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Review

The Efficacy of Retention Appliances after Fixed Orthodontic Treatment: A Systematic Review and Meta-Analysis

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Abstract: The purpose of this article is to evaluate the amount of the relapse of anterior crowding and the efficacy of retention appliances by reviewing the best available scientific evidence. A survey of articles published up to November 2019 about the stability of dental alignment and retention after fixed orthodontic treatment was performed using seven electronic databases. Study Selection: Only randomized clinical trials investigating patients previously treated with multi-bracket appliances with a follow-up period longer than 6 months were included. Data Extraction: Two authors independently performed the study selection, data extraction, and risk of bias assessment. All pooled data analyses were performed using a random-effects model. Statistical heterogeneity was evaluated. In total, eight randomized clinical trials (RCTs) were included, grouping data from 987 patients. The ages of the patients varied across the studies, ranging between 13 and 17 years. The observation period ranged between 6 and 24 months. The data showed no significant intercanine width modifications during the retention period with both fixed and removable retainers. A significant modification of Little's Index was found for the mandibular removable retainers with a mean difference of 0.72 mm (95% Cl, 0.47 to 0.98) and for the maxillary removable retainers with a mean difference of 0.48 mm (95% Cl, 0.27 to 0.68). No significant changes were found by evaluating Little's Index modification for the mandibular fixed retainers. The results of this meta-analysis showed that all the considered retainers were effective in maintaining dental alignment after fixed orthodontic treatment. However, fixed retainers showed greater efficacy compared to removable retainers.

Keywords: relapse; orthodontic retainers; stability; systematic review; meta-analysis

1. Introduction

Stable tooth position after orthodontic treatment is considered a treatment goal. However, evidence shows that the majority of orthodontic treatments move teeth from a stable to an unstable position [1]. In this way, the use of a retainer is considered the only method able to maintain occlusal results [2]. Post-treatment tooth stability can be affected by several different factors, including bone and soft tissue development [3], primary crowding [4–6], dental eruption [7], modification of arch form [8], post-treatment occlusion [9], and the characteristics of pre-treatment malocclusion [10]. Retention

can be performed by placing removable or fixed retainers. A recent Cochrane review reported a lack of evidence concerning the effectiveness different retention methods [11]. The efficacy of different retention appliances is of great interest for clinicians to support clinical retention protocols [12–14]. The literature does not provide meta-analytic data reporting and comparing the amount of relapse that occurs when using different retention appliances. The aim of this systematic review and meta-analysis was to evaluate the amount of relapse of anterior crowding and consequently to evaluate the efficacy of retention appliances used after fixed orthodontic treatment according to the best scientific evidence available [15].

2. Materials and Methods

The present systematic review with meta-analysis was performed according to the guidelines provided by the Cochrane Handbook for Systematic Reviews of Interventions (version 5.1.0) and was reported according to the PRISMA statement [16–19]. The protocol of this meta-analysis was preliminary registered on PROSPERO (https://www.crd.york.ac.uk/prospero/). Two authors independently carried out the selection of the studies, data collection, and the assessment of the risk of bias. Any disagreement was resolved by discussion with a third author. The level of agreement between the 2 reviewers was assessed by Cohen kappa statistics, for which a threshold value of 0.90 was preset.

2.1. Information Sources and Search

A survey of articles published up to November 2019 on stability and retention after orthodontic treatment was performed using several electronic databases (Table 1).

Table 1. Performed electronic searches.

Database of Published Trials	Search Strategy Used	Hits
MEDLINE searched via PubMed searched on November 18, 2019 via www.ncbi.nlm.nih.gov/sites/entrez/	((((incisor stability [tiab]) OR post treatment stability [tiab]) OR relapse [mesh])) AND (((orthodontic treatment [tiab] or Orthodontic fixed appliance [tiab]) Or orthodontic retainer [tiab])	254
OvidSP searched on November 18, 2019 via https://ovidsp.tx.ovid.com	(incisor stability OR post treatment stability OR relapse) AND (orthodontic treatment OR orthodontic fixed appliance OR orthodontic retainers)	1135
EMBASE searched via ScienceDirect searched on November 18, 2019 via www.embase.com	(incisor stability or post treatment stability or relapse) AND (orthodontic treatment or orthodontic fixed appliance or orthodontic retainers)	1174
Cochrane Database of Systematic Reviews searched via The Cochrane Library searched on November 18, 2019 via www.thecochranelibrary.com	(incisor stability OR post treatment stability OR relapse) AND (orthodontic treatment OR orthodontic fixed appliance OR orthodontic retainers)	2
Cochrane Central Register of Controlled Trials searched via The Cochrane Library searched on January 18, 2018 via www.thecochranelibrary.com	(incisor stability OR post treatment stability OR relapse) AND (orthodontic treatment OR orthodontic fixed appliance OR orthodontic retainers)	94
Scopus searched on November 18, 2019 via www.scopus.com	(incisor stability OR post treatment stability OR relapse) AND (orthodontic treatment OR orthodontic fixed appliance OR orthodontic retainers)	191
Web of Science searched on November 18, 2019 via http://scientific.thomson.com/products/wos	(incisor stability or post treatment stability or relapse) AND (orthodontic treatment or orthodontic fixed appliance or orthodontic retainers)	745
Total		3595

