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Analysis of the effectiveness of the fiber-reinforced composite lingual retainer: A systematic review and meta-analysis

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Introduction: Orthodontic fixed retainers are preferred as they depend less on patient compliance. Recently, researchers tried to use fiber-reinforced composite (FRC) to replace the multistranded stainless-steel wire (MSW) of the fixed retainers to enhance the mechanical properties and esthetics. This systematic review aimed to analyze the effectiveness of the FRC retainers. **Methods:** We searched the electronic databases (May 1, 2021), including Medline, the Cochrane Library, EMBASE, PubMed, Web of Science, and CINAHL. We applied no language or date restrictions in the searches of the databases. Only randomized controlled trials (RCTs) and prospective clinical controlled trials were included. The revised Cochrane risk of bias tool for randomized trials and risk of bias in nonrandomized studies of interventions were used to evaluate the risk of bias in RCTs and non-RCTs, respectively. The outcomes were pooled using Review Manager 5.4. The primary outcome of this review was teeth relapse, and the secondary outcomes were bonded retainer failure rate, adverse effect on oral health, and patient's satisfaction. **Results:** Eleven out of 99 studies, which included 873 participants, were used in this review, with the follow-up ranging from 6 months to 6 years. Ten studies compared the FRC retainers with MSW retainers, and 1 study compared FRC retainers with a different fiber material. Ten studies were RCT, and 1 was non-RCT. There was 0.39 less relapse with the FRC retainers than with MSW retainers (mean difference, -0.39 ; 95% confidence interval [CI], -0.41 to -0.37 ; $P < 0.00001$). There was no statistically significant difference in the failure rate between the FRC and MSW with the whole retainer as an outcome unit risk ratio of 1.72 (95% CI, 0.57-5.14; $P = 0.33$) or with the teeth as an outcome unit risk ratio of 0.85 (95% CI, 0.47-1.52; $P = 0.58$). There was insufficient evidence to conduct the meta-analysis of the adverse effect on oral health and patient satisfaction. **Conclusions:** Low-quality evidence is available to suggest that the effectiveness of the FRC is comparable to the MSW with no significant difference in the failure rate. However, we have very low certainty on these results. It is worth conducting future robust clinical studies to assess the effectiveness of FRC retainers with long follow-up. (Am J Orthod Dentofacial Orthop 2022; ■: ■-■)

Orthodontic treatment is prone to instability and the possibility of posttreatment dental change. Retainers are essential in preventing this trend after orthodontic treatment,¹ and they can stabilize

teeth in their new position, but it can be impossible to avoid tooth movement completely. During the retention phase, some tooth movement can be beneficial, which allows for a gradual increase in occlusal contacts; this leads to occlusal settling, which can improve the stability of the dentition.² One of the key domains for posttreatment dental change is the mandibular anterior teeth; Reidel³ suggested maintaining arch form as it cannot be permanently changed by orthodontic appliance therapy. Little⁴ analyzed 600 sets of patient records for >35 years and concluded that regardless of whether the arch was expanded during treatment, the mandibular intercanine width decreased. Furthermore, the crowding of the mandibular anterior teeth is persistent and unpredictable. Therefore, it is also recommended that retainers

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be worn for life.⁵ Commonly used retainers can be categorized into removable and fixed retainers. Fixed retainers are becoming more popular because of their low speech impact and esthetic appeal. More importantly, it is easy to wear for life and requires less compliance.⁶

Initially, fixed retainers were constructed from plain round or rectangular orthodontic wires.⁷ Zachrisson^{8,9} proposed using multistranded wire to prepare fixed retainers, which were then bonded to the lingual surface of all anterior teeth. Then, many researchers improved the fabrication of retainers by using wires of different diameters or materials and using resin fiberglass strips.¹⁰ Multistranded stainless-steel wire (MSW) retainers have sufficient mechanical strength but are still flexible enough to allow physiological movement of the tooth. However, stainless-steel fixed retainers are complex to fabricate and need to be completely passively bonded to the tooth to prevent unwanted teeth movement under force. In addition, deformation of the wire can cause the tooth to move, and bonding failure leads to the loss of the retainer. In addition, it can increase the potential for plaque and calculus accumulation compared with removable retainers.¹¹

With the advancement of dental materials, fiber-reinforced composite (FRC) lingual retainers have received more attention in recent years.¹² They are more esthetically pleasing, have good mechanical properties, and can be placed in the mouth for life.^{13,14} In addition, FRC retainers can be used for patients with nickel allergies. It consists mainly of a resin matrix and reinforcing fibers. Currently, the main addition to common FRC retainers is glass fiber, the main component of which is amorphous silica with a homogeneous structure. Commonly used glass fibers can be divided into E glass fibers and S glass fibers. The latter are stronger and offer greater stiffness and resistance to plastic deformation. In addition, commercially available Ultra High Molecular Weight Polyethylene fiber resin lingual fixed retainers have a dense structure, high specific strength, and specific modulus and are chemically inert. The performance of FRC fixed retainers is closely related to the matrix, the type of fiber, and the fiber content. However, because of their high rigidity, they can restrict the physiological movement of the tooth and lead to ankylosis.^{15,16} To address this disadvantage, spot bonding techniques have been proposed, which reduce the rigidity without compromising the mechanical properties.¹⁷

Studies in recent years have reported varying failure rates of FRC lingual retainers,¹⁸⁻²² which led to different views on using FRC retainers. Animal studies also reported the adverse effect of FRC lingual retainers on periodontal health.¹⁶ Previous systematic

reviews have assessed the effectiveness and adverse effects of different fixed retainers.²³⁻²⁹ However, there is still no comprehensive evaluation of FRC retainers.

OBJECTIVES

This systematic review aimed to evaluate the effectiveness, failure rate, impact on oral health, and patient satisfaction of FRC retainers for orthodontic retention.

MATERIAL AND METHODS

Protocol and registration

The protocol of this review was registered on PROSPERO (CRD42021246603).

Eligibility criteria

The following selection criteria were applied for the review.

1. Study design: randomized controlled trials (RCTs) and prospective controlled clinical trials.
2. Participants: patients with fixed lingual retainers after orthodontic treatment. Exclusion criteria included patients treated with orthognathic surgery, patients with cleft lip or palate or another craniofacial deformity/syndrome, active periodontal disease, or gingival recession.
3. Intervention: FRC fixed retainer.
4. Control: any fixed retainers irrespective of the wire type, bonding materials, and the number of teeth bonded.
5. Outcome measures: the main outcome measure was relapse. Secondary outcome measures include failure of retainer, adverse effects on oral health, and patient satisfaction.

In the posttreatment dental change, the movement of teeth is the most important and easiest to measure; therefore, the main outcome was determined to be the postmovement teeth movement, usually called relapse. The outcome measure of relapse was done using Little's irregularity index (LII). LII was originally devised as a means of objectively scoring mandibular incisor alignment. Its traditional application involves horizontal linear measurement of the displacement of the anatomic contact points of each mandibular incisor from the adjacent tooth anatomic point, representing the relative degree of anterior irregularity; The sum represents the relative degree of irregularity.^{30,31} Now, LII can be used to maxillary and mandibular.³²⁻³⁴

Assessment of retainer failure was done by measuring the number of retainers that exhibited the following: (1) bonded retainer partial loosening or completely

detached from the teeth,^{18-21,35-37} (2) bonded retainer fractured or distortion,^{20,35-37} and (3) orthodontic relapse of any retained teeth.³⁷

The outcome measure of patient satisfaction was done using a visual analog scale,¹⁸ which can measure an attitude that is believed to range across a continuum of values. Patients generally completed it by remarking on what they liked and the points they believed represented their perception. The score is measured in millimeters from the left-hand end of the line to the point the patient marks.

