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Original article

Gingival recession in mandibular incisors and symphysis morphology—a retrospective cohort study

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Summary

Objective: To evaluate if the morphology of the mandibular symphysis is associated with the development of gingival recession.
Materials and methods: A cohort of 177 patients was followed longitudinally for up to 5 years post-treatment. Based on the width of the symphysis, participants were divided into three groups: *narrow* ($n = 57$); *average* ($n = 63$), and *wide* symphysis ($n = 57$). Morphology of the symphysis and inclination of incisors were measured on lateral cephalometric radiographs before treatment (T_s), at the end of treatment (T_0) and 5 years after treatment (T_5). Gingival recession and the change of clinical crown heights in mandibular incisors were measured on plaster models made at T_S, T_0, and T_5.
Results: From T_S to T_5 the change in inclination was comparable in the *narrow*, *average*, and *wide* groups. At T_5, gingival labial recession was present in 19.3 per cent of patients with *narrow* symphysis, 20.6 per cent with *average* symphysis, and 14 per cent of patients with *wide* symphysis. The difference was not significant. The mean change of clinical crown height was <1 mm ($T_S - T_5$). The regression model showed some evidence that incisor inclination at T_s might have been associated with the change of mean clinical crown height (–2.51, 95% CI: –4.6 to –0.4, $P = 0.02$). The logistic regression model demonstrated that H1 (Height 1) might be associated with the development of gingival recession (OR = 0.75, 95% CI: 0.58 to 0.96, $P = 0.03$).
Conclusion: Within the limitations of this study, there is no evidence that the overall morphology of the mandibular symphysis is associated with gingival recession development.

Introduction

Gingival recession, that is exposure of the root surface caused by apical displacement of the gingival margin past the cemento-enamel junction (CEJ) (1), is a common problem in humans. Depending on the population, it can be present in over 90 per cent of healthy people who are 50 years of age or older (2). The aetiology of gingival recession is unclear, however, traumatic tooth brushing and the presence of inflammation in periodontal tissue are regarded as the two most important aetiologic factors (3). It has also been suggested that the morphology of the gingival tissue, that is gingival biotype, is related to the occurrence of gingival recession (1, 4) or to the effectiveness of the surgical coverage of recession (5, 6). Gingival tissue can be broadly categorized as thick, average, or thin. Thick gingival tissue is densely fibrous and significantly keratinized, whereas thin gingival tissue is delicate with less keratinization compared to thick gingival tissue (7, 8). It is implied that thick gingiva is protective against recession, whereas thin tissue is conducive to the occurrence of gingival recession (1).

Orthodontic patients have an increased risk in developing gingival recession (9, 10). Slutzkey and Levin (9) found recession sites in 14.6 per cent of evaluated young Israeli conscripts. The prevalence, extent, and severity of the recession were associated with past orthodontic treatment and oral piercing. Renkema *et al.* (10). compared orthodontically treated and untreated young adults and showed that participants with a history of orthodontic treatment were 4.5 times more likely to have recession sites compared to untreated controls. The exact mechanism by which orthodontic treatment could induce the development of gingival recession development is not fully understood. However, proclination of mandibular incisors in a narrow alveolar process can facilitate the formation of alveolar bone dehiscences and result in the occurrence of gingival recession (10).

The quantity of the alveolar bone could be associated with the development of gingival recession. Studies on immediately placed implants indicated an association between the thickness of the buccal bone wall and the alterations of alveolar crest that occurred after implant placement into extraction sockets. The thicker the buccal alveolar bone, the less vertical resorption of alveolus was observed (11, 12). In contrast, orthodontic studies did not provide evidence implying a similar relationship. A possible reason is that researchers usually attempted to identify a relationship between occurrence of gingival recession (13) or alveolar bone defect (14) with the facial type assuming that facial type is closely associated with morphology of the alveolar process. In this investigation, we will test the null hypothesis (H_0) that participants with a narrow symphysis have comparable gingival recession long-term following orthodontic treatment as participants with an average or wide symphysis.

Materials and methods

This study respected the Declaration of Helsinki with regard to research in human subjects. According to Dutch law on medical research the use of anonymized data gathered during patient care does not fall within the remit of the Medical Research Involving Human Subjects Act (WMO). Therefore, this investigation could be carried out without an individual approval by an accredited research ethics committee.

This was a retrospective study in which participants were followed longitudinally for 8.2 years, from the start of orthodontic treatment to five years after completion of therapy.

The post-treatment archive at the Department of Orthodontics and Craniofacial Biology, Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands, was searched for participants meeting the following inclusion criteria: treated with full fixed appliances; a bonded lingual retainer placed directly after active orthodontic treatment; no orthodontic re-treatment; initial, end-of-treatment, and long-term after treatment dental casts made at the ages of approximately 12.5 years (pre-treatment, T_S), 15 (end-of-treatment, T_0), and 20 (long-term, T_5) years available. The choice of age was dictated by the time when typical orthodontic treatment starts, and by the protocol for post-treatment records collection used at Radboud University Nijmegen Medical Centre. All participants had a lingual retainer, either bonded only to the mandibular canines or bonded to all six mandibular anterior teeth during the entire post-treatment period. In all patients four mandibular incisors were present at T_5. Exclusion criteria were: combined orthodontic/surgical treatment, restorative treatment (except for single crowns) after orthodontic therapy, and dental casts of poor quality, particularly in the area of gingival margin.

