Review

Effect of bonded and removable retainers on occlusal settling after orthodontic treatment: A systematic review and meta-analysis

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Abstract

This systematic review and meta-analysis aimed to summarize the effectiveness of bonded and removable retainers (the Hawley and Essix retainers) in terms of improving occlusal settling (occlusal contact points/areas) after orthodontic treatment. We searched the Cochrane Library, PubMed, CINAHL Plus, and Dental & Oral Sciences Source (DOSS), as well as SIGLE, Google Scholar and ClinicalTrials.gov for eligible studies. We included randomized and non-randomized controlled trials along with cohort studies. Studies that reported occlusal contacts/areas during retention with fixed bonded and removable retainers were included. To assess the quality of the randomized controlled trials (RCTs), the Cochrane Collaboration risk-of-bias (RoB) tool was utilized, whereas the Newcastle–Ottawa Scale (NOS) was used to assess the quality of cohort studies.

We included 6 articles in our systematic review after scrutinizing 219 articles and eliminating the illegible ones based on duplication, titles, abstracts, and objectives. Bonded retainers (BRs) allowed faster and better posterior occlusal settling as compared to the Hawley retainer (HR). However, HR showed good occlusal settling in the anterior dental arch. The Essix retainer (ER) showed a decrease in occlusal contact during the retention phase. Meta-analysis showed no statistically significant difference between BRs and removable retainers. In conclusion, HR allowed better overall occlusal settling as compared to other retainers. However, BRs allowed faster settling in the posterior tooth region. The Essix retainer showed poor settling of occlusion. Overall, there is an insufficient number of high-quality RCTs to provide additional evidence, and further high-quality RCTs are needed.

Keywords: orthodontic retainers, occlusal contact, vacuum-formed

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Introduction

Retention is considered to be part of orthodontic treatment and plays an important role in post-orthodontic clinical success.[1] Immediate relapse after orthodontic treatment is caused by multiple factors, including the elastic recoil of gingival fibers, malocclusion present before the treatment, the alveolar bone and root condition, differential jaw growth, and unequal pressure from soft tissues.[2] It is crucial to note that it takes nearly 3–4 months for the periodontal ligament (PDL) and 6–12 months for gingival fibers to reorganize and heal. Thenceforth, during this unstable period, occlusal settling via the solid cusp and fossa relationship plays an important role in preventing relapse.[3,4] Among the different factors that need to be controlled after orthodontic treatment, occlusion settling requires no active control and is considered to be a beneficial form of relapse.[5]

Generally, there are two types of retention protocols available, i.e., fixed and removable, which are favored based on the clinician's and patient's choice. The most routinely utilized removable retainers are the Hawley plate and the Essix splint.[6] The Hawley retainer (HR), despite being unesthetic, can be utilized in various clinical situations due to the ease of fabrication and modification. On the other hand, the Essix retainer (ER), which is a vacuum-formed retainer (VFR), may not be very versatile in terms of usage, but is very esthetic and popular among orthodontic patients.[7] Removable retainers also have an inherent disadvantage of dependency on patient compliance, which makes bonded retainers (BRs) an attractive option. Bonded retainers allow the permanent retention of the teeth with minimum patient compliance, provide good esthetics and do not encroach on the occlusal surfaces.[8,9] Considering occlusal settling, conventional HRs and BRs have an advantage over ERs, as they do not cover the occlusal surfaces and allow the passive eruption of the teeth.

Recently, a systematic review compared different aspects of VFR and HR after orthodontic treatment, and found better incisor stability and patient satisfaction with VFR.[10] Similarly, in another systematic review, the authors found BRs to result in good periodontal health and lower incisor stability after orthodontic treatment.[11] However, to the best of our knowledge, no systematic review has compared occlusal settling after debonding between bonded and removable (HR and ER) retainers. The purpose of this systematic review and meta-analysis was to compare BRs with removable retainers (HRs/ERs) in terms of occlusal settling during the retention period.

Material and methods

Protocol and registration

The current systematic review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review protocol was registered at PROSPERO (an international database at the University of York, UK) (CRD42020179410).

Eligibility criteria

Based on our inclusion and exclusion criteria, we included randomized controlled trials (RCTs) and prospective/retrospective cohort studies that assessed the primary outcome.

