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EVALUATE THE TOOTH MOVEMENT ON CHANGES IN ALVEOLAR BONE IN BOTH JAWS DURING ORTHODONTIC TREATMENT: A SYSTEMATIC REVIEW AND META-ANALYSIS

Sedigheh Moayedi[1], Ali Shahi Ardakani[2*], Milad Soleimani[3], Morteza Faghani[4]

[1]Postgraduate Student of Orthodontics, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran.

[2]Undergraduate Student, Shahed Dental School, Shahed University, Tehran, Iran.

[3]Assistant Professor, Department of Orthodontics, School of Dentistry, Alborz University of Medical Sciences, Karaj, Iran.

[4]Resident of Prosthodontics, Department of Prosthodontics, Dental School, Guilan University of Medical Sciences, Rasht, Iran.

Abstract :

One of the topics discussed during orthodontic treatment is bone reconstruction. In this regard, it is necessary to understand the patient's ability to regenerate bone and determine the amount of tooth movement before orthodontic treatment. Therefore the aim of current systematic review with meta-analysis study was evaluate the tooth movement on changes in alveolar bone in both jaws during orthodontic treatment.

Key words: tooth movement, alveolar bone, orthodontic treatment

Introduction :

Bone remodeling secondary is very important in orthodontic treatments due to the movement of the teeth. Bone remodeling is mostly influenced by the morphology of the alveolar bone and the orthodontic procedures used(1). It has been reported that orthodontic movement should allow the tooth to remain within the bone. Also in skeletal Class III malocclusion and patients with high-angle, alveolar bone morphology has been reported to be thinner than patients with low-angle (2-4). As a result of the anatomy of the alveolar bone and the amount of tooth movement, it can be said that the anterior teeth are vulnerable to alveolar bone loss(5). There are several methods for examining alveolar bone loss, including conventional two-dimensional radiography, lateral cephalograms, and panoramic radiography, Cone-beam computed tomography (CBCT)(6). The first three methods can not accurately assess alveolar bone loss, so the use of CBCT is appropriate because it can determine the morphology of the tooth root and alveolar bone in three dimensions, so the use of CBCT in diagnosis and planning Orthodontic treatment has become common(7, 8). Previous reports using CBCT have been able to examine the alveolar bone changes in the anterior region during orthodontic treatment, however, the results show conflicting results. The extent of alveolar bone loss on the lingual side or the extent of alveolar bone enlargement on the labial side is not known and should be evaluated. One study found that alveolar lip changes in the maxillary anterior teeth were minimal(9). In another study, an increase in labial alveolar bone thickness was reported during orthodontic treatment(10). In patients with special periodontal disease, orthodontic treatment should be considered. There is insufficient evidence that tooth movement in patients with periodontitis can affect the level of alveolar bone(11). One of the topics discussed during orthodontic treatment is bone reconstruction. In this regard, it is necessary to understand the patient's ability to regenerate bone and determine the amount of tooth movement before orthodontic treatment. Therefore the aim of current systematic review with meta-analysis study was evaluate the tooth movement on changes in alveolar bone in both jaws during orthodontic treatment.

Method :

Search strategy

From the electronic databases, PubMed, Scopus, LILACS, Web of Science, EBSCO, LIVIVO, and Embase have been used to perform a systematic literature over the last five years between 2016 and September 2021. The reason for choosing studies in the last five years is to be able to provide sufficient evidence in this area and use newer studies. Therefore, a software program (Endnote X8) has been utilized for managing the electronic titles.

Searches were performed with mesh terms:

("Orthodontics"[Mesh]) OR "Tooth Movement Techniques"[Mesh]) AND "Cone-Beam Computed Tomography"[Mesh]) OR ("Tomography, X-Ray Computed"[Mesh] OR "Tomography, Spiral Computed"[Mesh])) AND ("Alveolar Bone Loss"[Mesh] OR "Alveolar Bone Grafting"[Mesh])) OR "Hyperostosis"[Mesh]) OR "Alveolar Process"[Mesh]) AND "Odontodysplasia"[Mesh]) AND "Jaw"[Mesh]) OR "Mandible"[Mesh]) OR "Maxilla"[Mesh]

This systematic review has been conducted on the basis of the key consideration of the PRISMA Statement–Perfumed Reporting Items for the Systematic Review and Meta-analysis(12), and PICO strategy (Table1).

