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Comparison of skeletal anchorage distalizers effect in maxillary buccal segment: A systematic review

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SUMMARY

Objective. The aim of this systematic review was to evaluate and compare distalization effect in maxillary buccal segment between Palatal Skeletal Anchorage (PSA) and Zygoma Gear Appliance (ZGA) in evidence-based way.

Materials and Methods. Relevant studies published between January 2007 till December 2017 in PubMed, ScienceDirect, AJO-DO and Scopus electronic databases were identified. Inclusion criteria were: English language, study performed on humans, randomized or non-randomized clinical trials, assessment of buccal segment distalization by Palatal or Zygomatic skeletal anchorage and patient's clinical preoperative and post-operative evaluation measured by cephalometric analysis. Quality assessment of included studies was performed.

Results. A total of 357 scientific publications, articles, clinical trials related to the used keywords were identified during the search. Thirteen articles fulfilled our inclusion criteria. PSA system showed maxillary molar distalization distance range between 1.8 mm to 6 mm. ZGA presented molar distalization range from 4.37 mm to 5.31 mm. Results of maxillary buccal segment distal movement distance, treatment duration, adverse treatment effects or failure of mini-implants and the appliance were evaluated.

Conclusion. There was evidence that both of skeletal anchorage systems are effective non-extractive therapy for Angle Class II malocclusion and maxillary buccal segment distalization in greater than 3 mm space deficiency.

Key words: orthodontic implant, skeletal anchorage device, molar distalization.

INTRODUCTION

Maxillary buccal segment distalization previously was complex treatment approach with unreliable results. Nowadays, thanks to introduction of new anchorage systems, such treatment approach presents successful clinical results and become non-extractive treatment option for Angle class II malocclusion (1). Skeletal anchorage, by the meaning of bone level force origin temporary anchorage device (TAD), has become a routine approach of contemporary orthodontics. It promotes a solution for previously described non-skeletal, conventional anchorage adverse effects (2) and eliminates patient's compliance factor of extra-oral anchorage methods. Despite the benefits of skeletal anchorage, only few locations of skeletal zone have an impact on maxillary buccal segment distalization.

Palatal Skeletal Anchorage (PSA) represents a group of anchorage locations which utilize anterior palatal zone as an indirect, non-surgical skeletal temporary anchorage location method. PSA employs a single or few mini-implants (MI) within the "T-zone" which is located posteriorly to the third palatal rugea (3). Such anchorage is utilized to engage maxillary buccal segment in a combination with modified conventional intraoral distalizing appliance. Easy MI insertion location and incorporation with intraoral distalization device were found to be convenient for the clinician's treatment planning and application.

Alternative skeletal zone for Zygoma Gear Appliance (ZGA) also known as Zygoma Anchorage System (ZAS) introduced by Nur *et al.* and Sugawara (4, 5) employs direct anchorage using mini-plate with three integrated MI on zygomatic buttress applied surgically. The zygomatic buttress may contribute for increased skeletal anchorage structural stability. It allows higher force genera-

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tion upon target dentition and presence of significantly less bulky intraoral devices.

According to previously published literature, space deficiency greater than 3 mm per side requires orthodontic extractive therapy (6). The aim of this systematic review was to evaluate whether it is possible to gain more than 3 mm space by buccal segment distalization under non-extractive therapy and to compare distalization effect between Palatal Skeletal Anchorage and Zygoma Gear Appliance.

MATERIAL AND METHODS

Protocol and registration

This systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement (7).

Focus question

Evaluating the results of scientific researches hypothesis arises whether it is possible to gain more than 3 mm distance of buccal segment distalization under non-extractive therapy with PSA or ZGA. The following focus question was developed according to the population, intervention, comparison, and outcome (PICOS) study design (Table 1).