We followed the PICOS model:

– **P**opulation – patients in the retention phase after orthodontic treatment;
– **I**ntervention – removable retainers (Essix or all Hawley retainer possibilities);
– **C**omparison – bonded retainers (all possibilities of fixed retainers);
– **O**utcome – occlusal contact points/areas (occlusal settling);
– **S**tudy – randomized and non-randomized clinical trials, and cohort studies.

The secondary outcome to be assessed was the improvement in biting force with different retention protocols.

We excluded studies in which participants had any surgical correction involving orthodontic treatment, craniofacial syndrome, failure with compliance, or a retention period of fewer than 2 months.

Information sources and search strategy

A comprehensive literature search was carried out from January 2007 to May 2021 in 4 major health databases (Cochrane Library, PubMed (NLM), CINAHL Plus (EBSCO), and Dental & Oral Sciences Source (DOSS), including hand searches). To identify any grey literature and unpublished data, SIGLE was explored, and a manual search of Google Scholar and the database of www.clinicaltrials.gov was also performed using the following MeSH terms: ("Orthodont*" OR "Dental" OR "Dentist*") AND ("Dental occlusion" OR "Occlusion") AND ("Essix" OR "Hawley" OR "Hawley retainer*" OR "Fixed bonded lingual retainer*" OR "Fixed orthodontic appliance*" OR "Bonded retainer*").

Study selection and data extraction

We included RCTs and prospective/retrospective cohort studies that evaluated the primary outcome. Two authors (USA and AA) independently scrutinized the articles based on their titles and abstracts, and assessed the

eligibility of the studies to be included. Any disagreement between the authors was sorted by consulting a third author (KZ).

Risk of bias in individual studies

For assessing the risk of bias in the RCTs individually, the Cochrane Collaboration tool was used. Terms such as a high risk of bias, an unclear risk of bias and a low risk of bias were assigned to individual RCT studies. The prospective/retrospective cohort studies were assessed for the risk of bias by using the Newcastle–Ottawa Scale (NOS).

Risk of bias across studies

The overall risk of bias for the RCTs was assessed with the Cochrane Collaboration tool. It consists of 7 domains determining the grade of bias risk as a low, unclear or high. The prospective/retrospective cohort studies were assessed for the risk of bias with NOS.

Certainty assessment

To assess the certainty of evidence for occlusal settling (outcome), the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) approach was applied.

Data analysis

Data analysis was limited to reporting the mean values of occlusal contact points/areas with different retention methods. A meta-analysis was performed for studies with quantitative data, using the RevMan software, v. 5.3 (Cochrane). For the computation of the summary effects, a random effect model was utilized due to high heterogeneity. The I^2 statistics was utilized to assess the heterogeneity among the selected studies.

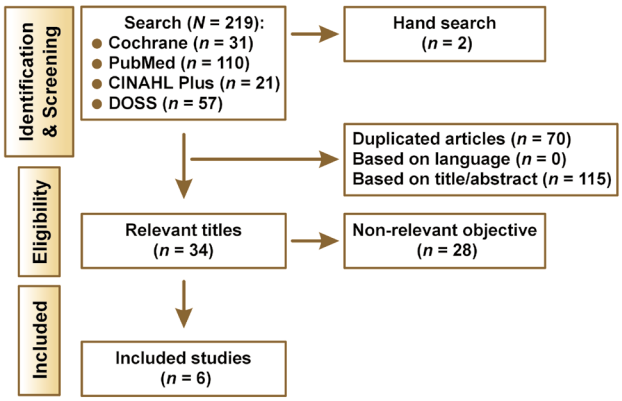

Fig. 1. Study selection PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram

DOSS – Dental & Oral Sciences Source.

Results

Study selection and characteristics

In the initial search of the literature, we found 219 studies across the major databases. After the removal of duplicates, we had 149 articles. Upon scrutinizing the articles based on title and abstract, non-relevant articles were excluded from this systematic review. A total of 6 articles were included – 2 RCTs,[12,13] and 2 prospective[14,15] and 2 retrospective[16,17] cohort studies. The details of the process of study selection are given in the PRISMA flow diagram along with the reasons for the exclusion of a particular study (Fig. 1). The characteristics of the included studies along with their method of outcome assessment are summarized in Tables 1 and 2.