Previous systematic reviews and meta-analyses on this topic were also identified, and their reference lists were scanned to find additional trials. No restriction was applied to language, publication year, or status.

2.2. Selection of Studies

Duplicated reports were preliminary excluded. All retrieved records were screened on the basis of their titles and abstracts, and the full texts of the remaining articles were assessed for eligibility in the final analysis.

Studies were considered eligible if they met the following criteria (reported according to the PICO format): clinical trials on human subjects, orthodontic patients treated with multi-bracket appliances with no craniofacial deformity (population), orthodontic retention performed with fixed or removable retainers (intervention), a comparable control group (control group), results analyzed at the beginning of retention and after a follow-up period longer than 6 months (outcomes measured), and analyzed treatment effects that were not influenced by concomitant and/or additional therapeutic procedures.

2.3. Data Extraction and Management

A data extraction form was developed to collect the characteristics (study design, type of retention appliance, sample size, age, sex, orthodontic treatment characteristics, setting, observation time, type of measurements, and follow-up) and outcomes from the included studies. Relapse after orthodontic treatment was investigated by using two parameters: Little's Irregularity Index (LII) for assessment of the degree of crowding and intercanine width for assessment of the transversal anterior dental arch width.

2.4. Assessment of Risk of Bias

The risk of bias assessment was performed using the Cochrane Collaboration's risk of bias tool (Review Manager version 5.2; Nordic Cochrane Centre, Cochrane Collaboration, Copenhagen, Denmark, 2012). Each randomized clinical trial (RCT) was assigned an overall risk of bias rating: low risk (low for all key domains), high risk (high for ≥1 key domain), or unclear risk (unclear for ≥1 key domain).

2.5. Summary Measures and Data Analysis

Two outcomes were considered for the meta-analytic analysis: Little's Irregularity Index and Intercanine width. The published clinical trials evaluating retention protocols do not have a control group with un-retained patients for ethical reasons. As a consequence, all the published trials compare two or more treatment protocols. In order to obtain a quantitative estimation of occlusal changes occurred with different retention protocols, we considered the single-arm data of clinical trials as the data obtained from case-series studies, and we performed a meta-analysis extrapolating and combining these data. In terms of data characteristics, the single-arm data from the RCTs and case series studies data are equivalent, as both studies report data with a mean value and standard deviation. However, the data extrapolated from the single-arm RCTs present less bias compared to the data from the case series studies. Finally, our strategy was supported by the literature. Indeed, when clinical trials with untreated control groups are not available, case-series studies without a control group can be used to perform a meta-analysis [20–22].

The considered effects size used for the meta-analysis was the difference between the outcome values at the end of treatment with fixed appliances and the outcome values after the retention period. Some studies reported the interquartile range rather than standard deviation, and the data extracted from those studies were properly adjusted [23]. The mean differences (MDs) and their corresponding 95% confidence intervals (95% Cls) were used to summarize and combine the data. A random-effects model was applied to estimate all the pooled data. This analysis was performed by means of the OpenMeta [Analyst] computer program (http://www.cebm.brown.edu/openmeta/) [24]. A third outcome (i.e., the fixed retainer failure rate) was considered only for qualitative evaluation.

2.6. Assessment of Heterogeneity

Clinical heterogeneity was evaluated by examining the types of participants and the interventions for the outcome in each included study. For all analyses, heterogeneity was assessed with the I^2 index, which is an indicator of true heterogeneity in percentages [14–19].

2.7. Assessment of Quality of Evidence

The quality of evidence was assessed using the Grades of Recommendation, Assessment, Development, and Evaluation Pro software (GRADEPro) [25]. The strength of the recommendation for each outcome investigated was assessed using the Strength of Recommendation Taxonomy (SORT) Grading system [26], which addresses the issue of patient-oriented (effectiveness) versus disease-oriented evidence (efficacy). POEMs (patient oriented evidence that matters) allows clinicians to filter information from the medical literature and focus only on what is in fact important for the patient [26].

