The effects of fixed and removable orthodontic retainers: a systematic review

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Abstract

Objective: In the view of the widespread acceptance of indefinite retention, it is important to determine the effects of fixed and removable orthodontic retainers on periodontal health, survival and failure rates of retainers, cost-effectiveness, and impact of orthodontic retainers on patient-reported outcomes.

Methods: A comprehensive literature search was undertaken based on a defined electronic and gray literature search strategy (PROSPERO: CRD42015029169). The following databases were searched (up to October 2015); MEDLINE via OVID, PubMed, the Cochrane Central Register of Controlled Trials, LILACS, BBO, ClinicalTrials.gov, the National Research Register, and ProQuest Dissertation and Thesis database. Randomized and non-randomized controlled clinical trials, prospective cohort studies, and case series (minimum sample size of 20) with minimum follow-up periods of 6 months reporting periodontal health, survival and failure rates of retainers, cost-effectiveness, and impact of orthodontic retainers on patient-reported outcomes were identified. The Cochrane Collaboration’s Risk of Bias tool and Newcastle-Ottawa Scale were used to assess the quality of included trials.

Results: Twenty-four studies were identified, 18 randomized controlled trials and 6 prospective cohort studies. Of these, only 16 were deemed to be of high quality. Meta-analysis was unfeasible due to considerable clinical heterogeneity and variations in outcome measures. The mean failure risk for mandibular stainless steel fixed retainers bonded from canine to canine was 0.29 (95 % confidence interval [CI] 0.26, 0.33) and for those bonded to canines only was 0.25 (95 % CI: 0.16, 0.33). A meta-regression suggested that failure of fixed stainless steel mandibular retainers was not directly related to the period elapsed since placement (P = 0.938).

Conclusion: Further well-designed prospective studies are needed to elucidate the benefits and potential harms associated with orthodontic retainers.

Keywords: Orthodontic retainer, Periodontal, Survival rate, Failure rate, Cost-effectiveness, Patient-reported outcomes

Review

Introduction

Retention procedures are considered necessary to maintain the corrected position of teeth following orthodontic treatment and to mitigate against characteristic age-related changes which, if unchecked, are known to culminate in mandibular anterior crowding [1]. Retention procedures are continually being refined with a recognition that existing protocols are infallible [2]. Nevertheless, both fixed and removable retainers continue to be in vogue, although adjunctive procedures including interproximal enamel reduction and minor oral surgical procedures have also been advocated.

A recent Cochrane review exposed a lack of high-quality evidence to favor one method of retention over another in terms of stability [3]. Given this absence of definitive evidence, retainer selection is often based on individual preference. This is evidenced by marked geographical variation with maxillary Hawley or vacuum-formed retainers and mandibular fixed lingual retainers with full-time wear of removable retainers most popular in the USA [4, 5]. In Australia and New Zealand, mandibular fixed and maxillary vacuum-formed retainers are shown to be the most prevalent combination [6], while a preference for the use of fixed retainers in both arches has been shown in the Netherlands [7].

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The duration of wear of orthodontic retainers has long been a dilemma in orthodontics. However, there is now widespread acceptance of the necessity for indefinite retention to minimize both relapse and maturational changes [5, 8]. Prolonged retention may pose increased risk to the periodontium and dental hard tissues; it is therefore important to investigate the implications of the long-term use of fixed and removable retainers on the supporting tissues [3, 9, 10].

A further consideration is patient experiences of retention and compliance with prolonged retention regimes; it is intuitive to expect that co-operation with retention regimes would decline over time. Moreover, both fixed and removable retainers are prone to breakage, loss, and degradation [2, 11]. Repeated breakage and requirement for replacement may have implications for the cost-effectiveness of both fixed and removable approaches. There is however limited evidence concerning the cost-effectiveness of either approach [12, 13].

The primary aim of this systematic review was to determine the influence of fixed and removable orthodontic retainers on periodontal health in patients who have completed orthodontic treatment with fixed appliances. A secondary aim was to evaluate survival and failure rates, impact of orthodontic retainers on patient-reported outcomes, and cost-effectiveness.

Materials and methods
This protocol for this systematic review was registered on PROSPERO (www.crd.york.ac.uk/prospero; CRD42015029169). The following selection criteria were applied:

- Study design: randomized and non-randomized controlled clinical trials, prospective cohort studies, and case series (with a minimum sample size of 20 patients) with minimum follow-up periods of 6 months
- Participants: patients having had orthodontic treatment with fixed or removable appliances followed by orthodontic retention
- Interventions: fixed retainers, removable retainers, and interproximal reduction
- Outcome measures: periodontal outcomes, survival and failure rates (including detachment of fixed retainers, breakages, retainer loss, or the need for replacement), patient-reported outcomes, and cost-effectiveness measures

Search strategy for identification of studies
The following databases were searched up to October 2015 without language restrictions: MEDLINE via OVID (Appendix 1), PubMed, the Cochrane Central Register of Controlled Trials (CENTRAL), and LILACS and BBO databases. Unpublished trials were searched electronically using ClinicalTrials.gov (www.clinicaltrials.gov), the National Research Register (www.controlled-trials.com), and ProQuest Dissertation and Thesis database (http://pqdtopen.proquest.com).

Assessment of relevance, validity, and data extraction
Full texts of relevant abstracts were retrieved. Data was tabulated using pre-piloted data collection forms by two authors (DA, PSF). Data extracted included: (1) study design; (2) sample: size, demographics, and clinical characteristics; (3) intervention: fixed appliances, removable appliances, or interproximal reduction; (4) follow-up period; (5) maxillary/mandibular arch; and (6) outcomes (primary and secondary).

Risk of bias (quality) assessment
For randomized controlled trials sequence generation, allocation concealment, blinding of outcome assessors, incomplete outcome data, selective reporting, and other biases were assessed using the Cochrane Collaboration’s Risk of Bias tool. Any disagreement was resolved by joint discussion (DA, PSF). Only studies at low or unclear risk of bias overall were to be included in the meta-analysis. The methodological quality of the included non-randomized studies was assessed using the Newcastle-Ottawa Scale. Studies adjudged to be of moderate or high methodological quality overall (more than five stars) were to be included in the meta-analysis. The authors of the included studies were contacted for clarification if required.