Assessment of the risk of bias within the studies

Randomized controlled trials

We utilized the Cochrane Collaboration risk of bias (RoB) tool to determine the overall and individual risk

Table 1. Studies included in the systematic review

No.	Study	Year	Journal	Sample size	Participants' age [years]	Design
1	Alkan and Kaya[12]	2020	Journal of Oral Rehabilitation	60	N/A	RCT
2	Varga et al[13]	2017	American Journal of Orthodontics and Dentofacial Orthopedics	176	16 (15–18)	RCT
3	Hoybjerg et al.[14]	2013	American Journal of Orthodontics and Dentofacial Orthopedics	90	15.2 (11.1–34.8)	prospective cohort
4	Kara and Yilmaz[15]	2020	American Journal of Orthodontics and Dentofacial Orthopedics	90	18.2 ±7.3	prospective cohort
5	Sari et al.[16]	2009	Angle Orthodontics	70	16.3 ±3.0	retrospective cohort
6	Başçiftçi et al.[17]	2007	American Journal of Orthodontics and Dentofacial Orthopedics	60	HR group: 15.3 ±2.2 FR group: 16.1 ±3.4	retrospective cohort

Data presented as mean ± standard deviation (*M* ±*SD*) or as mean (interquartile range) (*M* (*IQR*)). HR – Hawley retainer; FR – fixed retainer; RCT – randomized clinical trial; N/A – data not available.

Table 2. Characteristics of the included studies

Study	Intervention	Measuring technique	Outcome	Follow-up
Alkan and Kaya[12]	HR/BR/VFR	T-Scan III	OSA and occlusal force distribution	6-month
Varga et al[13]	U/L – ER, U/L –wrap-around retainer and U – ER/L – BR	occlusal force-meter; occlusal contacts were determined using plastic foil	MVBF and NOC	10-week
Hoybjerg et al.[14]	U/L – HR, U – HR/L – BR and U – ER/L –BR	ABO discrepancy index and CRE	alignment/rotation, marginal ridges, buccolingual inclination, overjet, occlusal contacts, occlusal relationship, interproximal contacts, and root angulation	1-year
Kara and Yilmaz[15]	ER group, HR group and BR group	3Shape Ortho Analyzer software	occlusal contact areas and CRE score changes	1-year
Sari et al.[16]	HR and BR	silicon based inter-occlusal registration	occlusal contact points	1-year
Başçiftçi et al.[17]	modified wrap-around HR and maxillary Jensen plate with mandibular FR	silicone-based impression bites	occlusal contact points	1-year

BR – bonded retainer; VFR – vacuum-formed retainer; U – upper arch; L – lower arch; ER – Essix retainer; ABO – American Board of Orthodontics; CRE – cast–radiograph evaluation; OSA – occlusal surface area; MVBF – maximum voluntary bite force; NOC – number of occlusal contacts.

of bias present within the studies. In both studies,[12,13] the blinding of the outcome assessment was not reported; therefore, it was considered a high risk of bias. Similarly, the blinding of participants was not possible due to the nature of the intervention, making it a high risk of bias. The overall risk of bias across the studies was high for the blinding of participants and the outcome assessment. The quality of evidence is summarized in Fig. 2.

Prospective/retrospective cohort studies

The prospective/retrospective cohort studies were assessed for the risk of bias with NOS. All the included studies had a good quality of evidence. The quality of evidence is summarized in Table 3.

Table 3. Assessment of the risk of bias of the included cohort studies, using the Newcastle–Ottawa Scale (NOS)

Study	Selection (4)	Comparability (2)	Outcome (3)	Quality assessment
Hoybjerg et al.[14]	***	*	**	good
Kara and Yilmaz[15]	***	*	**	good
Sari et al.[16]	***	*	**	good
Başçiftçi et al.[17]	***	*	**	good

Good quality: 3 or 4 stars in the selection domain AND 1 or 2 stars in the comparability domain AND 2 or 3 stars in the outcome domain.
Fair quality: 2 stars in the selection domain AND 1 or 2 stars in the comparability domain AND 2 or 3 stars in the outcome domain.
Poor quality: 0 or 1 stars in the selection domain OR 0 stars in the comparability domain OR 0 or 1 stars in the outcome domain.

