European Journal of Orthodontics, 2018, 115–125
doi:10.1093/ejo/cjx036
Advance Access publication 26 May 2017

Systematic Review

Performance of Hawley-type retainers: a systematic review of randomized clinical trials

Wafa Jaber Al Rahma, Eleftherios G. Kaklamanos and Athanasios E. Athanasiou

Hamdan Bin Mohammed College of Dental Medicine, Mohammed Bin Rashid University of Medicine and Health Sciences, Dubai, United Arab Emirates

Correspondence to: Eleftherios G. Kaklamanos, Hamdan Bin Mohammed College of Dental Medicine, Mohammed Bin Rashid University of Medicine and Health Sciences, Dubai Healthcare City, P.O. Box 505055, Dubai, United Arab Emirates. E-mail: eleftherios.kaklamanos@mbru.ac.ae; kaklamanos@yahoo.com

Summary

Background: Although post-treatment changes are almost inevitable, and retention has long been recognized as one of the most critical and routine problems faced by orthodontists, there remains a lack of certainty regarding the parameters of any definitive retention protocol following orthodontic treatment.
Objective: To investigate the performance of the Hawley-type retainers.
Search methods: Search without restrictions in 15 databases and hand searching until December 2016.
Selection criteria: Randomized clinical trials comparing the performance of Hawley-type retainers to other removable appliances or comparing different Hawley-type retainers' wearing schedules.
Data collection and analysis: Following study retrieval and selection, data extraction and individual study risk of bias assessment using the Cochrane Risk of Bias Tool took place. The overall quality of the available evidence was assessed with the Grades of Recommendation, Assessment, Development, and Evaluation approach.
Results: Finally, 10 studies were identified involving 854 individuals, followed for up to 1 year after debonding. Eight studies compared subjects using Hawley and clear thermoplastic retainers; another compared Hawley to positioner and, finally, one trial involved individuals allocated to different Hawley appliance wearing schedules. Three studies were considered as being of low, four of unclear, and three of high risk of bias. In general, few differences were observed between the Hawley and other removable retainers regarding outcomes relevant to maxillary and mandibular dental arch measurements, dental arch relationships and occlusal contacts, speech evaluation, patient reported outcomes, adverse effects, and problems related to the appliances, as well as economic evaluation related outcomes. Moreover, no differences were observed between the compared Hawley wearing schedules. Overall, the quality of the available evidence was considered low.
Conclusions: Given the overall quality of the available evidence and the multitude of parameters, which may have affected the results of the included trials, good practice would suggest further research in the respective field in order to increase both the quantity and quality of information available.
Registration: PROSPERO (CRD42015029279)
Funding: No funding was received for the present systematic review.

Introduction

Rationale

Orthodontic treatment involves the application of forces, which create a cellular response resulting in tooth movement (1,2). Once the teeth have moved, the supporting tissues need to remodel to maintain them in the new position. Other factors affecting teeth position after treatment include occlusal factors, soft tissues, growth, and physiologic dento-alveolar adaptation (1,2). All of the above-mentioned parameters interact to move teeth back toward their pre-treatment position, a phenomenon that is observed in the vast majority of orthodontic patients (3–6). It has been reported that up to 90 per cent of orthodontic patients may have an unacceptable dental alignment 10 years after orthodontic treatment (7).

As post-treatment changes are almost inevitable, retention has long been recognized as one of the most critical and routine problems faced by orthodontists in treating patients (8). Various types of retainers are currently used to assist this process, including Hawley-type retainers, clear thermoplastic retainers, and fixed retainers (9–11). Nevertheless, there remains a lack of certainty regarding the parameters of any definitive retention protocol in orthodontic treatment. Much of current practices seem to be contradictory regarding the type, daily regimen and total duration of orthodontic retention, indicating the need to develop evidence-based practice guidelines (9–15).

Objectives

The objective of the present systematic review was to critically investigate the available data on the performance of Hawley-type retainers and evaluate their quality.

Materials and methods

Protocol and registration

The present review was based on a specific protocol developed and piloted following the guidelines outlined in the PRISMA-P statement (16) and registered in PROSPERO (CRD42015029279). Furthermore, conduct and reporting followed the Cochrane Handbook for Systematic Reviews of Interventions (17) and the PRISMA statement (18), respectively.

Eligibility criteria

The eligibility criteria were based on the PICOS (Participants, Intervention, Comparison, Outcomes, Study design) acronym. In the present systematic review, Randomized Clinical Trials (RCTs), investigating the performance of Hawley-type appliances during the retention period, were included. Animal studies, non-comparative studies (case reports and case series), systematic reviews and meta-analyses were excluded (Supplementary Table 1).

Information sources and search strategy

Overall, 15 databases were searched until December 2016. One author (WJAR) developed detailed search strategies for each database. They were based on the strategy developed for MEDLINE but revised appropriately for each database to take account of the differences in controlled vocabulary and syntax rules (Supplementary Table 2).

No restriction was placed on the language, date, or status of publication. In addition, efforts to obtain additional or ongoing trials were made and the reference lists of all eligible studies, as well as relevant reviews, were searched.

Study selection

Two authors (WJAR and EGK) assessed the retrieved records for inclusion independently. They were not blinded to the identity of the authors, their institution, or the results of the research. Subsequently, they obtained and assessed, again independently, the full report of records considered by either reviewer to meet the inclusion criteria. Disagreements were resolved by discussion or consultation with the third author (AEA).

Data collection and data items

The same two authors performed data extraction independently and any disagreements were again resolved by discussion or consultation with the third author. Predetermined and pre-piloted data collection forms were used to record the desired information (Supplementary Table 1).

Risk of bias in individual studies

Two authors (WJAR and EGK) assessed the risk of bias in individual studies, independently and in duplicate, using The Cochrane Collaboration's Risk of Bias assessment tool for RCTs. Studies were judged as being of low (plausible bias unlikely to seriously alter the results), unclear (bias that raises some doubt about the results) or high risk of bias (bias that seriously weakens confidence in the results) (17). Any disagreements were resolved by discussion or consultation with the third author (AEA).

Summary measures and synthesis of results

Continuous data were planned to be expressed either in the form of the Weighted Mean Difference or in the form of the Standardized Mean Difference together with the relevant 95 per cent Confidence Interval, in order to enable quantitative synthesis (19). The random effects method for meta-analysis was to be used to combine data (20,21). To identify the presence and extent of between-study heterogeneity, the overlap of the 95 per cent CI for the results of individual studies was to be inspected graphically and the I^2 statistic was to be calculated (17). Significance (a) was set at 0.05, except for the 0.10 used for the heterogeneity tests (22).