Information sources, search strategy, and study selection

Detailed search strategies were developed for each database. They were based on the search strategies developed for Medline but modified appropriately for each database to take account of differences in controlled vocabulary and syntax rules. The Medline subject search used a combination of controlled vocabulary and free-text terms.

Databases searched. The following databases were searched: (1) Medline (Supplementary Table I), (2) The Cochrane Library (Supplementary Table II), (3) Embase (Supplementary Table III), (4) PubMed (Supplementary Table IV), (5) Web of Science (Supplementary Table V), and (6) CINAHL (Supplementary Table VI).

There were no restrictions on language or date of publication in the searches of the electronic databases.

In addition, the bibliographies of papers and review articles identified were checked. When we came across information not mentioned in the article but relevant to our research topic, we contacted the first author to obtain the data.

Study selection, assessment of the risk of bias, and data extraction were made independently by the authors (S.L and A.E). Any disagreements were discussed between the 2 authors; however, further disagreement was resolved by discussion with a third author (N.S). We contacted the authors directly and categorized the study as awaiting assessment if more information was required.

Data items and collection

We extracted and entered data into a customized data collection form designed especially for this review. We recorded the following: author and year of study, a summary of the study design, participants (sample size and age), intervention (type of retainer, dimensions of wire, no. of teeth bonded), observation period (follow-up of patients), and outcomes.

Risk of bias/quality assessment in individual studies

Two review authors (S.L and A.E) independently conducted a risk of bias assessment for each of the included studies as specified in the Cochrane Handbook.³⁸ During this process, the negotiation was made to resolve the dispute in case of a conflict.

The revised Cochrane risk of bias tool for randomized trials was used for a randomized clinical trial.³⁹ Based on this tool, 7 domains were assessed: sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other sources of bias. Each domain includes ≥ 1 specific entries in the table. We graded studies into the following categories: (1) low risk of bias (plausible bias that is unlikely to alter the results seriously) if all domains were at low risk of bias, (2) high risk of bias (plausible bias that seriously weakens confidence in the results) if ≥ 1 domains were at a high risk of bias, (3) unclear risk of bias (plausible bias that raises some doubt about the results) if ≥ 1 domains were at unclear risk of bias.

For nonrandomized clinical trials, a risk of bias assessment was performed using the Cochrane Collaboration risk of bias in nonrandomized studies of interventions tool⁴⁰ according to the recommendation of the Cochrane Handbook. The tool also contains 7 domains and assesses bias because of confounding, bias in the selection of participants, bias in classification of interventions, bias because of deviations from intended interventions, bias because of missing data, bias in the measurement of the outcome, and bias in the selection of the reported result. We graded studies into the following categories: (1) low risk of bias, if all domains were at low risk of bias; (2) moderate risk of bias, if all domains were at low or moderate risk of bias; (3) serious risk of bias, if ≥ 1 domains were at serious risk but not at critical risk of bias in any domain; and (4) critical risk of bias, if ≥ 1 domains were at critical risk of bias.

Summary measures and approach to synthesis

For studies considered eligible for this review, we used the following Cochrane guideline-compliant analyses. We expressed estimates of intervention effects for dichotomous outcomes as risk ratios (RR) and 95% confidence intervals (CI). For continuous outcomes, mean differences (MD) and 95% CIs were used to summarise the data from each study. Meta-analyses were only performed if at least 2 studies of low or unclear risk were reported, reporting similar comparisons with similar outcomes. Meta-analysis was performed via

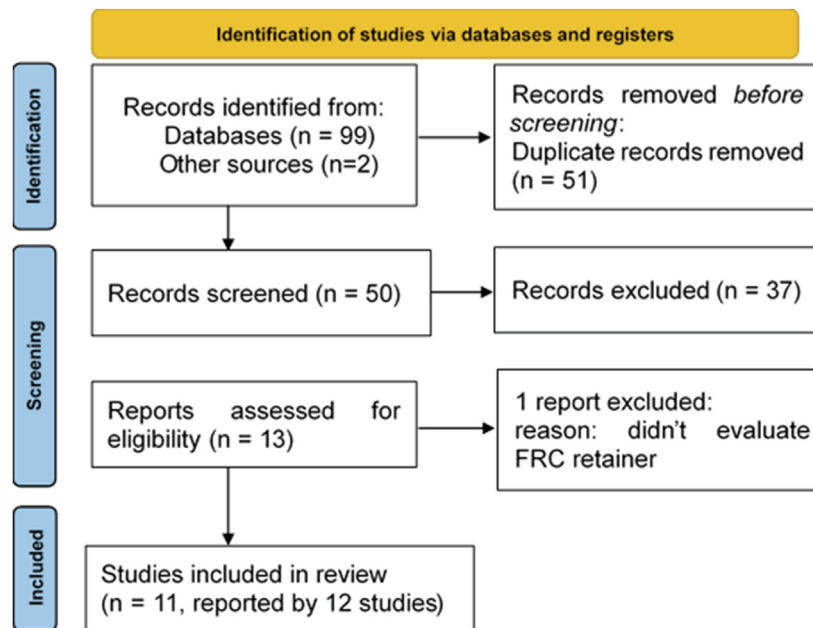


Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses study flow chart.

RevMan software (version 5.3; Nordic Cochrane Centre, Cochrane Collaboration, Copenhagen, Denmark).

Risk of bias across studies

In this review, we attempt to minimize potential reporting bias, including publication bias, repeat publication bias, and language bias. If there were >6 trials in any meta-analysis, we assessed publication bias on the basis of the recommendations described in Higgins³⁸ regarding the funnel plot asymmetry test. If we found asymmetry, we examined the possible causes.

Additional analyses

We assessed the significance of any discrepancies in each pooled result across trials by using χ^2 test and considered heterogeneity significant if the P value was <0.1. We used the I^2 statistic to quantify heterogeneity: an I^2 of 0%-40% might not be important; 30%-60% may represent moderate heterogeneity, 50%-90% may represent substantial heterogeneity, and 75%-100% considerable heterogeneity. A fixed-effects model will be used if $P \geq 0.1$ and $I^2 \leq 50\%$. Random-effect models will be applied if $P < 0.1$ or $I^2 > 50\%$. If heterogeneity were identified, the sources of heterogeneity would also be evaluated through sensitivity analysis.