2.8. Sensitivity Analysis

A sensitivity analysis was conducted to evaluate the LII modification in the lower arch with the mandibular removable retention appliances, excluding the RCT with the highest risk of bias (Figure S1).

3. Results

3.1. This Study Selection

Figure 1 shows the flow diagram for the selection of studies. Supplementary Table S1 reports the number of excluded studies and the reasons for exclusion. Eleven studies [21–31] were selected for the qualitative analysis and eight studies for the final quantitative synthesis [21–28] (Table 1). The inter-reviewer agreements for study selection were suitable, with a kappa value of 0.987.

3.2. Study Characteristics

The characteristics of the 11 RCTs included for the qualitative synthesis are summarized in Table 2. All eight RCTs selected for the meta-analysis evaluated the efficacy of different type of retention appliances (both removable and fixed) after orthodontic treatment with a multi-bracket appliance; the majority of trials took place in university settings. The total number of pooled observed patients was 987. Six studies [27,30–34] included both male and female participants, while in two studies [28,31], the authors did not specify the numbers of male and female participants. Five studies [27,29,30,33,34] reported the patients' ages, with an age range between 13 and 17 years. The appliance features were heterogeneous among the selected studies: Six trials evaluated the effects of vacuum-formed retainers [27,30–34], four trials evaluated the effects of bonded fixed retainers [27–31], two trials evaluated the effects of a Hawley retainer [33,34], one trial evaluated the effects of a Begg retainer [31], and one trial evaluated the effects of a positioner [27].