Risk of bias across studies and additional analyses

If a sufficient number of studies were identified, analyses were planned for 'small-study effects' and publication bias (17). If deemed possible, exploratory subgroup analyses were planned according to participant and intervention characteristics. In addition, the quality of evidence at the longest follow up available was assessed based on the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) approach (23).

Results

Study selection

The flow of records through the reviewing process is shown in Figure 1. We initially identified 1174 records, but excluded 630 as duplicates, and 516 more on the basis of their title and abstract. Finally, 10 full-text reports were included in the systematic review (24–33).

Study characteristics

The characteristics of the studies included in the present systematic review are presented in Tables 1 and 2. The papers, which were

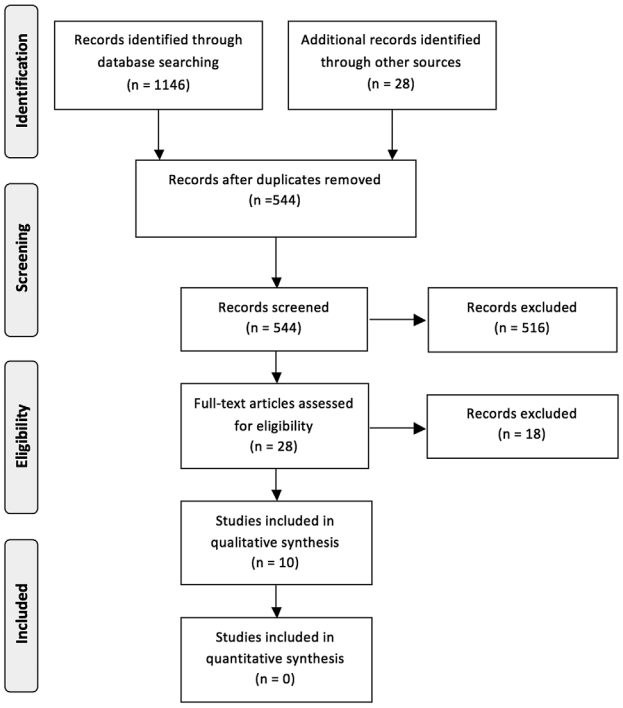

Figure 1. Flow of records through the reviewing process.

published between 2003 and 2016, randomized in different groups 1024 subjects referred for retention after a full course of orthodontic treatment, and analysed various outcomes in 854 of them that were followed for a maximum period of 1 year after debonding.

Eight of the eligible publications investigated individuals using Hawley appliances or clear thermoplastic retainers (25-28,30-33). Two of the aforementioned publications comprised part of a larger trial. Another study (24) compared the Hawley appliance to positioner use during the retention period. Finally, one study (29) involved patients allocated to groups using different wearing schedules for Hawley retention appliances.

Risk of bias within studies

Table 3 presents the summary findings of the risk of bias assessment for the included studies; more details can be found in Supplementary Table 3. Three studies were considered as being of low risk of bias (27,29,33), four of unclear (24,26,28,32), and three (25,30,31) of high risk of bias.

In general, most studies included were considered to present a low risk of bias regarding the domains of random sequence generation and allocation concealment, although some were categorized as unclear because of insufficient information to form a definite judgment. Blinding of the participants, caregivers, and the personnel providing the instructions was not feasible or easily achievable in most cases. However, in the context of the present research design, there was no reason to suggest that bias could be introduced because of absence of blinding in these cases. Moreover, the review authors did not believe that bias could be introduced by the methods described in most studies regarding blinding of outcome assessment. In addition, most studies exhibited low risk of bias due to the observed dropouts, whereas, more than half of them where considered to be at unclear or high risk of reporting bias. Finally, the risk of the included studies of presenting other potential threats to validity was considered unclear in most cases because it was impossible to determine how the subjects' compliance to the recommended retention protocol could have influenced the results, as the relative information was sparse and inadequately reported.

Results of individual studies

The results of the studies included in the present review are presented below. Because of the lack of extensive relevant data, differences in the methodology used and the statistical elaboration of the obtained results, data synthesis was not possible (17).

Comparison between Hawley and clear thermoplastic retainers

Regarding different dental arch measurements at different follow-ups, Rowland and co-workers (27) showed significantly greater changes in Little's Irregularity Index in the Hawley retainer group than in the subjects wearing the clear thermoplastic retainers at 6 months. At 9 months, a significantly greater proportion of maxillary teeth rotations had relapsed in subjects wearing Hawley retainers (25). Otherwise, no statistically significant differences were observed (25,27,28) (Table 4).

Overall, there was no statistically significant difference observed in overjet and overbite between the subjects belonging to the two retainer groups at the 6 month evaluation (27). Regarding posterior occlusal contacts, as assessed by the thickness of silicon bite registrations in maximum intercuspation three months after debonding, few differences were observed (30) (Supplementary Table 4).

Evaluation of different aspects of speech revealed no statistically significant differences in the number of sound distortions at 3 months post-debond (33). In addition, Atik and co-workers (32) showed various effects on the formant frequencies of four sustained vowels [a, e, i, u] and combinations of vowel [a] with consonants in both groups at end of the 3 month evaluation period. However, Voice Onset Time values did not differ between individuals.

Patient self-reported compliance with the instructed wear regimen was not found to differ at 3 months after debonding (30). However, at the 6 month evaluation, individuals wearing clear retainers were self-reporting to be more compliant with the instructions they received (26). In the same study, participants in the clear retainer group reported less embarrassment than those wearing the Hawley appliances and a better overall assessment regarding their retainers compared with fixed appliances, but no statistically significant difference in the frequency of wearing the appliance away from home was observed nor in the amount of discomfort felt. Finally, regarding the subjective assessment of occlusion no statistically significant difference was observed at three months post debond (30) (Supplementary Table 5).

Overall, possible adverse effects related to the retainers were not investigated. Two papers eligible for inclusion in the present thesis gave comparison data on retainer failure (26,31). Hichens and co-workers (26) in their 6 month investigation compared the self-reported overall retainer failure of Hawley and clear thermoplastic appliances. Although more participants reported that they had broken their retainers in the first group, no difference was observed in the proportions of patients reporting having lost their appliances. In more long-term study, Sun *et al.* (31) also compared the failure of retainers as assessed by professionals, separately for the maxillary and the mandibular dental arches. Only in the mandibular dental arch was the proportion of clear retainers presenting with fractures or exhibiting overall failure greater than the proportion in the Hawley retainer group (Supplementary Table 6). Moreover, regarding overall survival no statistically significant difference was observed between maxillary (P = 0.254) and mandibular (P = 0.188) Hawley and clear thermoplastic retainers (31).

