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ORIGINAL ARTICLE

Transversal changes, space closure, and efficiency of conventional and self-ligating appliances

A quantitative systematic review

Transversale Veränderungen, Lückenschluss und Wirksamkeit von selbstligierenden vs. konventionellen Brackets

Ein quantitatives systematisches Review

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Abstract
Objective Self-ligating brackets (SLBs) were compared to conventional brackets (CBs) regarding their effectiveness on transversal changes and space closure, as well as the efficiency of alignment and treatment time.
Methods All previously published randomized controlled clinical trials (RCTs) dealing with SLBs and CBs were searched via electronic databases, e.g., MEDLINE, Cochrane Central Register of Controlled Trials, EMBASE, World Health Organization International Clinical Trials Registry Platform, Chinese Biomedical Literature Database, and China National Knowledge Infrastructure. In addition, relevant journals were searched manually. Data extraction was performed independently by two reviewers and assessment of the risk of bias was executed using Cochrane Collaboration's tool. Discrepancies were resolved by discussion with a third reviewer. Meta-analyses were conducted using Review Manager (version 5.3).
Results A total of 976 patients in 17 RCTs were included in the study, of which 11 could be produced quantitatively and 2 showed a low risk of bias. Meta-analyses were found to favor CB for mandibular intercanine width expansion, while passive SLBs were more effective in posterior expansion. Moreover, CBs had an apparent advantage during short treatment periods. However, SLBs and CBs did not differ in closing spaces.
Conclusions Based on current clinical evidence obtained from RCTs, SLBs do not show clinical superiority compared to CBs in expanding transversal dimensions, space closure, or orthodontic efficiency. Further high-level studies involving randomized, controlled, clinical trials are warranted to confirm these results.

Keywords Transversal changes · Orthodontic efficiency · Conventional brackets · Self-ligating bracket · Meta-analysis

Zusammenfassung
Ziel Selbstligierende Brackets (SLBs) und konventionelle Brackets (CBs) wurden hinsichtlich transversaler Expansion Lückenschluss, Nivellierungseffizienz und Behandlungszeit verglichen.
Methoden In klinischen Datenbanken (MEDLINE, Cochrane Central Register of Controlled Trials, EMBASE, World Health Organization International Clinical Trials

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Registry Platform, Chinese Biomedical Literature Database, China National Knowledge Infrastructure) wurde nach sämtlichen bisher publizierten randomisierten, kontrollierten klinischen Studien (RCTs) zu SLBSs und CBs gesucht. Zudem wurden relevante Periodika händisch durchgesehen. Die Daten wurden von 2 Reviewern unabhängig extrahiert, das Bias-Risiko wurde mit dem entsprechenden Cochrane-Collaboration-Tool ermittelt und Diskrepanzen wurden mit einem dritten Reviewer bis zur Konsensfindung diskutiert. Die Metaanalysen wurden mit der Software RevMan (Version 5.3) durchgeführt.

Ergebnisse Insgesamt 976 Patienten aus 17 RCTs wurden in die Studie aufgenommen, 11 RCTs eigneten sich für die quantitative Synthese, wobei bei zwei Studien ein geringes Bias-Risiko bestand. Metaanalysen zeigten, dass CBs hinsichtlich der Erweiterung der intercaninen Distanz im Unterkiefer überlegen waren. Passive SLBs dagegen waren effektiver bei der Expansion im Molarenbereich. Zudem zeigten sich CBs offensichtlich / scheinbar vorteilhaft bei kurzen Behandlungszeiten. Beim Lückenschluss unterschieden sich SLBs und CBs nicht.

Schlussfolgerungen Auf der Basis der aktuell verfügbaren klinischen Evidenz aus RCTs zeigten SLBs im Vergleich zu CBs keine klinische Überlegenheit hinsichtlich transversaler Expansion, Lückenschluss bzw. kieferorthopädischer Effizienz. Zur Bestätigung dieser Ergebnisse bedarf es weiterer qualitativ hochwertiger Forschung einschließlich randomisierter, kontrollierter klinischer Studien.

Schlüsselwörter Transversale Veränderungen · kieferorthopädische Effizienz · konventionelle Brackets · selbstligierende Brackets · Metaanalyse

Introduction

Self-ligating brackets (SLBs) have been widely adopted at clinics in recent years under claims of improved orthodontic effectiveness and efficiency. However, their clinical superiority has not been strongly proven yet. First introduced by Stolzenberg in 1935 [27], they were described as 'Russell lock' edgewise attachment. Since then, many other similar designs have appeared, including the Ormco Edgelok in 1972, Forestadent Mobil-Lock and Orec Speed in 1980, 'A' Company Activa in 1986, TimeLock bracket in 1998, and the Damon 2 and In-Ovation brackets in 2000 [24]. According to the mechanisms of lid closure, all these designs can be classified into two main categories: active and passive brackets. Active self-ligating brackets (ASLBs) have a spring clip that presses against the archwire for rotation and torque control. By contrast, passive self-ligating brackets (PSLBs) have a slide that closes without encroaching on the slot lumen, thus, exerting no active force on the archwire. However, the orthodontists are speculating if SLBs truly deliver the purported advantages and whether the conventional brackets (CBs) should be substituted by SLBs in clinics [18].