Strategy for data synthesis
Clinical heterogeneity was assessed according to the treatment interventions, wear regimen for removable retainers, measurement approach, and location of the retainers. For periodontal outcomes, the index used and surfaces examined were considered. Statistical heterogeneity was to be assessed by inspecting a graphic display of the estimated treatment effects from individual trials with associated 95% confidence intervals. Heterogeneity would be quantified using I-squared with values above 50% indicative of moderate to high heterogeneity which might preclude meta-analysis. A weighted treatment effect was to be calculated, and the results for retainer failure were expressed as odds ratios. All statistical analyses were undertaken using the Stata statistical software package (version 12.1; StataCorp, College Station, Tex).

Results
Description of the included studies
Sixty-four were considered potentially relevant to the review. Following retrieval of the full-text articles, 36 studies were excluded. Overall, 24 studies met the inclusion
criteria (Fig. 1). Reasons for exclusion at the final stage are presented (Appendix 2). The study design, characteristics of participants, comparison groups, follow-up period, and the outcomes of the included studies are presented in Table 1.

Risk of bias/methodological quality of included studies
The random sequence generation was adequately performed in 12 studies [11–22]. The assessor was adequately blinded in six trials [13, 14, 16, 19, 20, 22]. Overall, 11 randomized clinical trials were judged to be
| Study                        | Design          | Participants (overall) | Intervention/comparison                                                                 | Wear (part-time/full-time) | Follow-up period (mean ± SD) | Dental arch | Outcomes                                                                 |
|------------------------------|-----------------|------------------------|----------------------------------------------------------------------------------------|-----------------------------|-------------------------------|-------------|---------------------------------------------------------------------------|
| Al-Nimri et al. 2009 [25]    | Prospective cohort study | n = 62 (18 M, 44 F)   | - 0.036" round stainless steel fixed retainer (canines only) (n = 31; mean age, 20.23 ± 3.8 years)   | 21.31 months               | 19.35 months                   | Mandibular anterior teeth   | Plaque Index, Gingival Index, retainer failure, Oral Hygiene Index, Irregularity Index |
| Bazargani et al. 2012 [14]   | RCT             | n = 51                 | Overall mean age, 18.3 ± 1.3 years                                                      | 24.4 ± 4.7 months           | Mandibular anterior teeth     | Retainer failure, calculus accumulation, discoloration around composite pads |
| Störmann and Ehmer 2002 [15] | RCT             | n = 98                 | Overall age range, 13–17 years                                                          | 24 months                   | Mandibular anterior teeth     | Bleeding on probing, Plaque Index, failure rate, aesthetic problems, patient discomfort, Little’s irregularity index, occlusal discrepancies, intercanine width |
| Tynelius et al. 2014 [13]    | RCT             | n = 75 (30 M, 45 F)    | Overall mean age, 14.3 ± 1.5 years                                                      | 24 months                   | Maxillary and mandibular dentition | Cost-effectiveness and societal costs |
| Torkan et al. 2014 [16]      | RCT             | n = 30 (10 M, 20 F)    | - Fiber-reinforced resin composite fixed retainer (n = 15; mean age, 16.2 ± 1.9)        | 6 months                    | Maxillary and mandibular anterior teeth | Plaque Index, Calculus Index, Gingival Index, bleeding on probing, width of periodontal ligament |
| Sfondrini et al. 2014 [17]   | RCT             | n = 87 (35 M, 52 F)    | Overall average age, 24 years (14–62 years)                                             | 12 months                   | Mandibular anterior teeth     | Bond adhesive failure       |
| Study          | Design | n (M, F) | Overall age range | Treatment | Retainer Type | Retainer Details | Follow-up | Outcome Measures |
|---------------|--------|----------|------------------|-----------|---------------|------------------|-----------|------------------|
| Ardeshna et al. 2011 [26] | Prospective cohort study | 56 (76 fixed retainers) | - 0.53- or 1.02-mm fiber-reinforced thermoplastic fixed retainer with polyethylene terephthalate glycol matrix resin | 24 months | Maxillary anterior teeth (2 retainers), mandibular anterior teeth (21 retainers, 6 of them were bonded to canines only) | Survival and failure rates | |
| Salehi et al. 2013 [18] | RCT | 142 (59 M, 83 F) | Overall age range, 14–28 years | - Polyethylene woven ribbon fixed retainer (n = 68; mean age, 18.1 ± 5.23 years) | Maxillary and mandibular anterior teeth | Survival and failure rates | |
| Hichens et al. 2007 [12] | RCT | 355 (350 questionnaires completed at 6 months) (155 M, 242 F) | Overall mean age = 14–15 years | - Hawley retainer (n = 172) | Maxillary and mandibular dentition | Cost-effectiveness, patient satisfaction, failure rate, Little’s irregularity index | |
| Bolla et al. 2012 [39] | RCT | 85 (29 M, 56 F) | Overall mean age = 14–15 years | - Glass fiber-reinforced fixed retainer (n = 40; mean age for M, 23.4 years; mean age for F, 20.2 years) | Maxillary 2-2 (14 retainers) and mandibular (34 retainers) anterior teeth | Bond failure and breakage of retainers | |
| Tacken et al. 2010 [31] | RCT | 274 (135 M, 139 F) | Overall mean age, 14 years | - Glass fiber-reinforced fixed retainer (500 unidirectional glass fibers) (n = 45; mean age, 14.8 ± 1.3 years) | Maxillary 2-2 and mandibular anterior teeth | Failure rate, modified gingival index (MGI), bleeding on probing, Plaque Index (PI) | |
| Bovali et al. 2014 [19] | RCT | 63 (28 M, 35 F) | Overall age range: 12–38 years | - Direct bonding of 0.0215” multistrand stainless steel fixed retainer (n = 31; mean age, 19.8 ± 6.5 years) | Mandibular anterior teeth | Failure rate, time to fit retainers | |
| Study                          | Methodology | Sample Size | Characteristics                                                                 | Median Follow-up Period | Outcome Measures                                                                 |
|-------------------------------|-------------|-------------|---------------------------------------------------------------------------------|-------------------------|-----------------------------------------------------------------------------------|
| Pandis et al. 2013 [20]       | RCT         | n = 220 (60 M, 160 F) | Overall median age, 16 (IQR 2) years Overall age range, 12–47 years              | 2.19 years              | Mandibular anterior teeth Failure rate, adhesive remnant index scores              |
|                           |             |             | - Indirect bonding of 0.0215″ multistrand stainless steel fixed retainer (n = 32; mean age, 17.2 ± 3.1 years) |                     |                                                                                   |
|                           |             |             | - 0.022″ multistrand stainless steel fixed retainer bonded with chemical-cured composite (n = 110; median age, 16 (IQR 2) years) |                     |                                                                                   |
|                           |             |             | - 0.022″ multistrand stainless steel fixed retainer bonded with light-cured composite (n = 110; median age, 16 (IQR 2) years) |                     |                                                                                   |
| Sun et al. 2011 [11]          | RCT         | n = 111     | Overall mean age, 14.7 years Overall age range, 12–17 years                     | 12 months               | Maxillary and mandibular dentition Survival and failure rates                      |
|                           |             |             | - Hawley retainer (n = 56)                                                      | Full-time               |                                                                                   |
|                           |             |             | - Vacuum-formed retainer (n = 55)                                               | Full-time               |                                                                                   |
| Xu et al. 2011 [40]           | RCT         | n = 40 (16 M, 29 F) | Overall mean age, 13–16 years                                                   | 12 months               | Maxillary and mandibular dentition Survival and failure rates                      |
|                           |             |             | - Vacuum-formed retainer (n = 25)                                               | Full-time               |                                                                                   |
|                           |             |             | - 0.0195″ multistrand stainless steel fixed retainer with Hawley retainer (n = 15) | Part-time               |                                                                                   |
| Rose et al. 2002 [41]         | RCT         | n = 20 (12 M, 8 F) | Overall mean age, 22.4 ± 9.7 years                                              | 24 months               | Mandibular anterior teeth Survival and failure rates                                |
|                           |             |             | - 1-mm polyethylene woven ribbon fixed retainer (n = 10)                        |                        |                                                                                   |
|                           |             |             | - 0.0175″ multistrand stainless steel fixed retainer (n = 10)                   |                        |                                                                                   |
| Liu et al. 2010 [23]          | RCT         | n = 60      |                                                                        | 12 months               | Mandibular anterior teeth                                                                 |
|                           |             |             | - 0.75-mm fiber-reinforced composite fixed retainer (n = 30)                    |                        | Bleeding index, pocket depth, failure rate                                        |
|                           |             |             | - 0.9-mm multistrand stainless steel fixed retainer (n = 30)                   |                        |                                                                                   |
| Taner et al. 2012 [27]        | Prospective cohort study | n = 66 (14 M, 52 F) |                                                                   | 6 months                | Mandibular anterior teeth Failure rate                                              |
|                           |             |             | - Direct bonding of 0.016″ × 0.022″ multistrand stainless steel dead soft wire fixed retainer (n = 32; mean age, 15.96 ± 3.21 years) |                        |                                                                                   |
|                           |             |             | - Indirect bonding of 0.016″ × 0.022″ multistrand stainless steel dead soft wire fixed retainer (n = 34; mean age, 19.44 ± 6.79 years) |                        |                                                                                   |
| Artun et al. 1997 [28]        | Prospective cohort study | n = 49 |                                                                | 3 years                 | Mandibular anterior teeth Little’s irregularity index, failure rate, Plaque Index, Calculus Index, Gingival Index, probing attachment level |
|                           |             |             | - 0.032″ plain fixed retainer (canines only) (n = 11)                         |                        |                                                                                   |
|                           |             |             | - 0.032″ spiral wire fixed retainer (canines only) (n = 13)                    |                        |                                                                                   |
|                           |             |             | - 0.0205″ spiral wire fixed retainer (n = 11)                                  |                        |                                                                                   |
|                           |             |             | - Removable retainer (n = 14)                                                   | Unclear                 |                                                                                   |
Table 1 Characteristics of included trials (n = 24) (Continued)

