Original Article

Is there a relationship between mandibular cortical bone thickness and orthodontic treatment time?

Melissa Landin-Ramos[a]; Sumit Yadav[b]; Vaibhav Gandhi[c]; Madhur Upadhyay[b]; Aditya Tadinada[e]

ABSTRACT

Objectives: To determine whether there was a correlation between patients' bone thickness and time spent in orthodontic treatment. The secondary aim was to study the influence of Angle classification, extraction treatment, and age on overall treatment duration.

Materials and Methods: In this retrospective study, records of 971 orthodontic patients from two centers were reviewed and 500 subjects were included after imposing inclusion/exclusion criteria. The Mental Index was used to determine patients' bone density. For the Mental Index, a line perpendicular to the inferior border of the mandible was drawn on a panoramic radiograph so that it intersected the inferior border of the mental foramen. The mandibular cortical thickness was measured along this line. Two-sample *t*-test or a chi-square test, followed by multiple linear regression, were used to identify the factors affecting treatment duration.

Results: Mandibular cortical thickness was negatively associated with treatment time for all subjects ($P < .05$). After adjusting for covariables, it remained significant for center-1, but non-significant for center-2 subjects. Angle Class II and Class III malocclusion, extraction therapy, and age had significant positive correlations with treatment duration ($P < .05$).

Conclusions: There is a negative correlation between the mandibular cortical thickness and orthodontic treatment duration. An extraction treatment plan and treatment of Angle Class II and Class III malocclusions significantly increase the duration of orthodontic treatment. Additionally, patients over 12 years of age have shorter treatment times compared to patients under 12 years of age. (*Angle Orthod.* 2020;90:794–800.)

KEY WORDS: Bone thickness; Treatment time

INTRODUCTION

A predictable and reliable answer to a very commonly asked question, "How long am I going to be in braces?" would be beneficial to orthodontists and their patients. It is important for the patient to have an accurate estimation of their treatment duration so they can be mentally prepared and are able to stay motivated throughout the course of treatment, thus avoiding patient "burnout." From the orthodontist's perspective, accurate determination of treatment duration will help with each patient's treatment and with creating a more precise payment plan. There are many variables in orthodontic treatment that make the prediction of treatment duration challenging: case complexity, patient compliance, and experience of the clinician, to name a few.

Numerous factors have been investigated and implicated as potential causes for increased overall treatment duration. Grewe and Hermanson[1] found no relationship between treatment duration and three indices of malocclusion severity. Melo et al.[2] reported that missed appointments and appliance issues significantly affected variability in treatment time, but they were only able to predict 43.75% of the variance in treatment time. Although many different factors have been explored, none were able to fully and accurately predict the treatment time.[3–8] No previous studies

[a] Private Practice, North Haven, Connecticut, USA.
[b] Associate Professor, Division of Orthodontics, University of Connecticut Health, Farmington, Conn., USA.
[c] Research/Clinical Instructor, Division of Orthodontics, University of Connecticut Health, Farmington, Conn., USA.
[d] Associate Professor, Division of Oral and Maxillofacial Radiology, University of Connecticut Health, Farmington, Conn., USA.
Corresponding author: Dr Sumit Yadav, Division of Orthodontics, 263 Farmington Ave, Room L7063, University of Connecticut Health, Farmington, CT 06032, USA
(e-mail: syadav@uchc.edu)

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evaluated cortical bone thickness as a potential variable to predict overall treatment duration. Orthodontic treatment is based on the principle of alveolar bone modeling and remodeling in response to an applied force.

There are a few existing animal studies supporting the hypothesis that denser bone leads to slower tooth movement. Bridges et al.[9] compared tooth movement cycles and changes in alveolar tissue mineral densities made between young and adult rats. The young rats had significantly lower mineral densities before orthodontic treatment and also had greater overall tooth movement. Hashimoto et al.[10] found that orthodontic tooth movement was accelerated in rats with trabecular bone loss caused by ovariectomy. In addition, when the ovariectomized rats were treated with zoledronic acid, which suppresses trabecular bone loss, orthodontic tooth movement was concurrently suppressed. Both animal studies supported the hypothesis that a correlation exists between bone density and orthodontic treatment duration. It seems plausible that cortical bone thickness or bone density could be a variable predictive of orthodontic treatment duration in humans.