Grading the quality of evidence

The Grading of Recommendations Assessment, Development, and Evaluation was used to assess

confidence in cumulative evidence. The risk of publication, heterogeneity, indirectness, imprecision, and publication bias was assessed, and the results were divided into 4 levels: high, moderate, low, and very low.⁴¹

RESULTS

Study selection and characteristics

The database search in May 2021 identified 99 articles, and 2 additional articles were identified from additional sources. Of these, 51 were duplicates. Of the remaining 50 articles, 37 were discarded with title and abstract screening. The full text of the remaining 13 articles was then assessed. We excluded 1 study as it was not related to FRC retainers. The remaining 12 articles reported findings from 11 studies (Fig 1). Two articles reported on the same study.^{21,42} Therefore, 11 studies with 873 participants were considered eligible for inclusion in this review (Table I). Out of the 11 studies, 10 were RCTs^{18-22,35,36,42-45} and 1 prospective controlled study.³⁷ Nine studies were 2-arm trials, and 2 were 3-arm trials.^{20,36}

A total of 873 participants were recruited in the 11 included studies, with the sample size ranging from as low as 20 participants²² to as high as 184 participants.³⁶ The studies were undertaken on children and adults. The mean age of participants was ≤ 18 years in 4 studies,^{18,20,22,36} the mean age was >18 years in 5 studies,^{19,21,35,42,44,45} and 2 studies did not state the mean age of the participants.^{37,43}

Table I. Characteristics of included studies of the systematic review

Study	Study design	Observation period	Participants	Interventions	Outcomes
Ardeshna (2011) ³⁷	Prospective controlled clinical trial	Maximum 2 y, on a rolling basis over 3 y	51 patients	Maxilla: FRP formula A, 0.53 mm (n = 1) FRP formula A, 1.02 mm (n = 1) FRP formula B, 0.53 mm (n = 6) FRP formula B, 1.02 mm (n = 8) Mandible: FRP formula A, 0.53 mm (n = 15) FRP formula A, 1.02 mm (n = 6) FRP formula B, 0.53 mm (n = 10) FRP formula B, 1.02 mm (n = 29)	Retainer failure
Tacke et al (2010) ³⁶	Multicenter RCT study	2 y (follow-up: every 6 mo)	184 patients (90 males, 94 females), 22 were lost to follow-up	Glass fiber-reinforced (GFR500) Maxilla: lateral incisor to lateral incisor (n = 45) Mandible: canine-to-canine (n = 45) Glass fiber-reinforced (GFR1000) Maxilla: lateral incisor to lateral incisor (n = 48) Mandible: canine-to-canine (n = 48) 6-stranded coaxial wire, 0.0215-in Maxilla: lateral incisor to lateral incisor (n = 91) Mandible: canine-to-canine (n=91)	Success rate, modified gingival index, bleeding on probing, plaque index
Scribante et al (2011) ¹⁸	Parallel-group RCT	12 mo (follow-up at 30, 60, 120, 180, 360 d)	34 patients (9 males, 25 females)	Multistranded Stainless steel 0.0175-in Mandible: canine-to-canine (n = 17) Polyethylene ribbon-reinforced resin composite Mandible: canine-to-canine (n = 15)	Bond failure, visual analog scale (VAS)
Bolla et al (2012) ³⁵	Parallel-group RCT	3 y (follow-up: every 3 mo)	85 patients (29 males, 56 females)	Glass fiber-reinforced Maxilla: all incisors (n = 14); Mandible: canine-to-canine (n = 34) Multistranded wire, 0.0175-in Maxilla: all incisors (n = 18); Mandible: canine-to-canine (n = 32)	Bond failure, retainer fracture
Sfondrini et al (2014) ¹⁹	Parallel-group RCT	12 mo	87 patients (52 females, 35 males)	Glass fiber-reinforced Mandible: canine-to-canine (n = 40) Multistranded wire 0.0175 in Mandible: canine-to-canine (n = 47)	Bond failure
Torkan et al (2014) ²²	Parallel-group RCT	6 mo	40 patients: only 30 were analyzed (20 females, 10 males), 10 were withdrawn because of missed their final appointment or breakage was diagnosed along the retainer	Fiber-reinforced resin composite Maxilla: canine-to-canine (n = 15) Mandible: canine-to-canine (n = 15) MSW 0.0175-in Maxilla: canine-to-canine (n = 15) Mandible: canine-to-canine (n = 15)	Plaque index, calculus index, gingival index, bleeding on probing, periodontal ligament width

Table I. Continued

Study	Study design	Observation period	Participants	Interventions	Outcomes
Sobouti et al (2016) ²⁰	Prospective RCT	>2 y (follow-up: every mo)	150 patients: only 128 were analysed (68 females, 60 males), 22 were lost to follow-up	Flexible spiral wire 0.0175-in Mandible: canine-to-canine (n = 42) FRC splint Mandible: canine-to-canine (n = 41) Twisted wire 0.009-in Mandible: canine-to-canine (n = 45)	Bond failure
Nagani et al (2020) ²¹	Parallel-group RCT	12 mo (follow-up: every 3 mo)	54 patients: only 52 were analysed (44 females, 8 males), 2 were lost to follow-up	FRC retainers; Mandible: canine-to-canine (n = 26) MSW retainers 0.0175-in Mandible: canine-to-canine (n = 26);	LII, retainer failure, adhesive remnant index
Liu (2010) ⁴³	Parallel-group RCT	12 mo (follow-up at 0, 6, and 12 mo)	60 patients	FRC Mandible: canine-to-canine (n = 30) Multistrand stainless-steel wire Mandible: canine-to-canine (n = 30)	Bleeding index, pocket depth, bond failure, flexural modulus, maximum shear bond strength
Saleh et al (2013) ⁴⁴	Parallel-group RCT	18 mo (follow-up: every 3 mo)	156 patients: only 142 were analyzed (83 females, 59 males), 14 were lost to follow-up	Polyethylene woven ribbon Maxilla: canine-to-canine (n = 68) Mandible: canine-to-canine (n = 68) MSW retainers 0.0175-in Maxilla: canine-to-canine (n = 74) Mandible: canine-to-canine (n = 74)	Retainer failure
Rose et al (2002) ⁴⁵	Prospective RCT	24 mo (follow-up: every 3 mo)	20 patients (8 females, 12 males)	Polyethylene woven ribbon Mandible: canine-to-canine (n = 10) MSW retainers 0.0175-in Mandible: canine-to-canine (n = 10)	Retainer failure

Three studies were based in Italy,^{18,19,35} 3 were in Iran,^{20,22,44} 1 in China,⁴³ 1 in Pakistan,^{21,42} 1 in Belgium,³⁶ 1 in Germany,⁴⁵ and 1 in the United States.³⁷ Ten studies were carried out in the university hospital,^{18-22,36,37,42-45} and 1 study was not clear where it was conducted.³⁵

With the data available, it was possible to analyze the following outcomes: (1) posttreatment dental change by measuring the amount of relapse,⁴² (2) failure⁴² of retainers,^{18-21,35-37,44,45} (3) adverse effects on oral health,^{22,36,43} and participant satisfaction.¹⁸

Adverse effects on oral health were^{22,36,43,18} assessed using the following markers: plaque index,^{22,36} calculus index,²² gingival index,^{22,36} bleeding on probing,^{22,36} periodontal ligament width,²² bleeding²² index,⁴³ and pocket depth.⁴³

Risk of bias within studies

We have presented our risk of bias judgments separately for RCTs (Figs 2 and 3) and non-RCTs (Table II). After assessing the 10 RCT studies, we rated 1 study as at low risk of bias,^{21,42} 4 studies as high risk of bias,^{18,22,36,43} and 5 studies at unclear risk of bias.^{19,20,35,44,45} The non-RCT study³⁷ was rated as high risk of bias.