| Study                  | Design                      | Sample Size | Age Information                                      | Retainer Type                  | Duration | Teeth Type            | Outcome Measures                                                                 |
|------------------------|-----------------------------|-------------|-------------------------------------------------------|-------------------------------|----------|-----------------------|----------------------------------------------------------------------------------|
| Scribante et al. 2011  | RCT                         | n = 34      | Overall mean age, 14.3 years                          | - 0.0175" multistrand stainless steel fixed retainer | 12 months | Mandibular anterior teeth | Failure rate, patient satisfaction of the aesthetic result                      |
|                        |                             | (9 M, 25 F) |                                                        | - Polyelethylene fiber-reinforced resin composite fixed retainer |          |                       |                                                                                  |
| Zachrisson, 1977       | Prospective cohort study    | n = 43      | (14–17 years)                                         | - 0.032" or 0.036" blue Elgiloy fixed retainer bonded using a holding wire (canines only) | Mean, 15.7 months; Range, 12-30 months | Mandibular anterior teeth | Failure rate, calculus accumulation                                               |
|                        |                             | (14–17 years) |                                                        | (n = 22)                       |          |                       |                                                                                  |
|                        |                             |             |                                                        | - 0.032" or 0.036" blue Elgiloy fixed retainer bonded using a steel ligature (canines only) |          |                       |                                                                                  |
| Heier et al. 1997      | Prospective cohort study    | n = 36      | Overall mean age, 16.3 years                          | - 0.0175" multistrand stainless steel fixed retainer (n = 22) | 6 months | Maxillary and mandibular anterior teeth | Modified gingival index, bleeding on probing, Plaque Index, Calculus Index, gingival crevicular fluid flow |
|                        |                             | (12.8–21.1 years) |                                                        | - Hawley retainer (n = 14) |          | Maxillary and mandibular dentition |                                                                                  |
| Sobouti et al. 2016    | RCT                         | n = 128     | Overall mean age, 18 ± 3.6 years                      | - Fiber-reinforced composite fixed retainer (n = 42; mean age, 18.5 ± 3.6 years) | 24 months | Mandibular anterior teeth | Survival and failure rates                                                       |
|                        |                             | (60 M, 68 F) | Overall age range, 13–25 years                       | - 0.0175" flexible spiral wire fixed retainer (n = 41; mean age, 18.4 ± 3.7 years) |          |                       |                                                                                  |
|                        |                             |             |                                                        | - 0.0009" dead soft twisted wires fixed retainer (n = 45; mean age, 17 ± 3.3 years) |          |                       |                                                                                  |
| O’Rouke et al. 2016    | RCT                         | n = 82      | (23 M, 59 F)                                         | - Vacuum-formed retainer (n = 40, mean age: 16.95 ± 2.02 years) | Full-time for 6 months, followed by part-time for 6 months, then for every other night in the second year | Mandibular dentition | Little’s irregularity index, intercanine width, intermolar width, arch length, failure rate |
|                        |                             |             |                                                        | - 0.0175" stainless steel coaxial fixed retainer (n = 42; Mean age: 18.47 ± 4.41 years) |          |                       |                                                                                  |