Out of 500 potentially eligible participants, 177 (76 males and 101 females) met the inclusion criteria. Based on the width of the symphysis (W2 variable, described in detail in the *Measurements* subsection) and taking into account sexual dimorphism (15), males and females were divided separately into three groups of comparable sizes:

1. *Narrow symphysis* (males: N = 24 males, W2 < 7.3 mm; females: N = 33, W2 < 6.8 mm)
2. *Average symphysis* (males: N = 26, W2 ≥ 7.3 mm and < 8.3 mm; females: N = 37, W2 ≥ 6.8 mm and < 7.8 mm)
3. *Wide symphysis* (males: N = 26, W2 ≥ 8.3 mm; females: N = 31, W2 ≥ 7.8 mm).

Demographic data, such as gender, age at T_S, T_0 and T_5, and type of retainer, were obtained from the patient files. Malocclusion classification of Angle was determined on the right side of the initial (T_S) plaster models. Study size analysis was not performed before an initiation of the investigation. Instead, all eligible participants were included in the study.

Measurements

Morphology of mandibular symphysis was determined by a single investigator (KM) on lateral cephalometric radiographs according to Gütermann *et al* (16). In summary, height (H1 and H2), width (W1 and W2), and depth (D) of the symphysis were measured on pre-treatment (T_S) radiographs with mandibular plane (MP, a plane tangent to the lower border of the mandible) as a reference plane for all measurements. Inclination of incisors (Inc Inclin) relative to MP was determined on radiographs made before orthodontic treatment (T_S), at the end of treatment (T_0), and five years after treatment (T_5). Details of measurements are in Figure 1 and group characteristics are in Table 2.

The periodontal outcome variables recorded by a single investigator (AMR) were: 1) the presence of gingival labial recession in mandibular incisors, which was scored (*Yes* or *No*) on plaster models at T_S, T_0, and T_5 and 2) the change of clinical crown heights of mandibular incisors, also measured on the plaster models at T_S, T_0, and T_5. A *gingival recession* was noted (scored *Yes*) if the labial CEJ was exposed. The *clinical crown heights* were determined as the distances between the incisal edges and the deepest points of the curvature of

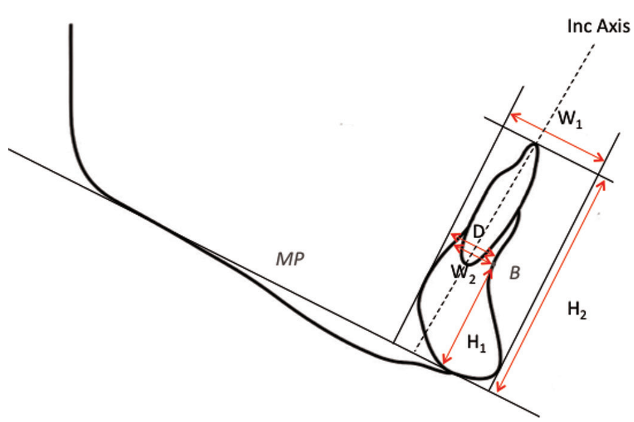

Figure 1. Details of measurements performed on cephalograms. Descriptions are in Table 1.

the vestibulo-gingival margins. The measurements were made with an electronic calliper (Digital 6, Mauser, Winterthur, Switzerland) by one investigator (AMR) with an accuracy of 0.01 mm. In this study only the mean crown heights of four mandibular incisors were used. The validation of the use of plaster casts for scoring gingival recession sites has been previously reported by Renkema *et al.* (10).

Potentially confounding variables such as plaque accumulation, bleeding on probing of gingival pockets, smoking, tooth-brushing habits were unknown and were not considered in the analysis.

Method error

Error of measurements on plaster models was described in Renkema *et al.* (10). The error of measurements on cephalometric radiographs was assessed with Bland–Altman plots (17) based on double measurements of 25 randomly selected radiographs performed in more than 2 weeks apart (Figure 2).

Statistical analysis

Descriptive statistics with means and standard deviations were calculated for the participant characteristics at T_S, T_0, and T_5. One-way analysis of variance and independent *t*-tests were used in order to identify potential differences in age, orthodontic treatment duration, morphological parameters H1, H2, W1, W2, D and incisor inclination at T_S, T_0, and T_5 between participants with *narrow*, *average*, and *wide* symphysis, and gender, respectively.

Fisher's exact test was used to assess differences in the prevalence of recession sites at T_S and T_5 among participants with *narrow*, *average*, and *wide* symphysis, and among males and females.

To assess the influence of variables effecting the development of gingival recession in mandibular incisors from T_S to T_5 (*dependent variable*), the following independent variables were considered: symphysis morphology (H1, H2, W1, W2, and D), gender, length of orthodontic treatment, incisor inclination before orthodontic treatment and change of incisor inclination during orthodontic treatment (*independent variables*). In order to do so, a random effects logistic regression model was applied. To estimate the influence of H1, H2, W1, W2, D, gender, length of orthodontic treatment, incisor inclination before orthodontic treatment and change of incisor inclination during orthodontic treatment (*independent variables*) on the change of the mean clinical crown height of all mandibular incisors (*dependent variable*), a random effect linear regression model was applied.

Table 1. Description of measurements—details in Figure 1.