Finally, regarding economic evaluation, based on the fact that Little's Irregularity Index was statistically significantly greater in the

Table 1. General characteristics of the studies included in the systematic review.

Study	Intervention characteristics	Included outcomes	Additional information
Atik et al., 2016 (32) **Turkey**	**Group 1: Hawley retainers:** Adams clasps, labial wire with vertical loops, and lingual acrylic (uniform thickness of 2–3 mm, trimmed into a horseshoe shape). **Group 2: Clear thermoplastic retainers:** Plastic, copolyester 0.75 mm Essix sheet materials constructed according to the manufacturer's instructions, and the maxillary retainers trimmed into a horseshoe shape. Patients were instructed to wear the retainers 24 hours/day for 6 months, including while eating, but to remove them when brushing. It was recommended that they not read paragraphs out loud to expedite speech adaptation.	**Formant frequencies of sustained vowels** [a, e, i, u] and of vowel [a] in combination with consonants [b, d, g, t, ş, ç, l, z, c, m, n] **Voice onset time (VOT) values** of voiceless [t] and voiced [d] stop consonants in combination with vowel [a] The speech sound assessments were performed by a speech–language pathologist. The recording procedure was repeated for each participant at four different time points: 1. first day, 2. 1 week later, 3. 4 weeks later, and 4. 3 months later. On the first day, the assessments were conducted prior to inserting the retainers, immediately after, individually, and with both retainers. The later assessments were conducted with both retainers worn. The recording order was the same.	**A priori sample calculation:** Thirty patients (power of 0.80; a = 0.05) For the most important five variables (ç, g, m, u, a), the sample sizes were calculated separately based on the difference in the groups between the different time points; maximum sample size was taken into account. The power analysis was via the two-way repeated measures. **Information on compliance:** No **Reliability of measurements:** NR
Hichens et al., 2007 (26) **United Kingdom**	**See Rowland et al. (2007)** (27)	**Patient satisfaction questionnaire:** at 3 and 6 months post-debonding **Costs to the National Health Service** **Costs to the orthodontic practice** **Costs to the patient** Unit costs in euros were used at 2003 prices. No adjustment or discount. All direct costs were included depended on the perspective. Total clinical time cost was calculated by multiplying the gross clinical time cost per min by the total clinical time spent in appointments, over 6 months.	**A priori sample calculation:** Existing, but not based on these outcomes. **Information on compliance:** Self-reported **Reliability of measurements:** NR
Liao, 2010 (28) **China**	**Group 1: Hawley retainers:** Circumferential molar clasps (0.9 mm), labial wire with vertical loops (0.8 mm), lingual acrylic. **Group 2: Clear thermoplastic retainers** 0.15 mm hard transparent sheet (Thermo-Forming Materials, Netherlands). Edges exceeded 1 mm from the gingival margin (vestibular side) and 2–3 mm from the palatal/lingual side. Patients were instructed to wear the retainers 24 hours a day, except meals, for 6 months.	**Intercanine and Intermolar width** **Arch length [canines and molars]** Measurements on dental casts taken at the removal of the appliances and 6 months after.	**A priori sample calculation:** NR **Information on compliance:** No **Reliability of measurements:** NR
Rohaya et al., 2006 (25) **Malaysia**	**Group 1: Hawley retainers:** Standard upper Hawley retainer, with a plain labial bow, Adam's clasps on the first molars and cold-cured acrylic. Patients were asked to wear the retainer full time for the first 3 months, followed by 6 months nighttime wear only. **Group 2: Clear thermoplastic retainers:** Vacuum-formed retainer made from Essix type C thermoplastic copolyester material (Raintree Essix Inc., Ortho-Care (UK)) with a 0.5 mm thickness after being thermoformed, full-arch tooth coverage and the edges extended about 2–3 mm into labial gingival. Patients were asked to wear the retainer full-time for one week, followed by evening and night-wear for three months and 6 months for night time wear only.	**Rotations of the upper teeth (labial segment and premolars)** were measured using a protractor on patients' casts at the end of the follow up period (9 months). Rotations were either scored as present (i.e. teeth that were rotated 15° or more from normal arch alignment) or absent. For the upper central incisors especially with V shaped arch, they were considered rotated disto-palatally if the angle between them was less than 90°.	**A priori sample calculation:** The intra and inter-examiner agreement analysed using Kappa statistics showed very good agreement of intra-examiner (k = 0.82) and moderate agreement of inter-examiner (k = 0.47). Most of the disagreement involved the upper labial segment, which can be difficult to assess due to the shape of their arch form. The disagreements were discussed and a standardized protocol agreed upon. **Information on compliance:** No **Reliability of measurements:** Yes.