*a Overall sample
of low risk of bias (Fig. 2) [12–14, 16–20, 22–24]. All six prospective cohort studies [25–30] (Fig. 3) were deemed to be of high quality in terms of sample selection, except for one study [25] which did not demonstrate the absence of pre-existing periodontal disease. Assessment of the outcome was deemed satisfactory in all but two studies [28, 29]. Overall, five prospective cohort studies were judged to be of moderate to high quality [25–28, 30].

Periodontal outcomes

Of the included trials, only seven trials assessed periodontal outcomes (Tables 2 and 3) [14, 16, 23, 25, 28, 30, 31]. Four of these were randomized controlled trials [14, 16, 23, 31], and the other three were prospective cohort studies [25, 28, 30]. Two trials did not report baseline scores [14, 25], and another two studies reported the periodontal outcome with no distinction made between maxillary and mandibular measurements [30, 31].

No significant difference was found between mandibular stainless steel fixed retainers bonded to the anterior teeth and canines only in terms of periodontal outcomes, at 12-month and 3-year follow-ups in two studies [25, 28]. With regard to periodontal outcomes of mandibular Hawley retainers in comparison to mandibular stainless steel fixed retainers, no significant difference was found at 3-year follow-up [28]. When mandibular fiber-reinforced composite was compared to mandibular stainless steel fixed retainers, no significant difference in probing depths, bleeding on probing, and calculus scores...
at 6-month follow-up was found [16, 23]. Probing depths and bleeding on probing were further measured at 12-month follow-up and showed no significant difference between the two groups [23]. However, gingival and plaque indices scores were found to be higher in maxillary and mandibular fiber-reinforced composite compared to stainless steel fixed retainers at 6-month follow-up [16]. Very few overlapping studies were identified, however. Meta-analysis was therefore not possible in view of heterogeneity.

In terms of the natural history of periodontal changes related to stainless steel fixed retainers, plaque and gingival indices scores on the lingual surfaces of mandibular anterior teeth increased from baseline to 6 months follow-up [16]. Very few overlapping studies were identified, however. Meta-analysis was therefore not possible in view of heterogeneity.

Survival and failure rates of retainers

The survival rate of fixed retainers was reported over 12 to 24 months [18, 24, 26]. In terms of retainer material, one study found fiber-reinforced thermoplastic fixed retainer with polyethylene terephthalate glycol matrix resin survived significantly less than fiber-reinforced thermoplastic fixed retainer with polycarbonate matrix resin [26]. Two other studies found no significant difference in the survival rate of multistrand stainless steel fixed and esthetic retainers made of polyethylene woven ribbon or polyethylene fiber-reinforced resin composite [18, 24]. No statistical difference was found in the survival rate between maxillary and mandibular fixed retainers [18, 26]. Interestingly, in one study, the survival rate of fiber-reinforced thermoplastic fixed retainers was directly related to the thickness of the wire and the number of teeth bonded [26].

All the studies that involved mandibular stainless steel retainers reported failures per patient [13, 14, 17–20, 22–25, 27, 28], except for two studies in which the failure was reported per tooth [17, 24] (Table 4). The mean failure risk for mandibular stainless steel fixed retainers bonded to canine to canine was 0.29 (95 % confidence interval [CI], 0.26, 0.33) based on nine studies (n = 555) (Fig. 4). The follow-up period ranged from 6 to 36 months. Similarly, the failure risk for mandibular stainless steel fixed retainers bonded to canines was 0.25 (95 % CI, 0.16, 0.33) based on three studies [13, 25, 28] (n = 79) over a follow-up period of 12 to 36 months (Fig. 5). Considerable statistical heterogeneity was noted in both analyses (I-squared = 89 %) reflecting high levels of inconsistency and limited numbers of events. A meta-regression shows that follow-up period was not a predictor of failure rate for mandibular stainless steel fixed retainers (P = 0.938).

One study reporting failure rates of mandibular Hawley retainers was unclear regarding the stipulated duration of wear [28]. However, two studies found around 12 % failure over a period of 6 months and 14 % at 3-year follow-up [12, 28]. Similarly, the failure rate for maxillary vacuum-formed retainers was found to be 10 % over 2 years [13], while a further study reported a higher rate of 17 % over 6 months [12].