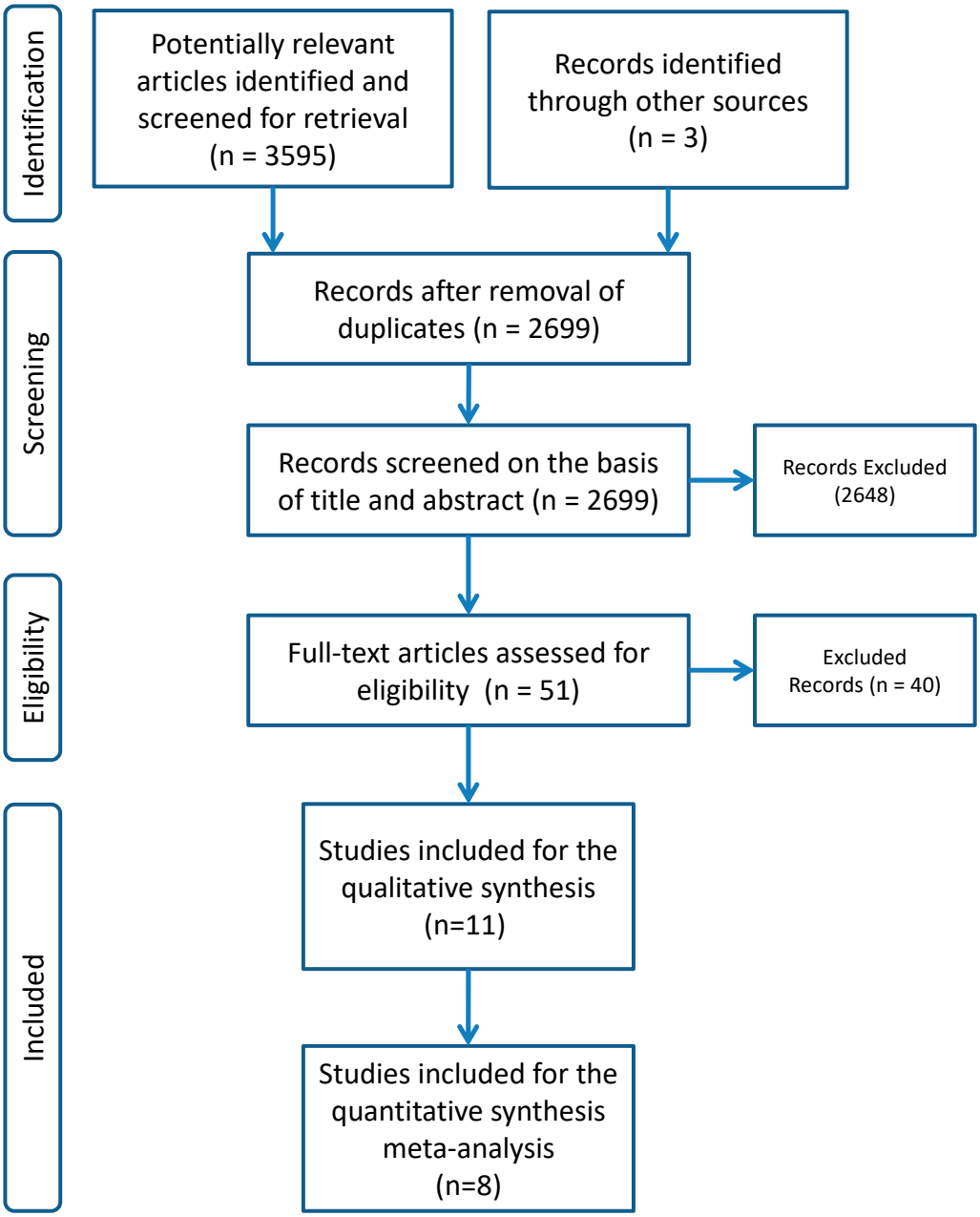

Figure 1. Flow Chart.

Seven studies [27,29,30,32–34] reported the percentage of patients treated with or without extraction, as shown in Table 2. The times of daily wear for the removable appliances (vacuum-formed retainers, Hawley retainers, Begg retainers, and positioners) varied between full-time and night-time among the RCTs, and the observation time varied from 6 to 24 months. The inter-reviewer agreements for study selection were suitable, with a kappa value of 0.968.

Table 2. Study characteristics.

Selected References	Maxillary Retention	Mandibular Retention	Sample	Sex	Age (y)	Orthodontic Treatment Characteristics	Setting	Observation Time	Methods of Measurement
Bolla et al. (2012)	Fixed Retainer (GFR) Fixed Retainer (MST)	Fixed Retainer (GFR) Fixed Retainer (MST)	GFR = 40 MST = 45	F = 28 M = 12 F = 28 M = 17	F = 20.2 M = 23.4 F = 22.6 M = 24.1	No Extraction: 100% Extraction: 0%	Italy	6 years	Failure rate.
Edman Tynelius et al. (2013)	Vacum-Formed Retainer Positioner	Fixed Retainer Positioner	VFR = 47 Positioner = 22 FR = 24	F = 45 M = 30	14,4	No Extraction: 0% Extraction: 100%	National Health Service (NHS) Ystad, Sweden	24 months	Little's irregularity index (LII), intercanine width.
Egli et al. (2017)	//	Fixed Retainer (DB) Fixed Retainer (IB)	FR (DB) = 30 FR (IB) = 30	//	//	//	Postgraduate orthodontic clinic University of Geneva, Switzerland.	24 months	Intercanine width, failure rate.
Forde et al. (2017)	Bonded Retainer Vacum-Formed Retainer	Bonded Retainer Vacum-Formed Retainer	BR = 30 VFR = 26	F = 15 M = 15 F = 18 F = 12	BR = 16 VFR = 17	No Extraction: 31,6% Extraction: 68,4%	St Luke's Hospital, Bradford and York Hospital and Leeds Dental Institute; UK.	12 months	Little's irregularity index (LII), intercanine width.
Gill et al. (2007)	Vacum-Former Retainer	Vacum-Former Retainer	Full-Time = 28 Part-Time = 29	F = 16 M = 12 F = 16 M = 13	FT = 13,7 (2,5) PT = 13,3 (1,4)	No Extraction: 35 Extraction: 65%	Hospital department, London, UK.	6 months	Little's irregularity index (LII), intercanine width.
Kumar et al. (2011)	Vacum-Formed Retainer Begg Retainer	Vacum-Formed Retainer Begg Retainer	VFR = 112 BR = 112	//	//	//	College of Dental Sciences, Davangere, India.	6 months	Little's irregularity index (LII).
O'Rourke et al. (2016)	//	Vacum-Former Retainer Fixed Retainer	VFR = 21 FR = 27	F = 59 M = 23	//	No Extraction: 53,6% Extraction: 46,4%	Hospital, London, UK.	18 months	Little's irregularity index (LII), intercanine width.
Rowland et al. (2006)	Vacum-Former Retainer Hawley Retainer	Vacum-Former Retainer Hawley Retainer	VFR = 201 HR = 196	F = 118 M = 83 F = 123 M = 73	VFR = 14 HR = 15	No Extraction: 66,2% Extraction: 33,8%	Taunton, Bristol, London, and Nottingham, UK.	6 months	Little's irregularity index (LII), intercanine width.
Salehi et al. (2013)	Fixed Retainer (PWR) Fixed Retainer (Multi-Stranded)	Fixed Retainer (PWR) Fixed Retainer (Multi-Stranded)	PWR = 68 Multi-stranded = 74	F = 39 M = 29 F = 44 M = 30	PWR = 18.1 (5,2) PT = 18,2 (4,8)	//	School of Dentistry, Shiraz University of Medical Sciences, Iran	18 months	Failure rate.
Shawesh et al. (2009)	Hawley Retainer	Hawley Retainer	Full-Time = 28 Part-Time = 24	F = 58,8% M = 41,2% F = 75,8% M = 24,2%	FT = 15,6 (1,6) PT = 15,8 (1,2)	No Extraction: 17,9% Extraction: 82,1%	Heaton Mersey, Manchester, UK.	12 months	Little's irregularity index (LII).
Störman et al. (2002)	//	Fixed Retainer (0.0195 Respond®) Fixed Retainer (0.0215 Respond®) Fixed Retainer (Prefabricated 3 to 3)	0.0195 Respond®= 31 0.0215 Respond®= 38 Prefabricated 3 to 3 = 34	//	13 to 17	//	Department of Orthodontics, University of Münster, Germany	24 months	Failure rate.