To date, many studies have investigated the clinical efficacy and efficiency of SLBs compared with CBs through various methods. Several systematic reviews of SLBs have been conducted in an attempt to form a conclusion, although these studies have varied greatly in methods and results [3, 4, 6, 10, 32]. Of these, two studies performed in 2010 obtained different results [4, 10]. One included 6 randomized controlled clinical trials (RCTs) and 11 controlled clinical trials (CCTs) but firm conclusions were not made due to lack of evidence [4]. The remaining studies included 2 RCTs, 10 CCTs, and 4 cross-sectional studies, which found SLBs to be advantageous with less chair time and incisor proclination [10]. Two systematic reviews concentrated on the specific aspects of these two techniques [3, 32]. One study focused on the initial pain, number of visits, and treatment time, which included only 4 studies; another focused on canine retraction and anchorage loss, which included 2 RCTs and 4 CCTs [3]. One meta-analysis of in vitro studies found that SLBs produce lower friction than CBs [6]. Until now, the published systematic reviews and meta-analyses have been based on in vitro or in vivo CCTs including prospective and retrospective trials due to the scarcity of RCTs. Since few RCTs of SLBs have been published in recent years, collecting and analyzing them will provide useful information for orthodontists.

Therefore, the goal of this study is to identify RCTs that compare SLBs with CBs and to investigate the transversal dimensional changes, space closure, and orthodontic efficiency of each design, also considering initial alignment and treatment time in patients undergoing fixed orthodontic treatment.

Methods

A customized procedure was preconducted in this study. The study selection, risk of bias assessment, and data extraction were performed by two expert reviewers. Furthermore, any discrepancies between them were resolved through a conference with a third reviewer to attain consensus. The following inclusion criteria were used: randomized controlled clinical trials, randomized split-mouth studies, participants who received fixed orthodontic treatment with self-ligating and conventional brackets, an intervention group of active or passive self-ligating brackets, a control group of conventional brackets, and outcomes of effectiveness demonstrating dimensional change, orthodontic space closures and efficiency in terms of alignment and treatment time. Exclusion criteria were as

follows: published studies with repetitive data, patients with other related or unrelated diseases that may affect the results, and patients without a full arch under orthodontic treatment. There was no limitation for selection regarding the publishing year or language.

Search strategy

Details of related published or ongoing studies were obtained through the following electronic databases: MEDLINE (1948 to December 2016), Cochrane Central Register of Controlled Trials (CENTRAL, issue 12, 2016), EMBASE (via OVID, 1974 to December 2016), World Health Organization International Clinical Trials Registry Platform (December 2016), Chinese Biomedical Literature Database (1978 to December 2016), China National Knowledge Infrastructure (1994 to December 2016) and Chinese Medical Journal Database (1989 to December 2016). A total of 19 relevant Chinese journals were manually searched based on their titles and abstracts. The reference lists of all included studies were also screened for applicable information.

The MeSH terms were combined with free text words as a search strategy, such as 'active', 'passive', 'self-ligating', 'conventional', 'orthodontic,' and 'brackets.' The Cochrane Highly-Sensitive Search Strategy was used to identify randomized trials. In the PubMed database, the terms used for searching were 'Orthodontic Appliances' [MeSH], 'bracket', 'braces' and 'self-ligat'. Titles and abstracts of publications were scanned to find potentially eligible studies. Once relevant studies were identified, full texts were obtained for further consideration of these studies to obtain details.

Risk of bias assessment

The Cochrane Collaboration tool for risk of bias assessment on RCTs was adopted with the following domains: sequence generation, allocation concealment, blinding of outcome assessors, incomplete outcomes, selective data reporting, and other bias [13]. Factors such as blinding of clinicians and patients were omitted due to an inherent feasibility problem since orthodontists can expertly distinguish bracket types. A given study was considered to be 'low risk of bias' if all the pertinent domains were judged as 'low risk,' 'unclear risk of bias' if any domain was judged as 'unclear risk,' and 'high risk of bias' if any domain was judged as 'high risk'.

Data collection and synthesis

Customized data extraction forms were independently developed by two reviewers and included the following items: article name, first author, published year of the study, demographic data of participants, settings, brands of SLB and CB, main inclusion criteria, treatment methods, time points, and results. Review Manager 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) was used for data analysis. Statistical heterogeneity was explored using the χ^2 test with a 10% significance level as the cutoff value due to its low power. The impact of statistical heterogeneity was quantified using the I^2 statistic. If $I^2 > 50\%$ and $P \leq 0.10$, the causes of the heterogeneity were analyzed followed by a subgroup analysis. If heterogeneity was found to be high ($I^2 > 50\%$), the random effects model was chosen for meta-analysis. Otherwise, the fixed effects model was adopted. For continuous data, the treatment effects were expressed as the mean difference (MD) at 95% confidence interval (CI). The statistical significance of the hypothesis test was set as $P < 0.05$ (by two-tailed z tests). A meta-analysis was performed on studies with similar methods and results, such as those that assessed the same measurement without high heterogeneity. Data that could not be pooled have been described herein. Subgroup analyses were addressed, depending on bracket type of included studies, to classify the self-ligating brackets into active and passive designs by the random effects model. Sensitivity analyses of study exclusion were adopted where heterogeneity may have been caused by one or several studies in the meta-analysis.

The GRADE profiler was employed to evaluate the quality of study methodology, precision of effect estimates, directness of evidence, risk of publication, and heterogeneity. The GRADE quality levels were set as high, moderate, low, and very low, and clinical recommendations were classified as strong or weak [12].

Results

Study selection and characteristics

A total of 114 published studies were identified by the electronic and manual search, 39 of which were considered eligible, and their full texts were assessed after screening their titles and abstracts. Finally, 17 studies with 536 participants in the SLB group and 440 participants in the CB group were included in the qualitative analysis, 11 of which qualified for the quantitative synthesis. The study inclusion process is depicted in Fig. 1.

