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Systematic Review

Non-Compliance Distalization Appliances Supported by Mini-Implants: A Systematic Review

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Abstract: Background: A common strategy for the correction of Class II malocclusion is to initially distalize the maxillary molars to create a Class I relationship. **Material and Methods:** PubMed, Embase, Cochrane Library, Google Scholar, and Clinicaltrials.gov databases were searched to identify and retrieve orthodontic articles that evaluated non-compliance distalization appliances supported by mini-implants up to 11 November 2022. **Results:** A total of 505 articles were initially identified, and after applying the inclusion criteria, 28 studies were enlisted for evaluation. For the prospective studies, the Risk of bias in non-randomized studies of interventions assessment tool was used, and for the retrospective studies, the Newcastle-Ottawa quality assessment scale. Regarding the palatal devices with mini-implants, the maxillary molars were distalized with a mean value ranging from 2.4 to 5.9 mm, along with a distal tipping ranging between 0.01° and 11°, while when Pendulums were used with mini-implants, the maxillary molars were distalized with a mean value from 1.8 mm to 7.9 mm, and the distal tipping ranged from 7.34° to 22.8°. Further, in the second subgroup, including the appliances placed buccally, the maxillary molars were distalized with a mean value ranging from 1.83 mm to 4.2 mm and a distal tipping ranging between 0.6° and 4.8°. **Conclusions:** Non-compliance appliances supported by mini-implants are effective in maxillary molar distalization, presenting no anchorage loss of the anterior dental unit in most of the appliances, while distal tipping was found to be more pronounced when the mini-implants were used with Pendulums.

Keywords: Class II malocclusion; non-compliance; maxillary molar distalization; miniscrew implants; systematic review

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1. Introduction

1.1. Background

A common strategy for the correction of Class II malocclusion, avoiding extractions, is to initially distalize the maxillary molars in order to create a Class I relationship [1,2]. A variety of approaches to distal molar movement with different appliances and biomechanics have been routinely used, including, among others, extraoral traction, removable appliances with springs, and Class II intermaxillary elastics [2,3]. Despite their efficacy in tooth movement, these treatments are highly dependent on the patient's cooperation. Since the patient's compliance is a precondition for the effectiveness of these modalities, the development and use of techniques and appliances that minimize the need for patient cooperation provide a reliable and more predictable treatment alternative [1–3]. The category of modalities with non-compliance mechanics includes a variety of intramaxillary appliances such as Jones jig, distal jet, Pendulum appliance, Keles slider, repelling magnets, compressed coil springs, and molar distalizing bows, which sometimes are combined with orthodontic implants or miniscrew implants [1–5].

Non-compliance devices for maxillary molar distalization have been widely used to efficiently distalize the maxillary molars by avoiding the need for the patient's cooperation [1–3]. All these appliances originally use tooth-borne anchorage to counteract the mesial-directed reciprocal forces. However, such distalization mechanics can generate unwanted reciprocal movement of the anchor teeth of the anterior segment [1–5]. These can be regarded as side effects and include: (1) anchorage loss of the maxillary premolars and flaring of the incisors during distalization of the maxillary molars, and (2) since the distalized molars are commonly used as an anchorage during the retraction of the premolars and anterior teeth that follow distalization, there is a considerable amount of posterior anchorage loss at this stage in terms of mesial movement of the molars [4–6].

To counteract these side effects of the anterior (and posterior) anchorage loss, the use of temporary anchorage devices (TADs), such as the mini-implants (MIs), miniplates (MPs), or osseointegrated palatal implants (PIs) can be used as anchorage reinforcement modalities instead of the teeth [5–10]. MIs are more usually used in contrast to MPs or PIs, because (a) they are minimally invasive and they can be very easily inserted, (b) they are not osseointegrated, but just mechanically retained in the bone, and consequently, they can be used immediately without waiting for osseointegration, and (c) they provide an effortless removal at the end of treatment [11,12]. Thus, a large number of authors introduced combinations of MIs and non-compliance distalization systems for maxillary molar distalization; nevertheless, the literature was lacking a comparable and classified review to categorize the numerous and complex appliances.

1.2. Aim

This systematic review aims to critically assess the currently existing evidence from prospective and retrospective studies on humans with Class II malocclusion undergoing distalization of the maxillary molars with non-compliance intra-arch distalization appliances supported by MIs in order to evaluate the efficiency and effectiveness of these appliances.