Patient-reported outcomes and cost-effectiveness

Patient-reported outcomes were reported in two studies [12, 24] (Table 5). Removable retainers were found to be associated with discomfort, with those in the Hawley
| Intervention | Periodontal outcomes | Index | Arch          | Teeth | Tooth surfaces          |
|--------------|----------------------|-------|---------------|-------|-------------------------|
| Al-Nimri et al. 2009 [25] | - 0.036" round stainless steel fixed retainer (canines only)  
- 0.015" multistrand fixed retainer | Plaque Index | 0 absence  
1 on probe  
2 visible  
3 abundant | Mandible | 3-3 | Labial/lingual/mesial/  
distal |
| | | Gingival Index | 0 absence  
1 mild | Mandible | 3-3 | Labial and lingual |
| | | Calculus | Part of Oral Hygiene Index  
Tooth with the highest score determine the index score for the segment (6 segments) | Maxilla and mandible | All teeth except mandibular  
labial segment | Labial and lingual |
| Bazargani et al. 2012 [14] | - 0.0195" multistrand fixed retainer  
with two-step bonded resin adhesive  
- 0.0195" multistrand fixed retainer  
with non-resin adhesive | Calculus | Present/absent | Mandible | 3-3 | Lingual |
| Torkan et al. 2014 [16] | - Fiber-reinforced resin composite fixed retainer  
- 0.0175" multistrand stainless steel fixed retainer | Plaque Index | Using disclosing  
0 absence  
1 visible on the probe  
2 visible  
3 abundant | Maxilla and mandible | 3-3 | Lingual |
| | | Calculus Index | 0 absence  
1 up to 1/3  
2 up to 2/3  
3 > 2/3 | Maxilla and mandible | All teeth | Unclear |
| | | Gingival Index | 0 absence  
1 mild  
2 moderate  
3 severe | Maxilla and mandible | Unclear | Lingual |
| | | Bleeding on probing | Present/absent | Maxilla and mandible | 3-3 | Unclear |
| Tacken et al. 2010 [31] | - Glass fiber-reinforced fixed retainer  
(500 unidirectional glass fibers)  
- Glass fiber-reinforced fixed retainer  
(1000 unidirectional glass fibers)  
- 0.0215" coaxial fixed retainer  
- Untreated control | Gingival Index | 0 absence  
1 mild (localized)  
2 mild (generalized)  
3 moderate  
4 severe | Unclear | Unclear | Unclear, 3 sites/tooth:  
mesial, distal, central |
| | | Bleeding on probing | 0 no bleeding  
1 point bleeding  
2 abundant bleeding | Unclear | Unclear | Unclear, 3 sites/tooth:  
mesial, distal, central |
| | | Plaque Index | Using disclosing  
0 no plaque  
1 spots at the cervical margin | Unclear | Unclear | Unclear, 3 sites/tooth:  
mesial, distal, central |
Table 2  Periodontal outcomes (Continued)

| Source               | Retainer Type                     | Index Description                                                                 | Area                  | Degree |
|----------------------|----------------------------------|-----------------------------------------------------------------------------------|-----------------------|--------|
| Artun et al. 1997    | - 0.032” plain fixed retainer    | Plaque Index 0 absence 1 on probe 2 visible 3 abundant                           | Mandible              | 3-3    |
|                     | (canines only)                   |                                                                                   |                       |        |
|                     | - 0.032” spiral wire fixed retainer (canines only)                                 |                       |                       |        |
|                     | - 0.0205” spiral wire fixed retainer                                        |                       |                       |        |
|                     | - Removable retainer                                                               |                       |                       |        |
|                     |                                                                                   |                       | Lingual, mesial, distal |        |
| Liu et al. 2010      | - 0.75-mm fiber-reinforced composite fixed retainer                               | Pocket depth Mean attachment loss                                                  | Mandible              | 3-3    |
|                     | - 0.9-mm multistrand stainless steel fixed retainer                               | Pocket depth Scores added together                                                | Mandible              | 3-3    |
|                     |                                                                                   | Bleeding on probing Scores added together                                           | Mandible              | 3-3    |
|                     |                                                                                   |                                                                                   |                       |        |
| Heier et al. 2010    | - 0.0175” multistrand stainless steel fixed retainer                             | Gingival Index 0 absence 1 mild (localized) 2 mild (generalized) 3 moderate 4 severe | Maxilla and mandible  | 3-3    |
|                     | - Hawley retainer                                                                |                                                                                   |                       |        |
|                     |                                                                                   |                                                                                   | Labial, lingual, interdental labial, interdental lingual |        |
|                     |                                                                                   | Bleeding on probing 0 absence 1 point bleeding 2 profuse                           | Maxilla and mandible  | 3-3    |
|                     |                                                                                   |                                                                                   | Labial, lingual, interdental labial, interdental lingual |        |
|                     |                                                                                   | Plaque Index Using disclosing 0 no plaque 1 spots at the cervical margin 2 thin band at the    | Maxilla and mandible  | 3-3    |
|                     |                                                                                   |                                                                                   | Labial, lingual        |        |
|                     |                                                                                   |                                                                                   |                       |        |
|                     |                                                                                   | Calculus Index Overall mean score                                                   | Maxilla and mandible  | 3-3    |
|                     |                                                                                   |                                                                                   | Labial, lingual (3 sites/surface) |        |
| Study                  | Intervention                                                                 | Plaque Index                              | Gingival Index                               |
|-----------------------|------------------------------------------------------------------------------|--------------------------------------------|----------------------------------------------|
| Al-Nimri et al. 2009  | - 0.036" Round stainless steel fixed retainer (canines only) \( n = 31 \) | Mean after at least 12 months, 1.02 ± 0.52 | Mean after at least 12 months, 1.19 ± 0.44   |
|                       | - 0.015" multistrand fixed retainer \( n = 31 \)                             | Mean after at least 12 months, 1.21 ± 0.48 | Mean after at least 12 months, 1.34 ± 0.39   |
| Bazargani et al. 2012 | - 0.0195" multistrand fixed retainer with two-step bonded resin adhesive \( n = 25 \) |                                            |                                              |
|                       | - 0.0195" multistrand fixed retainer with non-resin adhesive \( n = 26 \)   |                                            |                                              |
| Torkan et al. 2014    | - Fiber-reinforced composite resin fixed retainer \( n = 15 \)               | Maxilla: median 0 (baseline), 1.66 (6 months) | Maxilla: median 0.5 (baseline), 1 (6 months) |
|                       | - 0.0175" multistrand stainless steel fixed retainer \( n = 15 \)           | Mandible: median 0.91 (baseline), 2 (6 months) | Mandible: median 0.33 (baseline), 1 (6 months) |
| Tacken et al. 2010    | - Glass fiber-reinforced fixed retainer (500 unidirectional glass fibers) \( n = 45 \) | 6 months, 1.88 ± 0.74                      | 6 months, 1.20 ± 0.43                        |
|                       | - Glass fiber-reinforced fixed retainer (1000 unidirectional glass fibers) \( n = 48 \) | 12 months, 2.32 ± 0.93                     | 12 months, 1.00 ± 0.30                       |
|                       | - 0.0215" coaxial fixed retainer \( n = 91 \)                               | 18 months, 2.25 ± 0.78                     | 18 months, 1.28 ± 0.36                       |
| Liu et al. 2010       | - 0.75-mm fiber-reinforced composite fixed retainer \( n = 30 \)             | 24 months, 2.11 ± 0.73                     | 24 months, 1.51 ± 0.45                       |
|                       | - 0.9-mm multistrand stainless steel fixed retainer \( n = 30 \)             |                                            |                                              |
| Artun et al. 1997     | - 0.032" plain fixed retainer (canines only) \( n = 11 \)                   | Baseline, 0.32                             | Baseline, 1.01                               |
|                       | - 0.032" spiral fixed retainer (canines only) \( n = 13 \)                  | Baseline, 0.17                             | Baseline, 0.95                               |