Selection criteria

Inclusion criteria: Randomized controlled trials studies, controlled clinical trials, and prospective and retrospective cohort studies; in English. In vitro studies, case studies, case reports and reviews were excluded from the study.

Table1. PECO strategy

PECO strategy	Description
P	Population: Orthodontic patients
I	Intervention: treated with full-mouth brackets
C	Comparison: pre-treatment
O	Outcome: changes in alveolar bone in both jaws

Study selection, Data Extraction and method of analysis

The data have been extracted from the research included with regard to the study, years, study design, number of patients, mean of age, jaw, period of time, and measure alveolar bone.

The quality of the randomized control trial studies included was assessed using the Cochrane Collaboration's tool(13). The scale scores for low risk was 1 and for High and unclear risk was 0. Scale scores range from 0 to 6. A higher score means higher quality. The quality of non-randomized studies included was assessed using MINORS (13). This Methodological index have twelve items, with each case, it ranges from 0 to 2, so the total score is 24 for cohort study and 16 for self-controlled study. The mean difference with the 95% confidence interval (CI) was used. Forest plots in meta-analysis assessed using a commercially available software program (Comprehensive Meta-Analysis Stata.16).

For Data extraction, two reviewers blind and independently extracted data from abstract and full text of studies that included. Prior to the screening, kappa statistics was carried out in order to verify the agreement level between the reviewers. The kappa values were higher than 0.80.

Mean difference with 95% confidence interval (CI), fixed effect model and Inverse-variance method were calculated.

Random effects were used to deal with potential heterogeneity and I^2 showed heterogeneity. I^2 values above 50% signified moderate-to-high heterogeneity. The Meta analysis have been evaluated with the statistical software Stata/MP v.16 (The fastest version of Stata).

Result :

In the review of the existing literature using the studied keywords, 1552 studies were found. In the initial review, duplicate studies were eliminated and abstracts of 1534 studies were reviewed. At this stage, 1496 studies did not meet the inclusion criteria, so they were excluded, and in the second stage, the full text of 38 studies was reviewed by two authors. At this stage, 24 studies were excluded from the study due to incomplete data, inconsistency of results in a study, poor studies, lack of access to full text, inconsistent data with the purpose of the study. Finally, fourteen studies were selected (Figure1).