2. Materials and Methods

2.1. Protocol and Registration

The protocol of this review was conducted a priori according to the Cochrane Handbook for Systematic Reviews of Interventions and Prisma Statement [13,14]. Although this protocol was not registered, it is available upon request.

2.2. Literature Search

The literature search aimed to examine orthodontic articles that evaluated non-compliance distalization appliances supported by MIs, systematically done by one author (NK).

PubMed, Embase, Cochrane Library, Google Scholar, and Clinicaltrials.gov databases were used to identify and retrieve studies without any limitation up to 11 November 2022 (Table S1). In addition, reference and citation lists were screened for additional articles, as well as supplementary journals and gray literature by the same author. Different key search terms were applied in each of the databases.

2.3. Eligibility Criteria

All articles were selected according to the Participants-Comparison-Outcome-Study design model (PICOS):

- Prospective or retrospective studies
- Non-compliance maxillary molar distalization appliances supported by MIs for the management of Class II malocclusion
- Non-compliance maxillary molar distalization appliances anchored on permanent dentition for bilateral maxillary molar distalization with the presence of the 2nd molars
- Sample size: 10 patients minimum

- Treatment duration: 12 months maximum

Randomized clinical trials, controlled clinical trials, cohort studies, and case controls were included in the current evaluation, whereas meta-analysis, systematic reviews, case reports, and animal studies were excluded. There was no limitation regarding the language and the year of publication or status.

2.4. Study Selection

After the selection of the studies, two authors (NK and BRD) independently screened the sources to identify articles that met the inclusion criteria. The abstracts as well as the titles of all the included or excluded articles were double-checked by both authors (NK and BRD). In case of disagreements, the final decision was made after consulting the last author (MAP).

2.5. Data Collection and Data Items

Data collection from the identified records was performed through a pre-defined pilot checklist by two authors (NK and BRD). These criteria included: appliance design, sample size, starting age, mean treatment duration, first molar distal movement (in mm and degrees), reference plane, second molar distal movement (in mm and degrees), and force application (Table 1). Data were reassessed independently by both authors, and in case of inconsistencies, were compensated after surveying by a third author (INZ).

Table 1. Characteristics of the included studies.

Publication Year/Authors	Distalization Appliance	Number of Cases	Starting Age (Years)	Treatment Time (Months)	Reference Plane	First Molar Distalization (mm)	First Molar Tipping (°)	Second Molar Distalization (mm)	Second Molar Tipping (°)	MDM in mm (SD)	MI Dimension Diameter/Length (mm)	Skeletal Anchorage Site	Distalization Force Applied
2004 Gelgor et al. [7]	Intraosseous screw	25 (18F, 7M)	11.3	4.6	SN/ACP	3.9 mm	8.8°	NA	NA	3.9 (1.61)	1.8/14	Paramedian Palate	250 g/2
2006 Kirceli et al. [10]	BAPA	10 (9F, 1M)	13.5	7.0	FH/PVT	6.4 mm	10.9°	NA	NA	6.4 (1.3)	2/8	Paramedian Palate	NA
2007 Escobar et al. [15]	BSP	15 (6F, 9M)	13	7.8	SN/GOMe	6 mm	11.3°	NA	NA	6 (2.27)	2/11	Paramedian Palate	250 g/2
2007 Gelgor et al. [16]	VFV PFV	20 (8F, 12M) 20 (11F, 9M)	11.6 12.3	4.6 5.4	SN/ACP	3.95 mm 3.88 mm	9.05° 0.75°	NA	NA	3.95 (1.68) 3.88 (1.47)	1.8/14	Paramedian Palate	250 g/2
2007 Oberti et al. [17]	DFD	16 (4F, 12M)	14.3	5	SN/GoMe	5.9 mm	5.6°	NA	NA	5.9 (1.72)	2/11	Paramedian Palate	250–300 g/2
2008 Polat-Oszoy et al. [18]	BAPA CPA	22 (15F, 7M) 17 (10F, 7M)	13.61 13.62	6.8 5.1	SN/MP	4.8 mm 2.7 mm	9.1° 5.3°	3.3 mm 2.7 mm	9.5° 5.5°	4.8 (1.8) 2.7 (1.7)	2/8	Paramedian Palate	230 g/2
2009 Kinzinger et al. [19]	SDJ	10 (8F, 2M)	12.1	6.7	SN/ANS-PNS	3.92 mm	2.79°	NA	NA	3.92 (0.53)	1.6/8–9	Paramedian Palate	200 cN/2
2009 Yamada et al. [20]	Miniscrew	12 (11F, 1M)	28.2	8.4	NA	2.8 mm	4.8°	NA	NA	2.8 (1.6)	1.3–1.5/8	Interradicular Buccal between IIPM and IM	200 g
2010 Wilmes & Drescher [21]	Beneslider	18 (10F, 8M)	G1 12.4 G2 35.2	6–10	NA	4.6 mm	1.9°	NA	NA	4.6 (1.5)	Spider screw 2.0/11 Benefit 2.0/9–11—anterior 2.0/7–9—posterior	Median Palate	NA