3.3. Risk of Bias Assessment

Although we took only single arm data from the selected studies to perform the meta-analysis, all the pooled data come from RCTs. Therefore, in order to assess the risk of bias, we had to assess the methodological quality of the RCTs; we used the Cochrane Collaboration tool, which is considered the gold standard for this purpose (Table S1). Among the eight studies included for the quantitative synthesis and meta-analysis, only 1 RCT was evaluated to have a high risk of bias [34]. In two RCTs, the risk of bias was unclear [31,33], and five RCTs had a low risk of bias [26–30,32] (Table 3). Consequently, the summary assessments of risk of bias across the studies were considered to be low. The inter-reviewer agreements for risk of bias assessment were suitable, with kappa values of 0.925. Publication bias was not assessed as there were inadequate numbers of included trials to properly develop a funnel plot or more advanced regression-based assessments.

Table 3. Risk of bias assessment.

STUDIES	Risk of Bias						
	Sequence Generation	Allocation Concealment	Blinding of Participants, Personnel and Outcomes	Incomplete Outcome Data	Selective Outcome Reporting	Other Risk of Bias	Overall Risk of Bias
Bolla et al. (2012)	Unclear	Unclear	Unclear	High Risk	Unclear	High Risk	High Risk
Edman et al. (2013)	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Egli et al. (2017)	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Forde et al. (2017)	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Gill et al. (2007)	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Kumar et al. (2011)	Unclear	Unclear	Low Risk	Low Risk	Unclear	Unclear	Unclear
O'Rourke et al. (2016)	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Rowland et al. (2006)	Low Risk	Low Risk	Low Risk	Low Risk	Unclear	Low Risk	Unclear
Salehi et al. (2013)	Low Risk	Unclear	Low Risk	Low Risk	Low Risk	Low Risk	Unclear
Shawesh et al. (2009)	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	High Risk	High Risk
Störmann et al. (2002)	Unclear	Unclear	Low Risk	Low Risk	Low Risk	Unclear	Unclear

3.4. Quantitative Data Synthesis

The data showed that the mean difference of intercanine width during the retention period was 0.05 mm (95% Cl, −0.41 to 0.51; $P = 0.84$; $I^2 = 99\%$) for the mandibular fixed retainers (Figure 2a), 0.01 mm (95% Cl, −0.26 to 0.28; $P = 0.95$; $I^2 = 100\%$) for the mandibular removable retainers (Figure 2b), and −0.13 mm (95% Cl, −0.52 to 0.27; $P = 0.53$; $I^2 = 99\%$) for the maxillary removable retainers (Figure 2c). The mean difference of Little's Index during the retention period was 0.48 mm (95% Cl, −0.04 to 1.01; $P = 0.07$; $I^2 = 98\%$) for the mandibular fixed retainers (Figure 2d), 0.73 mm (95% Cl, 0.47 to 0.98; $P = 0.00001$; $I^2 = 100\%$) for the mandibular removable retainers (Figure 2e), and 0.48 mm (95% Cl, 0.27 to 0.68; P = 0.00001; $I^2 = 91\%$) for the maxillary removable retainers (Figure 2f).

