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ORIGINAL ARTICLE

Lower incisor inclination and thickness of the alveolar process and mandibular symphysis in the development of gingival recession: A retrospective cohort study

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KEYWORDS

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Abstract *Introduction:* Retrospective studies have found conflicting results regarding the relationship between lower incisor inclination and the development of gingival recession (GR) after orthodontic treatment.

Objective: This study aimed to investigate the relationship between lower incisor inclination and alveolar process (AP) and mandibular symphysis (MS) thickness in the development of GR.

Materials and Methods: Frontal intraoral photography and cephalometric radiography were conducted before (T0) and after (T1) orthodontic treatment of 62 subjects. The presence of GR was considered when the cementoenamel junction was visible in the lower incisor on the frontal intraoral photograph. The circumstances for improvement, stability, and worsening of the gingival situation were based on the reduction, maintenance, and increase in the number of lower incisors with GR before and after treatment. To measure the incisor-mandibular plane angle (IMPA) and the thickness of the AP and the MS were used the cephalometric radiographs.

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Results: Men had a significantly thicker MS than women at T0 and T1 ($p < 0.0004$). There was a significant reduction of approximately 10% in AP between T0 and T1 ($p < 0.0001$). Among subjects without GR at T0, 70.4% presented a stable gingival situation at T1. For subjects with 1 lower incisor with GR at T0, 50% showed improvement in the gingival situation at T1, 21.4% remained stable, and 28.6% experienced worsening. Sixteen lateral incisors presented a worsening gingival situation, representing an increase of 129% compared to the central incisors.

Conclusion: No relationship was found between lower incisor inclination and the thickness of the AP and MS in the development of GR.

1. Introduction

Functional balance in intermaxillary anteroposterior relationships can be achieved through a natural compensation mechanism involving lower incisor inclination. This compensation can also be achieved through orthodontic treatment (Molina-Berlanga et al., 2013).

The conditions of bone structure and gingival tissue are believed to be closely related to orthodontically-induced lower incisor inclination (Steiner et al., 1981). The movement of incisors beyond the labial and lingual limits of the alveolar process (AP) and mandibular symphysis (MS) can cause bone dehiscence and fenestration, as well as gingival recession (GR) (Nauert and Berg, 1999; Castro et al., 2016).

GR is characterized by the apical migration of the marginal gingiva, which can lead to the exposure of the cementoenamel junction (CEJ) (Kassab and Cohen, 2003). The development of GR is influenced by tooth movement, as well as bone and mucogingival dimensions (Steiner et al., 1981). In addition, factors such as pathologies, trauma, and oral hygiene can lead to the development of GR (Kassab and Cohen, 2003).

Retrospective studies have found conflicting results regarding the relationship between lower incisor inclination and the development of GR after orthodontic treatment (Ruf et al., 1998; Djeu et al., 2002; Allais and Melsen, 2003; Yared et al., 2006; Renkema et al., 2012; Closs et al., 2014; Kamak et al., 2015; Morris et al., 2017; Mazurova et al., 2018; Pernet et al., 2019). Allais and Melsen (2003) reported a higher prevalence of GR in treated subjects, who had lower incisor inclination, compared to the control group. Renkema et al. (2013) found a higher prevalence of GR in treated subjects and a greater risk of GR development in the lower incisors compared to other teeth. Pernet et al. (2019) discovered a relationship between the extensive inclination of the lower incisors and GR. While some studies measured the teeth before and after orthodontic treatment to assess gingival conditions, assessing the position of the gingival tissue and the teeth might lead to more accurate results (Renkema et al., 2013, Mazurova et al., 2018; Pernet et al., 2019).

Therefore, this study aimed to investigate the relationship between lower incisor inclination and AP and MS thickness in the development of GR.

2. Materials and methods

This study was approved by the Ethics Committee for Research on Human Subjects of the Federal University of Juiz de Fora (No. 2.771.641). All participants signed a written informed consent form to participate in the study.