All included studies were randomized controlled clinical trials, 3 of which were three-arm parallel trials, 3 were split-mouth studies, and 11 were two-arm parallel trials. Three studies compared ASLB with CB, while 13 studies compared PSLB with CB, and 1 study compared both

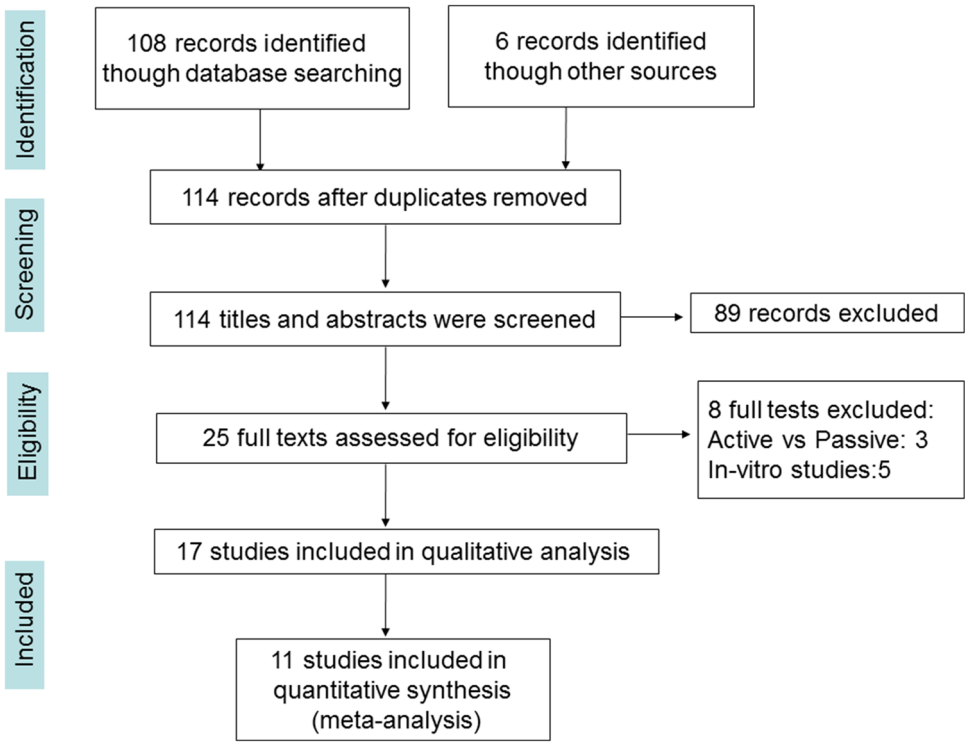

Fig. 1 Flowchart for study inclusion
Abb. 1 Flowchart zur Studienrekrutierung

ASLB and PSLB with CB. The details of included studies are shown in Table 1.

Risk of bias within studies

A total of 11 studies were included in the meta-analysis and their risks of bias were evaluated. Two included studies had low risks of bias, while the other 9 studies had unclear risks of bias (Table 2).

Transversal dimensional expansion

Six studies that were included in this analysis investigated the dimensional changes in the arch [1, 7, 11, 21, 22, 25], 4 of which reported changes in the mandibular intercanine and intermolar arch width and compared PSLBs with CBs [7, 21, 22, 25]. Figures 2 and 3 show that the meta-analyses show a higher efficacy of CBs in expanding mandibular intercanine width (MD − 0.51, 95% CI − 0.85 to − 0.17), while SLBs are apparently more efficient in expanding mandibular intermolar width (MD 0.50, 95% CI 0.11–0.90). However, the sample size used in this study was small and the risks of bias of two of the included studies were found to be unclear. Clinical heterogeneity such as variations in the arch structures was also seen [21, 25]. Thus, a sensitive analysis was performed; the results of which did not indicate any significant statistical difference between PSLB and CB in regard to mandibular intermolar width change (MD 0.37, 95% CI − 0.09 to 0.83, Fig. 4). Two other studies have also described noticeable maxillary arch width changes [1, 11]. One study compared both ASLBs and PSLBs with CBs and found no apparent difference between them [11]. Another study comparing PSLBs with CBs in Class I maxillary constriction patients demonstrated the similarity in their functions during transverse dimension changes. However, in the study, a quad-helix appliance was used in the CB group but not in PSLB group indicating the presence of heterogeneity [1].

Space closure

Five studies selected for this analysis focused on space closure in orthodontic treatment [2, 16, 17, 26, 28]. Three of these were split-mouth studies detailing canine retraction velocity with maxillary first premolar extraction [2, 16, 17], while the meta-analysis showed no difference between SLB and CB (MD 0.13, 95% CI − 0.09 to 0.35, Fig. 5). Two other studies that investigated the space closure without analyzing the canine retraction rate were excluded from the meta-analysis [26, 28]. Of these two analyses, one was discontinued after 3 months due to the absence of differences between PSLB and CB [28]. This might have been due to variation in the individual patient responses to the applied force. The second study compared ASLB, PSLB, and CB with different observation intervals. No variation was seen in the bracket types but differences were observed in the treatment of maxilla and mandible [26].