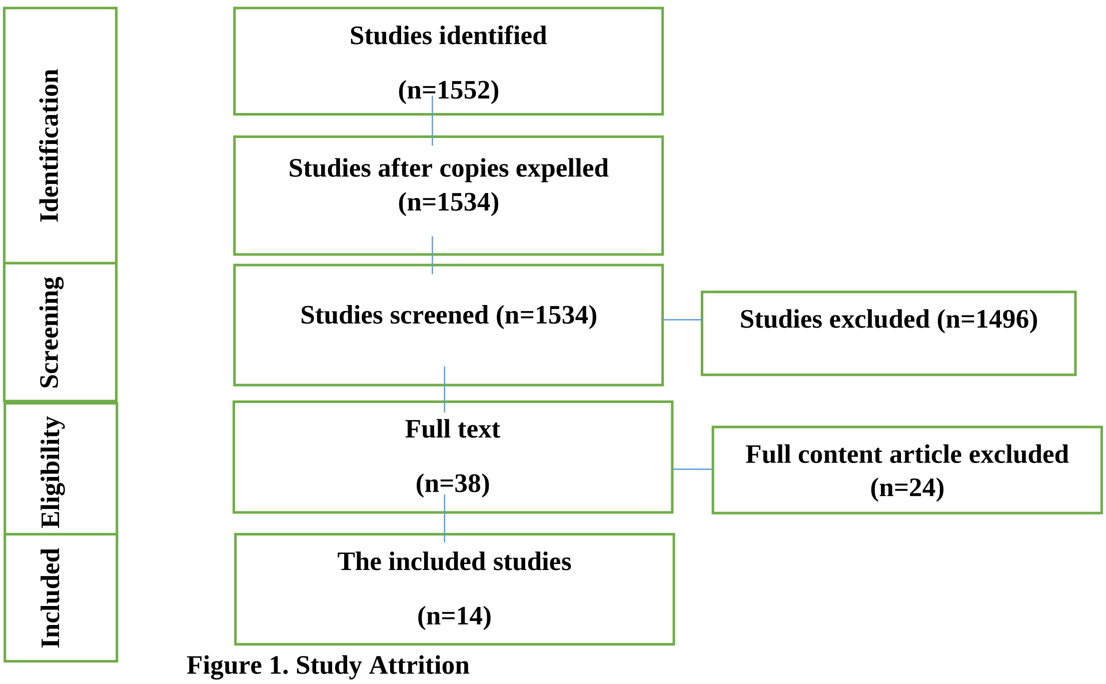

Figure 1. Study Attrition

Characteristics :

Fourteen studies (one cohort study, one Randomized controlled trial and 12 Self-controlled study) have been included in present article. The number of patients a total was 425 with mean age of 18.50 years. The study specifications are reported in Table 2.

Table2. Studies selected for systematic review and meta-analysis.

N	Study. Year	Study design	Number of patients	Mean of age	jaw		Duration of observation		Measure alveolar bone
					maxilla	mandible	T1	T2	
1	Matsumoto et al.,2020 (14)	SCS	60	11.54	-	central incisor	Pre-T	Post-T	Height and thickness of labial alveolar bone
2	Zasčiuret al.,2019 (15)	SCS	25	45.4	All the teeth		Pre-T	Post-T	alveolar bone-height
3	Maspero et al.,2019 (16)	SCS	22	13.14	anterior and posterior teeth	anterior and posterior teeth	Pre-T	Post-T	Alveolar bone height and thickness
4	Puttaravuttiporn et al.,2018 (17)	RCT	18	42.6	central incisor	-	Pre-T	Post-T	Height and thickness of labial alveolar bone
5	Wang et al.,2018(18)	SCS	37	14.7	central incisor	-	Pre-T	Post-T	Height and thickness of labial alveolar bone
6	Zhang et al.,2019 (19)	SCS	36	20.9	central incisor	central incisor	Pre-T	Post-T	Alveolar bone height and thickness
7	Zhou et al.,2018 (20)	SCS	40	13.1	central incisor and lateral incisor	-	Pre-T	Post-T	alveolar bone thickness
8	Morais et al.,2018 (21)	SCS	22	11.8	central incisor	-	Pre-T	Post-T	Height and thickness of labial alveolar bone
9	Xiang et al.,2018 (22)	SCS	22	11.6	central incisor and lateral incisor	-	Pre-T	3 mo. after retraction	Alveolar bone height and thickness
10	Ahn et al., 2016 (23)	Cohort study	15	23.4	-	central incisor, lateral incisor and canine	Pre-T	before surgery	Alveolar bone height and thickness on the labial side
11	Oliveira et al.,2016 (24)	SCS	11	21.14	anterior teeth	-	Pre-T	Post-T	alveolar bone thickness
12	Castro et al.,2016 (25)	SCS	30	13.4	anterior and posterior teeth	anterior and posterior teeth	Pre-T	Post-T	Alveolar bone-height

13	Garlock et al.,2016 (26)	SCS	57	18.7	central incisor	-	Pre-T	Post-T	Alveolar bone height and thickness
14	Yu et al., 2016 (27)	SCS	30	16.1	anterior teeth	anterior teeth	Pre-T	1 months	alveolar bone thickness

Self-controlled: SCS; RCT: Randomized controlled trial; pre-T: pre-treatment; Post-T: post-treatment

Bias assessment :

According to Cochrane Collaboration's tool, one studies had a total score of 5/6 with low risk of bias (Table3). According to MINORS tool, one study (cohort study) had a total score of 15/24 with moderate risk of bias (Table3). In Self-controlled studies, two studies had a total score of 14/16 and two studies had a total score of 12/16, one study had a total score of 13/16 and seven studies had a total score of 8/16; five studies with low risk of bias and seven studies with moderate low risk of bias (Table4).