Types of studies

The literature review included scientific articles taken from dental journals published between January

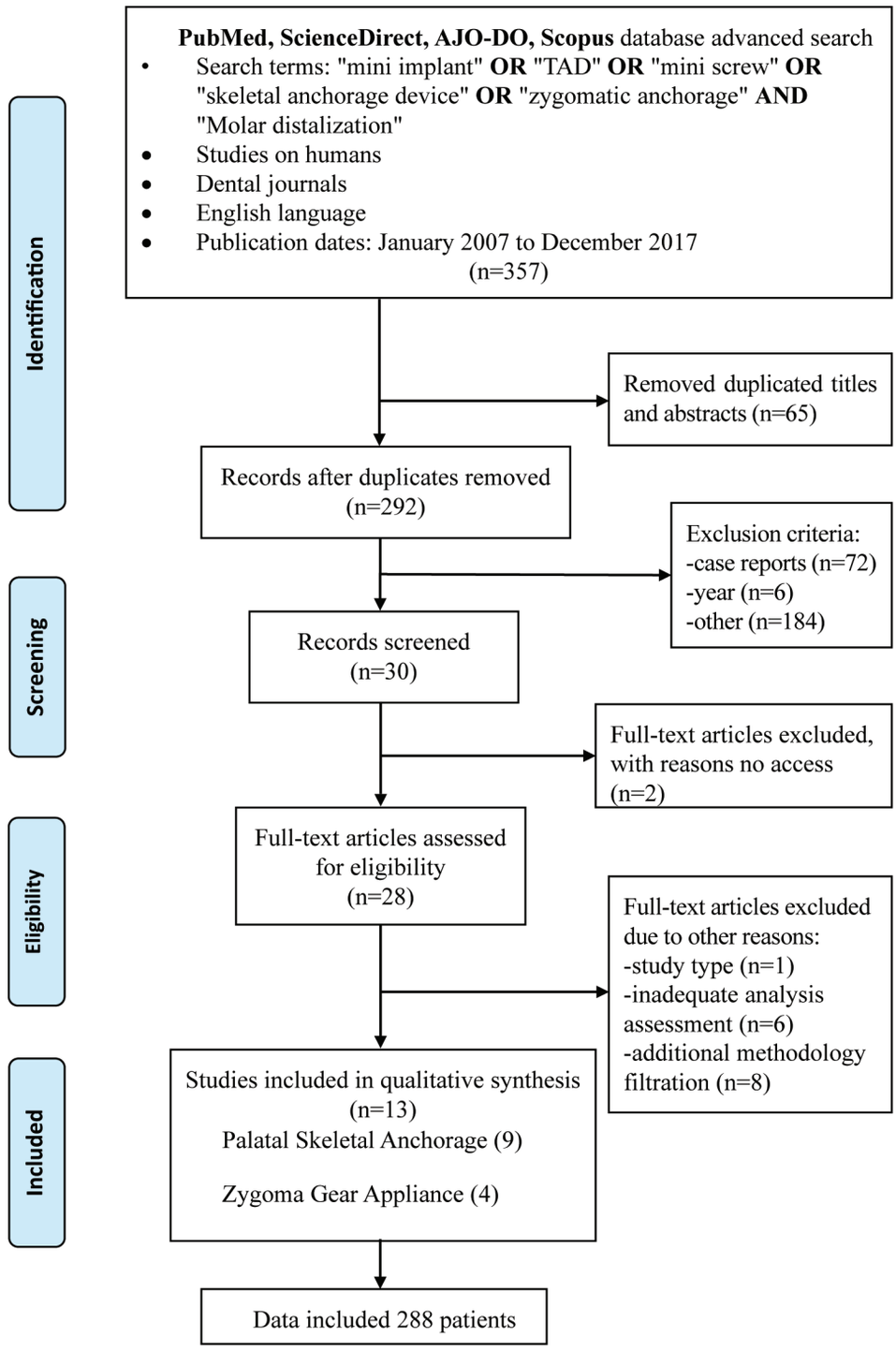

Fig. 1. PRISMA flow diagram

Table 1. PICOS table

Component	Description
Population	Patients with dental Angle Class II malocclusion treated with non-extractive therapy
Intervention	Maxillary buccal segment or molar distalization devices
Comparison	Palatal Anchorage and Zygoma gear appliance
Outcome	Changes in distalization amount, treatment duration and adverse effects or failure of mini-implants/the appliance
Study design	Randomized and non-randomized controlled comparative trials

first 2007 and December thirty 2017. Studies were performed on humans in addition to the included selected keywords. In total 357 scientific publications, articles, clinical trials reviews were identified and were related to keywords: mini implant, TAD, mini screws, skeletal anchorage device, zygomatic anchorage and molar distalization.