Tab. 1 Details of included studies
Tab. 1 Detaillierte Aufstellung der eingeschlossenen Studien

Study	Study design	Setting	ASLB	PSLB	Patients number/ mean age(years)	CB	Patients number/mean age (years)	Outcomes
Songra, 2008	2-Arm	UK		Damon 3	32/16.19	Synthesis	28/16.38	Alignment efficiency, dimensional change
Atik, 2014	2-Arm	Turkey		Damon 3MX	16/14.8	Roth	17/14.5	Dimensional change
Monini, 2014	Split-mouth	Brazil	In-Ovation R		25/adults	Ovation	25/adults	Orthodontic space closure
Burrow, 2010	Split-mouth	USA		Damon 3,SmartClip	43(19F, 24M)/ 14.8	Victory	43(19F, 24M)/ 14.8	Orthodontic space closure
Songra, 2014	3-Arm	UK	In-Ovation R	Damon 3MX	Damon 3MX:41, In-Ovation R:37/11-18	Omni	44/18.3	Alignment efficiency, orthodontic space closure
Pandis, 2011	2-Arm	Switzerland		Damon MX	25/13.2	Roth	25/13.4	Dimensional change
Fleming, 2019	2-Arm	UK		SmartClip	29(16F, 13M)/ 16.32	Victory	31(23F, 8M)/ 16.37	Dimensional changes
Fleming, 2013	3-Arm	UK, multicenter	In-Ovation C	Damon Q	ASLB:31/ 18.9,PSLB:28/ 22.5	Roth	28/18.6	Dimensional change
Wahab, 2012	2-Arm	Malaysia		Damon 3	14(11F, 3M)/21.9	Mini diamond	15(10F, 5M)/ 19.5	Alignment efficiency
Wong, 2013	3-Arm	UK		Damon 3MX	14(7F, 7M)/13.9	MBT	13(6F, 7M)/ 14.1, 13(10M, 3F)/13.7	Orthodontic space closure
DiBiase, 2011	2-Arm	UK		Damon 3	27	Synthesis	21	Treatment time
Fleming, 2009	2-Arm	UK		SmartClip	30/15.87	Victory	30/16.6	Alignment efficiency
Mezomo, 2011	Split-mouth	Brazil		SmartClip	15(10F, 5M)/18	Gemini	15(10F, 5M)/18	Orthodontic space closure
Johansson, 2012	2-Arm	Sweden	Time2		44(31F, 13M)/ 15.3	Gemini	46(33F, 13M)/ 15.0	Treatment efficiency
Miles, 2010	2-Arm	Australia	In-Ovation		30(19F, 11M)/ 13.5	Clarity	30(19F, 11M)/ 13.5	Alignment efficiency
Fleming, 2010	2-Arm	UK		SmartClip	28(17F, 11M)/ 16.11	Victory	26(19F, 7M)/ 15.48	Treatment time
Pandis, 2007	2-Arm	Greece		Damon 2	27/13.48	Microarch GAC	27/13.70	Alignment efficiency, dimensional change

ASLB active self-ligating bracket, *PSLB* passive self-ligating bracket, *CB* conventional bracket, *M* male, *F* female

Efficiency of initial alignment

Six studies compared SLB with CB in terms of alignment efficiency [8, 19, 21, 25, 26, 29], 4 of which calculated the required time for initial alignment as a part of the meta-analysis [8, 21, 25, 26]. No prominent difference was observed between the results obtained for PSLB and CB (MD 26.48, 95% CI − 12.75 to 65.71). However, results of one study comparing ASLB, PSLB, and CB deviated from the group (Fig. 6) [26]. The sensitive analysis indicated no difference in the alignment efficiency of PSLB and CB (MD − 4.69, 95% CI − 22.28 to 12.91). The two studies that were not included in the meta-analysis calculated and compared the irregularity scores to present alignment efficiency but did not find any difference between the two. One of these two studies compared ASLB with CB at intervals of about 10 weeks [19], while the other compared PSLB with CB at monthly intervals [29].

Tab. 2 Risk of bias assessment
Tab. 2 Einschätzung des Bias-Risikos

First author	Published year	Sequence generation	Allocation concealment	Blinding of outcome assessors	Incomplete outcome	Selective data reporting	Other bias	Total	Outcomes
Scott	2008	L	U	L	L	L	L	U	Dimensional change, alignment efficiency
Monini	2014	U	U	L	L	L	U	U	Orthodontic space closure
Burrow	2010	U	U	U	L	L	L	U	Orthodontic space closure
Songra	2014	U	L	L	L	L	L	U	Alignment efficiency
Pandis	2011	L	L	L	L	L	L	L	Dimensional change
Fleming	2009	L	L	L	L	L	L	L	Dimensional change, alignment efficiency
DiBiase	2011	L	U	U	U	U	L	U	Treatment time
Mezomo	2011	L	U	U	L	L	L	U	Orthodontic space closure
Johansson	2012	L	U	U	L	L	L	U	Treatment time
Fleming	2010	L	U	U	L	L	U	U	Treatment time
Pandis	2007	U	U	U	L	L	L	U	Dimensional change, alignment efficiency

L Low risk of bias, *U* unclear risk of bias

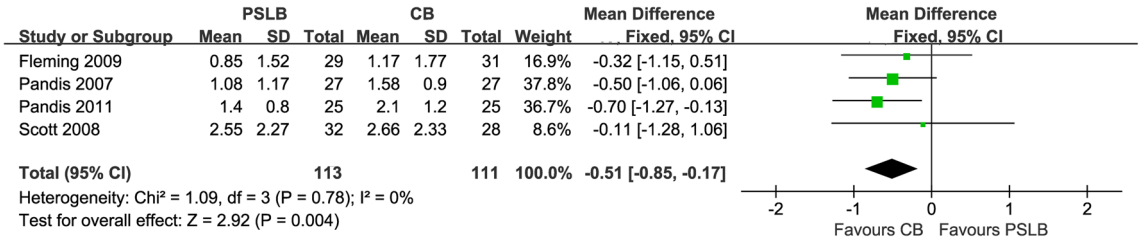

Fig. 2 Meta-analysis of mandibular intercanine width change of passive self-ligating brackets (PSLB) and conventional brackets (CB). *95% CI* 95% confidence interval, *SD* standard deviation
Abb. 2 Metaanalyse zur Änderung der intercaninen Distanz im Unterkiefer mit passiven selbstligierenden Brackets (PSLB) und konventionellen Brackets (CB). *95% CI* 95%-Konfidenzintervall, *SD* Standardabweichung