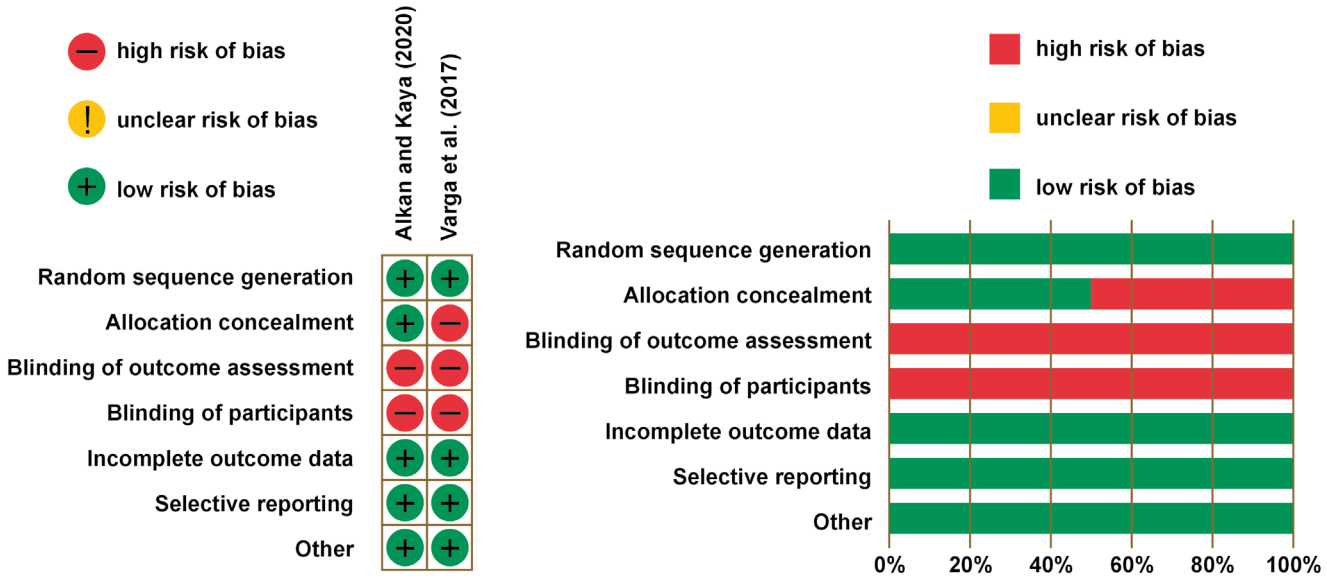

Fig. 2. Assessment of the individual and overall risk of bias of the included randomized controlled trials (RCTs), using the Cochrane Collaboration risk of bias (RoB) tool

Assessment of the certainty level

The certainty of evidence was assessed via the GRADE approach, which demonstrated a low and very low quality of evidence (Table 4).

Results of individual studies

Alkan and Kaya[12] divided the arch into 4 quadrants and reported an increase in the occlusal surface area (OSA) in the left and right posterior dental arches for the HR, BR and VFR groups through a follow-up period of 6 months. However, only HR brought statistically significant improvement in the anterior OSA ($p = 0.008$). Considering the occlusal force distribution, a statistically significant increase was observed in the anterior dental arches for the HR group ($p = 0.026$), whereas in the BR group, better posterior dental occlusal force distribution was reported ($p = 0.029$).

Varga et al.[13] reported an increase in the maximum voluntary bite force (MVBF) and the number of contacts (NOC) in all retainer groups, but the least improvement was observed in subjects with 2 ERs. The type of appliance, age and gender were reported to have a statistically significant impact on NOC ($p = 0.05$).

Hoybjerg et al.[14] reported that the combination of upper HR/lower BR exhibited the best occlusal settling, whereas the upper ER/lower BR combination showed the least amount of settling; however, these differences were statistically non-significant ($p = 0.819$). Similarly, they reported no statistically significant differences between extraction and non-extraction treatment modalities.

Kara and Yilmaz[15] reported a significant increase in occlusal contact areas for all teeth except for incisors in the HR and BR groups ($p < 0.001$). The BR group demonstrated the highest amount of occlusal settling, whereas the ER exhibited poor occlusal settling for the posterior teeth.