Table 1. *Cont.*

Publication Year/Authors	Distalization Appliance	Number of Cases	Starting Age (Years)	Treatment Time (Months)	Reference Plane	First Molar Distalization (mm)	First Molar Tipping (°)	Second Molar Distalization (mm)	Second Molar Tipping (°)	MDM in mm (SD)	MI Dimension Diameter/Length (mm)	Skeletal Anchorage Site	Distalization Force Applied
2012 Gomez et al. [22]	BPA PA	9 10	17.5 13	6 6	NA	3.56 mm 3.6 mm	7.34° 14.1°	NA	NA	3.56 (0.91) 3.6 (1.05)	2.0/11	Paramedian Palate	250 g
2013 Sar et al. [23]	MISDS BAPA	14 (8F, 6M) 14 (9F, 5M)	14.8 14.5	8.2 10.2	SN/PTV	2.8 mm 2.93 mm	1.65° 9°	NA	NA	2.81 (2.70) 2.93 (1.74)	2/8	Paramedian Palate	230 g/2
2013 Bechtold et al. [24]	MIs GroupA (1 MI) GroupB (2 MIs)	A = 12 (11F, 1M) B = 13 (11F, 2M)	23.58 22.92	9.08 11.27	SN/ANS-PNS	1.83 mm 2.91 mm	3.19° 1.55°	NA	NA	1.83 (1.23) 2.91 (0.96)	1.8/7	Interradicular Buccal, between IPM and IIPM	200 g 400 g
2014 Mariani et al. [25]	MGBM CPA	30 27	13.3 12.8	7 9	SN/PTV	4.9 mm 2.5 mm	10.5° 10.3°	4 mm 2.9 mm	10.1° 9°	4.9 (3.1) 2.5 (2.1)	1.5/10	Interradicular Palatal, between IIPM and IM	200 cN/2
2014 Cozzani et al. [26]	DS DJ	18 (10F, 8M) 18 (8F, 10M)	11.5 11.2	9.1 10.5	SN/PTV	4.7 mm 4.4 mm	2.8° 5°	NA	NA	4.7 (1.6) 4.4 (2.5)	1.5/11	Paramedian Palate	240 cN/2
2014 Nienkemper et al. [27]	Beneslider	51 (30F, 21M)	17.8	7.5	ANS/PNS	G1 3.6 mm G2 3.7 mm G3 3.3 mm	G1 4.3° G2 4.1° G2 2.9°	G2 2.7 mm G3 2 mm	G2 4.1° G3 2.2°	3.6 (1.9)	2.0/11—anterior 2.0/9—posterior	Median Palate	G1 2.4 N G2 5.0 N G3 5.0 N
2015 Caprioglio et al. [28]	PA DS	24 (14F, 10M) 19 (10F, 9M)	12.2 11.3	7 9	SN/PTV	4.7 mm 4.2 mm	9° 3.2°	4 mm 3.9 mm	10.2° 5.2°	4.7 (2.0) 4.2 (1.4)	2.2/11	Paramedian Palate	230–240 g/2
2016 Duran et al. [29]	HyraxScrew	21 (9F, 12M)	13.6	5.3	CT/FA	4.10 mm	11.0°	3.30 mm	9.06°	4.10 (1.57)	1.7/8	Paramedian Palate	NA
2016 Cozzani et al. [30]	MGBM DS	29 (13F, 16M) 24 (13F, 11M)	12.3 11.3	6 9	ANS-PNS/PTV	5.2 mm 3.2 mm	10.3° 3°	NA	NA	5.2 (6.2) 2.6 (3.2)	1.5/8–10 1.5–2/11	Interradicular Palate/ Paramedian Palate	NA