Table 1. *Continued*

Study	Intervention characteristics	Included outcomes	Additional information
Rowland et al., 2007 (27) **United Kingdom**	**Group 1: Hawley retainers:** The Hawley retainers were constructed with an acrylic base plate and Adams clasps fabricated of 0.7 mm diameter stainless steel wire on the first standing molars. A Hawley bow (open looped short labial bow) was also made from 0.7 mm stainless steel wire; it extended from canine to canine. The Hawley bow was then contoured with acrylic resin to contact the labial surfaces of the incisors. The patients were instructed to wear the maxillary and mandibular Hawley retainers 24 hours a day for 3months, including while eating, but to remove them when brushing their teeth. After 3 months, wear time was reduced to 12 hours a day. **Group 2: Clear thermoplastic retainers:** Constructed from an Erkodur blank (Erkodent, Erich Kopp, GmbH, Pfalzgrafenweiler, Germany) 1.5 mm in thickness. The retainer was trimmed to provide 1 to 2 mm buccal and 3 to 4 mm lingual extensions past the gingival margin. All occlusal surfaces were covered up to and including the most distal tooth. Patients were instructed to wear the VFRs 24 hours a day for the first week and remove them only for eating and brushing their teeth. After the first week, wear time was reduced to 12 hours a day.	**Tooth rotations:** The rotation of the incisors and the canines was determined by constructing a line that bisected 2 points per tooth that best marked its rotational angulation. The angle formed by the intersection of this line with the line forming arch depth gave the measurement of rotation of the tooth. Arch depth was defined as the length of a line perpendicular to the intermolar width that passed through the midpoint of the contact points of the central incisors. The measurement of rotation for the premolars was calculated by constructing a line that bisected the buccal and the palatal/lingual cusp tips. In premolars with 2 lingual/palatal cusps, the mesiopalatal/mesiolingual cusp was bisected to form the line. The angle formed by the intersection of this line with the line forming arch depth gave the rotation of the tooth. **Intercanine width** **Intermolar width** **Little's Irregularity Index:** Displacement between the midpoint of the incisor edges. Measurements on digitized images of study casts taken at debonding, 3 and 6 months after.	**A priori sample calculation:** Total sample size of 388 subjects would give a power of 80% with a 5%significance level to detect a true difference in contact point displacement of greater than 0.2 mm. **Information on compliance:** Self-reported **Reliability of measurements:** The intra-observer reliability coefficients ranged from 0.96 to 1.0 for linear measurements and from 0.93 to 1.0 for angular, demonstrating that the method had good reliability.
Shawesh et al., 2010 (29) **United Kingdom**	**Group 1: Hawley retainers full-time** 6 months full-time followed by 6 months night-only **Group 2: Hawley retainers part-time** 12 months night-only Hawley retainers. Adams' cribs on both upper first permanent molars; long labial bow soldered to the bridges of these cribs; labial acrylic; base plate with acrylic contacting the palatal/lingual surface of all teeth.	**Little's Irregularity Index:** The sum of the distances between the anatomic contact points from the mesial of the left canine to the mesial of the right canine in each labial segment **Incisor crowding:** The difference between the sum, in mm, of the canine-to-canine tooth widths and the space in the labial segment from canine to canine. The available space in the labial segment was measured by dividing the labial segment into two straight-line segments, extending from the distal contact point of the canine on each side to the midpoint between the central incisors. Measurements on study casts taken at debonding and 12 months after.	**A priori sample calculation:** Power of 90% to detect a clinically significant difference of 2 mm in labial segment alignment, assuming that the common standard deviation is 2 mm using a two-group t-test with a 0.05, two-sided significance level. **Information on compliance:** NR **Reliability of measurements:** Little's index/lower arch, 0.96; Little's index/upper arch, 0.95; labial segment crowding/lower arch, 0.90; and labial segment crowding/upper arch, 0.81.
Sun et al., 2011 (31) **China**	**Group 1: Hawley retainers:** Composed of a 2 mm thick acrylic resin base plate, one-arm clasps (0.9 mm stainless steel (SS) wire on the first molars, and a Hawley bow (0.7mm SS). The base plate covered most of the hard palate and was meticulously adapted to the lingual surfaces of the teeth.	**Retainer failure as judged by the professional:** Retainer fracture, retainer loss, retainer no longer fitting (because of retainer deformation) or tooth relapse, retainer with serious abrasion causing penetration. Retainers which had slight cracks on the surface were not considered as a breakage unless the retainers could not be worn because of crack expansion.	**A priori sample calculation:** NR **Information on compliance:** NR **Reliability of measurements:** Not applicable

Table 1. *Continued*

Study	Intervention characteristics	Included outcomes	Additional information
	Group 2: Clear thermoplastic retainers: 0.75 mm thick thermoplastic material (Biolon, Dreve Dentamid GmbH, Unna, Germany). The buccal edge paralleled the gingival margin, and the lingual portion extended 4 to 5 mm beyond the lingual gingival margin. The distal portion extended as far as the second molars, and all occlusal surfaces were tightly covered. Patients in both groups were required to wear the retainers full-time, except during meals	The numbers of each type of failure were totalled at the end of the 12 month follow-up period.	
Tsai, 2010 (30) **United States of America**	**Group 1: Hawley retainers:** Fabricated with ball clasps mesial to the first molar. **Group 2: Clear thermoplastic retainers:** Fabricated using Essix C+ and were trimmed 2 mm below the gingival margins. Both groups were instructed to wear their retainers full-time, except when eating and brushing.	**Occlusal contacts:** Quantified in the posterior area with an imaging software aiming at investigating the thickness of bilateral bite registrations taken in maximum intercuspation using a silicon bite registration material. **Subjective assessment of occlusion questionnaire:** Assessments at debonding, one and three months after the removal of fixed orthodontic appliances.	**A priori sample calculation:** NR **Information on compliance:** NR **Reliability of measurements:** NR
Wan et al., 2016 (33) **China**	**Group 1: Hawley retainers:** constructed with a 2 mm thick U-shaped acrylic base-plate, one-arm clasps with an 0.8 mm diameter stainless steel wire on the first standing molars, and a Hawley bow with 0.8 mm diameter stainless steel wire. **Group 2: Clear thermoplastic retainers:** 0.8 mm thick thermoplastic material, tightly covering all occlusal surfaces and trimmed to provide approximately 2 mm lingual extensions past the gingival margin. Patients instructed to wear the maxillary and mandibular retainers all the time, except while eating or brushing their teeth.	**Articulation of four long vowels and five voiceless fricatives** from the International Phonetic Alphabet: Patients asked to pronounce 36 words (four typical words for each symbol selected from a dictionary as a speech stimulus) at their comfort levels of pitch and loudness in a quiet, soundproof room. The recorded samples were analysed on the basis of their acoustic characteristics using specific software (Praat Software, version 5.4.21; Amsterdam, The Netherlands). **Formant frequencies of vowels** **Upper boundary frequency (UBF) of voiceless fricatives** Speech was evaluated immediately after wearing both upper and lower retainer, 24 hours later, 1 week later, 1 month later and 3 months later.	**A priori sample calculation:** G*Power software Version 3.1 (Heinrich-Heine-Universitat Dusseldorf, Dusseldorf, Germany), with an alpha value of 0.05 and a power of 80%; revealed the need for 10 subjects per group. **Information on compliance:** NR **Reliability of measurements:** NR
Zhang and Wang, 2003 (24) **China**	**Group 1: Hawley retainers:** No other details available. **Group 2: Positioners:** No other details available. No details available on wearing instructions.	**Plaque Index, Gingival Index, Probing Depth at 16, 13, 21, 36, 33, 41** [mesiobuccal angle, labial side (or buccal side), distobuccal angle and right in the middle of palatal (lingual) side] Examination was done 1 week, 1 month and 3 month after retainer placement.	**A priori sample calculation:** NR **Information on compliance:** NR **Reliability of measurements:** NR

NR: Not Reported.

Hawley group than in the group using thermoplastic retainers, the latter were considered more cost-effective from the perspectives of the United Kingdom National Health Service, the orthodontic practice and the individual, although for the last comparison the evidence was deemed to be weak (26, 27).

Comparison between Hawley and positioners

Only one study (24) compared the effects between Hawley retainers and positioners. They investigated the Plaque Index (PI), Gingival Index, and Probing Depth up to 3 months. Only the PI was observed to be statistically higher in the positioner group compared to the Hawley group.