Symbol	Definition	Description
MP	Mandibular plane	Plane tangent to the lower border of the mandible and passing through the most inferior point on the outer contour of the symphysis
Inc Axis	Axis of the incisor	Line passing through the edge and apex of mandibular incisor
B	Point B	Most posterior point of the bony curvature between the crest of the alveolar process and the chin
W1	Width of symphysis	Distance between the anterior and posterior tangents to the symphysis perpendicular to the mandibular plane
W2	Width of alveolus	Distance between point B and the posterior contour of the symphysis, measured parallel to the mandibular plane
H1	Height 1	Perpendicular distance from point B to mandibular plane
H2	Height 2	Perpendicular distance from incisal edge to mandibular plane
D	Depth	Distance between point B and the posterior tangent to the symphysis perpendicular to the mandibular plane
Inc Incl	Incisor inclination	Angle between the axis of the incisor and mandibular plane

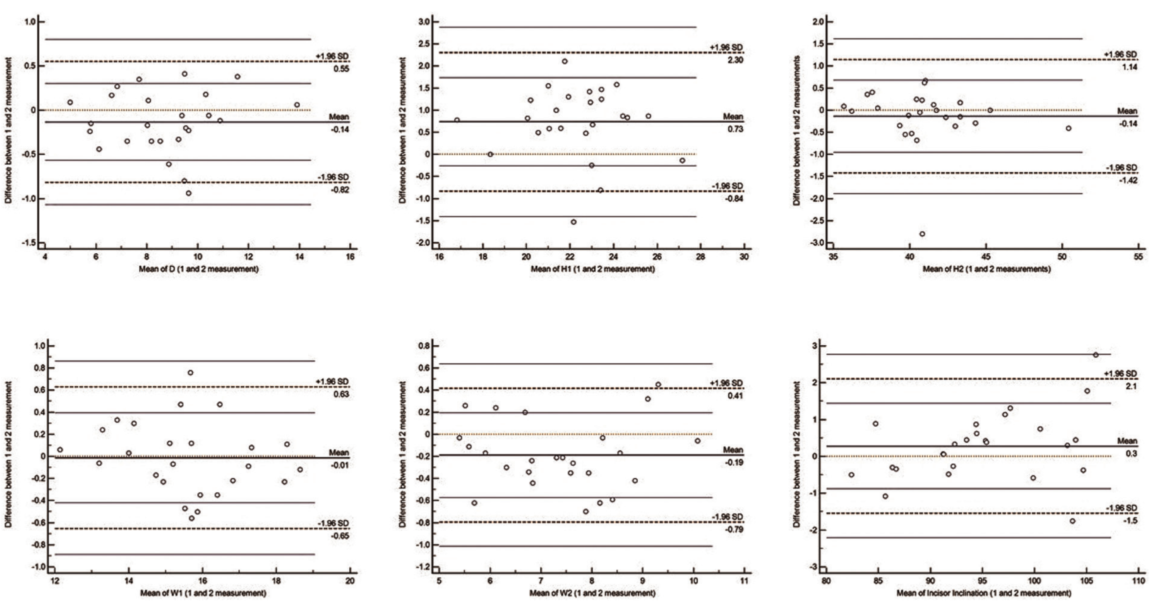

Figure 2. Bland–Altman plots demonstrating the bias for cephalometric variables.

Statistical analyses were conducted with Stata statistical software (v.14.2; Stata Corp, Texas, USA). Bland–Altman plots were made with MedCalc program (v. 15.4; MedCalc Software bvba, Ostend, Belgium).

Results

Sample

The proportion of males was comparable in *narrow*, *average*, and *wide* groups (31.5 per cent versus 34.2 per cent versus 34.2 per cent in *narrow*, *average*, and *wide* groups, respectively). All three groups were also well-matched regarding age at T_S, T_0, and T_5 (Table 2). The mean length of orthodontic treatment was 3 years in *narrow*, 2.6 years in *average*, and 2.7 years in *wide* groups respectively, and ranged from 1.2 to 5.2 years (*narrow*), from 1.4 to 5.5 years (*average*), and from 1.1 to 5.1 years (*wide*). However, comparing the *narrow* versus *average* and *wide* groups, orthodontic treatment lasted approximately 3–4 months longer in participants with narrow symphysis than in participants with average or wide symphysis (P = 0.04).

Symphysis morphology and incisor inclination

The *narrow*, *average* and *wide* groups were selected on the basis of different widths of alveolus (W2). In order to accommodate inter-gender differences, cut-off values for males were 0.5 mm larger than for females. There was an inter-gender difference for W2 (P = 0.03). The mean width of alveolus (W2) was 6.35 mm in the *narrow* group, 7.52 mm in the *average* group, and 8.81 mm in the *wide* group. The symphysis width (W1) was smaller by 1.28 mm in the *narrow* group in comparison to the *wide* group and 0.39 mm smaller in comparison to the *average* group (P < 0.001). The symphysis depth (D) was also smaller in the *narrow* group compared to the *average* group (difference = 1.49) and the *wide* group (difference = 3.06 mm, P < 0.001). However, both measures of symphysis height (H1 and H2) were comparable in all three groups (*narrow*, *average*, and *wide*).

The *narrow*, *average*, and *wide* groups differed regarding incisor inclination (Table 3), which was consistently larger in the *wide* group at all observation time points (T_S T_0, and T_5). However, the change of inclination during (T_S to T_0) and after (T_0 to T_5) orthodontic treatment was comparable in the *narrow*, *average*, and *wide* groups—incisors were proclined by about 5 degrees during treatment and remained stable until 5 years after orthodontic treatment.