Information sources

The search strategy incorporated examinations of electronic databases, supplemented by hand searches. The relevant literature studies were identified by searching in PubMed, Science Direct, AJO-DO and Scopus electronic databases. Titles and abstracts which derived from the broad search were independently screened to eliminate irrelevant publications. The final stage of screening involved full-text articles review and reading in order to certify study eligibility upon inclusion and exclusion criteria.

The inclusion criteria of the studies were: patient's clinical pre-operative and post-operative evaluation measured by cephalometric analysis; treatment of buccal segment distalization performed by Palatal or Zygomatic skeletal anchorage; all study subjects were humans; years of articles publication were limited to period from January 1st 2007 till December 30th 2017. The exclusion criteria were: in vitro studies; non-human studies; literature reviews, single case reports, editorials, commentaries; non-scientific topic irrelevancy.

Statistical analysis

No meta-analyses could be performed due to the heterogeneity between the studies.

RESULTS

Study selection

Article review and data extraction were performed according to the PRISMA flow diagram (Figure 1). The initial database search identified a total of 357 results from which 65 duplicated titles and abstracts were excluded. The preliminary exclusion was done by topic relevance. From the remaining 292 articles 72 presented case reports, 6 were beyond date limits and other 184 were excluded due to other exclusion reasons. 28 full-text articles were assessed for eligibility. Finally, 13 articles that met the predefined criteria were included in the systematic review.

Quality assessment

The Cochrane hand book was used for assessing risk of bias across the studies in order to identify study and methodological flaws (8). Based on the data given in each study potential risk of bias categorized into: low risk of bias (+), unclear risk of bias (?), or high risk of bias (-). The quality assessment of included studies revealed an unknown risk of bias (for one or more key domains) for the majority of the included studies (9-14, 16-20), two studies (15, 21) were classified as high risk of bias (for one of key domains) (Table 2).

Table 2. Risk of Bias summary

Author	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data addressed	Selective reporting	Other bias
Kaya *et al.* (9)	?	?	+	+	+	+	+
Su-Jung Mah *et al.* (10)	?	?	?	+	+	+	?
Escobar *et al.* (11)	?	?	+	+	-	+	+
Oberti *et al.* (12)	?	?	+	+	+	+	+
Kinzinger *et al.* (13)	?	?	+	+	+	+	?
Polat-Ozsoy *et al.* (14)	?	?	?	+	+	+	+
Nienkemper *et al.* (15)	-	?	?	+	+	+	+
Gelgor *et al.* (16)	?	?	+	+	+	+	+
Önçag *et al.* (17)	?	?	?	+	+	+	+
Sa'aed *et al.* (18)	?	?	?	+	+	+	+
Nur *et al.* (19)	?	?	+	+	+	+	+
Kilkis *et al.* (20)	?	?	+	+	+	+	+
Kaya *et al.* (21)	-	?	+	+	+	+	+

Characteristics of included studies

The included studies analysed maxillary buccal segment distalization of both skeletal anchorage location regarding to the number of participants; diameter, length and amount of MI utilized; distalization appliance and reported adverse treatment effects or failure of MI/the appliance. Nine studies represented the PSA and three studies represented ZGA, one study compared both of the methods (15). The included studies characteristics are described in Table 3.