The primary objective of this study was to determine whether a correlation exists between a patient's mandibular cortical bone thickness and overall treatment duration. Additionally, the aim was to also study the influence of Angle classification, extraction treatment, and age on overall treatment duration. The null hypothesis was that there would be no correlation between mandibular cortical bone thickness and overall treatment duration.

MATERIALS AND METHODS

Institutional review board approval was obtained (IRB# 17-117-2) from the University of Connecticut Health for the evaluation of patient records from two orthodontic centers. This retrospective study reviewed 971 records of patients who underwent orthodontic treatment. Patients from 10 to 18 years of age who had undergone comprehensive orthodontic treatment (CPT code D8080) between 1/1/2000 and 12/31/2016 were included in the study. Patient records had to include a panoramic radiograph capturing the entirety of the inferior border of the mandible in the area of the mental foramen prior to the bonding of orthodontic appliances. The records had to include patient gender, date of birth, dates of initial orthodontic wire placement and orthodontic appliance removal, pretreatment photographs, lateral cephalometric radiographs, and treatment classification performed (eg, non-extraction or extraction treatment and, if extraction treatment was performed, which extraction pattern was used (four premolar extraction, two upper premolar extraction, etc.). The overall treatment duration was measured from the day of initial arch wire placement to the removal of orthodontic appliances. Angle classification was determined using the pretreatment intraoral photographs. Lateral cephalograms were used to determine the skeletal malocclusion and growth pattern (Center 1). Angle ANB was used for sagittal discrepancy (0–4°: Class I, $>4°$ Class II, and $<0°$: Class III). Similarly, Mandibular plane (SN-MP) angle was considered for the growth pattern determination (27°–37°: normodivergent, $<27°$: hypodivergent, and $>37°$: hyperdivergent). The exclusion criteria were as follows because these might have affected the overall treatment duration: (1) craniofacial syndromes; (2) cleft lip or palate; (3) phase I orthodontic treatment; (4) patients with either missing teeth or impacted teeth; (5) use of TADs during orthodontic treatment; (6) surgical orthodontic treatment; and (7) molar protraction during orthodontic treatment.

Patient Bone Thickness Measurement

Each patient's mandibular cortical thickness was measured using the Mental Index on the pretreatment panoramic radiograph. The Mental Index is the thickness (mm) of the mandibular cortex below the mental foramen, measured on a panoramic radiograph along a line perpendicular to a tangent of the lower border of the mandible. It has been widely suggested for use as a predictor for osteoporosis because this site is not usually associated with any muscle attachment.[11–16] A line perpendicular to the inferior border of the mandible was drawn so that it intersected the inferior border of the mental foramen. The mandibular cortical thickness was measured along this line (Figure 1).

Each patient's Mental Index was adjusted for magnification by measuring the "L" that demarcated the left side of the panoramic radiograph (Figure 1). This "L" was captured at the same time as the image acquisition and had a standard size. By measuring the mandibular cortical thickness (Mental Index) and the length of the image "L" in the panoramic radiograph and comparing the length of "L" measured to a designated standard length of 10 mm, the value of the mandibular cortical width was adjusted for magnification using the following equation:

$$\textit{Adjusted Mandibular Cortical Thickness}\,(mm) = \frac{10\,(\mathrm{mm}) \times \textit{mandibular cortical thickness}\,(mm)}{\textit{Length of}\ \text{``L''}\,(mm)}$$

Statistical Analysis

Each variable was summarized overall and by the two different centers using mean and standard deviation or

