic treatment (ZOIZNER *et al.*, 2018). This could be caused by normal sexual dimorphism, fewer growth changes in women than in men, or the average age of the sample since growth changes in men occur later (NANDA and GHOSH, 1995).

Aki *et al.* (1994) observed a residual growth of up to 0.5 mm in men aged up to 30 years old in the thickness of the mandibular symphysis. In the present study, a change in the thickness of the mandibular symphysis was less than 0.2 mm in men, which may be due to the short time interval between analyses (an average of 3.6 years in the present study against an average of 8 years in Aki *et al.* (1994). However, this result is more likely related to an error to determine the point and/or mandibular symphysis measurement.

The thickness of the bone in the lower incisor region not only limits orthodontic treatment but also influences the entire treatment plan (HOANG *et al.*, 2016; QU *et al.*, 2017). Molina-Berlanga *et al.* (2013) associated the decrease in buccal bone thickness in the lower incisor region with an increase in IMPA. In contrast, Filipova *et al.* (2019) did not find a relationship between the extension of lower incisor movement and the thickness of the bone in the lower incisor region. However, the authors pointed out a possible statistical limitation due to the sample size. In the present study, although we observed a significant reduction in the alveolar process during orthodontic treatment, this might be explained by the difficulty in identifying the cortical bone in the cephalometric radiographs due to overlapping of the lower incisors. Cone bean computed tomography (CBCT) scans are preferred for these measurements since they provide clear visualization of the buccal and lingual cortical bones without interference from overlapping teeth (FUHRMANN *et al.*, 1999; CASTRO *et al.*, 2016). In contrast, periapical radiographs did not affect the IBC height measurement since both CBCT and periapical radiographs are useful for identifying interproximal bone defects (MISH *et al.*, 2006).

The individuals evaluated did not significantly vary in IMPA during orthodontic treatment probably because this is a retrospective, convenience sample, not selected based on the changes in IMPA. IMPA did not significantly correlate with the change in IBC height. However, when combined with the other variables, the higher natural IMPA of the individual (T0) was associated with a more apical position of the IBC height in T0 and a lower IBC height reduction during treatment (T1-T0). This is not necessarily associated with these individuals having IBC height positioned in a more incisal region at the end of treatment, but it may be that these individuals already had IBC height more apically positioned before treatment.

No studies have correlated IBC height with buccal-lingual orthodontic movement of lower incisors. Some studies have correlated orthodontic treatment and changes in the IBC height, reporting that lower incisor vestibularization contributes to the development of bone dehiscences (CHOI *et al.*, 2015; JING *et al.*, 2021), especially in regions of narrow bone. This is more common in Class III malocclusion patients, who present thinner mandibular symphysis (SPERRY, 1977; ARTUN and KROGSTAD, 1987). Vestibular cortical plaque in the mandibular symphysis region can be remodeled (MAZUROVA *et al.*, 2017). The thinner the buccal bone, the harder the cells to form new bone tissue (ARTUN and GRABERTY, 2001). Shaw (2019)

reported an increase in bone height in the buccal region of lower incisors after their lingual repositioning. However, this seems to be an isolated finding based on measurements on cephalometric radiographs, whose accuracy may have influenced the result.

We observed a significant correlation between the IBC height and the participants' age. The older the individuals, the more apically positioned, for both T0 and T1. This finding agrees with other studies in the literature, which state that interproximal bone loss occurs naturally with individuals' age, an aspect of human aging (BOLIN *et al.*, 1993, RUQUET *et al.*, 2015). Sheng *et al.* (2020) stated vestibular bone height loss rarely occurs before orthodontic treatment. Evangelista *et al.* (2010) and Yagci *et al.* (2012) reported that this type of bone flaw is common, regardless of the treatment, after finding bone dehiscence in individuals who have never undergone orthodontic treatment. For the present study, the findings lead us to believe that orthodontic treatment may be a risk factor for developing interproximal bone loss since IBC height is significantly reduced during orthodontic treatment. Other authors have also reported a decrease in bone height in the orthodontic treatment of the vestibular region (LUND *et al.*, 2012; CASTRO *et al.*, 2016; SHENG *et al.*, 2020), Castro *et al.* (2016) found an increase of 57% in the prevalence of bone dehiscence after orthodontic treatment. However, bone dehiscence does not necessarily mean that a gingival recession is or will be present since it is considered a predisposing factor, not a precipitating factor (MARINI *et al.*, 2004).

Individuals between 15 and 24 years old with no history of orthodontic treatment have a mean distance of 1.4 mm from CEJ to IBC height (PERSSON *et al.*, 1998). Even though the present study showed a significant decreased IBC height, the average value found after the orthodontic treatment (1.1mm) is still within the normal range for individuals in this age group. The changes in the IBC height during orthodontic treatment (T1-T0) are not significantly correlated to any of the variables isolated but with the combination of IMPA at T0, alveolar process at T1, thickness of the mandibular symphysis at T0, and treatment duration.

CONCLUSION

The inclination of the lower incisor is not correlated with the change in IBC during the orthodontic treatment duration. However, the IBC height decreased when adding IMPA, alveolar process, and thickness of the mandibular symphysis.

AUTHOR CONTRIBUTION STATEMENT

Carolina de Sá Werneck: study development and design, data collection, manuscript drafting, and final approval of the submitted version.

Fernanda Ramos de Faria: study development and design, data collection, manuscript drafting, and final approval of the submitted version.

Cassiano Kuchenbecker Rosing: critical review of the intellectual content and final approval of the submitted version.

Joana Godinho: manuscript drafting, critical review of the intellectual content, and final approval of the submitted version.

Robert Willer Farinazzo Vitral: provision of study materials, critical review of the intellectual content, and final approval of the submitted version.

Marcio José da Silva Campos: study development and design, data analysis and interpretation, manuscript drafting, critical review of the intellectual content, and final approval of the submitted version.

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