Comparison of different wearing schedules of Hawley retainers

Shawesh and co-workers (29) compared full-time wear (6 months for 24 hours per day followed by 6 months night-only) with part-time (1 year night-only) wear of Hawley retainers. No statistically significant differences were observed between the two retention regimens regarding maxillary and mandibular Little's Irregularity Index or labial segment crowding.

Table 2. Participant characteristics of the studies included in the systematic review.

Study	Eligibility criteria	Number of patients randomized and analysed
Atik et al., 2016 (32)	**Inclusion criteria:** Native Turkish speakers raised in a monolingual environment. At the beginning of the observation period, none of the patients had known cognitive deficits, definite dysmorphology such as cleft lip and/or palate, neurological disorders, phonological problems, articulation problems, or hearing loss. Patients were treated with non-extraction treatment protocol and had Class I and II malocclusion.	**Randomized:** 30 subjects **Group 1: Hawley retainers:** 15 **Group 2: Clear thermoplastic retainers:** 15 **Analysed:** 25 subjects **Group 1: Hawley retainers:** 12 (mean age 16.3 ± 2.56 years) **Group 2: Clear thermoplastic retainers:** 13 (mean age 15.3 ± 2.4 years)
Hichens et al., 2007 (26)	**See Rowland et al., 2007** (27)	**Randomized:** 397 subjects **Group 1: Hawley retainers:** 196 **Group 2: Clear thermoplastic retainers:** 201 **Analysed [Questionnaires]:** 350 subjects **Group 1: Hawley retainers:** 168 **Group 2: Clear thermoplastic retainers:** 182 **Analysed [Cost interview]:** 60 subjects **Group 1: Hawley retainers:** 41 **Group 2: Clear thermoplastic retainers:** 19
Liao, 2010 (28)	**Inclusion criteria:** Patients who just finished fixed orthodontic treatment.	**Randomized and analysed:** 50 subjects **Group 1: Hawley retainers:** 25 **Group 2: Clear thermoplastic retainers:** 25
Rohaya et al., 2006 (25)	**Inclusion criteria:** 1) Consecutively treated patients who had either upper fixed or upper and lower fixed appliances; with and without a prior phase of functional appliance therapy and with or without extraction of teeth. 2) Patients prepared to wear either a Hawley or a Vacuum-formed retainer. **Exclusion criteria:** 1) Patients who had undergone surgical repositioning of the jaws as part of their treatment. 2) Hypodontia treated by reopening spaces for prosthetic replacement of teeth. 3) Patients with marked alveolar bone loss related to treated periodontal disease (now stabilized), who usually need permanent bonded retainers. 4) Cases that required substantial expansion of the upper arch, which necessitated the use of either rapid maxillary expansion or a Quad-helix. 5) Cleft lip and palate patients or patients who presented with any craniofacial syndrome.	**Randomized:** 218 subjects **Analysed:** 139 subjects **Group 1:** Hawley retainers: 68 **Group 2:** Clear thermoplastic retainers: 71
Rowland et al., 2007 (27)	**Inclusion criteria:** Fixed appliance treatment involving both arches; pre-adjusted edgewise appliances; pretreatment records, treatment plan, and study models available; willing to wear maxillary and mandibular retainers. **Exclusion criteria:** Single-arch or sectional fixed appliance treatment, hypodontia requiring tooth replacement on the retainer as a temporary measure, rapid maxillary expansion, bonded retainers, poor periodontal status, early debonding, transfer patients, learning difficulties, or cleft lip or palate.	**Randomized:** 397 subjects **Group 1: Hawley retainers:** 196 **Group 2: Clear thermoplastic retainers:** 201 **Analysed:** 310 subjects **Group 1: Hawley retainers:** 155 **Group 2: Clear thermoplastic retainers:** 155
Shawesh et al., 2010 (29)	**Inclusion criteria:** 10–16 years of age, labial segment crowding or tooth contact point displacement at the start of orthodontic treatment, clinically acceptable labial segment alignment at the end of active treatment, and good oral hygiene. **Exclusion criteria:** Lack of consent, severe rotations or midline diastema suggesting the need for a bonded retainer, and patients with a restorative need in the labial segment, e.g. implant, bridges, or missing teeth.	**Randomized:** 67 subjects **Group 1: Hawley retainers full-time:** 34 **Group 2: Hawley retainers part-time:** 33 **Analysed:** 52 subjects **Group 1: Hawley retainers full-time:** 28 **Group 2: Hawley retainers part-time:** 24

Table 2. *Continued*

Study	Eligibility criteria	Number of patients randomized and analysed
Sun et al., 2011 (31)	**Inclusion criteria:** (1) Age 18 years. (2) All second molars erupted and in occlusal contact. (3) Agreement to the research procedures and signing of an informed consent, accompanied by a parent or legal guardian. **Exclusion criteria:** Allergic reaction to acrylic resin, rejection of either of the 2 types of retainers, individuals unable to comply with follow-up appointments during 12 months.	**Randomized:** 120 subjects **Group 1: Hawley retainers:** 61 **Group 2: Clear thermoplastic retainers:** 59 **Analysed:** 111 subjects **Group 1: Hawley retainers:** 56 **Group 2: Clear thermoplastic retainers:** 55
Tsai, 2010 (30)	**Inclusion criteria:** Completed full orthodontic treatment to Class I molar and canine relationships. **Exclusion criteria:** History of temporomandibular disorder, large restorations on posterior teeth, allergies to any materials used in the study and periodontal disease and /or muscular dysfunction. Subjects were also withdrawn from the study if they were non-compliant with regards to retainer wear, lost their retainers, or did not have longitudinal records.	**Randomized:** 60 subjects **Group 1: Hawley retainers:** 30 **Group 2: Clear thermoplastic retainers:** 30 **Analysed:** 40 subjects **Group 1: Hawley retainers:** 20 **Group 2: Clear thermoplastic retainers:** 20
Wan et al., 2016 (33)	**Inclusion criteria:** Native Chinese who completed active orthodontic treatment. **Exclusion criteria:** (1) cleft lip or cleft palate, (2) surgical correction of the jaws, (3) dialects,(4) hearing and speech disorders, (5) temporomandibular joint dysfunction syndrome, (6) younger than 18 years, or (7) suffering from serious periodontitis.	**Randomized and analysed:** 20 subjects **Group 1: Hawley retainers:** 10 (mean age 24.6 ± 2.6 years) **Group 2: Clear thermoplastic retainers:** 10 (mean age 24.1 ± 3.1 years)
Zhang and Wang, 2003 (24)	**Inclusion criteria:** Finished fixed orthodontic treatment, brushing carefully 3–5 minutes, 3 times per day. **Exclusion criteria:** Use of antibiotics. Before the start of the study all patients received periodontal treatment and their gingival conditions were good with normal colour and normal probing depths.	**Randomized and analysed:** 62 subjects (mean age 17.7; range: 9–26 years) **Group 1: Hawley retainers:** 31 **Group 2: Clear thermoplastic retainers:** 31

NR: Not Reported.