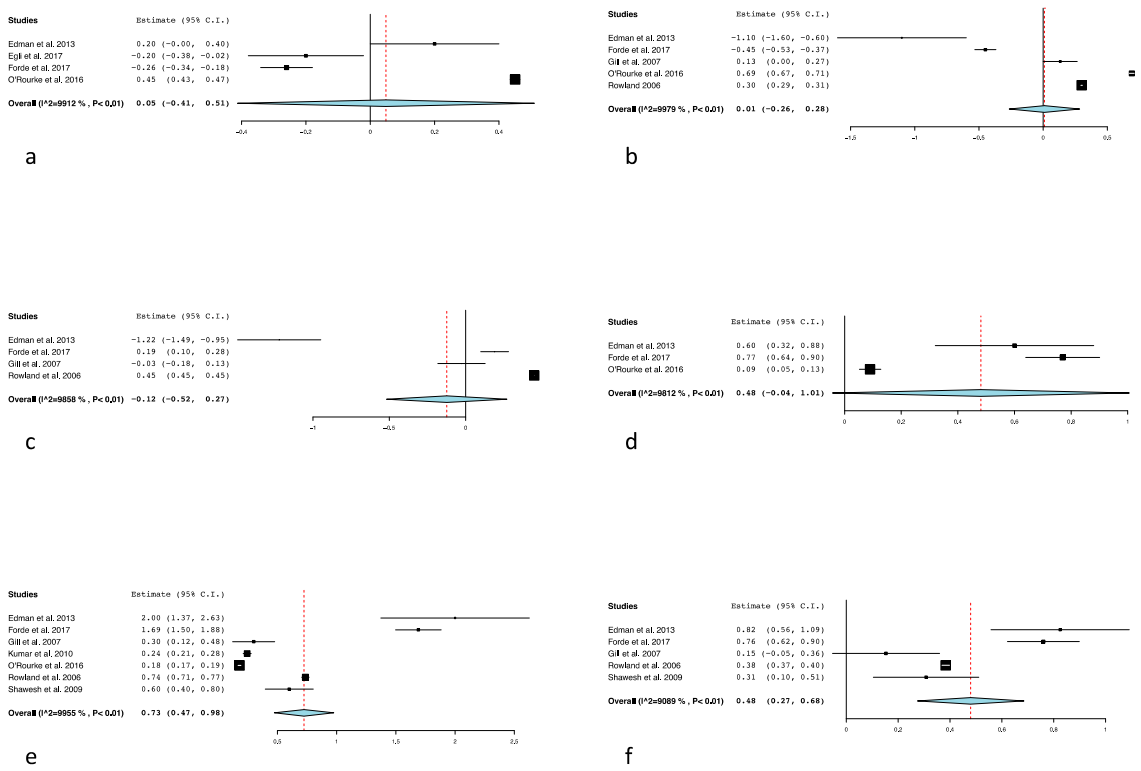

Figure 2. (**a**) Forest plot of the intercanine width modification: mandibular fixed retainers; (**b**) mandibular removable retainers; (**c**) maxillary removable retainers; (**d**) forest plot of the Little's Index modification: mandibular fixed retainers; (**e**) mandibular removable retainers; (**f**) maxillary removable retainers.

3.5. Fixed Retainer Failure Rate

Among the 11 studies included for qualitative synthesis, four RCTs [28,35–37] reported the failure rate of the fixed retainers during the observation period. The summarized failure rate was 41.3% (72/174) for the maxillary arch and 36.7% (115/313) for the mandibular arch (Table 4). Among the four studies, only one RCT had a high risk of bias [35]. For two RCTs, the risk of bias was unclear [36,37], and one RCT had a low risk of bias [28] (Table 3).

Table 4. Fixed retainer failure rate.

	Retainer Characteristics	Maxillary Arch	Mandibular Arch
Bolla et al. (2012)	Glass-Fiber reinforced	4/14 (28.5%)	7/34 (20.5%)
	Multistranded	7/18 (38.8%)	10/32 (31.2%)
Egli et al. (2017)	Direct Bonding	//	11/30 (37%)
	Indirect Bonding	//	13/30 (43%)
Salehi et al. (2013)	Polyethylene Woven Ribbon	27/74 (36.5%)	14/37 (37.8%)
	0.0175 in flexible spiral wire	34/68 (50%)	29/68 (42.6%)
Störmann et al. (2002)	0.0195 Respond®	//	10/30 (33.3%)
	0.0215 Respond®	//	18/36 (50%)
	Prefabricated 3 to 3	//	3/16 (18.7%)
Total		**72/174 (41.3%)**	**115/313 (36.7%)**

3.6. Assessment of Quality of Evidence

According to the GRADE [25], there was low level of evidence for all the LII outcomes (Table 5) and for the mandibular and maxillary intercanine width outcomes with both fixed and removable retainers (Table 6). According to the SORT approach [26], the strength of the recommendations was classified as A for LII and C for intercanine width (Table 7).