Table 3: Periodontal outcomes including the follow-up periods
| Retainer Type                                      | Baseline | Year 1 | Year 2 | Year 3 | Year 4 |
|---------------------------------------------------|----------|--------|--------|--------|--------|
| 0.0205° spiral wire fixed retainer (*n* = 11)     | 0.26     | 0.13   |        | 0.14   |        |
| Removable retainer (*n* = 14)                     | 0.31     | 0.13   |        | 0.80   |        |
| 0.0175° multi-strand stainless steel fixed retainer (*n* = 22) | 2.78     | 3.03   |        | 0.79   | 0.40   |
| Hawley retainer (*n* = 14)                        | 2.78     | 2.52   |        | 0.80   | 0.74   |

Heier et al. 2010 [30]
| Study                      | Calculus                          | Bleeding on probing             | Probing attachment level |
|---------------------------|-----------------------------------|--------------------------------|--------------------------|
| Al-Nimri et al. 2009 [25] |                                   |                                 |                          |
| Bazargani et al. 2012 [14]| 4 % (2 years)                     |                                 |                          |
|                           | 31 % (2 years)                    |                                 |                          |
| Torkan et al. 2014 [16]  | Maxilla: Median 0 (baseline and 6 months) | Maxilla: Median 0.16 (baseline), 0.5 (6 months) |                          |
|                           | Mandible: Median 0 (baseline), 0.33 (6 months) | Mandible: Median 0 (baseline), 0.66 (6 months) |                          |
|                           | Maxilla and mandible: Median 0 (baseline and 6 months) | Maxilla: median 0 (baseline), 0.5 (6 months) | Mandible: median 0 (baseline), 0.33 (6 months) |
| Tacken et al. 2010 [31]  | 6 months, 0.72 ± 0.22              | 12 months, 0.89 ± 0.19          | 18 months, 0.82 ± 0.23   |
|                           | 6 months, 0.76 ± 0.18              | 12 months, 0.81 ± 0.21          | 18 months, 0.89 ± 0.23   |
|                           | 6 months, 0.46 ± 0.18              | 12 months, 0.55 ± 0.19          | 18 months, 0.57 ± 0.21   |
| Liu et al. 2010 [23]     | Baseline, 3.50 |                                 |                          |
|                           | 6 months, 10.17                  | 12 months, 11.12                |                          |
|                           | Baseline, 3.67; 6 months, 8.89; 12 months, 9.24 |                                 |                          |
| Artun et al. 1997 [28]   | Baseline, 16.67 |                                 | Mean attachment loss at 3 years, 0.85 mm |
|                           | 3 years, 3.33                    |                                 |                          |
|                           | Baseline: 8.64 |                                 | Mean attachment loss at 3 years, 0.63 mm |
|                           | 3 years, 3.09                    |                                 |                          |
|                           | Baseline: 17.36                  |                                 | Mean attachment loss at 3 years, 0.62 mm |
|                           | 3 years, 17.36                   |                                 |                          |
|                           | Baseline: 9.52 |                                 | Mean attachment loss at 3 years, 0.72 mm |
|                           | 3 years, 8.33                    |                                 |                          |
| Heier et al. 2010 [30]   | Baseline and 6 months, 0.20      | Baseline, 0.32 |                           |
|                           | 6 months, 0.60                    | 6 months, 0.23 |                           |
|                           | Baseline, 0.05                  | Baseline, 0.34 |                           |
|                           | 6 months, 0.06                    | 6 months, 0.22 |                           |
| Study                          | Intervention                                                                 | Survival rate | Failure rate |
|-------------------------------|-------------------------------------------------------------------------------|---------------|--------------|
| Al-Nimri et al. 2009 [25]     | - 0.036" round stainless steel fixed retainer (canines only)                  | 4/31 (13 %)   | 9/31 (29 %)  |
|                               | - 0.015" multistrand fixed retainer                                          |               |              |
| Bazargani et al. 2012 [14]    | - 0.0195" multistrand fixed retainer with two-step bonded resin adhesive     | 1/25 (4 %)    |              |
|                               | - 0.0195" multistrand fixed retainer with non-resin adhesive                  | 7/26 (27 %)   |              |
| Tynelius et al. 2014 [13]     | - Vacuum-formed retainer in the maxilla and 0.7-mm spring hard wire fixed retainer in the mandible (canines only) | 2/24 (8.3 %)  | 15/24 (62.5 %) fixed retainer |
|                               | - Vacuum-formed retainer in the maxilla and interproximal enamel reduction in the mandibular anterior teeth | 3/25 (12 %)   |              |
|                               | - Prefabricated positioner                                                    | 0/25 (0 %)    |              |
| Sfondrini et al. 2014 [17]    | - 0.5-mm silanized-treated glass fiber-reinforced composite resin fixed retainer | 27/240 bonded teeth (11.25 %) |              |
| Ardeshna et al. 2011 [26]     | - 0.53- or 1.02-mm fiber-reinforced thermoplastic fixed retainer with polyethylene terephthalate glycol matrix resin | Median, 2.97 months | 22/23 (95.6 %) |
|                               | - 0.53- or 1.02-mm fiber-reinforced thermoplastic fixed retainer with polycarbonate matrix resin | Median, 11.37 months | 32/53 (60.3 %) |
| Salehi et al. 2013 [18]       | - Polyethylene woven ribbon fixed retainer                                   | Maxilla: mean 13.96 ± 4.53 months, Mandible: mean 14.26 ± 4.70 months | 34/68 in the maxilla (50 %), 29/68 in the mandible (42.6 %) |
|                               | - 0.0175" multistrand stainless steel fixed retainer                         | Maxilla: mean 15.34 ± 4.04 months, Mandible: mean 15.61 ± 3.61 months | 27/74 in the maxilla (36.5 %), 28/74 in the mandible (37.8 %) |
| Hichens et al. 2007 [12]      | - Hawley retainer                                                            | 40/344 (11.6 %) |              |
|                               | - Vacuum-formed retainer                                                     | 20/366 (17 %)  |              |
| Bovali et al. 2014 [19]       | - Direct bonding of 0.0215" multistrand stainless steel fixed retainer        | 7/29 (24.1 %)  |              |
|                               | - Indirect bonding of 0.0215" multistrand stainless steel fixed retainer      | 10/31 (32.2 %) |              |
| Pandis et al. 2013 [20]       | - 0.022" multistrand stainless steel fixed retainer bonded with chemical-cured composite | 47/110 (42.7 %) |              |
|                               | - 0.022" multistrand stainless steel fixed retainer bonded with light-cured composite | 55/110 (50 %) |              |
| Liu et al. 2010 [23]          | - 0.75-mm fiber-reinforced composite fixed retainer                           | 0/30 (0 %)     |              |
|                               | - 0.9-mm multistrand stainless steel fixed retainer                           | 0/30 (0 %)     |              |
| Taner et al. 2012 [27]        | - Direct bonding 0.016" × 0.022" multistrand stainless steel dead soft wire fixed retainer | 15/32 (46.8 %) |              |
| Study                  | Retainer Description                                                                 | Failure Rate |
|-----------------------|---------------------------------------------------------------------------------------|--------------|
| Artun et al. 1997 [28]| - Indirect bonding 0.016” × 0.022” multistrand stainless steel dead soft wire fixed retainer | 10/34 (29.4 %) |
|                       | - 0.032” plain fixed retainer (canines only)                                          | 1/11 (9.1 %)  |
|                       | - 0.032” spiral fixed retainer (canines only)                                         | 4/13 (30.7 %) |
|                       | - 0.0205” spiral wire fixed retainer                                                  | 3/11 (27.27 %) |
|                       | - Removable retainer                                                                  | 2/14 (14.28 %) |
| Scribante et al. 2011 [24]| - 0.0175” multistrand stainless steel fixed retainer                                   | 23/102 bonded teeth (23 %) |
|                       | - Polyethylene fiber-reinforced resin composite fixed retainer                        | 13/90 bonded teeth (14 %) |
| O'Rouke et al. 2016 [22]| - Vacuum-formed retainer                                                              | 3/42 (7.14 %)  |
retainer group reporting higher levels of embarrassment in terms of speech and esthetics [12].