Table 3. Summary of risk of bias assessment.

	Domain							
Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Summary assessment**
Atik et al., 2016 (32)	?	+	+	+	+	+	?	?
Hichens et al., 2007 (26)	+	+	+	+	+	?	?	?
Liao, 2010 (28)	?	?	+	?	+	−	?	?
Rohaya et al., 2006 (25)	+	+	+	+	−	−	?	−
Rowland et al., 2007 (27)	+	+	+	+	+	−	?	+
Shawesh et al., 2010 (29)	+	+	+	+	+	+	?	+
Sun et al., 2011 (31)	+	+	+	−	+	−	?	−
Tsai, 2010 (30)	?	?	+	?	−	?	?	−
Wan et al., 2016 (33)	+	+	+	+	+	?	?	+
Zhang and Wang, 2003 (24)	?	?	+	?	?	+	?	?

1: Random sequence generation; 2: Allocation concealment; 3: Blinding of participants and personnel; 4: Blinding of outcome assessment; 5: Incomplete outcome data; 6: Selective outcome reporting; and 7: Other potential threats to validity.

Risk of bias across studies and additional analyses

It was not possible to conduct analyses for 'small-study effects', publication bias or subgroup analyses.

Overall, regarding the comparison between Hawley and clear thermoplastic retainers, the quality of available evidence for the mandibular and maxillary Little's Irregularity Index was considered as low, whereas for patient reported outcomes and retainer failure as very low (Supplementary Table 7). For the other variables, the quality of evidence was assessed at best as low (Supplementary Tables 8–10).

Table 4. Comparative effects of Hawley and clear thermoplastic retainers on different maxillary and mandibular dental arch measurements at different follow-ups.

	Observation—6 months		Observation—9 months
	Rowland et al., 2007 (27)	Liao, 2010 (28)	Rohaya et al., 2006 (25)
Maxillary measurements			
Little's Irregularity Index	**0.013 [HR>CR]**		
Intercanine width	0.12	0.56	
Intermolar width	0.53	0.40	
Arch length [canines]		0.48	
Arch length [molars]		0.37	
Teeth rotations	>0.05		**0.04 [HR>CR]**
Mandibular measurements			
Little's Irregularity Index	**<0.001 [HR>CR]**		
Intercanine width	0.09		
Intermolar width	0.17		
Teeth rotations	>0.05		

HR: Hawley retainers; CR: Clear thermoplastic retainers.

Discussion

Summary of evidence

It is generally advised that almost all orthodontic patients should be provided with some type of retainers (11,34). Removable retainers, in particular, are often used, despite reservations about poor compliance, especially in adolescents (35). However, there are, as yet, no definite indications for choosing the optimal period of retention, or the type of retainer (6,34) and general protocols for ideal orthodontic retention practices still remain undetermined (14).

From the initially identified records, 10 full-text randomized controlled trials investigating the performance of Hawley-type retainers were included in this systematic review, reflecting the scarcity of relevant research at the top of a widely accepted hierarchy of scientific evidence. Considerable research has been done in trials that were not randomized, despite the generally accepted fact that well-designed and properly executed RCTs provide the best evidence on the efficacy of health care interventions (36,37). The consequent lack of extensive data of high evidence based potential is rather surprising bearing in mind post-treatment changes may occur in a significant proportion of the orthodontically treated population (7) and that a high percentage of orthodontists consider them as constituting an important area requiring guidelines (11). Thus, proper retention guidelines should be developed based on a well-established, firm scientific base (6,11), in order to support and consolidate the care provided.

Eight of the eligible publications investigated individuals using Hawley or clear thermoplastic retainers. In general, no statistically significant differences were observed regarding maxillary and mandibular dental arch measurements at different follow-ups (25, 27, 28). However, subjects wearing Hawley retainers had significantly greater proportion of maxillary teeth rotation (25) and significantly greater changes in Little's irregularity index (27). Moreover, no statistically significant differences were observed in overjet and overbite measurements (27), and almost no differences regarding occlusal contacts (30).

Evaluation of different aspects of speech did not reveal clear-cut differences between the two groups (33, 32). Patient self-reported compliance was observed to be greater in the clear retainer group. However, there was no statistically significant difference in the frequency of wearing the appliance away from home, the amount of discomfort felt (26), or the subjective assessment of occlusion (30). In addition, the proportion of broken retainers was greater for mandibular clear retainers (31). Finally, regarding economic evaluation, clear thermoplastic retainers were considered more cost-effective from the perspectives of the health system, the orthodontic practice and the individual patient (26). Almost no differences were observed in the comparison between Hawley retainers and positioners (24), or in the comparison of different wearing schedules of Hawley retention appliances (29).

In general, the quality of evidence (confidence in the observed estimates) assessed with the GRADE approach (23) was considered at best as low, indicating caution regarding the strength of the relevant recommendations for clinical practice.

Strengths and limitations

The strengths of the present review include using a methodology following well-established guidelines and the fact that it focused exclusively on randomized controlled trials, as it is widely accepted that well-designed and properly executed RCTs provide the best evidence, with decreased risk of bias, on the efficacy of health care interventions (36,37). Moreover, the search strategy employed in the present review was exhaustive, covering electronic, manual, and grey literature material up to December 2016. In addition the search was comprehensive including every available randomized trial, irrespective of language, date and status of publication; an approach that led to the retrieval of more relevant information compared to a recent systematic review (38). Every effort to decrease bias in the methodology employed was made. Screening, verification of eligibility, abstraction of information, assessment of risk of bias and of the quality of evidence were performed in duplicate, and any disagreement was resolved by discussion or consultation with the thesis co-supervisor until a final consensus was achieved.