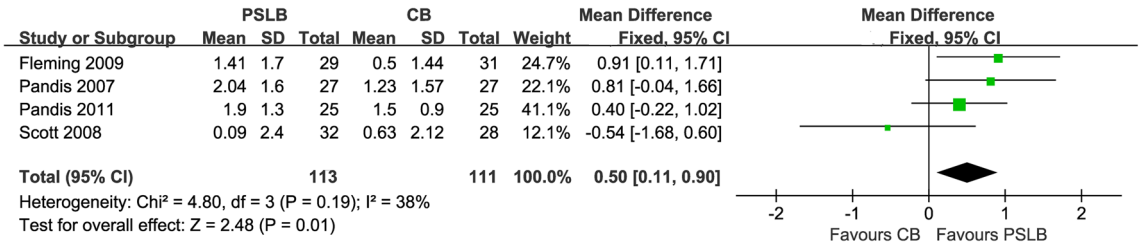

Fig. 3 Meta-analysis of mandibular intermolar change of passive self-ligating brackets (PSLB) and conventional brackets (CB). *95% CI* 95% confidence interval, *SD* standard deviation
Abb. 3 Metaanalyse zu transversalen Veränderungen im Molarenbereich im Unterkiefer mit passiven selbstligierenden Brackets (PSLB) und konventionellen Brackets (CB). *95% CI* 95%-Konfidenzintervall, *SD* Standardabweichung

Efficiency of treatment time

Three included studies analyzed the number of months required for a complete orthodontic treatment [5, 9, 14], whereby the meta-analysis indicated that CBs demand less treatment time than SLBs regardless of type—active or passive (MD 2.20, 95% CI 0.43–3.97). Moreover, when SLBs were further classified into ASLBs and PSLBs for

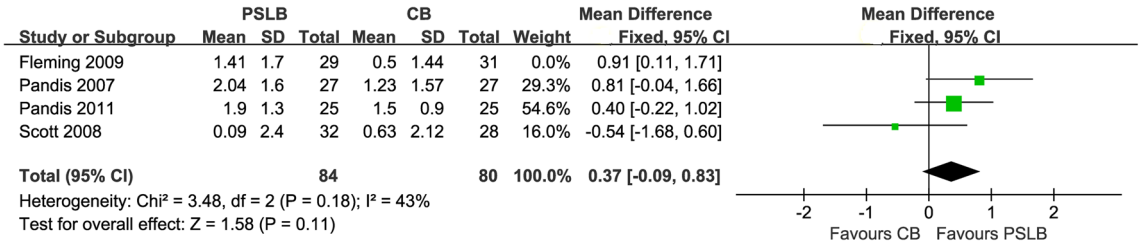

Fig. 4 Sensitive analysis of expanding mandibular molar width change of passive self-ligating brackets (PSLB) and conventional brackets (CB). *95% CI* 95% confidence interval, *SD* standard deviation

Abb. 4 Sensitivitätsanalyse zur Expansion im Molarenbereich mit passiven selbstligierenden Brackets (PSLB) und konventionellen Brackets (CB). *95% CI* 95%-Konfidenzintervall, *SD* Standardabweichung

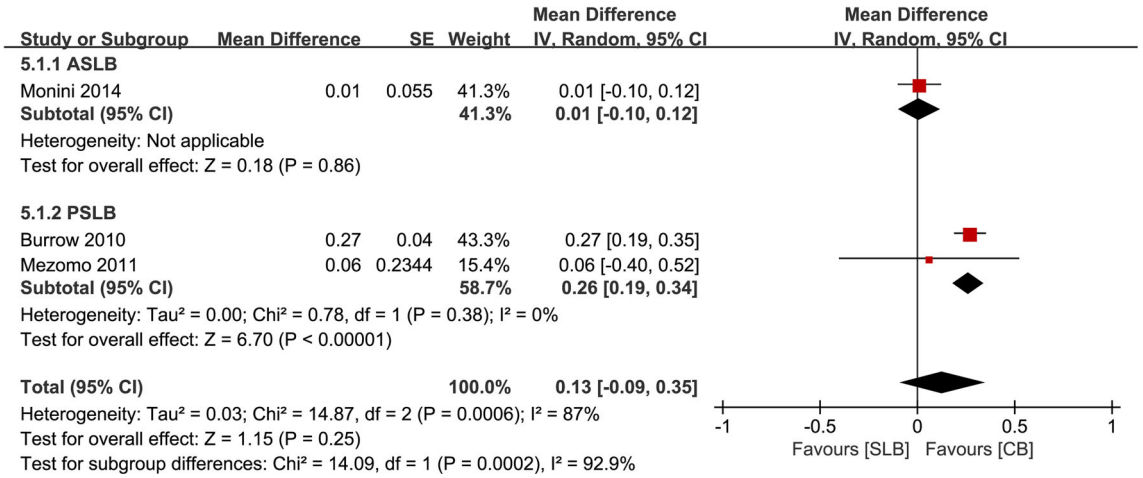

Fig. 5 Meta-analysis of orthodontic space closure of passive self-ligating brackets (PSLB) and conventional brackets (CB). *95% CI* 95% confidence interval, *SD* standard deviation

Abb. 5 Metaanalyse zum Lückenschluss mit passiven selbstligierenden Brackets (PSLB) und konventionellen Brackets (CB). *95% CI* 95%-Konfidenzintervall, *SD* Standardabweichung