Sari et al.[16] reported an increase in the occlusal contact points from 12.45 to 16.40 in the HR group ($p = 0.05$). Similarly, in the BR group, the combined occlusal contacts of all teeth increased by an average of 13.72 ($p < 0.001$). Both groups showed improvement in the posterior occlusal contacts; however, BR showed the greatest improvement.

Başçiftçi et al.[17] reported improvement in the vertical movement of the posterior teeth in both the modified upper/lower HR and upper Jensen/lower BR groups. The BR group showed an increased number of tooth contacts in the posterior segments ($p < 0.001$) as compared to the modified HR group at the end of the 1-year retention period ($p = 0.05$).

Synthesis of the results

We conducted a meta-analysis between BRs and HRs to compare occlusal contacts after debonding. We included 3 comparative studies[12,15,16] in the meta-analysis, which yielded statistically non-significant results. Similarly, in the comparison between BRs and ERs, we included two studies[12,15] and found no statistically significant difference between the 2 groups in terms of occlusal settling. The summary of the effect is depicted in Fig. 3 and 4, showing statistically non-significant results.

Discussion

The current systematic review was conducted to assess the improvement of occlusal contact points/areas in different retention protocols. Recently, a systematic review was also conducted on the effect of removable retainers on tooth stability.[10] However, there is a lack of published systematic reviews investigating the impact of BRs, HRs and ERs on occlusal settling.

Table 4. Summary of findings (Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) approach): Occlusal contact points/areas after orthodontic treatment utilizing different retention protocols (outcome)

Outcome		Starting level of evidence	Risk of bias	Inconsistency	Indirectness	Impreciseness	Reporting bias	Effect	Overall quality of evidence
Occlusal contact points/areas	2 RCTs	high	serious[1]	very serious[2]	no	no	no	all studies reported the worst occlusal settling with ER	very low
	4 cohort studies	low	no	very serious[2]	no	no	no	BR and HR allowed better occlusal settling	low
Improvement in biting force	2 RCTs	high	serious[1]	very serious[2]	no	no	no	BR and HR allowed better biting force	very low

GRADE Working Group grades of evidence*: high quality – further research is very unlikely to change our confidence in the estimate of effect; moderate quality – further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate; low quality – further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate; very low quality – any estimate of effect is very uncertain.

[1] both studies had a high risk of bias for the blinding of participants and the outcome assessment, similarly, 1 study did not report any concealment method; [2] a high level of heterogeneity is present between the comparison group and the method of assessment.

* Schünemann H, Brożek J, Guyatt G, Oxman A, eds. *GRADE Handbook*. Handbook for grading the quality of evidence and the strength of recommendations using the GRADE approach. GRADE Working Group; 2013.

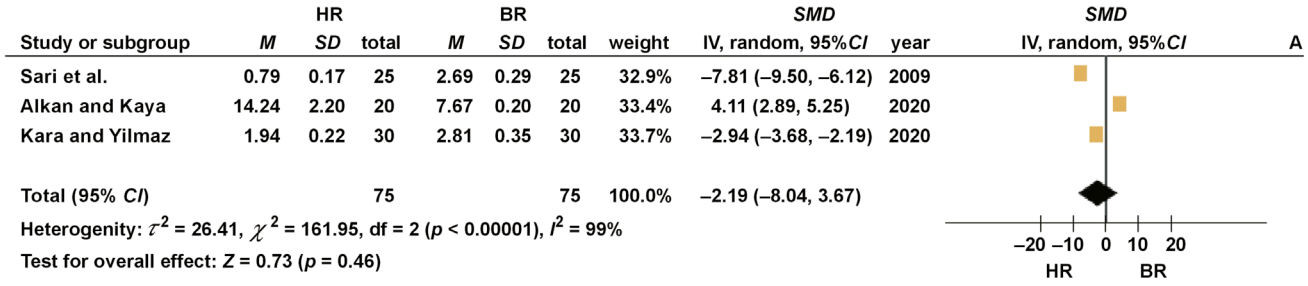

Fig. 3. Forest plot depicting the mean difference (*MD*) between Hawley retainers (HRs) and bonded retainers (BRs)
SMD – standardized mean difference; *CI* – confidence interval; df – degrees of freedom.