For the included RCTs, 1 study used an approach with a high risk of bias sequence generation.³⁶ Although in 5 studies,^{18,19,35,36,44,45} it is unclear how the sequence generation and allocation were performed. They were therefore rated as unclear risk or high risk in the domain of the randomization process. Blinding of operators who placed the retainers was considered impossible because

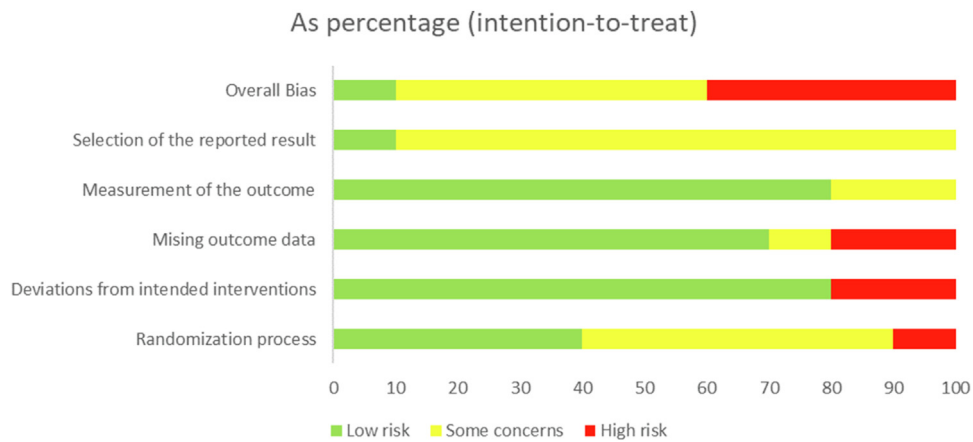


Fig 2. Risk of bias graph: review authors' judgments about each risk of bias item presented as percentages.

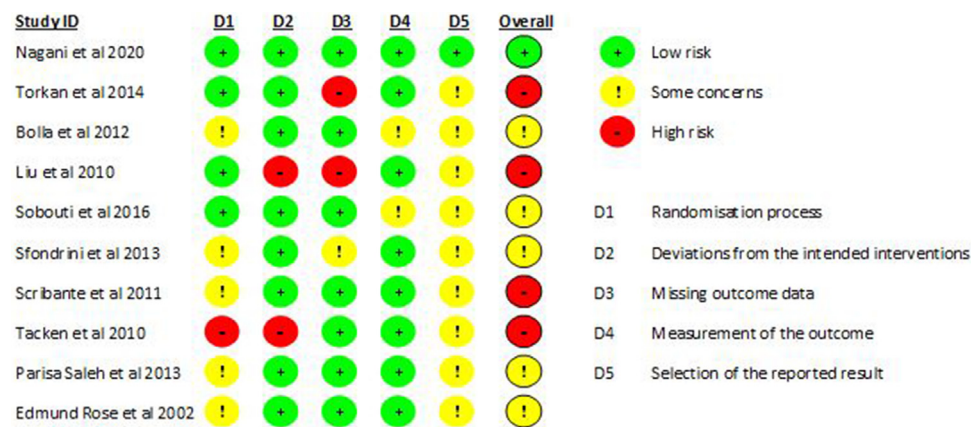


Fig 3. Risk of bias summary: review authors' judgments about each risk of bias item for each included study.

Table II. Risk of bias tables for non-RCTs[†] (judged with ROBINS-1)

Bias	Authors' judgment	Support for judgment
Bias because of confounding	High	Seldom methods were used to control confounding
Bias in the selection of participants for the study	Low	The study was on a rolling basis, and the start of follow-up and start of intervention coincided for every participant
Bias in the classification of interventions	Low	The classification of interventions is clear
Bias because of deviations from intended intervention	No Information	There were no deviations in the intervention mentioned
Bias because of missing data	High	Missing data (10%) and all the missing data were from group 1
Bias in the measurement of outcomes	Low	The definition of outcome is clear
Bias in the selection of the reported result	Low	The outcome measurements and analyses are clearly defined, and there is no indication of selection of the reported analysis from among multiple analyses
The overall risk of bias	High	

Note. Source: Ardeshta (2009).³⁷

[†]Judged with risk of bias in nonrandomized studies of interventions.

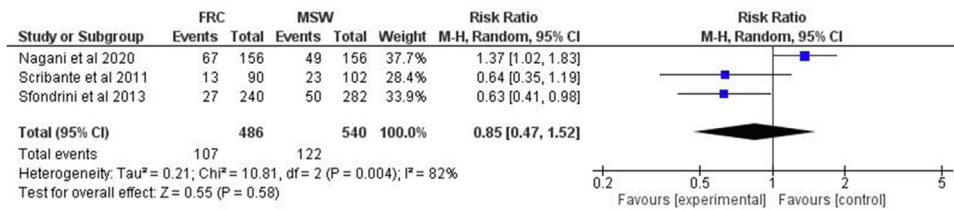


Fig 4. Comparison 1.2 failure of FRC retainers vs MSW retainers, teeth as outcome unit.

the appearance of different types of retainers varies greatly. It was also impossible for the assessors who assessed bonding failure to be blinded. Nevertheless, the outcome of bond failure was not easily open to manipulation, limiting the potential problems of deviations from intended interventions. However, 1 study²² assessed periodontal health explicitly mentioned attempts to blind the assessors. Blinding of participants was not mentioned in any reports; however, it is understandable that this can be difficult to apply.

Four studies reported an unclear risk of missing outcome data.^{19,22,43,44} The trial registration of 8 studies^{18-20,35,36,43-45} could not be found, indicating an unclear bias risk in the reported result.

For the non-RCT study, insufficient measures were used to control for confounding, no trial registration was found, and too many missing data made it subject to a high risk of bias.

Comparison of FRC retainers and MSW retainers

Ten studies compared FRC retainers with MSW retainers. Eight studies compared FRC retainers and 0.0175-in MSW retainers,^{18-22,35,43-45} 1 study compared FRC retainers and 0.0215-in MSW retainers,³⁶ and 1 study compared FRC retainers with 0.0175-in MSW retainers and 0.009-in twisted wire.²⁰ Of the 8 studies, 3 studies used polyethylene fiber as reinforced fiber,^{18,44,45} and 3 studies used glass fiber,^{19,35,36} and 2 did not report the composition of fiber they used. Three studies compared maxillary and mandibular retainers,^{22,35} and 5 only compared mandibular retainers.^{18-21,42,43}

Relapse. One trial rated as low risk of bias used LII to compare the relapse tendency of the mandibular incisor.⁴² The follow-up period was 12 months, and the LII was measured at 3, 6, 9, and 12 months. Irregularities increased in both groups as the follow-up time increased, and the difference also became greater. After 12-month insertion, there was a statistically significant less relapse with the FRC retainers than with MSW retainers (MD, -0.39 ; 95% CI, -0.41 to -0.37 ; $P < 0.00001$).