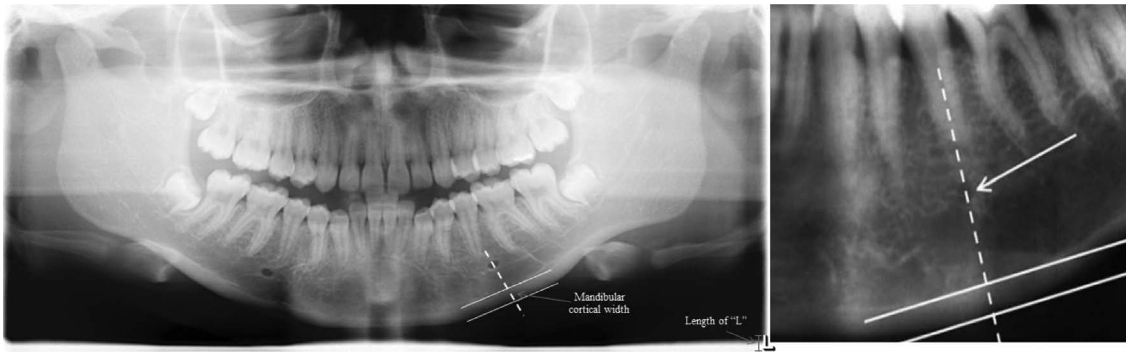

Figure 1. Method to measure the Mental Index on the panoramic radiograph. A line perpendicular to the inferior border of the mandible was drawn so that it intersected the inferior border of the mental foramen. The mandibular cortical thickness was measured along this line.

frequency and percentage. A two-sample *t*-test or a chi-square test was used to compare between subjects from two orthodontic centers. Mandibular cortical bone thickness was adjusted for magnification and then compared to overall orthodontic treatment time using a linear regression model and adjusted for potential confounding variables. The resulting regression coefficients, 95% confidence intervals, and *P* values were reported. Intra-examiner reliability was assessed statistically by analyzing the differences between duplicate measures of length of "L" (mm), mandibular cortical thickness (mm), and mandibular cortical thickness adjusted for magnification (mm) on 30 randomly selected patients (six patients from Center 1 and 24 patients from Center 2). A *P* value lower than 0.05 was deemed to be statistically significant. All the statistical analyses were performed using the statistical program R 3.4.3 (Lucent Technologies, New Jersey, USA).

RESULTS

Out of 971 patients reviewed, a total of 500 patients (114 from Center 1 and 386 from Center 2) were included in the study (Figure 2, Table 1). The primary reasons for exclusion were incomplete records, incomplete cases, phase 1 treatment done prior to comprehensive treatment, missing teeth, and impacted teeth. The mean treatment duration was 25.5 months at Center 1, 24.1 months at Center 2, and 24.4 months for combined Centers 1 and 2. The frequency distribution of the number of patients with the overall treatment duration at Center 1 and Center 2, and the combined samples are provided in Figure 3. Demographic information including gender, age, type of dental and skeletal malocclusion, facial divergence, extraction or non-extraction therapy, overall treatment time, and mandibular cortical thickness (mm, adjusted for magnification) are reported in Table 1. The intra-class correlations were high: 0.99 (95% CI: 0.98–1), 0.98 (95% CI: 0.95–0.99), and 0.91 (95% CI: 0.83–0.96) for length of "L" (mm), mandibular cortical width (mm), and mandibular cortical width adjusted for magnification (mm), respectively.

Mandibular cortical thickness adjusted for magnification had a significant negative correlation with overall treatment time at Center 1 (Table 2). This finding was

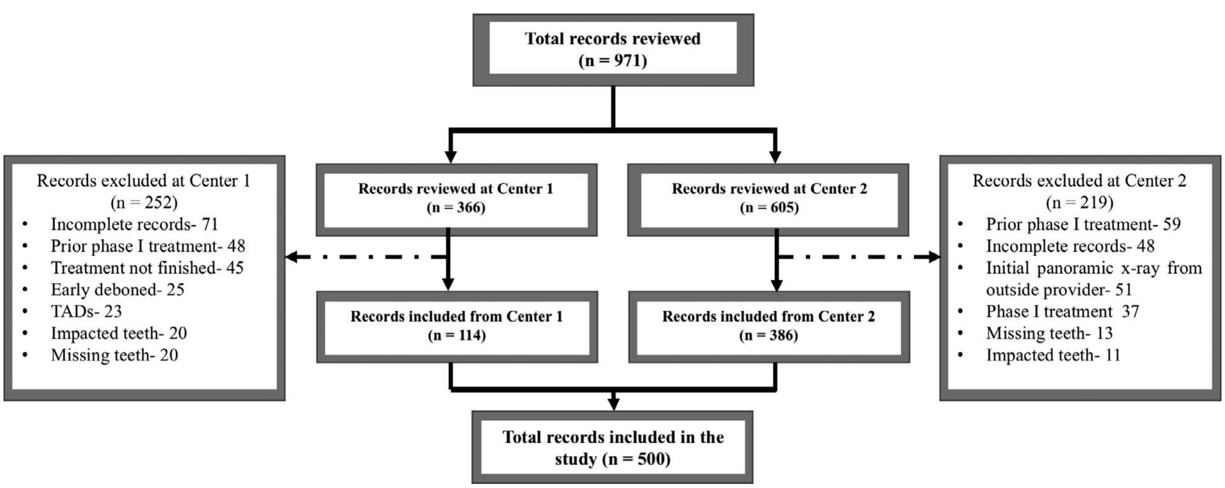

Figure 2. A flowchart showing the distribution of the study subjects from the two centers.