Table3. Risk of bias assessment (Cochrane Collaboration's tool(13))

study	Random sequence generation	allocation concealment	blinding of participants and personnel	blinding of outcome assessment	incomplete outcome data	selective reporting	Total score
Puttaravuttiporn et al.,2018 (17)	+	+	+	-	+	+	5

Low (+), unclear (?), high (-)

Table4. Risk of bias assessment (MINORS (13))

study	clearly stated aim	inclusion of consecutive patients	prospective collection of data	endpoints appropriate to the aim of the study	unbiased assessment of the study endpoint;	follow-up period appropriate to the aim of the study	follow-up less than 5%	study size	control group	contemporary groups	baseline equivalence of groups;	Adequate statistical analysis	Total
Matsumoto et al.,2020 (14)	2	0	0	2	2	2	0	0					8
Zasčiurinskienė et al.,2019 (15)	2	1	1	2	2	2	2	2					14
Maspero et al.,2019 (16)	2	0	0	2	2	2	0	0					8
Wang et al.,2018(18)	2	0	0	2	2	2	0	0					8
Zhang et al.,2019 (19)	2	0	0	2	2	2	0	0					8
Zhou et al.,2018 (20)	2	0	0	2	2	2	0	0					8
Morais et al.,2018 (21)	2	1	1	2	2	2	1	2					13
Xiang et al.,2018 (22)	2	1	0	2	2	2	0	0					12
Ahn et al., 2016 (23)	2	0	0	2	2	2	0	0	1	2	2	2	15
Oliveira et al.,2016 (24)	2	1	1	2	2	2	2	2					14
Castro et al.,2016 (25)	2	0	0	2	2	1	0	0					12
Garlock et al.,2016 (26)	2	0	0	2	2	2	0	0					8
Yu et al., 2016 (27)	2	0	0	2	2	2	0	0					8

Labial alveolar bone height :

Mean differences of Labial alveolar bone height between post and pre-treatment was 0.40 (MD, 0.40 95% CI 0.32, 0.49) among three studies with high heterogeneity (I^2=87.69%; p=0.00) (Figure2). There was statistically significant difference between post and pre-treatment.

Lingual alveolar bone height :

Mean differences of Lingual alveolar bone height between post and pre-treatment was 0.31 (MD, 0.31 95% CI 0.20, 0.42) among three studies with high heterogeneity (I^2=97.44%; p=0.00) (Figure2). There was statistically significant difference between post and pre-treatment.

Overall :

Mean differences of alveolar bone height between post and pre-treatment was 0.37 (MD, 0.37 95% CI 0.30, 0.44) with high heterogeneity (I^2=94.80%; p=0.00) (Figure2). The test of group differences showed there was no statistically significant difference between Labial and Lingual alveolar bone height.