Failure of retainers. Eight studies reported on the failure of bonded retainers.^{18-21,35,36,42,44,45} One study was rated as low risk of bias,^{21,42} 5 studies had an unclear risk of bias,^{19,20,35,44,45} and 2 studies were rated as a high risk of bias.^{18,36} Three studies compared polyethylene fiber-reinforced resin with MSW, and^{18,44,45} 3 studies compared glass fiber-reinforced with MSW.^{19,35,36} Two studies did not report the composition of fiber they used,^{20,21,42}; in these 2 studies, 1 study compared FRC retainers with twisted retainers.²⁰ Two studies compared maxillary and mandibular retainers,^{35,36} the remaining 4 compared mandibular retainers only. Three studies documented failure of individual teeth,^{18,19,21,42} and 5 studies used retainers as the unit of analysis.^{20,35,36,44,45}

In the 3 studies which used individual teeth as an outcome unit, the detachment of the number of teeth was recorded.^{18,19,21,42} Of the 3 studies, 1 had a low risk of bias,^{21,42} 1 had an unclear risk of bias,¹⁹ and 1 had a high risk of bias.¹⁸ All 3 studies reported on the mandibular retainers only, and the follow-up period was 12 months. The pooled estimate showed an RR of 0.85 (95% CI, 0.47-1.52; $P = 0.58$), indicating no statistically significant difference in the failure rates. There was high statistical heterogeneity between the studies ($P = 0.004$; $I^2 = 82\%$) (Fig 4). We conducted a subgroup analysis on the basis of the fiber type used in FRC. The result indicated that when grouped by fiber type, there is also no statistically significant difference in failure rate: polyethylene fiber-reinforced retainer (RR, 0.64; 95% CI, 0.35-1.19), common FRC retainer (RR, 0.95; 95% CI, 0.44-2.03) (Fig 5). When trials with a high risk of bias were removed, the results remained statistically insignificant and highly heterogeneous (RR, 0.95; 95% CI, 0.44-2.03; $P = 0.004$ and $I^2 = 88\%$) (Fig 6).

Different adhesive systems may also affect failure rates, so subgroup analyses were carried out. The adhesive system 1 applied the adhesive primer (3M ESPE, Seefeld, Germany) after etching, then cured for 15 seconds, and applied flowable composite resin (3M ESPE), then adapted the fiber ribbon and cured for 15 seconds. The adhesive system 2 located the retainers on teeth and

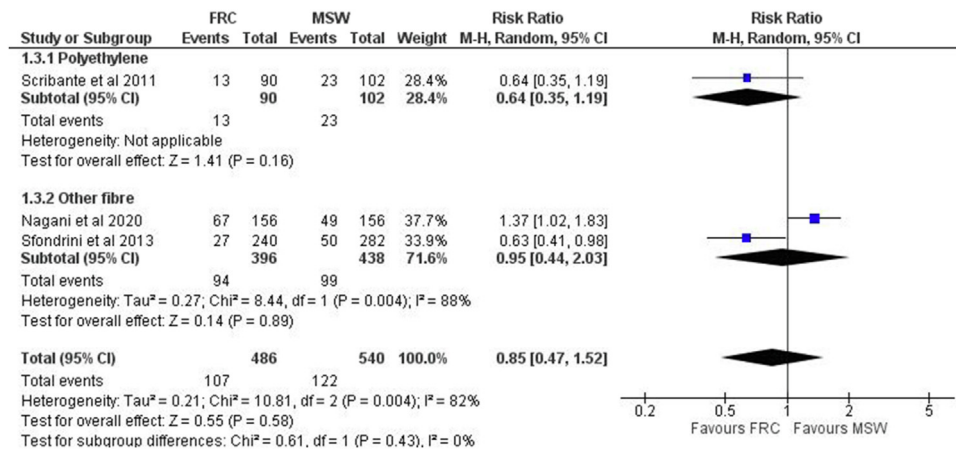


Fig 5. Comparison 1.3 failure of FRC retainers vs MSW retainers, subgroup analysis based on fiber type of studies with teeth as outcome unit.

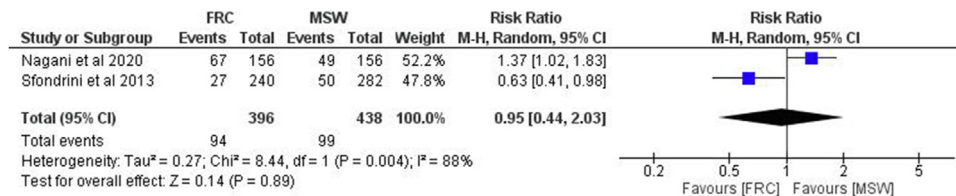


Fig 6. Comparison 1.4 failure of FRC retainers vs MSW retainers, removed studies with high risk of bias.

applied the Trasbond XT Primer (3M Unitek, Monrovia, Calif) after etching, then cured for 20 seconds; placed Trasbond XT Resin (3M Unitek) and cured for 40 seconds. When using adhesive system 1, the FRC group showed a statistically significant higher failure rate (RR, 1.37; 95% CI, 1.02-1.83; $P = 0.04$). However, when using adhesive system 2, there was a statistically significant difference with more failure in the MSW group (RR, 0.64; 95% CI, 0.45 to -0.91; $P = 0.01$) (Fig 7).

The breakage and detachment of retainers were recorded in the 5 studies that used the whole retainer as an outcome unit. Of the 5 studies, 4 were rated as unclear risk of bias,^{20,35,44,45} and 1 was rated as high risk of bias.³⁶ The follow-up period ranged from 18 months to 72 months. The pooled estimate (including both the maxilla and mandible) showed an RR of 1.76 (95% CI, 0.86-3.58; $P = 0.12$), indicating no statistically significant difference in the failure rates. There was high heterogeneity between the studies ($P < 0.00001$; $I^2 = 88\%$) (Fig 8). When trial with a high risk of bias were removed, the results remained statistically insignificant (RR 1.23, 95% CI 0.80 to 1.90; P value = 0.35), but heterogeneity changed to moderate heterogeneity

($P = 0.10$; $I^2 = 52\%$) (Fig 9). Therefore, the trial of Tacke et al³⁶ was hypothesized to be the source of heterogeneity, and we excluded it in subsequent subgroup studies. Subgroup analysis was done on the basis of grouping according to wire dimension in the control group; the 0.019-in wire groups showed no difference in the failure rates between the 2 retainer groups (RR, 2.01; 95% CI, 0.95-4.24; $P = 0.07$) and 0.0175-in (RR, 1.19; 95% CI, 0.94-1.50; $P = 0.15$) (Fig 10). In another subgroup analysis, the results for the mandible (RR, 1.23; 95% CI, 0.91-3.82; $P = 1.66$) and maxilla (RR, 1.25; 95% CI, 0.87-1.78; $P = 0.22$) showed no difference in the failure rate of 2 retainers groups (Fig 11).