During orthodontic treatment, the incisors were more proclined in females than in males (Table 3). As a result, the inclination of incisors was larger in females than in males by 3.52 degrees in both T_0 and T_5.

Table 2. Group characteristics.

	Narrow (*N* = 57)	Average (*N* = 63)	Wide (*N* = 57)	*P*
Symphysis shape				
Age pre-treatment (T_S)	12.27 (0.76)	12.40 (0.83)	12.38 (0.94)	0.65
Age at end of treatment (T_0)	15.28 (1.16)	15.08 (0.95)	15.02 (1.12)	0.44
Age after treatment (T_S)	20.56 (1.20)	20.64 (1.13)	20.55 (1.2)	0.89
Treatment time	3.01 (0.84)	2.69 (0.84)	2.66 (0.72)	**0.04**
W1	14.80 (1.48)	15.19 (1.52)	16.08 (1.73)	**<0.001**
W2	6.35 (0.51)	7.52 (0.35)	8.81 (0.81)	**<0.001**
H1	21.21 (2.30)	21.00 (2.00)	21.27 (2.06)	0.76
H2	40.25 (3.14)	40.19 (2.76)	41.16 (3.30)	0.16
D	7.03 (1.48)	8.52 (1.36)	10.09 (1.69)	**<0.001**
	Males (*N* = 76)	Females (*N* = 101)		
Gender				
Age pre-treatment (T_S)	12.45 (0.86)	12.28 (0.82)		0.19
Age at end of treatment (T_0)	15.21 (1.08)	15.07 (1.06)		0.40
Age after treatment (T_S)	20.72 (1.20)	20.49 (1.11)		0.20
Treatment time	2.75 (0.84)	2.81 (0.79)		0.66
W1	15.82 (1.61)	15.00 (1.61)		**<0.001**
W2	7.77 (1.24)	7.40 (1.05)		0.03
H1	21.53 (1.99)	20.87 (2.16)		0.04
H2	41.54 (3.27)	39.76 (2.70)		**<0.001**
D	8.70 (1.76)	8.43 (2.07)		0.36

Table 3. Incisor inclination in males and females with different symphysis shapes.

	Narrow (N = 57)	Average (N = 63)	Wide (N = 57)	*P*
Symphysis shape				
Incisor inclination pre-treatment	90.64 (5.91)	93.06 (7.97)	96.00 (6.45)	**<0.001**
Incisor inclination post-treatment	96.80 (6.02)	97.03 (7.17)	100.51 (6.58)	**0.00**
Incisor inclination 5 years after treatment	97.44 (6.96)	98.06 (7.53)	101.43 (6.60)	**0.01**
	Males (*N* = 76)	Females (*N* = 101)	Diff	
Gender				
Incisor inclination pre-treatment	92.11 (6.37)	94.06 (7.64)	−1.95	0.07
Incisor inclination post-treatment	96.07 (5.92)	99.59 (7.05)	−3.52	**<0.001**
Incisor inclination 5 years after treatment	96.94 (6.81)	100.46 (7.20)	−3.52	**0.01**

Gingival recession and crown heights

The prevalence of recession sites in the *narrow*, *average*, and *wide* groups at the end of treatment (T_0) and 5 years after treatment (T_5) is presented in Table 4. At the end of treatment (T_0) very few new recession sites developed in all three groups (*narrow*: 1.8 per cent, *average*: 1.6 per cent, and *wide*: 4 per cent). New recession sites developed in 19.3 per cent participants with narrow symphysis versus 20.6 per cent with average symphysis and 14 per cent participants with wide symphysis (T_5). There was no significant difference between groups. The prevalence of new recessions at the end of treatment (T_0) and 5 years after treatment (T_5) in males and females is presented in Table 5. There was evidence that height 1 (H1) was associated with the development of gingival recession (Table 6) (OR = 0.75, 95% CI: 0.58 to 0.96, P = 0.03). The odds of developing gingival recession were 25 per cent lower for every unit increase of height 1 (H1). In other words, the higher the symphysis the lower odds of recession.

The mean clinical crown heights were comparable in the *narrow*, *average*, and *wide* group, and in males and females, in all observation time points. The change of mean clinical crown height was <0.1 mm during orthodontic treatment (T_S to T_0) and was <1 mm during the whole observation period (T_S to T_5)—see Table 7. There was evidence that (Table 8) incisor inclination before treatment (T_S) (−2.51, 95% CI: −4.6 to −0.4, P = 0.02) was associated with the change of mean clinical crown height. Per every treatment year 0.16 mm less crown height was noticeable. The above mentioned regression models demonstrated a negative association between incisor inclination before treatment and crown height.

Time as an independent variable was a significant predictor of crown length (P < 0.001), meaning with time the crown length increased. The prediction of crown length over time, with the 95% CIs is presented in Figure 3.

Discussion

Mandibular incisors are frequently proclined during orthodontic treatment. Theoretically, if the alveolar process housing these teeth is narrow, and the bone covering labial aspect of the roots is thin, proclination of incisors may facilitate formation of dehiscences of alveolar bone. This, in turn, could promote the development of gingival recession. In this study, we tested the null hypothesis (H_0) that participants with a narrow symphysis had comparable gingival recession long-term following orthodontic treatment as participants with an average or wide symphysis. The present findings show that, overall, the morphology of the mandibular symphysis is not associated with the development of gingival recession nor with the increase of clinical crown heights, thus H_0 was accepted. Our findings agree with results of Closs *et al.* (18) who found no association between symphysis shape and alveolar ridge alterations after orthodontic treatment.