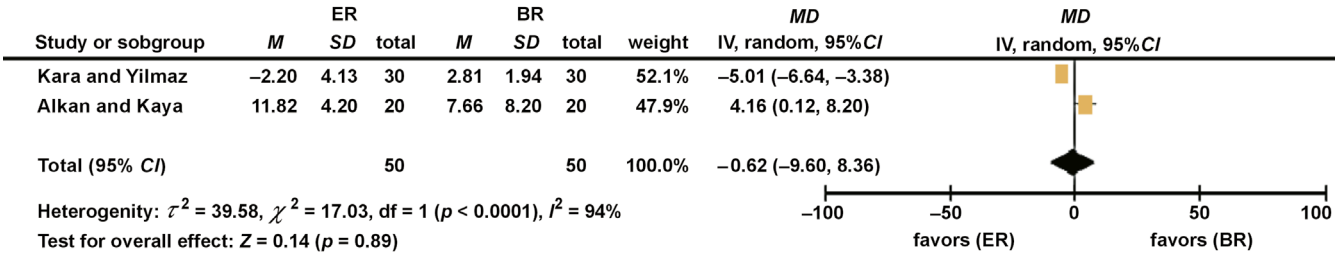

Fig. 4. Forest plot depicting the mean difference (*MD*) between Essix retainers (ERs) and bonded retainers (BRs)

Bonded retainer vs. Hawley retainer

Three studies[12,15,16] reported the improvement of occlusal contacts in the posterior region in both the BR and HR groups. However, BRs performed better in terms of efficient occlusal settling of the posterior teeth. Considering the anterior occlusal contacts, only one study[12] reported a statistically significant increase in the HR group as compared to the BR group. Other studies[15,16] failed to find any difference between the groups with regard to improvement in the anterior occlusal contacts. These results are in accordance with other studies, which found no significant improvement in the anterior occlusal contacts when using HRs.[18,19] Considering the secondary outcome, better occlusal force distribution was observed in the anterior region for the HR group as compared to the BR group. Contrary to this, the BR group showed a considerable decline in anterior occlusal forces, whereas posterior occlusal forces were higher as compared to the HR group.[12] Similarly, 2 studies[14,15] evaluated the retainer protocols based on the cast–radiograph evaluation (CRE), which was established by the American Board of Orthodontics (ABO) to assess the excellence of occlusion for board certification. In terms of CRE scores, the HR group performed particularly well in contrast to the BR group. The HR group exhibited the best post-treatment results with improvement in 5 criteria and demonstrated a statistically significant decrease in the total CRE scores.[15] This is in agreement with the study conducted by Aslan et al., who reported a reduction in the CRE scores with HR.[20]

Bonded retainer vs. Essix retainer

Conflicting results were found when comparing BR with ER. Varga et al.[13] found correlations between a reduced NOC and female gender and the ER protocol. On the contrary, Kara and Yilmaz[15] reported statistically significant improvement in occlusal contact, the marginal ridge and the overjet in the ER group, as determined by the CRE scores, but found a reduced OSA based on the OrthoAnalyzer software analysis. The authors found a reduced OSA in the ER group except for incisors as compared to the BR group, in which anterior occlusal contacts were found to be less.[15] When assessing VFRs, Sauget et al. reported no significant increases in the anterior and posterior occlusal contacts,[19] whereas Aslan et al. reported improved anterior occlusal contacts only.[20] However, when comparing the CRE scores of the BR and ER groups, one study[15] found BRs to be superior, although it was statistically non-significant. On the other hand, Hoybjerg et al.[14] reported a decrease in the total CRE scores with the Essix appliance. Alkan and Kaya[12] reported a statistically significant increase in OSA in the ER and BR groups. However, the ER group outperformed the BR group when anterior occlusal contacts were evaluated after 6 months of full-time wear. Interestingly, the wear time had no influence on anterior occlusal contacts, as one author[15] divided the wear time of ER equally into 6 months of full-time followed by nighttime wear only and found the same results at the end of a 1-year evaluation.