Evaluation of palatal anchorage in maxillary buccal segment distalization

Palatal Skeletal Anchorage evaluation composed

Table 3. Characteristics of the included studies

No.	Authors, year	N	Diameter and length of MI (mm)	Amount of MI	Appliance	Force (g)	Adverse effects and failure of MI/Appliance
Palatal anchorage							
1.	Kaya *et al.*, 2012 (9)	15	2×8	2	Pendulum	230	Not reported
2.1.	Su-Jung Mah *et al.*, 2016 (10)	7	Not reported	2	Lingual (palatal) arch	Not reported	Not reported
2.2.	Su-Jung Mah *et al.*, 2016 (10)	7	Not reported	2	Pendulum	Not reported	Not reported
3.	Escobar *et al.*, 2007 (11)	15	2×11	2	Modified pendulum	250	2 evidence of inflammation and MI failure
4.	Oberti *et al.*, 2009 (12)	16	2×11	2	Dual-Force	250-300	Not reported
5.	Kinzinger *et al.*, 2009 (13)	10	1.6×8-9	2	Distal Jet	200	Not reported
6.	Polat-Ozsoy *et al.*, 2008 (14)	22	2×8	2	Pendulum	230	1 case of pendulum spring breakage, 1 MI found unstable, 3 MI discovered as mobile in the end of treatment.
7.	Nienkemper *et al.*, 2014 (15)	51	2×11	2	Beneslider	240	2 MI slightly mobile after device removal
8.1.	Gelgor *et al.*, 2007 (16) Group 1	20	1.8×14	1	Nance holding arch	250	Slight incisors proclination and increased overjet + molar rotation and mesial tipping of premolars
8.2.	Gelgor *et al.*, 2007 (16) Group 2	20	1.8×14	1	Modified Nance holding arch	250	Not reported
9.	Önçag *et al.*, 2007 (17)	15	3.8×9	1	Pendulum	300	Not reported
10.	Sa'aed *et al.*, 2014 (18)	24	2×8	3	Palatal bar with two hooks	300	3 cases of soft tissue inflammation
Zygoma Gear Appliance							
1.	Nur *et al.*, 2012 (19)	15	2×5	3	Miniplate + Modified Headgear intraoral bow with Ni-Ti closed coil spring	300	2 cases of Zygomatic miniplate infection
2.	Kilkis *et al.*, 2016 (20)	21	2×5	3	Miniplate + headgear intraoral U-bow with coil spring	350	None
3.	Kaya *et al.*, 2012 (9)	15	Not reported	3	Miniplate + round bar and a cylindrical terminal unit	450	None
4.	Kaya *et al.*, 2009 (21)	15	2.3×7	3	Miniplate + Distal bent cylindrical unit with Ni-Ti closed coil spring	450	2 cases of gingival inflammation and infection

N - number of participants,
MI – mini-implant

of seven different types of distalizing appliances. The most common appliance was the pendulum device with its modification variations (5 groups) (9-11, 14, 17). Majority of routinely performed PSA utilized double paramedian MI anchorage (9-15). The active force load ranged between 200 g (13) to 300 g (12, 17, 18).

The comparison of cephalometric results between the methods is described in Table 4. Comparative evaluation performed regarding participants mean age presentation, first molar distalization amount by mm and tipping degree, second premolar or first premolar distalization and tipping, distalization rate per month and overall treatment duration until molar Class I correction achieved. The mean chronologic age ranges from 11.6 (15) to 19.2 (10). Mean molar distal movement ranges from 1.8 mm (10) to 6 mm (11), mean distal tipping of molar from 0.75° (16) to 11.3° (11). Premolars mean distalization range from 1.83 mm (9) to 4.85 mm (11) and mean distal tipping from 3° (13) to 9.9° (14). One article with two study groups reported mesial premolar tipping of 3.15° and 0.10° (16). The overall distalization duration ranged from 4.6 months (16) to 28 months (18) with unevenly distributed distalization rate per month. The greatest amount of distalization was reported by Escobar *et al.* (11) who used PSA with implant supported pendulum device. The amount of molar distalization was 6±2.27 mm and tipping of 11.3±6.2°. The premolars distalized by 4.85±1.96 mm and tipped distally by 8.6±5.08°. Overall treatment duration until Class I correction was 7.8±1.7 months.