In terms of cost-effectiveness (Table 5), vacuum-formed retainers were found to be significantly more cost-effective than Hawley retainers within the National Health Service over a 6-month retention period [12]. One study, over 2 years, found interproximal reduction as a retention method and positioners to be more cost-effective than mandibular stainless steel fixed retainers bonded to canines [13].

Discussion
This systematic review found a lack of evidence to endorse the use of one type of orthodontic retainer based on their effect on periodontal health, survival and failure rates, patient-reported outcomes, and cost-effectiveness. Largely, this finding can be attributed to a lack of high-quality, relevant research. In this respect, the results of the present systematic review are in line with previous systematic reviews [3, 9, 10]. Interestingly, it was found that failure of fixed stainless steel mandibular retainers was not directly related to the duration of follow-up. This suggests that other factors including the influence of operator technique and experience might override the effects of retainer design or materials, although follow-up did not extend beyond 3 years in the present review.

Generally, relatively minor changes in periodontal parameters were reported; however, given that most studies did not incorporate an untreated control, or indeed a control group without retention, it was unclear whether these changes were attributable to the intervention or temporal changes, in isolation. As such additional research including prospective cohort studies with matched controls incorporating baseline assessment would be helpful in providing more conclusive information. It is worthy of mention that the current standard of care is to recommend bonded retention to preserve orthodontic correction in those with a history of periodontal disease as these patients are known to be particularly susceptible to post-treatment changes [32, 33]. It is therefore important that there is greater clarity in relation to the compatibility of fixed retention with periodontal health and indeed on variations that may facilitate maintenance of optimal hygiene.

A minimum follow-up period of 6 months was set to distinguish between gingival inflammation associated...
with fixed orthodontic treatment and periodontal side-effects related to the orthodontic retainers [34]. Previous reviews have stipulated a minimum observation period of 3 months [3, 9] to 2 years [10]. However, a 3-month period might be insufficient to allow for the resolution of inflammatory changes related to the presence of active appliances. Using a minimum of 2-year observation period risks omission of a considerable amount of relevant research. Moreover, in this review, just one study focusing on periodontal outcomes involved follow-up in excess of 2 years [28]. It is therefore clear that the prolonged effect of orthodontic retention on periodontal health has not been adequately addressed in prospective research.

Intuitively, a significant difference in patient-reported outcomes and experiences could be expected with fixed or removable retainers in view of differences in appearance, size, and requirement for compliance. Notwithstanding this, only two studies reported on satisfaction with the appearance of retainers or on levels of associated embarrassment or discomfort [12, 24]. This tendency for researchers to concentrate on objective, often clinician-centered outcomes has recently been documented both within orthodontics and general dental research more broadly [35, 36]. Further studies incorporating patient-reported outcomes are therefore necessary to provide a more holistic assessment of benefits, harms, and experiences associated with orthodontic retainers.

While the primary focus of this review was to compare the effectiveness of retainer types, it was also possible to generate epidemiological data on the risk of failure of fixed retainers based on the primary studies. Failure risk of 0.29 was found for fixed wires bonded to the six anterior teeth and approximately one-quarter of retainers bonded to mandibular canines only, based on observation periods of 6 months to 3 years. This data highlights that the risk of failure is considerable and that fixed retention does not guarantee prolonged stability. Similar findings have been observed in observational studies [2]. The onus on realistic treatment planning with due consideration for placement of teeth into a zone of relative stability therefore remains [37].