Table 1. *Cont.*

Publication Year/Authors	Distalization Appliance	Number of Cases	Starting Age (Years)	Treatment Time (Months)	Reference Plane	First Molar Distalization (mm)	First Molar Tipping (°)	Second Molar Distalization (mm)	Second Molar Tipping (°)	MDM in mm (SD)	MI Dimension Diameter/Length (mm)	Skeletal Anchorage Site	Distalization Force Applied
2016 Mah et al. [31]	LA BPA	7 7	19.2 20.9	NA	NA	2.4 mm 1.8 mm	0.8° 1.5°	NA	NA	2.4 (3.1) 1.8 (1.2)	NA	Median Palate	NA
2017 Cambiano et al. [32]	BAPA	18 (14F, 4M)	14	4.8	SN/PP	3.45 mm	11.2°	3 mm	12.62°	3.45 (2.61)	2.4/14	Paramedian Palate	250 g
2018 Farag et al. [33]	BAPA LAMS	15 15	16	7.2 10.56	FH/PTV	7.9 mm 7.1 mm	22.8° 10.9°	NA	NA	7.9 (0.35) 7.1 (0.34)	1.8/8 1.8/8	Paramedian Palate Median Palate and Interradicular between IIPM and IM	300 g NA
2019 Cassetta et al. [34]	SDJ CA	10 10	13.1 12.3	6 6	SN/PTV	5.3 mm 0.9 mm	0.01° 0.6°	NA	NA	5.2 (2.1) 0.9 (0.9)	NA	Paramedian Palate	250 N
2020 Bechtold et al. [35]	VFV	19 (15F, 4M)	24.9	NA	SN/PTV	4.2 mm	0.6°	NA	NA	4.2 (2.0)	NA	Interradicular Buccal, between IIPM and IM	NA
2020 Bozkaya et al. [36]	HP CP	22 (14F, 8M) 21 (15F, 6M)	14.3 14.6	7 8.3	ANS/PNS	4.25 mm 3.21 mm	9.09° 9.86°	3.55 mm 2.86 mm	8.45° 9.86°	4.25 (0.95) 3.21 (1.79)	1.9/9	Paramedian Palate	NA
2020 Abdelhady et al. [37]	BDT	11F	12.4	4.9	ML	4.09 mm	2.48°	NA	NA	4.09 (0.92)	1.8/8	Interradicular Buccal, between IIPM and IM	250 g

Table 1. *Cont.*

Publication Year/Authors	Distalization Appliance	Number of Cases	Starting Age (Years)	Treatment Time (Months)	Reference Plane	First Molar Distalization (mm)	First Molar Tipping (°)	Second Molar Distalization (mm)	Second Molar Tipping (°)	MDM in mm (SD)	MI Dimension Diameter/Length (mm)	Skeletal Anchorage Site	Distalization Force Applied
2021 Negm et al. [38]	SFA	25 (16F, 9M)	13	NA	NA	4.14 mm	9.02°	NA	NA	4.14 (2.14)	2/6	Paramedian Palate	250 g
2022 Altieri et al. [39]	SDJ DJ	46 (26F, 20M)	13.2	NA	SN/PTV	4.3 mm 1.3 mm	0.1° 2.5°	NA	NA	4.3 (2.8) 1.5 (3.1)	Benefit 2, 2.3/7, 9, 11, 13	Paramedian Palate	250 N
2022 Rosa et al. [40]	IZC miniscrews	25 (14F, 11M)	13.6	7.7	ANS/PNS	4 mm	11.2°	3.53 mm	11.04°	4 (1.80)	2/12	Interradicular Buccal, between IM and IIM	350 g

SN: Sella-Nasion line, ACP: Anterior Clinoid Process, FH: Frankfurt Horizontal, PVT: Pterygoid Vertical, PP: Palatal Plane, CT: Cusp Tip, FA: Facial Axis, BAPA: Bone-Anchored Pendulum Appliance, BSP: Bone-Supported Pendulum, BPA: Bone-anchorage Pendulum, VFV: Vestibular Force Vector, PFV: Palatal Force Vector, DFD: Dual-Force Distalizer, CPA: Conventional Pendulum Appliance, SDJ: Skeletonized Distal Jet, MISDS: Miniscrew Implants Supported Distalization System, PA: Pendulum Appliance, DS: Distal Screw, NA = not available. MDM: molar distal movement, SD: standard deviation, NA: not available, IM: first molar, IIM: second molar, IPM: first premolar, IIPM: second premolar, IZC: infrazygomatic crest.