Two exams—frontal intraoral photography and cephalometric radiography—were conducted before (T0) and after (T1) orthodontic treatment of 62 subjects who were treated with an edgewise appliance (0.022″).

For independent sample extraction, the parameters were set as follows: alpha of 0.05, confidence interval of 95%, power of 80%, and a positive GR of 37.5%. An estimate with continuity correction determined a sample size of 62 subjects (Allais and Melsen, 2003; Renkema et al., 2013).

The inclusion criteria were as follows: a stage of maturation of cervical vertebrae above CS5 at T0, absence of extensive restorations in lower incisors, no previous orthodontic treatment, no systemic disease known to the patient affecting the bone and gingival tissue, no smoking habit, and no periodontal disease identified on X-rays or photographs at T0 or T1. Subjects with severe or very severe dental crowding (Little, 1975) at T0 were excluded. The type of malocclusion was not controlled in this study.

Initially, cephalometric radiographs and frontal intraoral photographs of each patient were scanned at 300dpi using an HP G4050 scanner (Hewlett-Packard, Palo Alto, United States) and imported into the software ImageJ (National Institute of Mental Health, Maryland, United States). The radiographs were scanned with a millimeter ruler to enable the correction of values for the dimensions of the evaluated structures.

The presence of GR was considered when the CEJ was visible in the lower incisor on the frontal intraoral photograph at both T0 and T1. The circumstances for improvement, stability, and worsening of the gingival situation were based on the reduction, maintenance, and increase in the number of lower incisors with GR before and after treatment.

The incisor-mandibular plane angle (IMPA) is defined as the angle between the long axis of the lower incisor and the mandibular plane. In this study, the IMPA was determined by the Gonion (Go) and Menton (Me) cephalometric points on cephalometric radiographs at T0 and T1. The inclination of the lower incisors during orthodontic treatment was determined by calculating the difference between the IMPA at T1 and T0. Positive values for the IMPA indicated an inclination of the dental long axis crown in the buccal direction, and negative values indicated an inclination of the dental long axis crown in the lingual direction.

To measure the thickness of the AP and the MS, points B and Pogonion (Pog) were selected on the cephalometric radiographs. From the mandibular plane (a line drawn from Go to Me), two parallel lines were drawn: one passing through point B and the other through Pog, extending toward the most posterior point of the MS contour. The midpoints of these two

parallel lines were connected to define the long axis of the MS. Subsequently, two perpendicular lines were drawn along the axis of the MS: one from point B toward the most posterior point of the MS contour (point B'), and the other passing through Pog toward the most posterior point of the MS contour (Pog'). The distance between B and B' determined the thickness of the AP, and the distance between Pog and Pog' determined the thickness of the MS at both T0 and T1.

All variables (GR, IMPA, AP, and MS) of 10 subjects at T0 were measured 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 ICC $\geq$ 0.750.

2.1. Statistical analysis

A Kolmogorov-Smirnov test and a Q-Q plot were used to assess and adjust the data distribution. Independent samples t-tests were conducted on the entire sample to compare the mean values of IMPA, AP, and MS between T0 and T1. Furthermore, paired samples t-tests were employed to compare men and women at T0, T1, and T1-T0. Pearson's chi-squared (X2) test was used to compare the number of subjects with different amounts of lower incisors with GR at T0 and T1. An analysis of variance (ANOVA) followed by the Bonferroni post hoc test was employed to compare the mean values of IMPA, AP, and MS among subjects with different amounts of lower incisors with GR at T0. The independent samples *t*-test was used to compare the initial values (T0) and changes during treatment (T1-T0) among subjects who presented improvement, stability, or worsening of the gingival situation. A confidence interval of 95% and a statistical significance level of 5% were considered for all tests. The statistical analysis was conducted using the Stata 15.0 statistical software (College Station, TX, United States).

3. Results

The sample consisted of 25 men (41.7%) and 35 women (58.3%). Table 1 shows the initial and final ages, along with the duration of orthodontic treatment. The values of IMPA, AP, and MS obtained for men, women, and the total sample at T0 and T1, as well as the comparison between times T0 and T1, are presented in Table 1. In the total sample, no significant change in IMPA was observed during treatment. However, the values of IMPA were widely distributed in the

Table 1 Mean values for age, time of treatment, incisor-mandibular plane angle, alveolar process, and mandibular symphysis at T0 and T1, including comparisons between period and sex.