Adverse effects on oral health. Three studies rated as high risk of bias reported the adverse effect of retainers on oral health.^{22,36,43} The follow-up period ranged from 6 months to 24 months. Torkan et al²² reported both the FRC and MSW groups showed deterioration in periodontal status after 6 months, but the calculus index and bleeding on probing were significantly worse in the FRC group. Liu et al⁴³ showed that the gingival bleeding index was significantly higher in both the FRC and MSW groups after 6 and 12 months of bonding, whereas the differences in periodontal probing depth

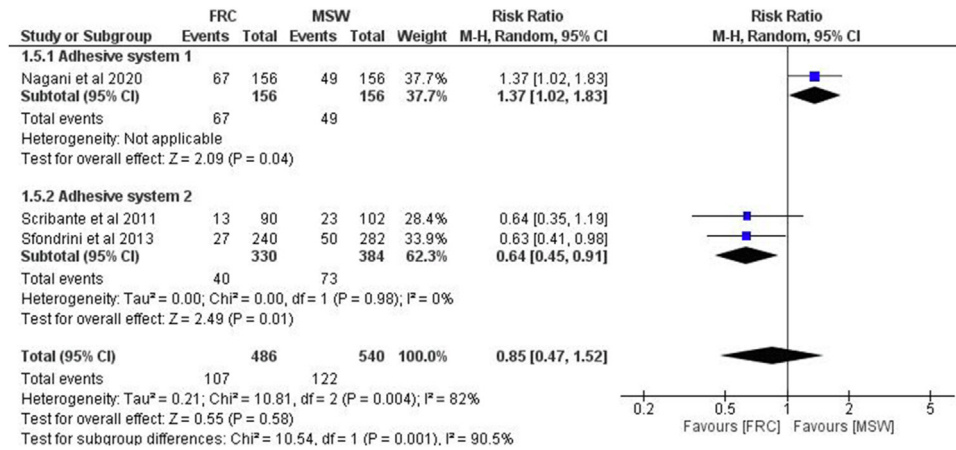


Fig 7. Comparison 1.5 failure of FRC retainers vs MSW retainers, subgroup analysis based on adhesive system with teeth as outcome unit, removed study with high risk of bias.

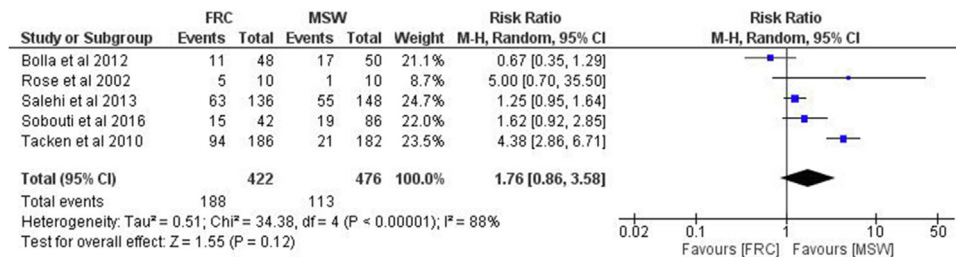


Fig 8. Comparison 1.6 failure of FRC retainers vs FSW retainers, retainer as outcome unit.

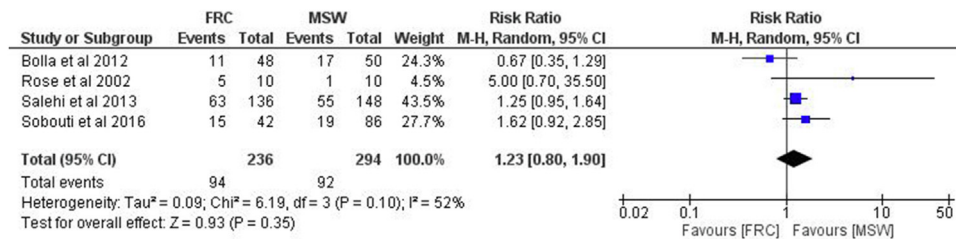


Fig 9. Comparison 1.7 failure of FRC retainers vs FSW retainers, retainer as outcome unit, removed study with high risk of bias.

and gingival bleeding index between the 2 groups were not statistically significant. Tackén et al³⁶ reported that the gingival index and bleeding on probing of FRC groups were significantly higher than the MSW group; however, there was no statistically significant difference in plaque index between the 2 groups. All 3 studies did not publish enough data to calculate the mean difference, and it was impossible to poll the result into a forest plot. Unfortunately, the authors did not respond to our queries about the data.

Patient satisfaction. One RCT study rated a high risk of bias reported on patient satisfaction using a visual analog scale.¹⁸ The follow-up period was 12 months. There was a statistically significant difference in patient satisfaction between the 2 retainers groups, with the participants finding the polyethylene ribbon-reinforced resin retainers more acceptable to wear (MD, 1.49; 95% CI, 0.80–2.18; P < 0.0001). The meta-analysis could not be done because only 1 study reported this outcome.

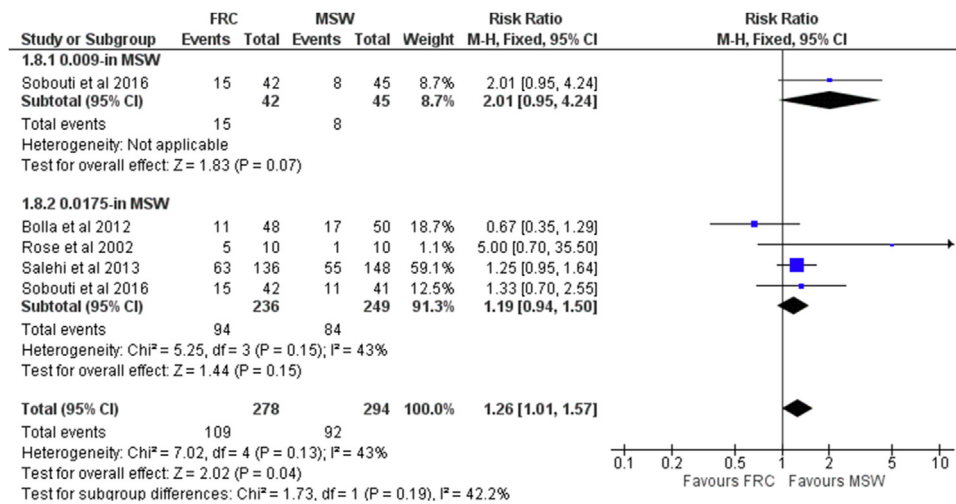


Fig 10. Comparison 1.8 failure of FRC retainers vs MSW retainers, subgroup analysis based on wire dimension of studies with retainer as outcome unit.

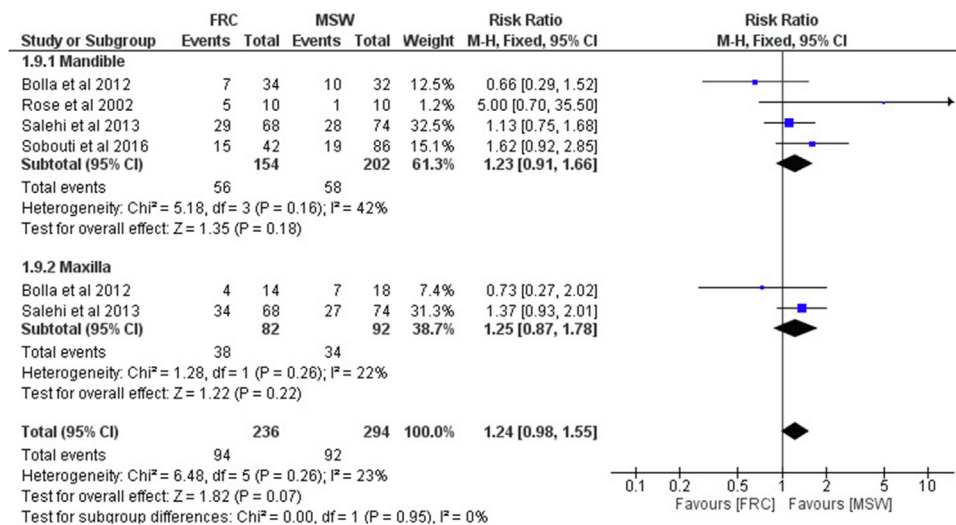


Fig 11. Comparison 1.9 failure of FRC retainers vs MSW retainers, subgroup analysis based on placement of studies with retainer as outcome unit.