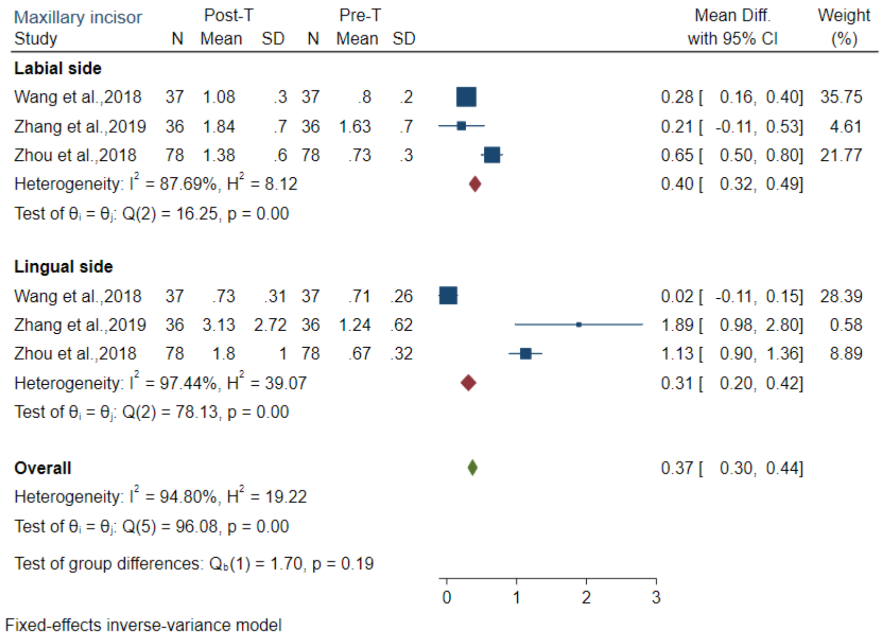

Figure2. Labial and Lingual alveolar bone height

Thickness of the labial alveolar bone (Maxillary incisor) :

Table 5 showed quantitatively evaluated bone thickness at the S1, S2, and S3 levels.

Subgroup meta-analysis :

Mean differences of Thickness of the labial alveolar bone between T0 and T1 of post-treatment at S1 level was -0.04 (MD, -0.04 95% CI -0.12, 0.05) with high heterogeneity (I^2=86.31%; p=0.01) (Table 5). Mean differences of Thickness of the labial alveolar bone between T0 and T1 of three months after retraction at S1 level was 0.68 (MD, 0.68 95% CI 0.47, 0.88) with high heterogeneity (I^2=95.07%; p=0.00) (Table 5). Mean differences of Thickness of the labial alveolar bone between T0 and T1 at S1 level was 0.06 (MD, 0.06 95% CI -0.01, 0.14) with high heterogeneity (I2=95.58%; p=0.00) (Table5). The test of group differences showed there was statistically significant difference between T0 and T1 of post-treatment and three months after retraction at S1 level (p=0.00).

Mean differences of Thickness of the labial alveolar bone between T0 and T1 of post-treatment at S2 level was -0.14 (MD, -0.14 95% CI -0.25, -0.04) with high heterogeneity (I^2=94.57%; p=0.00) (Table 5). Mean differences of Thickness of the labial alveolar bone between T0 and T1 of three months after retraction at S2 level was 0.52

(MD, 0.52 95% CI 0.27, 0.77) with high heterogeneity (I^2=96.49%; p=0.00) (Table 5). Mean differences of Thickness of the labial alveolar bone between T0 and T1 at S2 level was -0.04 (MD, -0.04 95% CI -0.14, 0.06) with high heterogeneity (I^2=95.68%; p=0.00) (Table5). The test of group differences showed there was statistically significant difference between T0 and T1 of post-treatment and three months after retraction at S2 level (p=0.00).

Table5. Thickness of the labial alveolar bone (Maxillary incisor)

	group	Study	Mean Difference	95% Conf. Interval		Weight (%)
				lower	upper	
S1	Post-T	Zhang et al.,2019	0.160	-0.003	0.323	21.50
		Zhou et al.,2018	-0.100	-0.194	-0.006	64.70
		theta	-0.035	-0.117	0.046	
	3 months after retraction	Xiang et al.,2018	0.170	-0.130	0.470	6.36
		Yu et al., 2016	1.110	0.832	1.388	7.43
		theta	0.676	0.473	0.880	
	Overall	theta	0.063	-0.013	0.139	100
S2	Post-T	Zhang et al.,2019	0.410	0.136	0.684	12.75
		Zhou et al.,2018	-0.240	-0.335	-0.125	72.09
		theta	-0.142	-0.248	-0.036	
	3 months after retraction	Xiang et al.,2018	0.130	-0.159	0.419	11.45
		Yu et al., 2016	1.720	1.212	2.228	3.71
		theta	0.519	0.268	0.77	
	Overall	theta	-0.042	-0.140	0.056	100
S3	Post-T	Zhang et al.,2019	0.420	-0.000	0.840	13.34
		Zhou et al.,2018	-0.570	-0.793	-0.347	47.41
		theta	-0.353	-0.550	-0.156	
	3 months after retraction	Xiang et al.,2018	0.170	-0.130	0.47	26.16
		Yu et al., 2016	1.280	0.856	1.704	13.09
		theta	0.540	0.295	0.785	
	Overall	theta	-0.002	-0.156	0.151	