2.6. Risk of Bias

The risk of bias was evaluated based on a methodological approach separately for the prospective and retrospective studies. For the prospective studies, the Risk of bias in non-randomized studies of interventions (Robins-I) assessment tool was used, and for the retrospective studies, the Newcastle-Ottawa quality assessment scale. An estimate of the risk of bias within original articles was conducted by one author (NK) and autonomously confirmed by a second one (BRD) while a third one (MAP) settled the disparities that arose.

3. Results

3.1. Study Selection

Using the search strategy, a total of 505 articles were initially identified, and after the removal of duplicates and screening of the titles/abstracts, only 88 full texts were assessed for eligibility, of which only 28 articles met the inclusion criteria and were enlisted for critical evaluation in the current analysis (Table S2).

These included 1 non-randomized clinical trial, 17 prospective cohort studies, and 10 retrospective cohort studies (Figure 1).

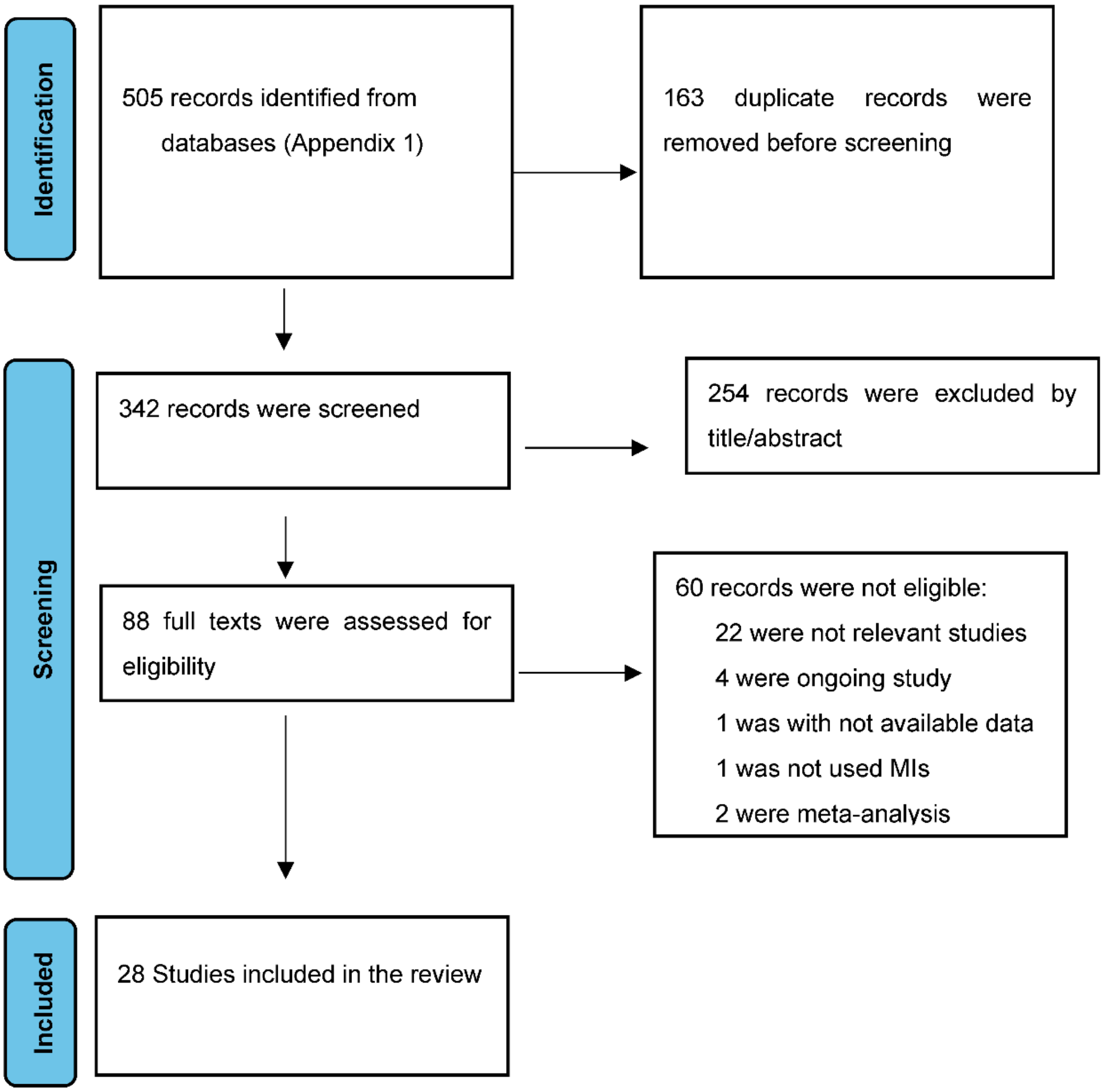

Figure 1. The PRISMA flow diagram of the study.