Combination of different retainers

Hoybjerg et al.[14] evaluated occlusal contacts in different retainer patterns, i.e., upper/lower HR, upper HR/lower BR and upper ER/lower BR. The authors reported that the best combination of retainers for reducing the CRE scores were upper HR/lower BR followed by upper/lower HR and upper ER/lower BR. In terms of occlusal contacts, each retainer combination showed a statistically significant reduction in the CRE scores (improvement in occlusal contacts) at 1-year follow-up.[14] This is in line with a study that reported a decrease in the CRE scores during retention and improvement in certain aspects of occlusion, i.e., the overjet, occlusal contacts and the marginal ridge.[21] Greco et al. reported increased CRE scores after the retention period with fixed and removable retainers.[22] However, in terms of occlusal settling, the upper HR/lower BR group showed the highest amount of occlusal settling.[14] The same authors evaluated the impact of extraction and non-extraction treatment on occlusal contacts, and reported no statistical difference between them. Yet, based on the initial severity of discrepancy, they reported a statistically significant difference between low and high discrepancy groups.[14] Başçiftçi et al.[17] compared upper Jensen plate/lower fixed bonded retainer to upper/lower modified HRs. They showed the same trend of faster and improved posterior occlusal contacts in the BR group as compared to the HR group.[17]

Outcome evaluation methods across different studies

One of the important considerations are the outcome evaluation methods used in the included studies for assessing the occlusal contact points/areas. More traditional methods of inter-occlusal registration via silicon-based impression material were utilized by 2 included studies.[16,17] These inter-occlusal registrations are evaluated under light to determine NOC. In the preceding literature, this is the most common and practical method to assess occlusal contacts.[23,24] This method might not be ideal, since light transmittance angles can influence the outcome. On the other hand, Varga et al.[13] assessed occlusal contacts by using plastic foil, which was 6 mm in width and 0.05 mm in thickness. The authors took into account contact points in areas where the foil could not be pulled out by heavy pulling during habitual occlusion.[13] The previously recorded error of this method is 10% of the mean value.[25] However, assessing occlusal contacts by utilizing silicone-based impression and plastic foil materials may provide inadequate information about posterior occlusal contacts. One study[14] utilized the ABO grading system, and assessed pre- and post-treatment occlusal contacts on orthodontic cast models, as recommended by Casko et al.[26] Two of the included studies[12,15] used modern digital technology to assess occlusal contact areas in their sample subjects. T-scan III was utilized by Alkan and Kaya,[12] who reported difficulty in the assessment of occlusal contacts, so they preferred recording OSA. This method has a low degree of validity for quantifying absolute force, but demonstrates a high degree of reliability in consecutive measurements.[27] These contemporary systems have been developed to accurately and precisely evaluate occlusal forces and contacts; however, they have some disadvantages as well. The pressure-sensitive plates used in dental prescale systems are 0.004-inch-thick, and due to the impenetrable nature of the plate, the overdetection of OSA is reported near the hinge axis.[28] Similarly, occlusal three-dimensional (3D) anatomy might not be fully captured, as in silicon or wax bite materials. To overcome these shortcomings, Kara and Yilmaz[15] scanned the pre- and post-treatment models with a 3D laser scanner (3Shape) separately in an occluded manner. To measure the occlusal region, the screenshots of each tooth were transferred to the OrthoAnalyzer software and two-dimensional (2D) area measurements were taken. This method has been found to be both reliable and repeatable.[29]

The risk of bias across RCTs was assessed with the help of the Cochrane Collaboration RoB tool. Both RCTs[12,13] performed randomizations, but provided no information on the method utilized. Similarly, Varga et al.[13] did not provide any information on allocation concealment. The risk of bias for the cohort studies was assessed with NOS, and each included study[14–17] demonstrated a good quality of evidence.

Limitations

The limitations of the present systematic review involve heterogeneity in the assessment of occlusal contact points/areas, a limited number of RCTs, different combinations of retainers, and different evaluation intervals for the assessment of occlusal contacts. Few of the studies[12,15] assessed OSA, which represents the functional state of the occlusal table, whereas other studies[13,14,16,17] reported occlusal contact points, which represent the static nature of occlusion. Similarly, retention follow-ups were a maximum of 1 year, which is not sufficient to conclude any strong recommendation regarding the retention protocols in review.

Conclusions

In conclusion, HRs performed well, particularly in the anterior segment of the arch, as compared to BRs, whereas BRs allowed better and faster occlusal settling in the posterior arch. The Essix retainer showed poor occlusal settling in the posterior region. As for the maximum biting force, HRs performed better in the anterior region and BRs in the posterior region.

Ethics approval and consent to participate

Not applicable.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

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