Table 1. Demographic Information of the Site Specific as Well as Overall Subjects Enrolled in the Study (*$P < .05$)

Variables		Center 1	Center 2	Combined	*P* Value
Number of subjects		114	386	500	-
Gender	Male	50 (43.86%)	159 (41.19%)	209 (41.8%)	.69
	Female	64 (56.14%)	227 (58.81%)	291 (58.2%)	
Age (y)		13.34 ± 1.85	12.00 ± 1.07	12.30 ± 1.41	<.001
Type of dental malocclusion	Class I	55 (48.25%)	200 (51.81%)	255 (51%)	.002
	Class II	45 (39.47%)	172 (44.56%)	217 (43.45%)	
	Class III	14 (12.38%)	14 (3.63%)	28 (5.6%)	
Skeletal classification	Class I	32 (28.07%)	-	-	-
	Class II	74 (64.91%)	-	-	
	Class III	8 (7.02%)	-	-	
Vertical (MP-SN)	Hyperdivergent	16 (14.04%)	-	-	-
	Hypodivergent	20 (17.54%)	-	-	
	Normodivergent	78 (68.42%)	-	-	
Extraction or non-extraction treatment	Extraction	29 (25.44%)	38 (9.84%)	67 (13.4%)	<.001
	Non-Extraction	85 (74.56%)	348 (90.16%)	433 (86.6%)	
Mandibular cortical thickness (mm)	Adjusted for magnification	4.08 ± 1.16	6.48 ± 1.20	5.94 ± 1.56	<.001
Overall treatment time (months)		25.50 ± 6.95	24.09 ± 6.60	24.41 ± 6.70	.056

consistent across models (models with mandibular cortical width adjusted for magnification only and with additional covariates including site, gender, age, type of malocclusion (Angle molar classification), skeletal classification (ANB), vertical classification (MP-SN), and extraction vs non-extraction therapy) (Table 2). However, the association between mandibular cortical bone thickness and orthodontic treatment time became non-significant at Center 2 after adjusting for other covariates (Table 3). Ultimately, the association between mandibular cortical bone thickness and orthodontic treatment time remained significant for the combined samples even after adjusting for other covariates (Table 4 and Figure 4).

Angle Class II and Class III malocclusions showed significant positive correlations with overall treatment duration for the samples from respective ($P < .05$). A significant increase ($P < .05$) in overall treatment duration was observed for patients with an extraction treatment plan. Additionally, patients older than 12 years old showed significant negative correlation ($P < .05$) with the overall length of the treatment.

DISCUSSION

The null hypothesis was rejected; a statistically significant "negative" correlation was found between mandibular cortical bone thickness and orthodontic treatment time for overall and Center 1 study subjects (Tables 2 and 4, Figure 4). Additionally, for Center 2 subjects, a non-significant correlation was found between these two parameters after adjusting for other covariables (Table 3). There are a few possible explanations that should be considered to understand the trends observed with these results.

First, this study used the Mental Index measured on patients' initial panoramic radiographs. The Mental Index was validated as a reliable index for measuring overall bone density by the "Osteodent Project," which confirmed that it positively correlated with overall bone density.[11–16] However, the Osteodent Project only studied female patients ranging from 45–70 years of age, considered a group with a high prevalence of osteoporosis, in contrast to the young, healthy patients under 18 years of age in the current study. This