A meta-analysis could not be performed because the retrieved studies were not homogenous with respect to many features, such as type of study, type of appliance, type of MIs, location of insertion of MIs, biomechanics of the distalization force, etc. In our opinion, with such high heterogeneity among the different papers, a meta-analysis might produce misleading results.

3.2. Risk of Bias within Studies

Robustness was evaluated by a methodological approach of two different methods accomplished by the authors, and from the total of 18 non-randomized prospective studies, the evaluation of the overall risk of bias was defined as serious, moderate, and low-quality studies. More specifically, nine studies were judged with moderate quality, while eight studies were judged with low and only one study was found with a serious risk of bias (Table 2). In addition, the retrospective studies were evaluated separately, resulting in eight studies of high quality and two studies of low quality using an assessment quality analysis (Table 3).

These two discrete methodological approaches took place in order to provide clarity, accuracy, and equal judgment to the included studies.

Table 2. Risk of bias in non-randomized studies used for the systematic review (ROBINS-I assessment tool).

Author/Risk of Bias	Bias due to Confounding	Bias in Selection of Participants	Bias in Classification of Interventions	Bias due to Deviations from Intended Interventions	Bias due to Missing Data	Bias in the Measurement of Outcomes	Bias in the Selection of the Reported Result	The Overall Risk of Bias
Gelgor et al. [7]	LOW	MODERATE	LOW	LOW	MODERATE	LOW	LOW	MODERATE
Kirceli et al. [10]	LOW	MODERATE	LOW	LOW	MODERATE	LOW	MODERATE	MODERATE
Escobar et al. [15]	LOW	LOW	LOW	LOW	MODERATE	MODERATE	MODERATE	MODERATE
Gelgor et al. [16]	LOW	MODERATE	LOW	LOW	LOW	LOW	MODERATE	MODERATE
Oberti et al. [17]	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
Kinzinger et al. [19]	LOW	MODERATE	LOW	LOW	LOW	LOW	LOW	MODERATE
Yamada et al. [20]	LOW	MODERATE	LOW	LOW	LOW	LOW	MODERATE	MODERATE
Sar et al. [23]	LOW	LOW	MODERATE	LOW	LOW	LOW	LOW	MODERATE
Bechtold et al. [24]	LOW	LOW	SERIOUS	MODERATE	LOW	MODERATE	LOW	SERIOUS
Cozzani et al. [26]	MODERATE	MODERATE	SERIOUS	LOW	LOW	LOW	LOW	MODERATE
Duran et al. [29]	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
Mah et al. [31]	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
Cassetta et al. [34]	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
Farag et al. [33]	LOW	LOW	LOW	MODERATE	LOW	MODERATE	MODERATE	MODERATE
Abdelhady et al. [37]	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
Negm et al. [38]	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
Altieri et al. [39]	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
Rosa et al. [40]	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW

Table 3. Risk of bias in non-randomized retrospective studies using the Newcastle-Ottawa quality assessment scale.

Author/Quality Evaluation	Representativeness of MIs Group	Selection of the Control Group	Ascertainment of MIs Group	Demonstration That the Outcome of Interest Is Not Present at the Start of the Study	Comparability of Participants between Treatment and Control Group	Assessment of Outcome	Adequacy of Follow-up	Lost to Follow-up Acceptable (<10% and Reported)	Total Quality Score
Polat-Oszoy et al. [18]	*		*		**	*	*	*	7 (H)
Gomez et al. [22]	*	*	*		*	*	*	*	7 (H)
Mariani et al. [25]	*	*	*	*	*	*	*	*	8 (H)
Nienkemper et al. [27]	*		*			*	*	*	5 (L)
Wilmes & Drescher [21]	*		*			*	*	*	5 (L)
Caprioglio et al. [28]	*	*	*	*	**	*	*	*	9 (H)
Cozzani et al. [30]	*	*	*		*	*	*	*	7 (H)
Cambiano et al. [32]	*		*	*		*	*	*	6 (H)
Betchtold et al. [35]	*	*	*		*	*	*	*	7 (H)
Bozkaya et al. [36]	*	*	*	*		*	*	*	7 (H)

H indicates high quality; L indicates low quality.