Heterogeneity summary

	group	df	Q	P>Q	I2 (%)	H2
S1	Post-T	1	7.31	0.007	86.31	7.31
	3 months after retraction	1	20.29	0.000	95.07	20.29
	Overall	3	67.93	0.000	95.58	22.64
S2	Post-T	1	18.42	0.000	94.57	18.42
	3 months after retraction	1	28.48	0.000	96.49	28.48
	Overall	3	69.51	0.000	95.68	23.17
S3	Post-T	1	16.62	0.000	93.98	16.62

	3 months after retraction	1	17.51	0.000	94.29	17.51
	Overall	3	65.09	0.000	95.39	21.70

Thickness of the Lingual alveolar bone (Maxillary incisor) :

Table 6 showed quantitatively evaluated bone thickness at the S1, S2, and S3 levels.

Subgroup meta-analysis :

Mean differences of Thickness of the Lingual alveolar bone between T0 and T1 of post-treatment at S1 level was -0.69 (MD, -0.69 95% CI -0.86, -0.51) with moderate heterogeneity (I^2=51.63%; p=0.15) (Table 6). Mean differences of Thickness of the Lingual alveolar bone between T0 and T1 of three months after retraction at S1 level was -0.40 (MD, -0.40 95% CI -0.74, -0.05) with moderate heterogeneity (I^2=64.80%; p=0.09) (Table 6). Mean differences of Thickness of the Lingual alveolar bone between T0 and T1 at S1 level was -0.63 (MD, -0.6395% CI -0.78, -0.47) with moderate heterogeneity (I^2=57.55%; p=0.07) (Table6). The test of group differences showed there was no statistically significant difference between T0 and T1 of post-treatment and three months after retraction at S1 level (p=0.00).

Mean differences of Thickness of the Lingual alveolar bone between T0 and T1 of post-treatment at S2 level was 0.21 (MD, 0.21 95% CI -0.08, 0.49) with high heterogeneity (I^2=94.98%; p=0.00) (Table 6). Mean differences of Thickness of the Lingual alveolar bone between T0 and T1 of three months after retraction at S2 level was -0.95 (MD, -0.95 95% CI -1.33, -0.57) with low heterogeneity (I^2=0%; p=0.55) (Table 6). Mean differences of Thickness of the Lingual alveolar bone between T0 and T1 at S2 level was -0.21 (MD, -0.21 95% CI -0.43, 0.02) with high heterogeneity (I^2=93.08%; p=0.00) (Table6). The test of group differences showed there was statistically significant difference between T0 and T1 of post-treatment and three months after retraction at S2 level (p=0.00).

Mean differences of Thickness of the Lingual alveolar bone between T0 and T1 of post-treatment at S3 level was 1.22 (MD, 1.22 95% CI 0.79, 1.65) with high heterogeneity (I^2=97.30%; p=0.00) (Table 6). Mean differences of Thickness of the Lingual alveolar bone between T0 and T1 of three months after retraction at S3 level was -0.90 (MD, -0.90 95% CI -1.71, -0.08) with high heterogeneity (I^2=89.65%; p=0.00) (Table 6). Mean differences of Thickness of the Lingual alveolar bone between T0 and T1 at S3 level was 0.77 (MD, 0.77 95% CI 0.39, 1.15) with high heterogeneity (I^2=95.50%; p=0.00) (Table6). The test of group differences showed there was statistically significant difference between T0 and T1 of post-treatment and three months after retraction at S3 level (p=0.00).