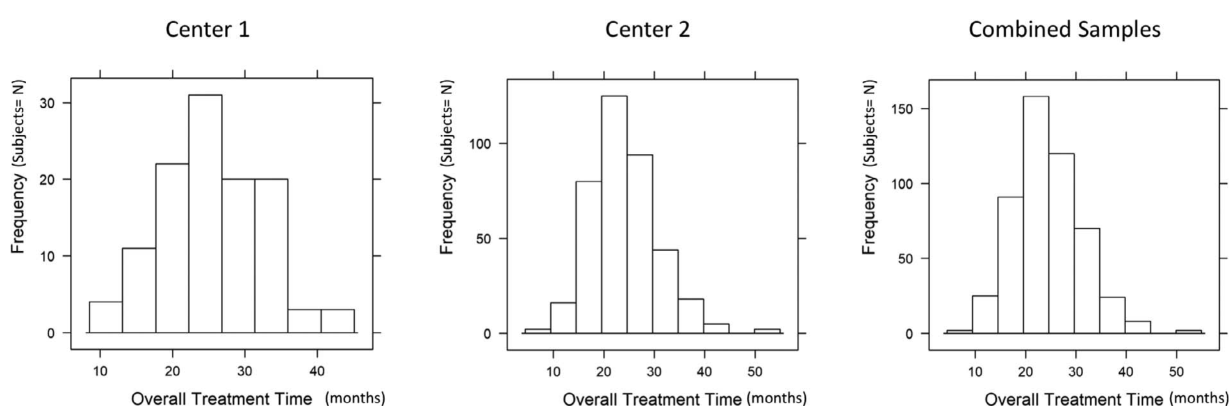

Figure 3. Frequency distribution of subjects (N) based on the overall treatment time (months) for center 1, center 2, and combined samples.

Table 2. Linear Regression Models for Center 1, Showing the Level of Significance Without (Model 1) and With (Models 2 And 3) Adjustment for Covariables (*$P < .05$)

Variables	Model 1			Model 2			Model 3		
	Estimate	95% CI	P	Estimate	95% CI	P	Estimate	95% CI	P
Location: Center 1	-	-	-	-	-	-	-	-	-
Gender: male	-	-	-	0.12	(-2.27, -2.51)	.921	0.19	(-2.24, 2.61)	.878
Age: >12 y	-	-	-	-2.47	(-4.48, -0.08)	.043	-2.01	(-4.64, 0.62)	.133
Type of malocclusion: Class II	-	-	-	1.13	(-1.47, 3.73)	.389	1.36	(-1.34, 4.06)	.320
Type of malocclusion: Class III	-	-	-	0.17	(-3.63, 3.97)	.93	0.02	(-3.87, 3.9)	.993
Skeletal classification (ANB): Class II	-	-	-	-	-	-	-0.6	(-3.41, 2.22)	.675
Skeletal classification (ANB): Class III	-	-	-	-	-	-	3.04	(-2.05, 8.14)	.239
Vertical (MP-SN): hyperdivergent	-	-	-	-	-	-	-1.11	(-4.7, 2.47)	.539
Vertical (MP-SN): hypodivergent	-	-	-	-	-	-	-1.12	(-4.53, 2.28)	.515
Extraction/non-extraction	-	-	-	5.37	(2.59, 8.14)	<.001	5.4	(2.49, 8.32)	<.001
Mandibular cortical thickness (mm, adjusted)	-1.33	(-2.42, -0.23)	.018	-1.1	(-2.13, -0.06)	.038	-1.29	(-2.35, -0.22)	.018
Adjusted R-square		4.03%			18.30%			17.42%	

younger group might not have shown the range of bone thickness found in the older patients studied in the Osteodent project and, so, values measured might not have correlated well to overall bone density.

Second, the Mental Index strictly measured cortical bone thickness at the inferior border of the mandible perpendicular to the lower border at the mental foramen.[11] Although the Osteodent Project confirmed the relationship between this index and overall bone density,[11–16] there is some skepticism that a cortical bone measurement can be directly linked to the trabecular bone in which the majority of tooth movement occurs in response to an externally applied force.

Lastly, this study looked at overall orthodontic treatment from the time of first active wire placement until fixed appliances were removed from the oral cavity. By assessing overall treatment time in this way, the period of treatment that was most correlated to bone density may have been missed. It is unlikely that bone density had a large role in the leveling and aligning or finishing stages of orthodontic treatment, where tooth movement through the alveolar housing was minimal. On the other hand, space closure, during which the tooth actually has to move through the alveolar housing, would be the most bone density-dependent step. This could have been one of the reasons why extraction treatment in this study increased the overall treatment time duration compared to non-extraction treatment.