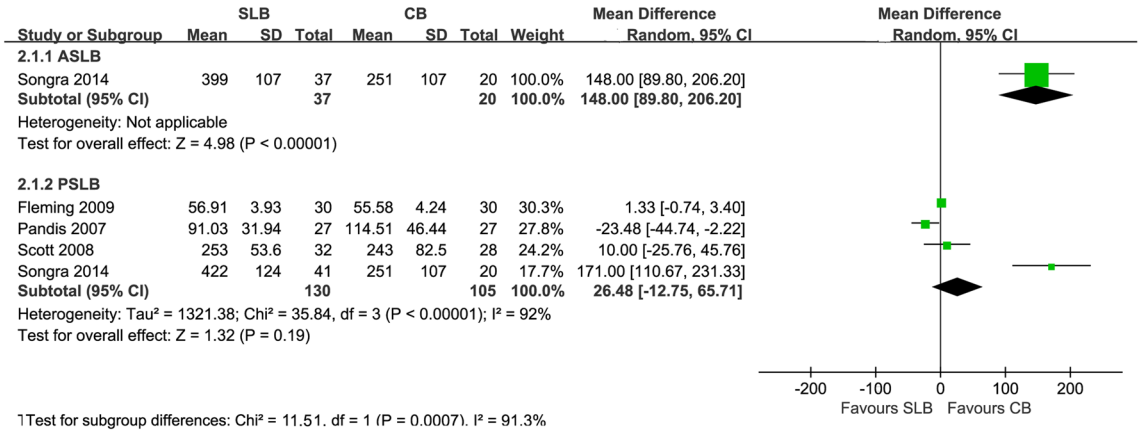

Fig. 6 Meta-analysis of initial alignment efficiency of self-ligating brackets (SLB) and conventional brackets (CB). *PSLB* passive self-ligating brackets, *ASLB* active self-ligating brackets, *95% CI* 95% confidence interval, *SD* standard deviation

Abb. 6 Metaanalyse zur Effizienz des initialen Alignments mit selbstligierenden Brackets (SLB) und konventionellen Brackets (CB). *PSLB* passive selbstligierende Brackets, *ASLB* aktive selbstligierende Brackets, *95% CI* 95%-Konfidenzintervall, *SD* Standardabweichung

detailed analysis, no significant statistical variation was observed (Fig. 7).

GRADE assessment

According to the GRADE quality analysis, the quality of the evidence for mandibular intermolar width and space

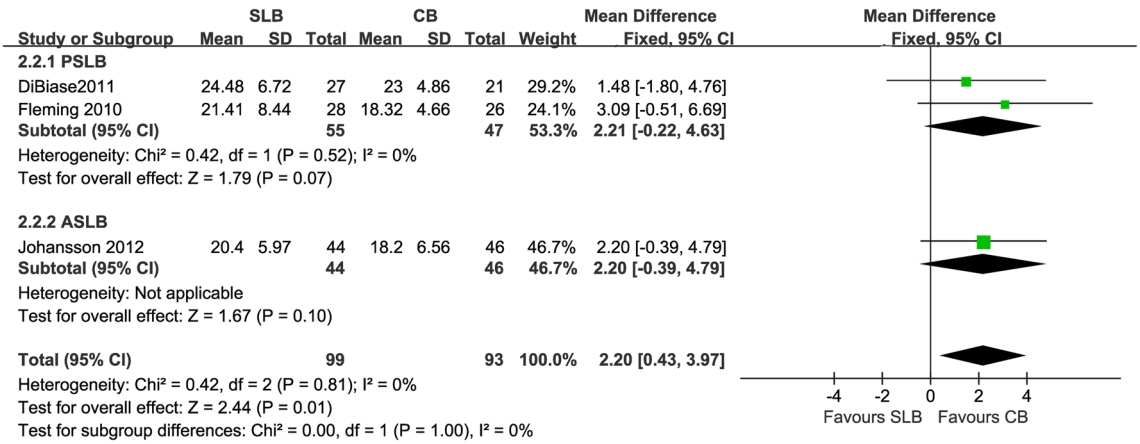

Fig. 7 Meta-analysis of treatment time of self-ligating brackets (SLB) and conventional brackets (CB). *PSLB* passive self-ligating brackets, *ASLB* active self-ligating brackets, *95% CI* 95% confidence interval, *SD* standard deviation

Abb. 7 Metaanalyse zur Behandlungszeit mit selbstligierenden Brackets (SLB) und konventionellen Brackets (CB). *PSLB* passive selbstligierende Brackets, *ASLB* aktive selbstligierende Brackets, *95% CI* 95%-Konfidenzintervall, *SD* Standardabweichung

closure outcomes was found to be low. In contrast, the quality of the evidence for mandibular intercanine width, initial alignment, and treatment time are moderate, and further research is required for confirmation.

Discussion

There are many uncontrolled factors which possibly influence clinical orthodontic treatment with brackets such as slot design and mode of operation (active or passive). The described factors may also affect the resistance to sliding, thus, affecting the bracket friction system and other facets of clinical applications [20]. However, in contrast to the present meta-analysis, most recent meta-analyses have not classified SLB into ASLB and PSLB. Seventeen RCTs focusing on the efficacy and competence of SLBs were included. Their clinical heterogeneities were also taken into consideration such as differences in treatment procedures, clinical and statistical methods, and the uniformity of response and oral healthcare habits of the patients [15]. Thus, only 11 of the 17 RCTs were further utilized for the meta-analysis.