		T0 Mean (SD)	**T1** Mean (SD)	**T1-T0** Mean (SD)	**Comparison T0 and T1** (*p*-value*)
Age	Men	17.4 (7.1)	21.5 (7.3)	–	–
	Women	17.6 (8.2)	22.3 (8.7)	–	–
	Total	17.5 (7.7)	22.0 (8.1)	–	–
Time of treatment (months)	Men	–	–	44.6 (13.5)	–
	Women	–	–	57.5 (31.8)	–
	Total	–	–	52.2 (26.5)	–
IMPA	Men	93.7 (6.0)	92.9 (6.1)	−0.8 (6.4)	
	Women	92.7 (8.6)	93.0 (7.6)	0.3 (6.8)	
	Total	93.2 (7.5)	93.0 (7.0)	−0.2 (6.6)	0.843
Alveolar process	Men	7.4 (0.3)	6.7 (1.7)	−0.7 (1.1)	
	Women	6.7 (0.2)	6.0 (1.3)	−0.7 (1.1)	
	Total	7.0 (1.5)	6.3 (1.5)	−0.7 (1.1)	< 0.0001
Mandibular symphysis	Men	15.1 (2.1) $^{+}$	15.3 (2.0) $^{+}$	0.2 (1.0)	
	Women	13.1 (1.9) $^{+}$	13.2 (2.1) $^{+}$	0.1 (0.9)	
	Total	13.9 (2.2)	14.0 (2.3)	0.1 (1.0)	0.421

SD: standard deviation. IMPA: incisor-mandibular plane angle. * *T*-test for paired samples. $^{+}$ Significant difference for independent samples in the *t*-test.

Table 2 Distribution of subjects in terms of the number of lower incisors with gingival recession at T0 and T1.

Teeth with GR	**Pre-treatment (T0)**			**Post-treatment (T1)**		
	Men N (%)	Women N (%)	Total N (%)	Men N (%)	Women N (%)	Total N (%)
0 incisor	10 (40,0)	17(48,5)	27 (43,3)	14 (56,0)	17(48,5)	31 (51,6)
1 incisor	6 (24.0)	8 (22.8)	14 (23.3)	5 (20.0)	5 (14.2)	10 (16.7)
2 incisors	5 (20.0)	5 (14.2)	10 (20.0)	3 (12.0)	7 (20.0)	10 (16.7)
3 incisors	2 (8.0)	3 (8.5)	5 (6.7)	2 (8.0)	4 (11.4)	6 (10.0)
4 incisors	2 (8.0)	2 (5.7)	4 (6.7)	1 (4.0)	2 (5.7)	3 (5.0)
p-value*	0.957			0.868		

GR: gingival recession. * Pearson's chi-squared (X2) test.

Table 3 Distribution of the number of lower incisors with gingival recession at T0 and T1.

Pre-treatment (T0)		Post-treatment (T1)				
		0 incisor	1 incisor	2 incisors	3 incisors	4 incisors
0 incisor	27	19	4	3	1	-
1 incisor	14	7	3	3	1	-
2 incisors	10	4	1	2	2	1
3 incisors	5	1	1	1	1	1
4 incisors	4	-	1	1	1	1

Improvement Stability Worsening of gingival situation during orthodontic treatment.

sample. There was a significant reduction of approximately 10% in AP between T0 and T1. Furthermore, men had a significantly thicker MS than women at T0 and T1.

Table 2 shows the number of lower incisors with GR among the evaluated subjects at T0 and T1. No significant difference was found in the distribution of subjects based on the number of lower incisors with GR at T0 and T1.

Table 3 displays the variations in the number of lower incisors with GR at T0 and T1. Among subjects without GR at T0, 70.4% presented a stable gingival situation at T1. For subjects with 1 lower incisor with GR at T0, 50% showed improvement in the gingival situation at T1, 21.4% remained stable, and 28.6% experienced worsening.