Table6. ***Thickness of the Lingual alveolar bone (Maxillary incisor)***

	group	Study	Mean Difference	95% Conf. Interval		Weight (%)
				lower	upper	
S1	Post-T	Zhang et al.,2019	-0.97	-1.39	-0.54	13.31
		Zhou et al.,2018	-0.63	-0.81	-0.44	66.77
		theta	-0.68	-0.859	-0.514	
	3 months after retraction	Xiang et al.,2018	-0.25	-0.63	-0.13	16.02
		Yu et al., 2016	-1.000	-1.78	-0.21	3.90
		theta	-0.397	-0.743	-0.051	
	Overall	theta	-0.629	-0.783	-0.474	100
S2	Post-T	Zhang et al.,2019	-1.41	-2.17	-0.647	8.78
		Zhou et al.,2018	0.46	0.15	0.76	55.74
		theta	0.20	-0.076	0.487	
	3 months after retraction	Xiang et al.,2018	-0.67	-1.67	0.33	5.10
		Yu et al., 2016	-1.000	-1.410	-0.590	30.38
		theta	-0.953	-1.332	-0.573	
	Overall	theta	-0.205	-0.431	0.021	100
S3	Post-T	Zhang et al.,2019	-1.42	-2.37	-0.46	15.89
		Zhou et al.,2018	1.89	1.41	2.37	62.63
		theta	1.22	0.79	1.64	
	3 months after retraction	Xiang et al.,2018	1.50	-0.21	3.21	4.88
		Yu et al., 2016	-1.6	-2.53	-0.66	16.6
		theta	-0.895	-1.715	-0.07	
	Overall	theta	0.76	0.38	1.14	100

Heterogeneity summary

	group	df	Q	P>Q	I^2 (%)	H2
S1	Post-T	1	2.07	0.15	51.63	2.07
	3 months after retraction	1	2.84	0.09	64.80	2.84
	Overall	3	7.07	0.07	57.55	2.36
S2	Post-T	1	19.94	0.00	94.98	19.94
	3 months after retraction	1	0.36	0.55	0.00	0.36
	Overall	3	43.46	0.00	93.08	14.45
S3	Post-T	1	36.98	0.00	97.3	36.98
	3 months after retraction	1	9.66	0.002	89.65	9.66
	Overall	3	66.74	0.00	95.50	22.25

Labial alveolar bone height of mandibular extraction treatment :

Mean differences of Labial alveolar bone height of mandibular extraction treatment between post and pre-treatment was 0.86 (MD, 0.86 95% CI 0.51, 1.22) with moderate heterogeneity (I^2=52.17%; p=0.12) (Figure3). There was statistically significant difference between post and pre-treatment.

Lingual alveolar bone height of mandibular extraction treatment :

Mean differences of Lingual alveolar bone height of mandibular extraction treatment between post and pre-treatment was 0.78 (MD, 0.78 95% CI 0.37, 1.19) with low heterogeneity (I^2=37.07%; p=0.21) (Figure3). There was statistically significant difference between post and pre-treatment.

Overall :

Mean differences of alveolar bone height of mandibular extraction treatment between post and pre-treatment was 0.83 (MD, 0.83 95% CI 0.56, 1.10) with high heterogeneity (I^2=31.88%; p=0.21) (Figure3). The test of group differences showed there was no statistically significant difference between Labial and Lingual alveolar bone height of mandibular extraction treatment.