Evaluation of Zygoma Gear Appliance in maxillary buccal segment distalization

For evaluation of Zygoma Gear Appliance effect in maxillary buccal segment distalization 4 articles and study groups dealing with ZGA were included. The study performed by Nur *et al.* (18) specified bilateral buccal segment distalization results. Two were comparative clinical studies: one between ZGA and Palatal Skeletal Anchorage (9), and another compared ZGA with Cervical Headgear (21). One study was presented indicating clinical results of unilateral molar distalization (20). All the studies sharing same amount of 3 MI utilization in a combination with mini-plate applied in surgical manner. The active force load ranged between 300g (19) to 450g (9, 21).

Comparative evaluation was performed in the same manner as with PSA. The results are described in Table 4. Mean initial chronologic age ranged from 14.7 (9) to 15.87 (19) years. The mean molar distal movement ranged from 4.37 mm (19) to 5.31 mm (20), and the mean molar distal tipping from 3.30° (19) to 6.39° (20). The greatest amout of molar distalization was reported by Kilkis *et al.* (20) who evaluated the effect of unilateral molar distalization – 5.31±2.45 mm with distalization rate of 0.98 mm per month.

Table 4. Characteristics of the included studies

No.	Mean age (years)	Molar distalization (mm)	Molar tipping (°)	Distalization rate (mm\month)	Premolar movement (mm)	Premolar tipping (°)	Treatment duration (months)
Palatal Anchorage Appliances							
1.	14.3±1.6	3.00±1.70	8.80±6.54	0.1–0.37	1.83±1.14	6.10±5.80	8.1±4.2
2.1.	19.2±4.4	2.4±3.1	0.8±2.0	-	-	-	-
2.2.	19.2±4.4	1.8 ±1.2	1.5±1.3	-	-	-	-
3.	13±2.1	6±2.27	11.3±6.2	-	4.85±1.96	8.6±5.08	7.8±1.7
4.	14.3	5.9±1.7	5.6±3.7	1.2	4.26±1.9	5.4±3.8	5
5.	12.1	3.92±0.53	2.79±2.51	-	1.87±0.74	3.00±2.69	6.7
6.	13.61±2.01	4.8±1.8	9.1±4.6	0.7	4.1±2.1	9.9±5.2	6.8±1.7
7.	17.8±9.6	3.6±1.9	1.5±6.7	0.6±0.4	-	-	7.5±2.9
8.1.	11.6-15.1	3.95±1.68	9.05±4.67	-	-	-3.15±3.36	4.6
8.2.	12.3-15.4	3.88±1.47	0.75±0.72	-	-	-0.10±0.38	5.4
9.	-	3.4±1.18	10±3.29	-	2.08±0.94	7.26±4.54	6.75
10.	12.4	3.06±0.54	1.53±0.98	-	-	-	28.0±8.2
Zygoma Gear Appliance							
1.	15.87±1.09	4.37±2.15	3.30±2.31	0.84	-	-	5.21±0.96
2.	15.68±2.18	5.31±2.45	6.39±5.39	0.98	1.63±1.90	4.05±3.47	5.4±0.12
3.	14.7±2.5	5.03±0.30	5.43±1.36	0.5–0.6	4.80 ±0.27	2.00±1.56	9.0±2.4
4.	14.74±0.65	5.27±1.53	5.77±4.99	-	5.17 ±1.52	2.27±5.70	9.03±0.62