Table 4 shows the variations in the gingival situation of each lower incisor during orthodontic treatment. Sixteen lateral incisors presented a worsening gingival situation, representing an increase of 129% compared to the central incisors.

As shown in Table 5, the average values of IMPA, AP, and MS at T0 were compared among subjects with different numbers of lower incisors with GR. Subjects with 4 lower incisors with GR had a significantly thicker MS than subjects with 2 lower incisors with GR.

Table 4 Gingival situation of each lower incisor during orthodontic treatment.

Lower incisor	Gingival situation between T0 e T1		
	Improvement	**Stability**	**Worsening**
Right lateral incisor	2	51	7
Right central incisor	11	47	2
Left central incisor	8	47	5
Left lateral incisor	7	44	9
Total	28	189	23

Table 5 Distribution and comparison of mean values for incisor-mandibular plane angle, alveolar process thickness, and mandibular symphysis thickness among subjects affected by GR at T0.

	Presence of gingival recession					*p*-value*
	0 incisor Mean (SD)	**1 incisor** Mean (SD)	**2 incisors** Mean (SD)	**3 incisors** Mean (SD)	**4 incisors** Mean (SD)	
IMPA (T0)	93.4 (7.9)	94.0 (8.5)	90.7 (7.1)	92.2 (7.0)	96.0 (4.7)	0.768
AP (T0)	7.0 (1.7)	6.7 (1.0)	7.1 (1.4)	7.7 (2.1)	7.1 (1.0)	0.862
MS (T0)	13.7 (1.9)	14.0 (2.1)	12.8 (2.1)[a]	15.1 (2.5)	16.4 (2.8)[a]	0.050

IMPA: incisor-mandibular plane angle. AP: alveolar process thickness. MS: mandibular symphysis thickness. * ANOVA. a: the post hoc test indicated a significant difference.

Table 6 Gingival situation during orthodontic treatment and comparison between variables at T0 and T1-T0.

	Gingival situation during orthodontic treatment		*p*-value*
	Improvement/Stability Mean (DP)	Worsening Mean (DP)	
IMPA (T0)	93.1 (7.4)	93.3 (8.1)	0.935
IMPA (T1-T0)	0.3 (6.8)	−1.7 (6.1)	0.285
AP (T0)	7.0 (1.4)	6.9 (1.8)	0.847
AP (T1-T0)	−0.6 (0.9)	−0.8 (1.5)	0.622
MS (T0)	14.2 (2.2)	13.3 (2.1)	0.206
MS (T1-T0)	0.2 (0.9)	−0.1 (1.0)	0.204

IMPA: incisor-mandibular plane angle. AP: alveolar process thickness. MS: mandibular symphysis thickness. * T-test for independent samples.

As illustrated in Table 6, no significant difference was observed in the values of IMPA, AP, and MS obtained at T0 and T1-T0 when comparing subjects who presented improvement/stability and those whose gingival situation worsened.

4. Discussion

Lower incisor inclination is often modified during orthodontic treatment (Mazurova et al., 2018). The thickness of the AP and MS poses limitations on the buccal and lingual movement of lower incisors (Nauert and Berg, 1999). Neglecting this limitation might contribute to the development of bone dehiscence and fenestration, as well as marginal gingival alterations (Castro et al., 2016).

Mazurova et al. (2018) demonstrated that the MS was significantly thicker in men than in women at the beginning of orthodontic treatment. This might be attributed to the greater Pog growth in men compared to women (Nanda and Ghosh, 1995). This corroborates the findings of the present study, in which men had higher MS at T0 and T1.

In this study, men demonstrated a lower incidence of GR in the lower incisors at T1 compared to women, which differs from the findings of Mazurova et al. (2018) and Pernet et al. (2019). Due to the multifactorial etiology of GR, these divergent results could be explained by multiple factors, such as oral hygiene quality and the force exerted on periodontal tissues during tooth brushing (Kassab and Cohen, 2003). Furthermore, the absence of smoking control in other studies might have influenced their results, as smoking directly affects the risk, extent, and severity of GR (Borojevic, 2012).