3.3. Study Characteristics

The characteristics of the included studies are presented in Table 1. Maxillary first and second molars were recorded for the amount of distalization (mm) and distal tipping (degrees). In addition, the type of appliances, number of cases, starting age, treatment time, reference planes, MIs dimensions, skeletal anchorage, and distalization force were documented from the retrieved studies.

Many authors have proposed several devices which differ in biomechanics, function, and type of movement, as well as distalization duration [41–43]. All these devices can be inserted either palatally or buccally, while the MIs can be applied either in the median or paramedian palate, or even in the inter-radicular space [44–46].

In the present study, we formed two different subgroups in order to evaluate the different devices efficiently and clearly avoid any confusion and mixing of the above appliances. The first subgroup included the non-compliance appliances anchored to the palate, whereas the second subgroup enlisted the appliances placed buccally.

To distinguish the Pendulums with TADs from all other devices with TADs, two more subgroups were created within the first subgroup since the latter appliances seem to present far lower distal tipping in comparison with the Pendulum appliances. Thus, the maxillary first molars in the Pendulums and TADs group were distalized with a mean value from 1.8 mm to 7.9 mm; meanwhile, the distal tipping ranged from 7.34 to 22.8°. In addition, all other TAD-equipped devices in the first subgroup, with the exception of Pendulums, were distalized with a mean value ranging from 2.4 to 5.9 mm and a distal tipping range from 0.01 to 11°. Further, in the second subgroup, the mean value was estimated to be from 1.83 mm to 4.2 mm, while the angular distalization rate was from 0.6 to 4.8°.

Additionally, the subgroup of the TADs showed no anchorage loss besides the MGBM (G.B Maino, A. Giannelly, R. Bernard, P. Mura) appliance, while the Pendulum subgroup concluded in any loss of anchorage using the BAPA (Bone Anchored Pendulum Appliance) and BSP (Bone supported Pendulum) appliances in the premolars and in the anterior segment. Furthermore, there is no anchorage loss with the buccal placement appliances.

4. Discussion

During the last decades, MIs have been introduced effectively as TADs in order to distalize maxillary molars or the entire maxillary dentition [47–49]. Miniscrew implants are globally utilized by orthodontists because they can provide sufficient and reliable anchorage, expressing a popular solution to the above-mentioned problems [19,50–52]. Nevertheless, treatment outcome depends on various biomechanics as well as the appropriate selection of the non-compliance appliance. Some of them need additional laboratory constructions that seem to be less tolerated by patients providing complicated adaptations or activations by the clinician wasting valuable time on the treatment outcome [18,53–56]. In addition, some appliances can provide unilateral and bilateral maxillary molar distalization, establishing a precious tool in the hands of experts.

Non-compliance distalization appliances supported by mini-implants have a global impact on daily orthodontic practice, offering valuable clinical use while many studies have justified their dentoalveolar and skeletal effects [23,38,39].

The existing systematic review was performed to evaluate the efficiency and effectiveness of the noncompliance appliances for maxillary molar distalization in patients with Class II malocclusion.

4.1. Angular and Linear Molar Distalization Movement

4.1.1. Characteristics of the Appliances Positioned Palatally

According to the results of the current investigation, it has been shown that linear and angular changes of the maxillary first molars varied from 1.8 mm utilizing a modified pendulum appliance [31] to 7.9 mm using the BAPA [33], while distal molar tipping ranged from 7.34° [22] to 22.8 with the BAPA. Meanwhile, in the first subgroup including all the palatal devices with TADs, the maxillary first molars distalized from 2.4 mm using a lingual modified appliance, according to Mah et al., to 5.9 mm using the Dual Force Distalizer appliance according to Oberti et al. [17], while distal molar tipping ranged from 0.01° using the miniscrew-supported distal jet (SDJ) [34] to 11° using a hyrax screw type distalizer [29]. Our results showed the palatal devices with TADs have lower distal tipping than the Pendulums with TADs [15,18,36], and thus are in agreement with the systematic review of Mohamed et al. and Bayome et al. [57,58].

Measurements for the distalization of maxillary second molars were inadequate and were available only in 8 out of 28 articles. Second molar distalization with the palatal distalization appliances supported with TADs was evident and ranged from 2 mm using the Beneslider appliance [27] to 4 mm using the MGBM, an intraoral distalization system with palatal-anchored MIs [25]. In addition, the second molar distal tipping ranged between 2.2° using the Beneslider and 12.62° using the BAPA [32].