In this study, symphysis morphology was used to classify participants to groups—males where the width of the alveolus (W2 measurement) was <7.3 mm were classified as having *narrow* symphysis, respectively males where the width of the alveolus (W2 measurement) was ≥7.3 mm were classified as having an *average* symphysis, while males where W2 ≥ 8.3 mm were classified as having *wide* symphysis. For females the cut-off values were 6.8 and 7.3 mm for *narrow* and *wide* groups, respectively. One should bear in mind, however, that external dimensions of the symphysis (i.e. *narrow* versus *average* versus *wide* symphysis) are not *per se* tantamount with the increased or reduced thickness of alveolar bone supporting incisors. Hypothetically, it is possible that a participant with wide symphysis has a thin alveolar bone, and vice versa. Unfortunately, with the available records, it was not possible to determine the thickness of the alveolar bone in our participants. Several studies, however, provide circumstantial evidence that symphyseal shape is indeed associated with the quantity of alveolar bone—Sadek *et al.* (19), Hoang *et al.* (20), and Molina-Berlanga *et al.* (21) analysed alveolar bone thickness, symphysis shape, and facial type (long, average, and short) and found correlations—participants with a long face and a steep mandibular plane (defined by the value of the angle between mandibular plane and sella-nasion line) had a narrower symphysis, and thinner alveolar bone supporting anterior teeth than participants with a short face with a flat mandibular plane. Therefore, our assumption that *narrow* symphysis is related to thin alveolar bone and wide symphysis is associated with thick alveolar bone, seems realistic.

Orthodontic tooth movement takes place after a force has been applied to the tooth. Because of force application, compression and tension sides form within the periodontal ligament. On the compression side, the alveolar bone is resorbed by osteoclasts, while osteoblasts lay down the new bone on the tension side (22). Normally, bone resorption and bone apposition are coupled and the mechanism that regulates both processes ensures that the alveolar bone around a tooth socket remodels and the bone can 'follow the tooth movement', as one of orthodontic axioms holds (23, 24). During proclination of incisors, however, the root approximates the cortical plate. It is not clear to which extent the buccal cortical plate in the anterior region of the mandible can remodel. Unfortunately, several review papers published in the last decade (22, 25–29) did not provide sufficient explanation. Hypothetically, if remodelling were complete, then ample amount of the alveolar bone would cover root surface; if remodelling were minimal, then dehiscence in the crest of alveolar

Table 4. Prevalence of new recessions at the end of treatment (T_0) and 5 years after treatment (T_5) in different symphysis shapes.

Number of participants with new recession sites at T_0	Narrow (N = 57)	Average (N = 63)	Wide (N = 57)
No new recession sites	56	62	55
1 new recession site	1	1	2
2 new recession sites	0	0	0
3 new recession sites	0	0	0
4 new recession sites	0	0	0
Number of participants with new recession sites at T_5	**Narrow (N = 57)**	**Average (N = 63)**	**Wide (N = 57)**
No new recession sites	46	50	49
1 new recession site	4	9	4
2 new recession sites	5	3	3
3 new recession sites	1	1	1
4 new recession sites	1	0	0

Table 5. Prevalence of new recessions at the end of treatment (T_0) and 5 years after treatment (T_5) in males and females.

Number of participants with new recession sites at T_0	Males (*N* = 76)	Females (*N* = 101)
No new recession sites	75	98
1 new recession site	1	3
2 new recession sites	0	0
3 new recession sites	0	0
4 new recession sites	0	0
Number of participants with new recession sites at T_5	**Males (*N* = 76)**	**Females (*N* = 101)**
No new recession sites	60	85
1 new recession site	10	7
2 new recession sites	4	7
3 new recession sites	2	1
4 new recession sites	0	1

Table 6. Random effects logistic regression model with recession sites as dependent variables.

Independent variable	OR	LL 95% CI	UL 95% CI	*P*
Gender				
Male	Reference			
Female	0.81	0.28	2.33	0.69
Length of orthodontic treatment (per unit years)	0.94	0.48	1.87	0.87
W1 (per unit mm)	1.12	0.81	1.54	0.50
W2 (per unit mm)	0.84	0.52	1.33	0.45
H1 (per unit mm)	0.75	0.58	0.96	**0.03**
H2 (per unit mm)	0.88	0.74	1.05	0.16
D (per unit mm)	0.90	0.69	1.17	0.43
Change of incisor inclination during treatment (per unit degrees)	1.04	0.96	1.14	0.33

Table 7. Change of mean clinical crown heights during observation period.