DISCUSSION

Our systematic review evaluated and compared distalization effect and efficiency between 2 contemporary skeletal anchorage locations. It is hard to make precise conclusions about the effectiveness of PSA appliances because of the variations between their designs. Seven different types of distalizing appliances were analysed. As we know, the appliance design is very critical since the direction of activation plays a major role in the vectors of distalization forces and activation rate. If there is excessive degree of distal tipping, it indicates too long force application distant from the dentition's center of resistance. Different design means possible different side effects. The most common appliance used was the pendulum. It was used in 5 out of 10 studies (9-11, 14, 17). But even comparing the cephalometric results of this same appliance - the amount of distalization varies from 1.8±1.2 mm (10) to 6±2.27 mm (11), and tipping varies from 1.5±1.3° (10) to 11.3±6.2°(11). The distribution of the results is very wide. We can presume that the small details in the construction of the appliance and the fact that dental technician is involved gives us the results in such a great of inequality. Using ZGA appliance the results are more consistent. The distalization of molars varies between 4.37±2.15 mm (19) to 5.31±2.45 (20), and degree of tipping between 3.3±2.31° (19) to 6.39±5.39° (20). It could be due to less complicated construction of this appliance. PSA presented large variations of cephalometric results which did not follow any harmony between the study groups within any of the compared elements in comparison with ZGA groups. But despite these inconsistencies, based on our analyzed cephalometric results, we can state that both of the treatment options found to be successful in distalizing more than 3 mm in buccal segment and are effective treatment alternative to extractive orthodontic treatment in order to correct Angle Class II malocclusion. Only in one study (10) the amount of molar distalization with PSA appliance was less than 3 mm and in two studies ~6 mm (11, 12). The advantage we have noted with ZGA appliance is more predictable final result.

The clinical guide for safe load of skeletal anchorage systems rely on the principle of subdividing load among skeletal anchorage devices amount in relation to involved target dentition or by type of distalization. The amount of MI is directly related to expression of indirect force generation which the anchorage may withstand under controlled and safe distalization without anchorage loss. The amount of forces with PSA appliances varied between 200-300g in the studies. It looks like this amount of force is sufficient for buccal segment distalization and the inconsistencies of the amount of distalization rate were because of the differences in the design of the appliances. Based on our analysis we discovered that one article identified anchorage loss by the meaning of mesial premolar tipping of 3.15° (16) in addition to increased incisors proclination, increased overjet and appearance of first molar rotation. The single MI loaded by 250 g of force may contribute for increased potential of acting reciprocal forces distribution along the loaded target dentition, represented by overload and resulted in undesired dentition formation. Based on our findings, every skeletal anchorage device is subjected to specific amount of load. Non-surgical PSA approach recommended load is limited to 300 g of force generation. Furthermore, despite the diameter and length of the MI, it is not recommended to apply more than 200 g of force to single mini-implant. While surgical approach may facilitate higher force magnitude in order to facilitate greater segmental distalization but more than 350 g is not recommended. Looking at the distalization rate per month in ZGA appliance group we noticed that excessive force is ineffective for distalization rate of molars: 0.98 mm per month using 350 g of force (20), and only 0.5-0.6 mm per month using 450 g of force (9).

Patients comfort factor is a crucial element for treatment success. The PSA rely on basic principle of utilizing anchorage devices which are located in the center and anterior palate in addition to bulky intraoral device which engages on target dentition. Patients are required to undergo strict oral hygiene regiment and dental follow-up visits. The relatively larger appliance contributes to overall patient discomfort which expressed by esthetic and functional changes, such as phonetics and speech, mastication adaptation and chewing discomfort (5). The surgical method utilizing the zygomatic buttress by ZGA, involves surgical exposure of the zygomatic process and mini-plate head express into the oral cavity connected to the active distalizing device. The concept of subsequent surgical exposure of the site and partially submerged object leaving a connection between sterile bone zone to the oral cavity may potentially lead to a variety of infections pathological conditions, soft tissue and mini plate infections as the main clinical complication (19, 21). However, the ZGA offers smaller intraoral distalizing device which contributes to improved intraoral comfort during the distalization period.

All study types evaluated in this systematic review found to be prospective comparative clinical trials or retrospective comparative clinical trials. The

most powerful scientific tool for high quality clinical evaluation and comparison are randomized clinical trials, so far lacking within involved study types dealing with our issued topic. More randomized trials should be conducted in order to promote higher level of evaluation of the effect of temporary skeletal anchorage distalizers in order to clearly conclude which distalization system proved its effectiveness in buccal segment distalization together with minimization of anchorage failure and adverse treatment responses.

CONCLUSIONS

There was evidence that both of skeletal anchorage systems were effective non-extractive therapy alternative for Angle Class II malocclusion and maxillary buccal segment distalization in greater than 3 mm space deficiency.

Conflicts of interest

The authors state no conflict of interest**.**

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