Data for transversal dimensional arch width change and orthodontic space closure were extracted and synthesized from the results of the included RCTs. The meta-analysis showed CB to be more beneficial in mandibular intercanine width expansion and SLB as more effective in intermolar use without stability. No major difference was seen between SLB and CB in incisor inclination control and canine retraction speed. However, the results should be assessed carefully while considering all kinds of factors. As for the dimensional change, a published meta-analysis that included one RCT and two CCTs found no differences in their results [4]. Although the present meta-analysis includes four RCTs, the included sample size was limited and heterogeneity such as differences in race may not have been effectively avoided [31]. Moreover, one included RCT was a multicenter study and two had unclear risks of bias [25]. Furthermore, all studies included for meta-analysis of orthodontic space closure were split-mouth trials with maxillary first premolar extraction but with different bracket types and closing methods, such as NiTi springs or elastic coils. One published systematic review also considered orthodontic space closure, but included only one CCT and no definite conclusion was made [10].

Data regarding the efficiency of initial alignment and complete treatment time were synthesized from different RCT studies. The conducted meta-analyses favored CBs for shortened treatment time and these results were consistent with another published systematic review that included only two studies having a standard mean difference. However, when comparing the time taken for complete treatment using SLBs, clinical heterogeneities such as variations in the time interval and patient compliance must not be overlooked [3]. A published meta-analysis included three retrospective cohort studies and found no difference between SLB and CB in regard to the total treatment time [4]. Hence, further research is required to obtain substantial data for these aspects. As for the initial alignment, the sensitive analysis was conducted to confirm consistency in initial alignment efficiency between PLSB and CB. A novel approach to network meta-analysis was carried out to compare ASLB, PSLB, and CB for initial orthodontic alignment, including 6 RCTs and 4 CCTs, which provided direct, indirect, and mixed evidence by advanced statistical

methods [23]. The efficiency of initial orthodontic alignment was also reported in a systematic review that included 6 RCTs and 11 CCTs, although results were described only superficially without actual quantitatively synthesized evidence [10]. In another meta-analysis, only RCTs were included but the study effectively focused on the oral hygiene of self-ligating brackets, neglecting the determination of effectiveness or efficiency [30].

We only included randomized controlled clinical trials that have been considered to have high-quality clinical evidence in the present systematic review and meta-analysis. Moreover, our review has been conducted strictly according to standards set forth in the Cochrane Handbook and have included analysis of reasonable search strategy, risk-of-bias assessment, and multianalyses. However, some potential limitations could not be avoided. For example, selection bias could not be completely avoided, which is a common problem for all systematic reviews. Electronic databases and ongoing studies were searched thoroughly for relevant information. Manual searching was also performed, which may have restricted the endemic bias to a certain degree. However, the manual searching was limited to Chinese language publications due to the unavailable access to other language journals. Clinical heterogeneity was discovered to be pervasive and not entirely avoidable due to differences in brands of SLBs and CBs, treatment strategies, appointment intervals, and archwire sequences. Moreover, the participant population included in each study was not large, resulting in deficient statistical power and lack of prominent significant results. In addition, the number of published studies included in this meta-analysis was limited. There is a strong need for more quality analyses in the future in order to obtain clear, definite, and reliable outcomes.

Our findings in this systematic review and meta-analysis of RCTs do not suggest the superiority of SLBs for the orthodontic clinical application. In fact, our results appear to support CBs as being more advantageous in regard to expanding the mandibular intercanine width and overall treatment, which requires immediate and detailed exploration. Although initial results seem to favor PSLB to expand the mandibular intermolar width, the sensitive analysis did not confirm this. In addition, the results show no difference at low or moderated GRADE quality. Taken together, the obtained results indicate that more high-quality orthodontic studies are necessary to obtain significant comparative data on the effectiveness and efficiency of SLB and CB. When choosing bracket design for clinical use, it is recommended that orthodontists consider factors like patient preference, main treatment purpose, and cost-effectiveness over the popularity of a technique.

Conclusions

On the basis of this systematic review and meta-analysis, which collected and synthesized current evidence from RCTs regarding the clinical use of orthodontic brackets, CBs appear to have an advantage over SLBs in expanding the mandibular intercanine arch width, while SLBs appear to be superior for utilization on intermolars without stability. Furthermore, no difference in the clinical effectiveness of orthodontic space closure between bracket types was found. Moreover, current evidence does not favor SLBs or CBs in terms of alignment efficiency, although investigated evidence supports the utilization of CBs in terms of overall treatment efficiency. However, because evidence is not compelling, more high-quality RCTs with low risk of bias are required for the confirmation of these results. For the best results, orthodontist's choice of bracket types should be based on an understanding of clinical evidence, which has been largely covered in this study.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest.

References

1. Atik E, Clger S (2014) An assessment of conventional and self-ligating brackets in Class I maxillary constriction patients. Angle Orthod 84:615–622
2. Burrow SJ (2010) Canine retraction rate with self-ligating brackets vs conventional edgewise brackets. Angle Orthod 80:626–633
3. Celar A, Schedberger M, Dorfler P, Bertl M (2013) Systematic review on self-ligating vs. conventional brackets: initial pain, number of visits, treatment time. J Orofac Orthop 74:40–51
4. Chen SSH, Greenlee GM, Kim JE, Smith CL, Huang GJ (2010) Systematic review of self-ligating brackets. Am J Orthod Dentofac Orthop 137:726.e1–726.e18
5. DiBiase AT, Nasr IH, Scott PP, Cobourne MT (2011) Duration of treatment and occlusal outcome using Damon3 self-ligated and conventional orthodontic bracket systems in extraction patients: a prospective randomized clinical trial. Am J Orthod Dentofac Orthop 139:111–116
6. Ehsanl S, Mandich MA, El-Bialy TH, Flores-Mir C (2009) Frictional resistance in self-ligating orthodontic brackets and conventionally ligated brackets. A systematic review. Angle Orthod 79:592–601
7. Fleming PS, DiBiase AT, Sarri G, Lee RT (2009) Comparison of mandibular arch changes during alignment and leveling with 2 preadjusted edgewise appliances. Am J Orthod Dentofac Orthop 136:340–347
8. Fleming PS, DiBiase AT, Sarri G, Lee RT (2009) Efficiency of mandibular arch alignment with 2 preadjusted edgewise appliances. Am J Orthod Dentofac Orthop 135:597–602
9. Fleming PS, DiBases AT, Lee RT (2010) Randomized clinical trial of orthodontic treatment efficiency with self-ligating and