An important consideration in the retrospective design of this study is the possibility of assessing the presence of GR through the visualization of the CEJ in frontal intraoral photographs taken before and after orthodontic treatment. Previous studies (Renkema et al., 2012; Mazurova et al., 2018; Pernet et al., 2019) have relied on the difference between initial and final measurements of the lower incisor crown in study models to determine the presence of GR. However, differences in the lower incisor crown size before and after orthodontic treatment does not necessarily reflect the apical positioning of the marginal gingival, since various factors can influence tooth length, such as dental wear and extrusion (Raymond et al., 1996), as well as the quality and fragility of study models (Allais and Melsen, 2003).

In the sample examined in this study, the frequency of GR was higher in the left lower lateral incisors than in other lower incisors at T1. This finding is congruent with previous studies (Allais and Melsen, 2003; Kamak et al., 2015). This might be explained by the fact that 90% of the global population is right-handed (Raymond et al., 1996), leading to a tendency to favor the opposite side during oral hygiene, resulting in increased movement and force applied to that area (Sangnes and Gjermo, 1976).

In this study, subjects whose gingival situation worsened during treatment had a narrower MS at T0. A similar finding was reported by Mazurova et al. (2018). The reduced limitations on the orthodontic movement of lower incisors might increase the possibility of bone dehiscence and fenestration, as well as gingival alteration. However, these subjects did not present a narrower AP at T0, suggesting that the susceptibility of GR in this sample is not related to the AP, but rather to the thickness of the MS.

Considering the small percentage of subjects who had their gingival situation worsened during orthodontic treatment, similar to Ruf et al. (1998), this finding might be associated with oral hygiene quality (Yared et al., 2006), thickness and amount of gingiva (Amid et al., 2020), and thickness of the AP and MS (Nauert and Berg, 1999). Determining the criteria of what constitutes worsening of the gingival situation relied on the assessment of the lower incisors of the entire sample. If individuals were assessed separately, it would become apparent that the gingival situation had improved in some incisors and worsened in others.

In this study, orthodontic treatment significantly reduced the thickness of the AP by approximately 10%. A similar result was found by Pernet et al. (2019). However, the AP is found in a region that contains the alveolar bone and the root of the lower incisor, and this portion comprises the greatest part of what constitutes the thickness, so the percentage of bone reduction could be higher. Therefore, considering that the thickness of the lower incisor root either does not change or only slightly changes during orthodontic treatment, the calculated percentage only represents the bone of the AP.

The relationship between orthodontically-induced lower incisor inclination and the development of GR has been a topic of debate in the literature (Joss-Vassalli et al., 2010). Some studies have reported an relationship between lower incisor inclination and GR after orthodontic treatment (Allais and Melsen, 2003; Pernet et al., 2019), while other studies have not found such relationship (Djeu et al., 2002; Yared et al., 2006; Closs et al., 2014; Kamak et al., 2015; Morris et al., 2017). A systematic review, which included only two retrospective studies with adult samples and different methodologies, reported that, up to that moment, there was insufficient evidence to support the conclusion that lower incisor inclination could cause GR (Tepedino et al., 2018).

The present study did not find a relationship between lower incisor inclination and the development of GR. However, the moment of GR assessment was the same as Allais and Melsen (2003), which was conducted shortly after orthodontic removal, unlike other studies (Renkema et al., 2013; Pernet et al., 2019). This was to avoid the influence of age, as it is considered a risk factor for the development of GR (Sarfati et al., 2010).

Orthodontic treatment can modify the inclination of lower incisors, which can interfere with the marginal gingiva. However, the results of this study corroborate the majority of other studies, which failed to find a relationship between lower incisor inclination and GR development. Nevertheless, these results must be evaluated with caution, because several variables might have influenced them.

5. Conclusion

No relationship was found between lower incisor inclination and the thickness of the AP and MS in the development of GR.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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