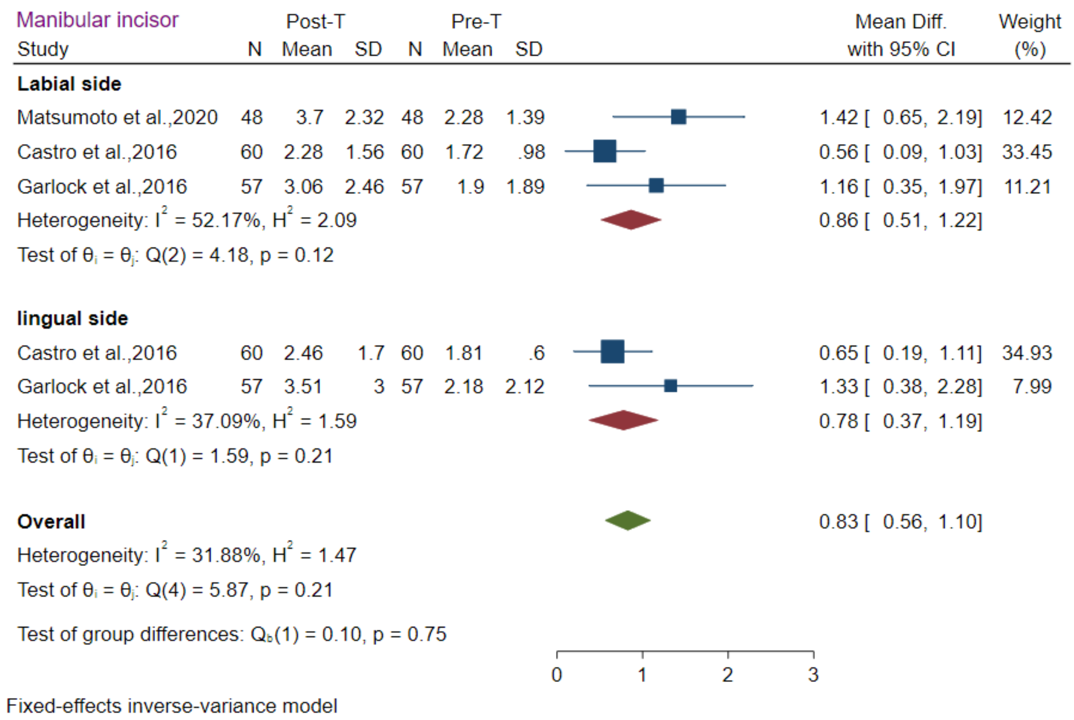

Figure3. Labial and Lingual alveolar bone height of mandibular extraction treatment

Discussion :

The aim of current Systematic Review and Meta-Analysis was evaluate the tooth movement on changes in alveolar bone in both jaws during orthodontic treatment. Alveolar bone deficiencies during fenestration and dehiscence are very common during orthodontic treatment(19, 28). There is insufficient evidence for a link between tooth movement and alveolar bone change. Meta-analysis showed that in the extraction group, vertical alveolar bone loss was observed on both labial and lingual sides. At the S1 level after orthodontics, the lingual alveolar bone thickness was significantly reduced, at the S3 level the labial and lingual alveolar bone thickness was stable. Changes in bone thickness in both maxillary and mandibular teeth are consistent with the pressure-tension theory of bone position on the extensor side and bone resorption on the pressure side(29).

The findings of the present study showed that bone remodeling mainly involves bone resorption on the lingual side, while bone deposition on the labial side is limited. In the extraction group, the mandibular anterior teeth are more vulnerable compared to the maxillary anterior teeth. Studies have shown that the decrease in bone density returns to its original density after two years of maintenance. One study found that lingual movement of anterior teeth during retraction, approximately 3.05 mm, could result in 5.48 mm bone loss(30). According to the study findings, no significant changes in labial and lingual bone levels in the maxillary anterior teeth have been reported(16). The repair ability of alveolar bone after the retraction period remains controversial. In our subgroup analysis, the decrease in lingual bone thickness and the increase in labial bone thickness were obvious 1-3 months after retraction. However, these changes were less obvious after orthodontic treatment, indicating that bone regeneration is not stable after retraction. Some studies suggest that bone remodeling occurs continuously during the retention period(2, 9). Sarikaya et al., showed that bone deposition took place after 4 months of retention, although it did not return to the original level(9). In contrast, Ahn et al., observed no spontaneous bone apposition after retraction(31).

The present study had some limitations, including the quality of moderate studies, and high heterogeneity between studies. The studies did not have a control group, so they were evaluated before and after treatment. Orthodontic procedures are always associated with the risk of bias. Numerous factors such as the amount and type of tooth movement and the amount of orthodontic forces are generally not well reported. The initial anatomy of the bone and the initial position of the tooth should also be considered in bone reconstruction. Methodological heterogeneity was also considered in the present study. Most studies, including bone thickness, measured at three levels (cervical, middle, and apical levels).

Conclusions :

Meta-analysis showed a decrease in alveolar bone height and thickness in both labial and lingual movement of anterior teeth. After three months of treatment, alveolar bone loss was observed in both labial and lingual, an increase in alveolar bone was also evident. In the mandible, a high risk of alveolar bone loss was identified.

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