Studies have shown contradictory evidence regarding the correlation between the type of Angle malocclusion and its influence on overall orthodontic treatment duration.[6] Vig et al.[17] reported a significant difference ($P = .0001$) in the mean treatment time between patients with Class I (24.6 ± 11.6 months) and Class II (29.0 ± 11.2 months) malocclusions. Colela et al.[18] concluded that, on average, the treatment time for Class II malocclusion was approximately five months longer than Class I. However, Melo et al.[2] reported a non-significant difference between the patients with Class I and Class II malocclusions. This contradiction may have been due to differences in patient demographics and research methodology. Vig et al.[17] considered overjet, whereas Melo et al.[2] considered the canine relationship as the determinant of the type of malocclusion. Popowich et al.[19] conduct-

Table 3. Linear Regression Models for Center 2, Showing the Level of Significance Without (Model 1) and With (Model 2) Adjustment for Covariables (*$P < .05$)

Variables	Model 1			Model 2		
	Estimate	95% CI	P	Estimate	95% CI	P
Location: Center 1	-	-	-	-	-	-
Gender: male	-	-	-	0.64	(-0.55, 1.82)	.291
Age: >12 y	-	-	-	-4.28	(-5.85, -2.71)	<.001
Type of malocclusion: Class II	-	-	-	5.02	(3.8, 6.23)	<.001
Type of malocclusion: Class III	-	-	-	5.21	(2.12, 8.29)	.001
Skeletal classification (ANB): Class II	-	-	-	-	-	-
Skeletal classification (ANB): Class III	-	-	-	-	-	-
Vertical (MP-SN): hyperdivergent	-	-	-	-	-	-
Vertical (MP-SN): hypodivergent	-	-	-	-	-	-
Extraction/non-extraction	-	-	-	2.23	(0.27, 4.19)	.026
Mandibular cortical thickness (mm, adjusted)	-1.000	(-1.54, -0.46)	<.001	-0.33	(-0.82, 0.17)	.194
Adjusted R-square		3.10%			26.41%	

Table 4. Linear Regression Models for Overall Subjects, Showing the Level of Significance Without (Model 1) and With (Model 2) Adjustment for Covariables (*$P < .05$)

Variables	Model 1			Model 2		
	Estimate	95% CI	*P*	Estimate	95% CI	*P*
Location: Center 1	-1.16	(-2.96, 0.64)	.205	0.79	(-0.99, 2.56)	.386
Gender: male	-	-	-	0.35	(-0.71, 1.41)	.516
Age: >12 y	-	-	-	-3.66	(-4.96, -2.36)	<.001
Type of malocclusion: Class II	-	-	-	4.16	(3.05, 5.27)	<.001
Type of malocclusion: Class III	-	-	-	3.37	(1.05, 5.7)	.005
Skeletal classification (ANB): Class II	-	-	-	-	-	-
Skeletal classification (ANB): Class III	-	-	-	-	-	-
Vertical (MP-SN): hyperdivergent	-	-	-	-	-	-
Vertical (MP-SN): hypodivergent	-	-	-	-	-	-
Extraction/non-extraction	-	-	-	3.22	(1.64, 4.81)	<.001
Mandibular cortical thickness (mm, adjusted)	-1.07	(-1.56, -0.59)	<.001	-0.54	(-0.99, -0.09)	.018
Adjusted R-square		4.04%			23.56%	

ed a multicentric comparative study between Angle Class I and Class II malocclusion patients. They reported that patients from two out of three offices showed a significant difference in overall treatment duration. In the current study, a significant difference was observed between not only Angle Class I and Class II patients (4.16 months, 95% CI = 3.05–5.27 months, $P < .001$) but also between Class I and Class III patients (3.37 months, 95% CI = 1.05–5.7 months, $P = .005$) (Table 4, Figure 4). Similar patterns were observed for the patients from individual locations as well (Tables 2 and 3).

The influence of an extraction treatment plan on overall treatment duration was also examined. In the current study, 13.4% (67/500) of the patients were in the extraction group and the rest (86.6%, 433/500) had non-extraction treatment (Table 1). Extraction significantly increased overall treatment duration compared to non-extraction treatment. This was true for combined as well as for individual patient centers ($P < .05$, Tables 2–4, Figure 4). These results were supported by Vig et al.[17] who also compared extraction (n = 411) and non-extraction (n = 583) groups and reported the overall treatment duration to be 24.0 ± 11.2 and 29.4 ± 11.3 months, respectively ($P < .05$). On the other hand, Melo et al.[2] found a non-significant difference in treatment duration between extraction and non-extraction treatment groups. The experience and expertise of the individual orthodontist, patient compliance, and differences in the orthodontic biomechanics could be possible explanations for this contradiction.