Table 5. Should fixed retainers or removable retainers be used for maintaining the alignment of anterior teeth?

Certainty Assessment							№ of Patients		Effect		Certainty	Importance
№ of Studies	**Study Design**	**Risk of Bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other Considerations**	**Fixed Retainers**	**Removable Retainers**	**Relative (95% CI)**	**Absolute (95% CI)**		
Mandibular Fixed												
3	randomised trials	not serious	very serious [a]	not serious	not serious	none	96	96	-	MD 0.48 higher (0.04 lower to 1 higher)	⨁⨁◯◯ LOW	CRITICAL
Mandibular Removable												
7	randomised trials	very serious [b]	very serious [a]	not serious	not serious	none	818	818	-	MD 0.72 higher (0.47 higher to 0.98 higher)	⨁◯◯◯ VERY LOW	CRITICAL
Maxillary Removable												
5	randomised trials	very serious [c]	very serious [a]	not serious	not serious	none	605	605	-	MD 0.8 higher (0.35 higher to 1.24 higher)	⨁◯◯◯ VERY LOW	CRITICAL
Acrylic Removable Retainers (mandibular)												
3	randomised trials	very serious [b]	very serious [a]	not serious	not serious	none	360	360	-	MD 1.08 higher (0.53 higher to 1.63 higher)	⨁◯◯◯ VERY LOW	CRITICAL
Vacum-Formed Removable Retainers (mandibular)												
5	randomised trials	serious [d]	very serious [a]	not serious	not serious	none	436	436	-	MD 0.51 higher (0.33 higher to 0.69 higher)	⨁◯◯◯ VERY LOW	CRITICAL

CI: Confidence interval; **MD:** Mean difference. (**a**) Heterogeneity > 75%; (**b**) in one study, the risk of bias was unclear for "Sequence generation", "Allocation concealment", "Selective Outcome Reporting", and "Other Risk of bias". In one study, the risk of bias was unclear for "Selective Outcome Reporting". In one study, the risk of bias was high for "Other Risk of bias"; (**c**) in one study the risk of bias was unclear for "Selective Outcome Reporting". In one study, the risk of bias was high for "Other Risk of bias"; (**d**) in one study, the risk of bias was unclear for "Sequence generation", "Allocation concealment", "Selective Outcome Reporting", and "Other Risk of bias". In one study, the risk of bias was unclear for "Selective Outcome Reporting".

Table 6. Should fixed retainers or removable retainers be used for maintaining intercanine width?

Certainty Assessment							№ of Patients		Effect		Certainty	Importance
№ of Studies	**Study Design**	**Risk of Bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other Considerations**	**Fixed Retainers**	**Removable Retainers**	**Relative (95% CI)**	**Absolute (95% CI)**		
Mandibular Fixed												
4	randomised trials	not serious	very serious [a]	not serious	not serious	none	126	126	-	MD 0.05 higher (0.41 lower to 0.51 higher)	⨁⨁◯◯ LOW	CRITICAL
Mandibular Removable												
5	randomised trials	not serious	very serious [a]	not serious	not serious	none	542	542	-	MD 0.01 higher (0.27 lower to 0.28 higher)	⨁⨁◯◯ LOW	CRITICAL
Maxillary Removable												
4	randomised trials	not serious	very serious [a]	not serious	not serious	none	553	553	-	MD 0.13 lower (0.52 lower to 0.27 higher)	⨁⨁◯◯ LOW	CRITICAL

CI: Confidence interval; **MD:** Mean difference. (**a**) Heterogeneity > 75%.

Table 7. Strength of recommendations for each outcome investigated in the present study.

Outcomes	Study Quality *	Consistency *	Strength of Recommendation *	Explanation
Intercanine width				
Mandibular fixed retainer	Level 3	Yes	C	Disease-oriented outcome Meta-analysis including 4 RCTs
Mandibular removable retainer	Level 3	Yes	C	Disease-oriented outcome Meta-analysis including 5 RCTs
Maxillary removable retainer	Level 3	Yes	C	Disease-oriented outcome Meta-analysis including 4 RCTs
Irregularity Index				
Mandibular fixed retainer	Level 1	Yes	A	Patient-oriented outcome Meta-analysis including 3 RCTs
Mandibular removable retainer	Level 1	Yes	A	Patient-oriented outcome Meta-analysis including 7 RCTs
Maxillary removable retainer	Level 1	Yes	A	Patient-oriented outcome Meta-analysis including 5 RCTs
Acrylic removable retainer	Level 1	Yes	A	Disease-oriented outcome Meta-analysis including 3 RCTs
Vacuum-Formed Removable retainer	Level 1	Yes	A	Disease-oriented outcome Meta-analysis including 5 RCTs

* Reports of the levels of study quality, consistency of measured outcomes, and strength of recommendations according to the Strength of Recommendation Taxonomy (SORT) system.