Comparison of FRC retainers with a different formula

One non-RCT study with a high risk of bias compared the FRC retainers of 2 different formulas.³⁷ The recruitment was on a rolling basis over 3 years. Formulation A was composed of E fiberglass and 6 thermoplastic resins—polyethylene terephthalate glycol with the glass transition temperature at 74°C and a clinical forming temperature range from 105°C to 135°C. Formulation B was composed of S3 fiberglass and polycarbonate

with the glass transition temperature at 140°C and a clinical forming temperature range from 170°C to 200°C.

Relapse. Relapse was not reported.

Failure of retainers. Ardeshtna³⁷ (non-RCT) reported a statistically significant increase in the failures in the formula A group compared with the formula B group (RR, 1.58; 95% CI, 1.25–2.00; $P = 0.0001$). The meta-analysis was deemed impossible because only 1 study reported this outcome.

Adverse effects on oral health. Adverse effects on health were not reported.

Patient satisfaction. Patient satisfaction was not reported.

Risk of bias across studies

Tests for publication bias were not undertaken as ≤ 6 studies were included in an individual meta-analysis.

DISCUSSION

Comparison of FRC retainers and MSW retainers

This systematic review found limited evidence to endorse using FRC retainer on the basis of the stability and failure rate. In this respect, the results of the present systematic review are in line with previous systematic reviews.^{25,28} However, in terms of periodontal health, this systematic review has weak evidence expressing concern about the adverse effects of FRC retainers on periodontal health. This systematic review is the first to evaluate patient satisfaction with FRC retainers and found weak evidence to support a patient preference.

We found limited evidence with low certainty to suggest that FRC retainers allow less relapse during retention than MSW retainers (MD, -0.39 ; 95% CI, -0.41 to -0.37 ; $P < 0.00001$). This is based on only 1 study which assessed relapse in the mandibular arch. The small sample size of this study also reduces its credibility. More rigorous studies and larger sample sizes are needed to confirm this difference. It was noted that with increased follow-up duration, the difference between the 2 groups also increased. This suggests that future studies may require longer follow-ups to demonstrate the long-term effectiveness of the retainer.

We found weak evidence from 8 studies comparing failure rates of the 2 types of retainers. We pooled the studies that used the individual teeth as the outcome unit and the studies with the whole retainers as the outcome unit together in a separate analysis. Statistical analysis showed no statistically significant differences in the failure rate between the 2 groups, neither with the retainers as outcome unit nor tooth as outcome unit. There was considerable heterogeneity in the included studies; therefore, subgroup analysis was used.

Subgroup analysis based on fiber materials did not alter the outcome significantly. Although using Trasbond XT Primer (3M Unitek) and Trasbond XT Resin (3M Unitek), the FRC group had fewer failures. In contrast, the MSW group had a higher failure rate when using 3M ESPE. This suggests that the different adhesive systems could significantly influence the failure rate of retainers.

In the analysis of studies using retainer as an outcome unit, there was no statistical difference between the FRC and MSW in either the maxillary or mandibular group. In the subgroup analysis with stainless-steel wire diameter groupings, no significant difference in failure rate was found in both 0.009-in twisted wire and 0.0175-in wire. Considering the effect of the adhesive system, because the 3 studies with retainers as outcome units used 3 different adhesive systems, it was impossible to do the subgroup analysis.

There was little evidence in assessing the adverse effect of FRC and MSW retainers on oral health. We could not pool the result into a meta-analysis because of the lack of enough published data in both studies.^{22,36,43} However, both studies reported a statistical increase in the bleeding on probing in the FRC groups compared with the MSW group.^{22,36} The FRC groups also showed significantly higher C and gingival index. Although, the difference in the correlation index between the 2 groups was not statistically significant, there was an increase in the gingival bleeding index compared with the initial wear.⁴³ Therefore, it seems that the wear of FRC retainers has some adverse effects on oral health that cannot be ignored.

There was limited evidence with very low certainty that FRC retainers have higher patient satisfaction than MSW retainers.¹⁸ However, because this is based on the results reported from only 1 study, it should be treated with more caution.

Comparison of FRC retainers with a different formula

Ardeshtna³⁷ showed that FRC retainers with formula A have a higher failure rate than formula B. However, this outcome must be interpreted cautiously as the study was rated as a high risk of bias. In addition, this study had many variables (eg, bonding position, retainer thickness, number of teeth overlap, which will influence the outcome, and only a very small sample of each group [1-24]). Thus, it was impossible to conclude that S2 fiberglass and polycarbonate were better retainer materials.

Overall completeness and applicability of evidence

Overall, we included 11 studies investigating the application of FRC retainers in the current review. Ten studies compared FRC retainers with MSW retainers. One study compared FRC retainers with different formulas.

The quality of included studies was variable (Tables III and IV). Bolla et al,³⁵ Sfondrini et al,¹⁹ and Scribante et al¹⁸ did not provide enough information on allocation,

Table III. Summary of findings: FRC retainers compared with MSW retainers for orthodontic retention

Outcomes	No. of participants (studies) follow-up	Certainty of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with MSW retainers	Risk difference with FRC retainers
Stability	52 (1 RCT)	⊕⊕○○ Low [†]	–		MD: –0.39 (–0.41 to –0.37)
Follow-up: 12 mo					
Failure rate (teeth as outcome unit)	1026 (3 RCTs)	⊕⊕○○ Low [‡]	RR: 0.85 (0.47-1.52)	226 per 1000	–34 per 1000 (–120 to –117)
Follow-up: 12 mo					
Failure rate (retainer as outcome unit)	898 (5 RCTs)	⊕⊕○○ Low [§]	RR: 1.76 (0.86-3.58)	237 per 1000	180 more per 1000 (–33 to 612)
Follow-up: 24-72 mo					
Adverse effects on oral health	274 (3 RCTs)	⊕⊕○○ Low	–	Not pooled	Not pooled
Follow-up: 6-24 mo					
Patient satisfaction	32 (1 RCT)	⊕○○○ Very low [?]	–		MD: 1.49 (0.80-2.18)
Follow-up: 12 mo					

Note. Patient or population: orthodontic retention; Intervention: FRC retainers; Comparison: MSW retainers. The risk in the intervention group (and its 95% CI) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI). Grading of Recommendations Assessment, Development, and Evaluation (GRADE) Working Group grades of evidence: High certainty: we are very confident that the true effect lies close to that of the estimate of the effect; Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different; Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect; Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[†]Only 1 study assessed the relapse and the study sample was small; [‡]In these 3 studies, 2 had unclear risk of bias and 1 was at low risk of bias. The results of 1 study were the exact opposite of the other 2 studies; [§]In the 3 studies, 2 had a high risk of bias and 1 was rated as unclear risk of bias; ^{||}All 3 studies were at high risk of bias; [?]This single study was at high risk of bias. Only 1 study assessed patient satisfaction, and the study sample was small.