There are also some limitations to the present review, arising mainly from the nature and the characteristics of the data retrieved during the review process, which resulted in the assessment of the level of available evidence as, at best, low. The scarcity of relevant high quality hierarchically evidence based information from RCTs, precluded meta-analytic procedures for all outcomes. Another limitation of the data retrieved in this study stems from the small number of patients analysed resulting in problems regarding the precision of the effect estimates. Also the data on adverse effects and problems related to the employed appliances were very sparse. In addition, the

results obtained were derived from specific populations, appliances, and retention protocols, thus curtailing the generalizability of the retrieved information to other clinical settings or situations. Hence even this limited set of data cannot be applied with certainty in clinical settings characterized by a different patient mix or variable type and frequency of retention modalities.

Finally, the generalizability of the data found is limited by two additional factors. Firstly, the lack of long-term data. Investigations up to now have been relatively short term in nature and show there is little difference between various retention protocols. It is unclear, however, which retention strategy is most effective in the long term. 'What retainer(s) and for how long should I use them?' are questions yet to be answered based on methodologically rigorous randomized clinical trials (39). Patients who spent months or years in treatment and the orthodontist who provided it, would be very much interested in having an insight into the effectiveness of various retention approaches over periods exceeding the 1 year forming the longest follow up of patients in the studies included in the present systematic review. Secondly, as one of the most important factors in retention is patient co-operation, it would be useful to have more details on patients' compliance. Current data on this topic from studies where compliance was assessed as objectively as possible suggest that patients tend to wear their retainers less than the prescribed daily schedule (35,40-44).

Recommendations for future research

As the overall quality of the relevant available evidence was considered low, and appropriate guidelines and protocols for ideal orthodontic retention practice are still not determined (14), further research is recommended. Proper retention guidelines should be developed based on a well-established, firm scientific base (6,11).

Well-designed and properly executed RCTs provide the best evidence with decreased risk of bias on the efficacy of health care interventions (36,37). In addition, there is a need to determine which approach is most effective in the long term through adequate follow-up periods. Retention studies are not easy to undertake, as long-term follow-up of participants is difficult in practice and financially demanding. However, given that the vast majority of people requiring orthodontic treatment undergo a phase of retention, this vital area of orthodontic research should be given priority.

Furthermore, as the evidence-based data up to the present have involved specific appliance protocols used in a particular populations, future research should also be directed to alternative protocols, as well as, different populations according to type of malocclusion, age, and growth pattern, so as better understanding of the different aspects of retention can be achieved. In addition, every effort should be made to increase the number of patients analysed in such studies. Increasing the number of patients analysed will increase the precision of effect estimates (45).

Finally, future studies including objective assessment of patients' compliance with retainer wearing, and correlating patients' compliance with tooth stabilization could be important. Such studies could provide an answer regarding the 'optimal' wear time for maintaining the final orthodontic outcome, so that treatment protocols could be readjusted accordingly and support in a more meaningful way the care provided.

Conclusions

Based on the findings of the present systematic review, conducted following well-established guidelines, few differences were observed in the performance of Hawley appliances compared to other removable retainers, in patients followed for a period up to one year after debonding. Greater changes in Little's Irregularity Index and greater proportion of maxillary anterior teeth rotation were observed with Hawley retainers. Patient self-reported compliance with the instructed wear regimen was greater and embarrassment in wearing the retainer was less in the clear retainer group. Although, mandibular clear thermoplastic retainers seem to exhibit failure more often they are considered more cost-effective. Moreover, no differences were found between different appliance wearing schedules and protocols. Given the overall quality of the available evidence, the short-term follow-up and the multitude of parameters, which may have affected the results of the included trials, good practice would suggest further research in the respective field to seriously augment the body of high quality information.

Supplementary Material

Supplementary data are available at *European Journal of Orthodontics* online.

Funding

No funding was received for the present systematic review.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

1. Thilander B. (2011) Tissue reactions in orthodontics. In Graber T.M., Vanarsdall R.L. and Vig K.W.L. (eds.), *Orthodontics: Current Principles and Techniques*. Elsevier, Philadelphia, PA, pp. 247–286.
2. Maltha J.C., Vandevska-Radunovic V. and Kuijpers-Jagtman A.M. (2015) The biological background of relapse of orthodontic tooth movement. In Krishnan V. and Davidovitch Z. (eds.) *Biological Mechanisms of Tooth Movement*. John Wiley & Sons, Chichester, UK, pp. 248–259.
3. Joondeph D.R. (2011) Stability, Retention and relapse. In Graber T.M., Vanarsdall R.L. and Vig K.W.L. (eds.), *Orthodontics: Current Principles and Techniques*. Elsevier, Philadelphia, PA, pp. 991–1019.
4. Blake M. and Garvey M.T. (1998) Rationale for retention following orthodontic treatment. *Journal of Canadian Dental Association*, 64, 640–643.
5. Blake M. and Bibby K. (1998) Retention and stability: a review of the literature. *American Journal of Orthodontics and Dentofacial Orthopedics*, 114, 299–306.
6. Melrose C. and Millett D.T. (1998) Toward a perspective on orthodontic retention? *American Journal of Orthodontics and Dentofacial Orthopedics*, 113, 507–514.
7. Thilander B. (2000) Orthodontic relapse versus natural development. *American Journal of Orthodontics and Dentofacial Orthopedics*, 117, 562–563.
8. Oppenheim A. (1934) The crisis in orthodontia. Part I. 2. Tissue changes during retention. Skogsborg's septotomy. *International Journal of Orthodontia and Dentistry for Children*, 20, 639–644.
9. Wong P.M. and Freer T.J. (2004) A comprehensive survey of retention procedures in Australia and New Zealand. *Australian Orthodontic Journal*, 20, 99–106.
10. Keim R.G., Gottlieb E.L., Nelson A.H. and Vogels D.S. III. (2008) JCO study of orthodontic diagnosis and treatment procedures. Part 1: Results and trends. *Journal of Clinical Orthodontics*, 42, 625–640.
11. Renkema A.M., Sips E.T., Bronkhorst E. and Kuijpers-Jagtman A.M. (2009) A survey on orthodontic retention procedures in The Netherlands. *European Journal of Orthodontics*, 31, 432–437.
12. Singh P., Grammati S. and Kirschen R. (2009) Orthodontic retention patterns in the United Kingdom. *Journal of Orthodontics*, 36, 115–121.