4.1.2. Characteristics of the Appliances Positioned Buccally

Maxillary molar distalization using appliances positioned buccally, supported by TADs, ranged from 1.83 mm using a single MI [24] to 4.2 mm using the Vestibular Force Vector [35], while the distal tipping was extended from 0.6° to 4.8° using a single MI [20].

However, miniscrew placement in the buccal interradicular site showed dissimilar distalization features, using one MI or two MIs as an anchorage unit. Distalization movement with one MI varied from 1.83 mm to 2.8 mm along with distal tipping from 3.19° to 4.8° [20,24]. Additionally, when two MIs were inserted buccally, they resulted in 2.91 mm–4.2 mm of distalization, while distal tipping ranged from 0.6° to 2.48° [37].

In general, the current study revealed that distalization appliances anchored in the palate and supported by TADs achieved greater distalization bodily movement along with minimal distal tipping of the maxillary first molars in comparison with the Pendulums or the buccal methods supported by TADs.

4.2. One MI vs. Two MIs on Molar Distalization

In the recent review, studies that compared the single with a dual miniscrew support for maxillary molar distalization concluded that the dual unit produced a greater molar distalization rate in relation to the single MI. Bechtold et al. [24] compared two different groups, in which showed 1.83 mm of distal bodily movement and 3.19° of distal tipping with a single MI in the time that found 2.91 mm and 1.55° with two MIs, respectively. However, the same author recently published improved results with 4.2 mm of distal movement and 0.6° of distal tipping using the same intraoral mechanics with an individual MI [35]. Another study by Yamada et al. demonstrated a particular miniscrew providing 2.8 mm of distal movement and 4.3 degrees of distal tipping [20]. Abdelhady et al. [37] performed a clinical trial that is in accordance with Yamada et al. while opposing the results of Bechtold et al. [24], introducing 4.09 mm and 2.48° distalization movement together with tipping with a closed coil spring and a buccal MI. Mainly, the greater success of the two MIs may be assigned to an increased magnitude of force in comparison with the single unit [40]. Although the infra-zygomatic process, which inserted the miniscrews in the infrazygomatic alveolar crest, appears to be more effective, our results primarily focused on the interradicular method, which was the method mostly provided in our included articles [58].

4.3. MI Placement in Palate vs. in Interradicular Area

The preferable site for the miniscrew insertion is the median or paramedian region of the palate, according to the literature. In our review, 18 studies selected the paramedian region, 2 articles the median palate region, and 8 of the studies utilized the interradicular area. The paramedian site is considered the safest solution for MI insertion since it presents high cortical bone thickness while being apart from the neighboring root teeth. Buccally, the optimal site is between the second premolar and first molar together with the first and second molar.

4.4. Anchorage Loss

Non-compliance appliances are associated with some undesirable side effects that decrease their clinical success, such as anchorage loss of the anterior dental unit indicated by forwarding movement and proclination of the anterior teeth, distal tipping and rotations of the maxillary molars, and posterior anchorage loss in terms of mesial movement of the molars, during the anterior tooth retraction [16,21,26,28]. All the mentioned non-compliance appliances that were placed palatally or buccally showed no anchorage loss among the Pendulum and TADs subgroup. However, Marianni and Cozzani confirmed that the MGBM appliance produced some anchorage loss, with the mesial tipping of the first premolars by 2.5° and 4.3° along with proclination of the maxillary incisor with 1.4° and 1.8°, respectively [30].

4.5. Limitations

The limitations of this systematic review were related to the heterogeneity of the data of the originally included studies along with the lack of descriptive data, which did not allow to perform a meta-analysis, i.e., to quantitatively analyze the current evidence.

5. Conclusions

According to the results of this investigation, it can be concluded that:

1. Non-compliance appliances supported by mini-implants are effective in maxillary molar distalization, presenting no anchorage loss of the anterior dental unit in most of the appliances besides the MGBM, which presented anchorage loss of the first premolars and in proclination of the anterior dental unit.
2. Distal tipping of the maxillary molars was found to be more pronounced when the mini-implants were used with Pendulums or when they were inserted in the buccal sides.
3. The use of two mini-implants for the anchorage instead of one mini-implant to support maxillary molar distalization seems to be more effective.
4. Due to the lack of high-quality studies and the large heterogeneity, the results of this review should be considered with some caution while additional high-quality, well-designed prospective clinical trials are needed to ascertain the impact of various designs on distalization.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app13085176/s1.

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