Table IV. Summary of findings: Formula A compared with Formula B for orthodontic FRC retainers

Outcomes	Anticipated absolute effects (95% CI)		Relative effect (95% CI)	No. of retainers (studies)	Certainty of the evidence (GRADE)
	Risk with Formula B	Risk with Formula A			
Failure rate	604 per 1000	954 per 1,000 (755 to 1,000)	RR: 1.58 (1.25-2.00)	76	⊕○○○Very low [†]
Follow-up: 3 y					

[†]Only 1 study assessed the failure rate of retainers with different formula and the study sample was small.

Note. Patient or population: orthodontic FRC retainers; Intervention: Formula A; Comparison: Formula B. The risk in the intervention group (and its 95% CI) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI). Grading of Recommendations Assessment, Development, and Evaluation (GRADE) Working Group grades of evidence: High certainty: we are very confident that the true effect lies close to that of the estimate of the effect; Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different; Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect; Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

and the last 2 studies also did not show clear baseline data on gender. Torkan et al²² and Tacken et al³⁶ suffered significant dropouts during the follow-up periods, raising the risk of attrition bias. Only 1 study compared the relapse of FRC and MSW retainers with a low risk of bias. There is a need for better-designed studies.

Limitations

None of the included studies had a follow-up period of ≥3 years, with only 4 studies with a follow-up period

≥2 years, and 1 study with only half a year of follow-up. Given that fixed retainers are always expected to be worn long-term, with some clinicians aiming for lifetime wear, more evidence from long-term trials is needed to strengthen the conclusions.

Several confounding factors could affect the effectiveness of FRC retainers, such as initial malocclusions, age of patients, materials of fiber, and adhesive systems used. It was impossible to assess the impact of various factors on the effectiveness of FRC retainers in this

review. Thus, the influence of different factors can be studied in future research.

CONCLUSIONS

On the basis of this review, we can conclude that there is limited low-quality evidence to suggest the following.

1. The FRC retainers showed less relapse than MSW retainers after a bonding period of 12 months; however, the clinical significance of this difference can be debatable.
2. There is low-quality evidence to suggest that the failure rate during the 3 years of FCR retainers is similar to MSW.
3. There is weak evidence to suggest that both FRC and MSW retainers may cause minimal adverse oral health impact, especially the periodontal impact caused by FRC retainers.
4. Little evidence suggests that patients were more satisfied with the FRC retainers.

More high-quality long-term studies should be conducted comparing these 2 retainers.

AUTHOR CREDIT STATEMENT

Shiyao Liu contributed to conceptualization, methodology, data curation, and original draft preparation; Ahmed El-Angbawi contributed to conceptualization, methodology, supervision, data curation, and original draft preparation; and Nikolaos Silikas contributed to manuscript review, editing and supervision.

SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.ajodo.2022.07.003>.

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Supplementary Table I. Medline (Ovid) search strategy*Search strategy*

1. randomized controlled trial.pt.
2. controlled clinical trial.pt.
3. randomized.ab.
4. placebo.ab.
5. drug therapy.fs.
6. randomly.ab.
7. trial.ab.
8. groups.ab.
9. 9. or/1-8
10. exp animals/ not humans.sh.
11. 9 not 10
12. exp orthodontics/
13. orthodontic\$.mp.
14. or/12-13
15. (retention or retain*).mp.
16. (FRC or fiber\$ or fiber\$.mp.
17. 14 and 15 and 16
18. 11 and 17

Supplementary Table II. Cochrane Library search strategy*Search strategy*

- #1 ORTHODONTICS explode all trees
- #2 orthodontic*
- #3 (#1 or #2)
- #4 (retention or retain*)
- #5 (fiber* or fiber* or FRC)
- #6 (#3 and #4 and #5)

Supplementary Table III. Embase (Ovid) search strategy*Search strategy*

1. random\$.ti,ab.
2. factorial\$.ti,ab.
3. (crossover\$ or cross over\$ or cross-over\$.ti,ab.
4. placebo\$.ti,ab.
5. (doubl\$ adj blind\$.ti,ab.
6. (singl\$ adj blind\$.ti,ab.
7. assign\$.ti,ab.
8. allocat\$.ti,ab.
9. volunteer\$.ti,ab.
10. CROSSOVER PROCEDURE.sh.
11. DOUBLE-BLIND PROCEDURE.sh.
12. RANDOMIZED CONTROLLED TRIAL.sh.
13. SINGLE BLIND PROCEDURE.sh.
14. or/1-13
15. (exp animal/ or animal.hw. or nonhuman/) not (exp human/ or human cell/ or (human or humans).ti.)
16. 14 not 1
17. exp orthodontics/
18. orthodontic\$.mp.
19. or/17-18
20. (retention or retain*).mp.
21. (FRC or fiber\$ or fiber\$.mp.
22. 19 and 20 and 21
23. 16 and 22

Supplementary Table IV. Pubmed search strategy*Search strategy*

- #1 (orthodont*[Title/Abstract]) AND retainer*[Title/Abstract]
- #2 (orthodont*[Title/Abstract]) AND retention[Title/Abstract]
- #3 (FRC[Title/Abstract] OR fiber*[Title/Abstract] OR fiber*[Title/Abstract])
- #4 (#1) OR #2
- #5 (#3) AND (#4)

Note. Filters: RCT and clinical trial.

Supplementary Table V. Web of Science search strategy*Search strategy*

#1 TS=(random\$ OR factorial\$ OR crossover\$ OR cross over\$ OR cross-over\$ OR placebo\$ OR (doubl\$ adj blind\$) OR (singl\$ adj blind\$) OR assign\$ OR allocat\$ OR volunteer\$ OR CROSSOVER PROCEDURE OR DOUBLE-BLIND PROCEDURE OR RANDOMIZED CONTROLLED TRIAL OR SINGLE BLIND PROCEDURE)

#2 TS=(orthodont* AND retain*)

#3 TS=(FRC OR fiber* OR fiber*)

#4 #1 AND #2 AND #3

#1 TS=(random\$ OR factorial\$ OR crossover\$ OR cross over\$ OR cross-over\$ OR placebo\$ OR (doubl\$ adj blind\$) OR (singl\$ adj blind\$) OR assign\$ OR allocat\$ OR volunteer\$ OR CROSSOVER PROCEDURE OR DOUBLE-BLIND PROCEDURE OR RANDOMIZED CONTROLLED TRIAL OR SINGLE BLIND PROCEDURE)

Supplementary Table VI. CINAHL search strategy*Search strategy*

S1 (MH "Orthodontics+")

S2 orthodontic*

S3 S1 or S2

S4 (fiber* or fiber* or FRC)

S5 S3 and S4