13. Valiathan M. and Hughes E. (2010) Results of a survey-based study to identify common retention practices in the United States. *American Journal of Orthodontics and Dentofacial Orthopedics*, 137, 170–7; discussion 177.
14. Pratt M.C., Kluemper G.T., Hartsfield J.K. Jr, Fardo D. and Nash D.A. (2011) Evaluation of retention protocols among members of the American Association of Orthodontists in the United States. *American Journal of Orthodontics and Dentofacial Orthopedics*, 140, 520–526.
15. Vandevska-Radunovic V., Espeland L. and Stenvik A. (2013) Retention: type, duration and need for common guidelines. A survey of Norwegian orthodontists. *Orthodontics*, 14, e110–e117.
16. Shamseer L. *et al.*; PRISMA-P Group. (2015) Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ (Clinical research ed.)*, 349, g7647.
17. Higgins J.P.T. and Green S. (2011) *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0. [updated March 2011]*. The Cochrane Collaboration, 2011. www.cochrane-handbook.org (31 October 2016, date last accessed).
18. Liberati A.*et al.* (2009) The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Journal of Clinical Epidemiology*, 62, e1–e34.
19. Deeks J.J., Altman D.G. and Bradburn M.J. (2001) Statistical methods for examining heterogeneity and combining results from several studies in meta-analysis. In Egger M., Davey Smith G. and Altman D.G. (eds.) *Systematic Reviews in Health Care*. BMJ Books, London, UK, 2nd edn, pp. 285–312.
20. Borenstein M., Hedges L.V., Higgins J.P.T. and Rothstein H.R. (2009) *Introduction to Meta-Analysis*. Wiley, Chichester, UK.
21. DerSimonian R., Laird N. (1986) Meta-analysis in clinical trials. *Controlled Clinical Trials*, 7, 177–188.
22. Ioannidis J.P. (2008) Interpretation of tests of heterogeneity and bias in meta-analysis. *Journal of Evaluation in Clinical Practice*, 14, 951–957.
23. Guyatt G.H., Oxman A.D., Schünemann H.J., Tugwell P. and Knottnerus A. (2011) GRADE guidelines: a new series of articles in the Journal of Clinical Epidemiology. *Journal of Clinical Epidemiology*, 64, 380–382.
24. Zhang B. and Wang Q. (2003) Periodontal implication of positioner versus removable retainer. *Beijing Journal of Stomatology*, 3, 146–7.
25. Rohaya M.A.W., Shahrul Hisham Z.A. and Doubleday B. (2006) Randomised clinical trial: comparing the efficacy of vacuum-formed and Hawley retainers in retaining corrected tooth rotations. *Malaysian Dental Journal*, 27, 38–44.
26. Hichens L., *et al.* (2007) Cost-effectiveness and patient satisfaction: Hawley and vacuum-formed retainers. *European Journal of Orthodontics*, 29, 372–378.
27. Rowland H., *et al.* (2007) The effectiveness of Hawley and vacuum-formed retainers: a single-center randomized controlled trial. *American Journal of Orthodontics and Dentofacial Orthopedics*, 132, 730–737.
28. Liao Y. (2010) The research of clinic application of Hawley retainer and transparent wraparound retainer. *Journal of Luzhou Medical Colllege*, 4, 416–417.
29. Shawesh M., Bhatti B., Usmani T. and Mandall N. (2010) Hawley retainers full- or part-time? A randomized clinical trial. *European Journal of Orthodontics*, 32, 165–170.
30. Tsai C. (2010) *Comparison of the effects of an Essix and Hawley retainer on post-orthodontic occlusion*. MSc Thesis, Saint Louis University, Saint Louis, MO.
31. Sun J., *et al.* (2011) Survival time comparison between Hawley and clear overlay retainers: a randomized trial. *Journal of Dental Research*, 90, 1197–1201.
32. Atik E., Esen Aydınlı F., Kulak Kayıkçı M.E. and Ciğer S. (2016) Comparing the effects of Essix and Hawley retainers on the acoustics of speech. *European Journal of Orthodontics*. First published on Aug 9, 2016, 10.1093/ejo/cjw050
33. Wan J., Wang T., Pei X., Wan Q., Feng W. and Chen J. (2017) Speech effects of Hawley and vacuum-formed retainers by acoustic analysis: A single-center randomized controlled trial. *Angle Orthodontist*, 87, 286–292.
34. Johnston C., Burden D. and Morris D. (2008) *Clinical guidelines: Orthodontic Retention* (Revised July (2013) by Parvizi, F., Morris, D., Atack, N.). British Orthodontic Society, London, UK.
35. Ackerman M.B. and Thornton B. (2011) Posttreatment compliance with removable maxillary retention in a teenage population: a short-term randomized clinical trial. *Orthodontics*, 12, 22–27.
36. Moher D., *et al.* (2010) CONSORT (2010) explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *BMJ (Clinical research ed.)*, 340, c869.
37. Howick J., *et al.* (2011) *The Oxford (2011) Levels of Evidence*. Oxford Centre for Evidence-Based Medicine, Oxford, UK. http://www.cebm.net/index.aspx?o=5653 (31 July 2016, date last accessed).
38. Littlewood S.J., Millett D.T., Doubleday B., Bearn D.R. and Worthington H.V. (2016) Retention procedures for stabilising tooth position after treatment with orthodontic braces. *Cochrane Database of Systematic Reviews*, 1, CD002283.
39. Lai C.S., Grossen J.M., Renkema A.M., Bronkhorst E., Fudalej P.S. and Katsaros C. (2014) Orthodontic retention procedures in Switzerland. *Swiss Dental Journal*, 124, 655–661.
40. Kourakou M. (2016) *Objective assessment of patients' compliance with thermoplastic vacuum-formed retainers following fixed appliances*. MSc Thesis, Aristotle University of Thessaloniki, Thessaloniki, Greece.
41. Pauls A., Nienkemper M., Panayotidis A., Wilmes B. and Drescher D. (2013) Effects of wear time recording on the patient's compliance. *Angle Orthodontist*, 83, 1002–1008.
42. Schott T.C., Schlipf C., Glasl B., Schwarzer C.L., Weber J. and Ludwig B. (2013) Quantification of patient compliance with Hawley retainers and removable functional appliances during the retention phase. *American Journal of Orthodontics and Dentofacial Orthopedics*, 144, 533–540.
43. Tsomos G., Ludwig B., Grossen J., Pazera P. and Gkantidis N. (2014) Objective assessment of patient compliance with removable orthodontic appliances: a cross-sectional cohort study. *Angle Orthodontist*, 84, 56–61.
44. Hyun P., Preston C.B., Al-Jewair T.S., Park-Hyun E. and Tabbaa S. (2015) Patient compliance with Hawley retainers fitted with the SMART(®) sensor: a prospective clinical pilot study. *Angle Orthodontist*, 85, 263–269.
45. Ellis P.D. (2010) *The Essential Guide to Effect Sizes: An Introduction to Statistical Power, Meta-Analysis and the Interpretation of Research Results*. Cambridge University Press, Cambridge, UK.