Attempts were made to identify all trials meeting the inclusion criteria in the present review with no restrictions based on either publication date or language. Furthermore, we planned to include both prospective cohort studies and randomized controlled trials. Cohort studies were included, in particular, to permit assessment of periodontal outcomes as they are more likely to involve more prolonged periods of follow-up, which may be necessary to reveal the extent of prolonged periodontal

| Study                  | ES (95% CI)     | Weight |
|------------------------|-----------------|--------|
| Tynelius et al., 2014  | 0.63 (0.43, 0.82) | 19.55 |
| Al-Nimri et al., 2009  | 0.13 (0.01, 0.25) | 52.67 |
| Artun et al., 1997     | 0.21 (0.05, 0.37) | 27.78 |
| Overall (I-squared = 89.3%, p = 0.000) | 0.25 (0.16, 0.33) | 100.00 |

![Fig. 5 Risk of failure of mandibular stainless steel fixed retainers bonded to canines only](image-url)
| Study                  | Intervention                                                                 | Patient-reported outcomes | Cost-effectiveness                        |
|-----------------------|------------------------------------------------------------------------------|----------------------------|-------------------------------------------|
| Tynelius et al. 2014  | - Vacuum-formed retainer in the maxilla and 0.7-mm spring hard wire fixed retainer in the mandible (canines only) | - Embarrassment: 29/168 (17 %) Discomfort: 109/168 (65 %) | Costs of scheduled appointments, €12,425 Costs of unscheduled appointments, €804 |
|                       | - Vacuum-formed retainer in the maxilla and interproximal enamel reduction in the mandibular anterior teeth |                            | Costs of scheduled appointments, €11,275 Costs of unscheduled appointments, €303 |
|                       | - Prefabricated positioner                                                   |                            | Costs of scheduled appointments, €10,500 Costs of unscheduled appointments, none |
| Hichens et al. 2007   | - Hawley retainer                                                           | Embarrassment: 13/182 (7 %) Discomfort: 112/182 (62 %) | Mean cost to the NHS, €122.02 (€120.84, €123.21) per patient |
|                       | - Vacuum-formed retainer                                                    |                            | Mean cost to the orthodontic practice, −€34.00 (−€34.57, −€33.34) per patient |
|                       |                                                                             |                            | Mean cost to the patient, €6.92 (€5.29, €8.53) per patient |
| Scribante et al. 2011 | - 0.0175″ multistrand stainless steel fixed retainer                        | Mean, 8.24 ± 1.39; median, 8.50; range, (4.50–10.00) (using visual analog scale) | Mean cost to the NHS, €152 (€150.86, €153.15) per patient |
|                       | - Polyethylene fiber-reinforced resin composite fixed retainer              | Mean, 9.73 ± 0.42; median, 10.00; range, (9.00–10.00) (using visual analog scale) | Mean cost to the orthodontic practice, −€1.00 (−€1.78, −€0.22) per patient |
|                       |                                                                             |                            | Mean cost to the patient, −€1.00 (−€1.78, −€0.22) per patient |
effects. Meta-analysis was not undertaken in view of the clinical heterogeneity between the limited number of included studies, which made statistical pooling inappropriate in relation to periodontal health, survival and failure rates, patient-reported outcomes, and cost-effectiveness. This inability to undertake meta-analysis is common to many orthodontic systematic reviews with meta-analysis found in just 27% of 157 reviews over a 14-year period with a median of just 4 studies for those that did incorporate meta-analysis [38]. The onus on producing high-quality primary research studies in orthodontics remains.

Conclusions
There is a lack of high-quality evidence to endorse the use of one type of orthodontic retainer based on their effect on periodontal health, risk of failure, patient-reported outcomes, and cost-effectiveness. Further well-designed prospective studies are therefore required to provide further definitive information in relation to the benefits and potential harms of prolonged retention.

Appendix 1
Database: Ovid MEDLINE(R) <1946 to Present>
Search Strategy:
1 RANDOMIZED CONTROLLED TRIAL.pt. (413632)
2 CONTROLLED CLINICAL TRIAL.pt. (91880)
3 RANDOM ALLOCATION.sh. (86446)
4 DOUBLE BLIND METHOD.sh. (135365)
5 SINGLE BLIND METHOD.sh. (21423)
6 or/1-5 (586980)
7 (ANIMALS not HUMANS).sh. (4033465)
8 CLINICAL TRIAL.pt. (506935)
9 exp Clinical Trial/ (849000)
10 (clin$ adj25 trial$).ti,ab. (308227)
11 ((singl$ or doubl$ or trebl$ or tripl$) adj25 (blind$ or mask$)).ti,ab. (146187)
12 PLACEBOS.sh. (34034)
13 placebo$.ti,ab. (174121)
14 random$.ti,ab. (804059)
15 RESEARCH DESIGN.sh. (84544)
16 or/9-15 (1594056)
17 16 not 7 (1478011)
18 17 not 8 (977433)
19 8 or 18 (1484368)
20 exp ORTHODONTICS/ (46224)
21 orthod$.mp. (53863)
22 20 or 21 (61325)
23 (retain$ or retent$).mp. (294935)
24 (fixed$ or removable$ or bonded$ or Essix$ or Hawley$).mp. (221824)
25 22 and 23 and 24 (1152)
26 25 and 19 (174)

Appendix 2
Table 6 Excluded studies with reasons for exclusion (n = 36)

| Reason for exclusion                        | Studies |
|---------------------------------------------|---------|
| Irrelevant outcome to the systematic review | [42–63] |
| Cross sectional study                       | [64–67] |
| Follow-up less than 6 months                 | [68–70] |
| Subjects did not undergo orthodontic treatment | [71, 72] |
| Retrospective study                         | [73–76] |
| No control group                            | [77]    |

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Availability of data and materials
Data and materials supporting the findings are presented in the paper.

Authors’ contributions
DA and PSF designed the systematic review and undertook the literature search and screening of the relevant studies, the data extraction, the quality assessment, the interpretation of the results, and the writing of the manuscript. NP undertook the statistical analysis and the interpretation. All three authors approved the submitted version.

Competing interests
The authors declare that they have no competing interests.

Consent for publication
Not applicable.

Ethics approval and consent to participate
Not applicable.

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