4. Discussion

To the best of our knowledge, this is the first review with meta-analysis that investigates the current literature with the best evidence (RCTs) on the efficacy of orthodontic retainers to maintain the occlusal results after fixed orthodontic treatment. The results of this meta-analysis will provide clinicians a quantitative evaluation of the efficacy of fixed and removable retainers and consequently a quantitative evaluation of orthodontic relapse during the retention period.

The pooled data show that the intercanine width does not change significantly during retention with all evaluated retention appliances [37–44].

The data show that the fixed retainers are also able to avoid significant modifications of LII ($p = 0.07$). However, this datum should be interpreted with caution because of the fewer number of considered trials. Conversely, the use of removable retainers showed a significant increase of LII. This datum was obtained by pooling the data from five trials for the maxillary arch (Figure 2f) and from seven trials for the mandibular arch (Figure 2e); it can be considered a consistent meta-analytic datum. The amount of variation for LII is 0.48 and 0.72 mm, respectively, for the maxillary and mandibular arch. This result clearly shows that, despite the use of a removable retainer appliance, the teeth of both arches present a small statistically significant (but clinically insignificant) alignment alteration. These results, especially for intercanine width, must be interpreted with caution due to the young age of the sample participants, as this type of alteration can influence the outcome due to residual growth and patient compliance.

Interestingly, our data show a significant alteration of LII in the absence of modification of the intercanine width. These results could be explained by interpreting the alteration of LII as a consequence of a single tooth rotational relapse, rather than a transversal inter-canine diameter relapse. The reported modifications of LII could be related to specific factors associated with the use of removable retainers, such as patient compliance and the limitations of using retainers nocturnally. This last hypothesis, however, does not seem to be supported by the evidence. Indeed, one of the considered RCTs compared

removable retainers used full time and removable retainers used part-time [45–55]. The authors did not find significant differences in terms of relapse after 12 months of retention.

Compliance is certainly an issue related to removable retainers. However, the results of this review clearly show that fixed retainers are not free of issues. In fact, the failure rate of fixed retainers (caused by wire breakage or bonding failure) is, on average, 41% and 36% for maxillary and mandibular retainers, respectively (Table 4). These data are in accordance with previously published data [14,56–61].

One limitation of this meta-analysis is the small number of included trials; this aspect affected the I2 index, undervaluing the extent of between-study heterogeneity [62,63]. The I2 values reported a high total variation across the studies, with a mean value and a standard deviation equal to 97.8% and 2.2%, respectively. This variation was assumed to be due to the clinical heterogeneity of the different appliances used in the considered RCTs. Moreover, the source of heterogeneity could be related to other factors such as patient compliance, final occlusal results, orthodontist expertise, type of malocclusion, and type of treatment (with or without extractions) [13,64–77].

The I2 values potentially affected the level of evidence of our findings, which ranged from very low to low, according to the GRADE approach. Although we selected only published trials offering the highest level of evidence (RCTs), the GRADE score showed that the included studies provided, in most cases, a very low quality of evidence (Tables 5 and 6). This result should be assessed while considering the difficulties in conducting RCTs for orthodontics [46].

All these aspects increased the heterogeneity of the different clinical trials and, consequently, contributed to limiting the methodological GRADE score of the orthodontic trials.

The SORT approach (Table 7) revealed a high strength of recommendations for the LII outcome and a poor strength of recommendations for the intercanine width outcome, likely because the LII represents a clinical outcome that directly affect smile aesthetics and appearance (i.e., a patient-oriented outcome).

The sensitivity analysis showed a similar outcome compared with the results of this meta-analysis for the same parameter (0.74) (95% Cl, 0.47 to 1.01; $P = 0.00001$; $I^2 = 100\%$), confirming the validity of the performed meta-analysis.

5. Conclusions

The results of this meta-analysis show that all the considered retainers are effective in maintaining dental alignment after fixed orthodontic treatment. However, the fixed retainers showed greater efficacy than the removable retainers.

The most important issues for fixed and removable retainers are, respectively, the risk of failure and patient compliance. Further RCT studies with longer observation periods are needed in order to assess the long-term efficacy of orthodontic retainers.

Supplementary Materials: The following are available online at http://www.mdpi.com/2076-3417/10/9/3107/s1, Table S1: Excluded articles with reason for exclusion. Figure S1: Sensitivity analysis.

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