	Narrow (*N* = 57)	Average (*N* = 63)	Wide (*N* = 57)
Symphysis shape			
Crown length pre-treatment	7.98 (0.77)	8.25 (0.61)	7.90 (0.71)
Crown length post-treatment	8.03 (0.93)	8.27 (0.80)	7.81 (0.88)
Crown length 5 years after treatment	8.94 (0.97)	9.08 (8.77)	8.67 (1.11)
Change of crown length during treatment	0.05	0.02	0.09
Change of crown length during the whole observation period (T_S to T_5)	0.96	0.83	0.77
	Males (*N* = 76)	Females (*N* = 101)	Diff
Gender			
Crown length pre-treatment	8.16 (0.71)	7.97 (0.70)	0.19
Crown length post-treatment	8.13 (0.91)	7.97 (0.87)	0.16
Crown length 5 years after treatment	9.04 (0.93)	8.80 (1.13)	0.24
Change of crown length during treatment	0.03	0	0.03
Change of crown length during the whole observation period (T_S to T_5)	0.88	0.83	0.05

bone could form. A clinical study (30) looking at behaviour of the alveolus following retraction of anterior teeth during four-premolar extraction treatment demonstrated that lingual movements of incisors reduced the lingual alveolar bone in both arches. For example retraction of mandibular incisors by 10 degrees (the angle between the mandibular plane and incisal axis was reduced from 101 degrees to 91 degrees) resulted in thinning of the lingual aspect of the alveolus by about 90 per cent (i.e. thickness of the alveolar bone covering the lingual aspect of tooth #42 diminished from 0.9 to 0.1 mm). Similar observations by other authors (31, 32) suggest that the alveolar bone supporting roots of incisors does not remodel completely to preserve initial bone thickness.

In our sample, mandibular incisors were proclined by approximately 5 degrees (from 4.5 degrees in participants with wide symphysis to 6.2 degrees in participants with *narrow* symphysis respectively 4.0 degrees in participants with *average* symphysis). The amount of movement of the anterior aspect of the mandibular incisor root depends on the location of the centre of rotation. In uncontrolled tipping, the centre of rotation lies somewhere near 1/3 of the root length apical to the alveolar crest. In a controlled tipping, the centre of rotation lies at the apex of the root. Assuming that the average root length (i.e. from CEJ to the apex) of mandibular central incisors is 12.5 mm (33) and the distance between the CEJ to the alveolar crest is 1 mm (34) the 11.5 mm part of the root is in contact with the alveolar bone.

Table 8. Random effect linear regression model of crown height as dependent variable (continuous) associated with variables and adjusted for time.

Independent variable	Coefficient	LL 95% CI	UL 95% CI	*P*
Gender				
Male	Reference			
Female	−0.19	−43.2	4.2	0.11
W1 (per unit mm)	0.06	−1.5	12.7	0.12
W2 (per unit mm)	0.03	−13.5	7.0	0.54
H1 (per unit mm)	0.03	−2.2	9.0	0.23
H2 (per unit mm)	0.02	−1.6	6.0	0.26
D (per unit mm)	0.00	−6.4	5.8	0.92
Incisor inclination before treatment (per unit degrees)	−2.51	−4.6	−0.4	**0.02**
Change of incisor inclination during treatment (per unit degrees)	−0.28	−2.3	1.7	0.78

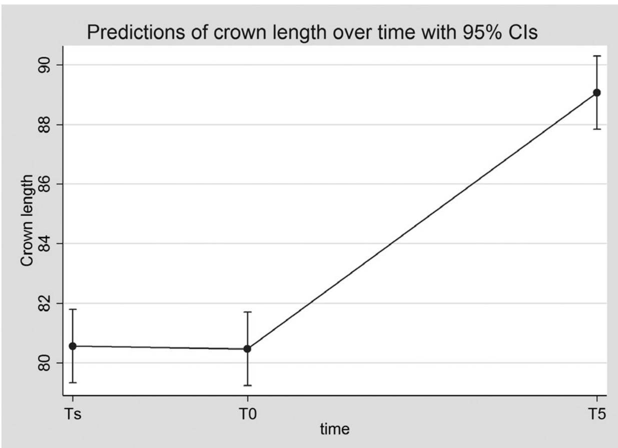

Figure 3. Predictions of crown length over time with 95% CIs. Crown length unit is represented in tens of mm.

If a mandibular central incisor is proclined by 5 degrees, the anterior aspect of the root at the level of the alveolar crest moves forward from approximately 0.4 mm in uncontrolled tipping to 1.1 mm in controlled tipping. After 10 degrees proclination, the movement is twice as much—from 0.8 to 2.2 mm for uncontrolled and controlled tipping, respectively. The spatial relationship between the root surface and alveolar bone depends also on the alveolar bone thickness (35). CBCT images (36) showed that the mean thickness of bone supporting mandibular incisors was 0.9 to 1 mm; in patients with bidentoalveolar protrusion, bone thickness is reduced to approximately 0.5 mm (37). All these factors considered, it is likely that following proclination of incisors, anterior aspects of their roots at crestal level were still within the alveolar bone in the majority of our participants. In other words, there might have been sufficient amount of alveolar bone to prevent dehiscence formation, which is a prerequisite for gingival recession. Unfortunately, the relatively low prevalence of gingival recession in our sample and low number of patients who had mandibular incisors proclined >10 degrees precluded further analysis.

Limitations

Periodontal parameters, such as plaque accumulation and bleeding on probing, habits (e.g. smoking), and periodontal biotype, which are potential confounders, were not included in the analysis.

Due to the retrospective study design, the above mentioned parameters could not have been included in the baseline assessment and therefore could reduce the external validity of our results. The need for further prospective investigation, which includes periodontal clinical examination and patient behaviour as risk factors, is needed. Selection bias may have occurred, as this is a retrospective study. Selection bias may occur if the participants are truly not comparable with unexposed but eligible participants.