conventional fixed orthodontic appliances. Am J Orthod Dentofac Orthop 137:738–742
10. Fleming PS, Johal A (2010) Self-ligating brackets in orthodontics: a systematic review. Angle Orthod 80:575–584
11. Fleming PS, Lee RT, Marinho V, Johal A (2013) Comparison of maxillary arch dimensional changes with passive and active self-ligation and conventional brackets in the permanent dentition: a multicenter, randomized controlled trial. Am J Orthod Dentofac Orthop 144:185–193
12. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, Schunemann HJ, GRADE Working Group (2008) GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ 336:924–926
13. Higgins JPT, Altman DG (2008) Assessing risk of bias. In: Higgins JPT, Green S (eds) Cochrane handbook for systematic reviews of interventions. Wiley, Chichester, pp 8.1–8.44
14. Johansson K, Lundstrom F (2012) Orthodontic treatment efficiency with self-ligating and conventional edgewise twin brackets: a prospective randomized clinical trial. Angle Orthod 85:929–934
15. Jongsma MA, van der Mei HC, Atema-Smit J, Busscher HJ, Ren Y (2014) In vivo biofilm formation on stainless steel bonded retainers during different oral health-care regimens. Int J Oral Sci 69:1–7
16. Monini AC, Jnior GG, Martins RP, Vianna AP (2014) Canine retraction and anchorage loss self-ligating versus conventional brackets in a randomized split-mouth study. Angle Orthod 84:846–852
17. Mezomo M, Lima ES, Menezes LM et al (2011) Maxillary canine retraction with self-ligating and conventional brackets: a randomized clinical trial. Angle Orthod 81:292–297
18. Miles PG (2009) Self-ligating brackets in orthodontics: do they deliver what they claim? Aust Dent J 54:9–11
19. Miles P, Weyant R (2010) Porcelain brackets during initial alignment: are self-ligating cosmetic brackets more efficient? Aust Dent J 26:21–26
20. Nucera R, Giudice AL, Matarese G, Artemisia A, Bramanti E, Crupi P, Cordasco G (2013) Analysis of the characteristics of slot design affecting resistance to sliding during active archwire configurations. Prog Orthod 14:35
21. Pandis N, Polychronopoulou A, Eliades T (2007) Self-ligating vs conventional brackets in the treatment of mandibular crowding a prospective clinical trial of treatment duration and dental effects. Am J Orthod Dentofac Orthop 132:208–215
22. Pandis N, Polychronopoulou A, Kataros C, Eliades T (2011) Comparative assessment of conventional and self-ligating appliances on the effect of mandibular intermolar distance in adolescent nonextraction patients: a single-center randomized controlled trial. Am J Orthod Dentofac Orthop 140:e99–e105
23. Pandis N, Fleming PS, Spineli LM, Salanti G (2014) Initial orthodontic alignment effectiveness with self-ligating and conventional appliances: a network meta-analysis in practice. Am J Orthod Dentofac Orthop 145:152–163
24. Rinchuse DJ, Miles PG (2007) Self-ligating brackets: present and future. Am J Orthod Dentofac Orthop 132:216–222
25. Scott P, DiBiase AT, Sherriff M, Cobourne MT (2008) Alignment efficiency of Damon3 self-ligating and conventional orthodontic bracket systems: a randomized clinical trial. Am J Orthod Dentofac Orthop 134:470.e1–470.e8
26. Songra G, Clover M, Atack NE, Ewings P, Sherriff M, Sandy JR, Ireland AJ (2014) Comparative assessment of alignment efficiency and space closure of active and passive self-ligating vs conventional appliance in adolescents: a single-center randomized controlled trial. Am J Orthod Dentofac Orthop 145:569–578
27. Stolzenberg J (1935) The Russell attachment and its improved advantages. Int J Orthod Dent Child 2:837–840
28. Wong H, Collins Tinsley D, Sandler J, Benson P (2013) Does the bracket-ligature combination affect the amount of orthodontic space closure over three months? A randomized controlled trial. J Orthod 40:155–162
29. Wahab RM, Idris H, Yacob H, Ariffin SH (2011) Comparison of self- and conventional-ligating brackets in the alignment stage. Eur J Orthod 34:176–181
30. Yang X, Su N, Shi Z, Xiang Z, He Y, Han X, Bai D (2016) Effects of self-ligating brackets on oral hygiene and discomfort: a systematic review and meta-analysis of randomized controlled clinical trials. Int J Dent Hyg 15:16–22
31. Zhou B, Wang J, Stein EM, Zhang Z, Nishiyama KK, Zhang CA, Nickolas TL, Shane E, Guo XE (2014) Bone density microarchitecture and stiffness in Caucasian and Caribbean Hispanic postmenopausal American women. Bone Res 16:1–9
32. Zhou Q, Ul Haq AA, Tian L, Chen X, Huang K, Zhou Y (2015) Canine retraction and anchorage loss self-ligating versus conventional brackets: a systematic review and meta-analysis. BMC Oral Health 15:136