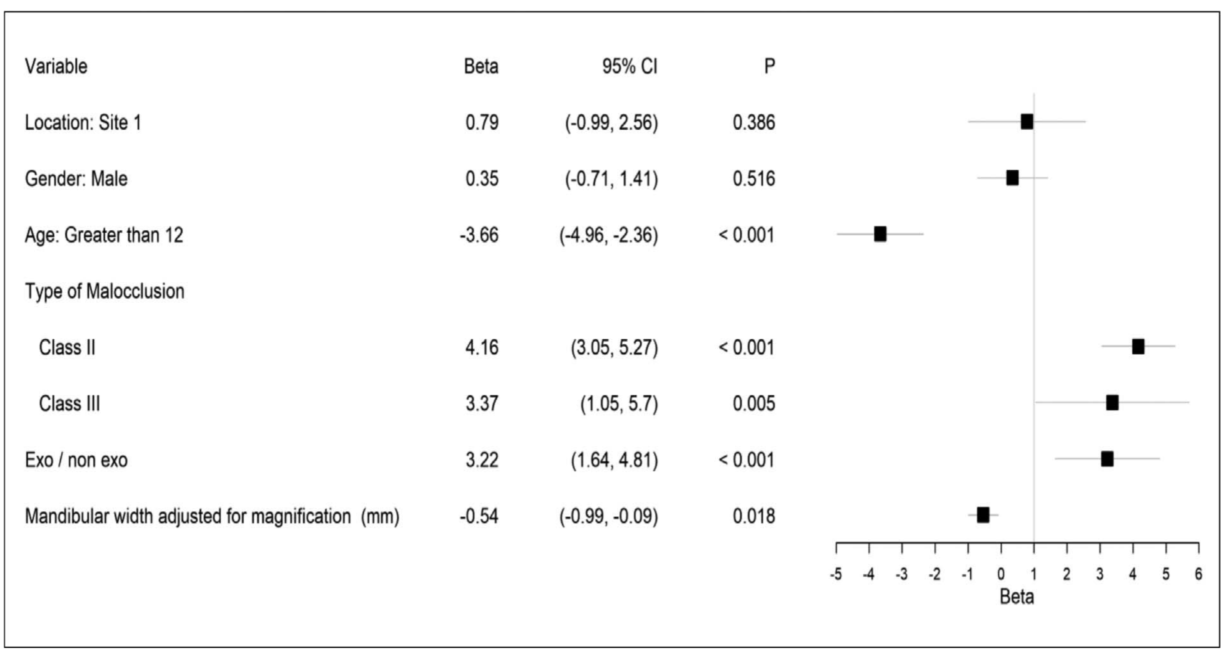

Figure 4. The forest plot showing the influence of covariables on orthodontic treatment duration (Exo: Extraction, non exo: non-extraction).

In this study, the average age of the participants from Center 1 was 13.34 ± 1.85 years, Center 2 was 12.00 ± 1.07 years, and for the entire study was 12.30 ± 1.41 years (Table 1). Patients greater than 12 years of age exhibited a statistically significant "negative" correlation with the overall length of treatment (Tables 2–4, Figure 4). Patient compliance in the younger group could be more challenging compared to older patients. This result was supported by Vayda et al.[20] who also reported that the treatment duration for older patients (>15 years old) was significantly shorter compared to younger patients (<15 years old). On the other hand, Dyer et al.[21] reported no statistically significant difference in the treatment duration between young (age: 12.5 ± 0.67 years) and adult (age: 27.57 ± 5.38 years) patients. There are a few possible explanations for this contradiction: (1) there was a difference between the ages of subjects in each study, (2) the study by Dyer et al. included subjects with Class II malocclusion, whereas, in the current study, subjects with all three Angle classes of malocclusion were included, and (3) only female participants were included in the study by Dyer et al., with male and female subjects in the current study.

CONCLUSIONS

- There is a negative correlation between cortical bone thickness and overall orthodontic treatment duration.
- The extraction treatment plan significantly increases the overall treatment duration.
- The presence of Angle Class II and Class III malocclusions significantly increases the length of treatment.
- Patients over 12 years of age experience shorter treatment time compared to those under 12 years of age.

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