Lateral cephalograms were used to establish the shape of the mandibular symphysis. Unfortunately, these two-dimensional radiographs cannot provide exact spatial information on the morphology of symphysis and roots, particularly in regions other than the region housing central incisors. More accurate measurements of the labial bone of the anterior part of the symphysis, such as proposed by Rossell *et al.* (38), could clarify differences between the *narrow*, *average*, and *wide* groups. Also, the use of three-dimensional radiographs could provide additional information regarding the anatomy of symphysis. However, alveolar bone is difficult to visualize (39).

As discussed previously, we did not directly measure the thickness of alveolar bone supporting anterior teeth because we lacked appropriate records. Instead, based on the literature, we assumed that the shape of the symphysis is associated with the quantity of the alveolar bone.

The passive tooth eruption implies apical migration of the gingiva until it stabilizes approximately 1–2 mm from the CEJ (40). It is not clear whether the passive eruption ceases in preadolescence (41) or later (40). The passive eruption was not assessed in this study and could have been a potential confounder of the measurements of the changes of clinical crown heights.

Conclusion

Within the limitations of this study, we conclude that the overall morphology of the mandibular symphysis is not associated with the development of gingival recession, nor with the increase of clinical crown heights. Therefore, evaluation of the shape of symphysis on cephalometric radiographs in order to predict the development of gingival recessions in the anterior region of the mandible, seems not to be a reliable method.

Conflict of Interest

None to declare.

References

1. Merijohn, G.K. (2016) Management and prevention of gingival recession. *Periodontology* 2000, 71, 228–242.
2. Löe, H., Anerud, A. and Boysen, H. (1992) The natural history of periodontal disease in man: prevalence, severity, and extent of gingival recession. *Journal of Periodontology*, 63, 489–495.

3. Vassalli, J., Grebenstein, C., Topouzelis, N., Sculean, A. and Katsaros, C. (2010) Orthodontic therapy and gingival recession: a systematic review. *Orthodontics & Craniofacial Research*, 13, 127–141.
4. Rasperini, G., Acunzo, R., Cannalire, P. and Farronato, G. (2015) Influence of Periodontal biotype on root surface exposure during orthodontic treatment: a preliminary study. *International Journal of Periodontics Restorative Dentistry*, 35, 665–675.
5. Ahmedbeyli, C., Ipçi, Ş.D., Cakar, G., Kuru, B.E. and Yılmaz, S. (2014) Clinical evaluation of coronally advanced flap with or without acellular dermal matrix graft on complete defect coverage for the treatment of multiple gingival recessions with thin tissue biotype. *Journal of Clinical Periodontology*, 41, 303–310.
6. Kahn, S., Almeida, R.A., Dias, A.T., Rodrigues, W.J., Barceleiro, M.O. and Taba, M. Jr. (2016) Clinical considerations on the root coverage of gingival recessions in thin or thick biotype. *International Journal of Periodontics Restorative Dentistry*, 36, 409–415.
7. Claffey, N. and Shanley, D. (1986) Relationship of gingival thickness and bleeding to loss of probing attachment in shallow sites following nonsurgical periodontal therapy. *Journal of Clinical Periodontology*, 13, 654–657.
8. Olsson, M. and Lindhe, J. (1991) Periodontal characteristics in individuals with varying form of the upper central incisors. *Journal of Clinical Periodontology*, 18, 78–82.
9. Slutzkey, S. and Levin, L. (2008) Gingival recession in young adults: occurrence, severity, and relationship to past orthodontic treatment and oral piercing. *American Journal of Orthodontics and Dentofacial Orthopedics*, 134, 652–656.
10. Renkema, A. M., Fudalej, P.S., Abbas, F., Bronkhorst, E. and Katsaros, C. (2013) Gingival labial recessions in orthodontically treated and untreated individuals: a case–control study. *Journal of Clinical Periodontology*, 40, 631–637.
11. Ferrus, J., Cecchinato, D., Pjetursson, E.B., Lang, N.P., Sanz, M. and Lindhe, J. (2010) Factors influencing ridge alterations following immediate implant placement into extraction sockets. *Clinical Oral Implants Research*, 21, 22–29.
12. Koh, R.U., Oh, T.J., Rudek, I., Neiva, G.F., Misch, C.E, Rothman, E.D. and Wang, H.L. (2011) Hard and soft tissue changes after crestal and subcrestal immediate implant placement. *Journal of Periodontology*, 82, 1112–1120.
13. Mazurova, K., Renkema, A. M., Navratilova, Z., Katsaros, C. and Fudalej, P.S. (2015) No association between gingival labial recession and facial type. *European Journal of Orthodontics*, 38, 1–6.
14. Enhos, S., Uysal, T., Yagci, A., Veli, l., Ucar, F.I. and Ozer, T. (2012) Dehiscence and fenestration in patients with different vertical growth patterns assessed with cone-beam computed tomography. *The Angle Orthodontist*, 82, 868–874.
15. Mangla, R., Singh, N., Dua, V., Padmanabhan, P. and Khanna, M. (2011) Evaluation of mandibular morphology in different facial types. *Contemporary Clinical Dentistry*, 2, 200–206.
16. Gütermann, C., Peltomäki, T., Markic, G., Hänggi, M. Schätzle, M., Signorelli, L. and Patcas. R. (2014) The inclination of mandibular incisors revisited. *The Angle Orthodontist*, 84, 109–119.
17. Bland, J.M. and Altman, D.G. (1986) Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet*, 1, 307–310.
18. Closs, L.Q., Bortolini, L.F., Dos Santos-Pinto, A. and Rösing, C.K. (2014) Association between post-orthodontic treatment gingival margin alterations and symphysis dimensions. *Acta Odontologica Latinoamericana*, 27, 125–130.
19. Sadek, M.M., Sabet, N.E. and Hassan, I.T. (2015) Alveolar bone mapping in subjects with different vertical facial dimensions. *European Journal of Orthodontics*, 37, 194–201.
20. Hoang, N., Nelson, G., Hatcher, D. and Oberoi, S. (2016) Evaluation of mandibular anterior alveolus in different skeletal patterns. *Progress in Orthodontics*, 17, 22.
21. Molina-Berlanga, N., Llopis-Perez, J., Flores-Mir, C. and Puigdollers, A. (2013) Lower incisor dentoalveolar compensation and symphysis dimentsions among Class I and III malocclusion patients with different facial vertical skeletal patterns. *The Angle Orthodontist*, 83, 948–955.
22. Isola, G., Matarese, G., Cordasco, G., Perillo, L. and Ramaglia, L. (2016) Mechanobiology of the tooth movement during the orthodontic treatment: a literature review. *Minerva Stomatologica*, 65, 299–327.
23. Reitan, K. (1963) Influence of variation in bone type and character on tooth movement. *European Orthodontic Society Transactions*, 39, 137–154.
24. Reitan, K. (1964) Effects of force magnitude and direction of tooth movement on different alveolar bone types. *The Angle Orthodontist*, 34, 244–255.
25. Masella, R.S. and Meister, M. (2006) Current concepts in the biology of orthodontic tooth movement. *American Journal of Orthodontics and Dentofacial Orthopedics*, 129, 458–468.
26. Krishnan, V. and Davidovitch, Z. (2006) Cellular, molecular, and tissue-level reactions to orthodontic force. *American Journal of Orthodontics and Dentofacial Orthopedics*, 129, 1–32.
27. Krishnan, V. and Davidovitch, Z. (2009) On a path to unfolding the biological mechanisms of orthodontic tooth movement. *Journal of Dental Research*, 88, 597–608.
28. Henneman, S., Von den Hoff, J.W. and Maltha, J.C. (2008) Mechanobiology of tooth movement. *European Journal of Orthodontics*, 30, 299–306.
29. Feller, L., Khammissa, R.A., Schechter, I., Thomadakis, G., Fourie, J. and Lemmer, J. (2015) Biological events in periodontal ligament and alveolar bone associated with application of orthodontic forces. *Scientific World Journal*, 2015, 876509.
30. Sarikaya, S., Haydar, B., Ciğer, S. and Ariyürek, M. (2002) Changes in alveolar bone thickness due to retraction of anterior teeth. *American Journal of Orthodontics and Dentofacial Orthopedics*, 122, 15–26.
31. Yodthong, N., Charoemratrote, C. and Leethanakul, C. (2013) Factors related to alveolar bone thickness during upper incisor retraction. *The Angle Orthodontist*, 83, 394–401.
32. Nayak Krishna, U.S., Shetty A., Girija, M.P. and Nayak, R. (2013) Changes in alveolar bone thickness due to retraction of anterior teeth during orthodontic treatment: a cephalometric and computed tomography comparative study. *Indian Journal of Dental Research*, 24, 736–741.
33. Wheeler, C.R. (1974) *Dental Anatomy, Physiology and Occlusion*. Saunders, Philadelphia, PA, 5th edn.
34. Wehrbein, H., Fuhrmann, R. and Diedrich, P. (1995) Human histologic tissue response after long-term orthodontic tooth movement. *American Journal of Orthodontics and Dentofacial Orthopedics*, 107, 360–371.
35. Morad, G., Behnia, H., Motamedian, S.R., Shahab, S., Gholamin, P., Khosraviani, K., Nowzari, H. and Khojasteh, A. (2014) Thickness of labial alveolar bone overlying healthy maxillary and mandibular anterior teeth. *Journal of Craniofacial Surgery*, 25, 1985–1991.
36. Patcas, R., Müller, L., Ullrich, O. and Peltomäki, T. (2012) Accuracy of cone-beam computed tomography at different resolutions assessed on the bony covering of the mandibular anterior teeth. *American Journal of Orthodontics and Dentofacial Orthopedics*, 141, 41–50.
37. Nahm, K.Y., Kang, J.H., Moon, S.C., Choi, Y.S., Kook, Y.A., Kim, S.H. and Huang, J. (2012) Alveolar bone loss around incisors in Class I bidentoalveolar protrusion patients: a retrospective three-dimensional cone beam CT study. *Dentomaxillofacial Radiology*, 41, 481–488.
38. Rossell, J., Puigdollers, A. and Girabent-Farrés, M. (2015) A simple method for measuring thickness of gingiva and labial bone of mandibular incisors. *Quintessence International*, 46, 265–271.
39. Lascala, C.A., Panella, J. and Marques, M.M. (2004) Analysis of the accuracy of lineal measurements obtained by cone beam computed tomography (CBCT-NewTom). *Dentomaxillofacial Radiology*, 33, 291–294.
40. Marrow, L.A., Robbins, J.W., Jones, D.L. and Wilson, N.H.F. (2000) Clinical crown length changes from age 12–19 years: a longitudinal study. *Journal of Dentistry*, 28, 469–473.
41. Volchansky, A. and Cleaton-Jones, P. (1976) The position of the gingival margin expressed by clinical crown height in children aged 6–16 years. *Journal of Dentistry*, 4, 116–122.