Systematic Review Article

Comparison of flash-free and conventional bonding systems: *A systematic review and meta-analysis*

He Wang[a]; Ge Feng[b]; Bo Hu[c]; Haonan Tian[d]; Yunchun Kuang[e]; Tingwei Zhang[f]; Jinlin Song[g]

ABSTRACT

Objectives: To review the literature systematically to compare the performance of adhesive precoated flash-free bonding systems with conventional adhesive precoated (APC) and operator-coated (OPC) bonding systems.

Materials and Methods: PubMed, Cochrane Library, Web of Science, and Embase were searched for potential eligible studies. Study selection and data collection were conducted independently. Statistical analysis was performed by Review Manager 5.3. The Cochran Q test was used to test heterogeneity in the included studies. Risk of bias was evaluated using Cochrane RoB 2.0 tool for randomized controlled trials.

Results: Six studies were included and the overall risk-of-bias judgment was low risk of bias to some concerns. The results of the meta-analyses showed that flash-free required significantly less bonding time than APC (mean difference [MD]: −1.56; 95% confidence intervals [CIs]: −2.56 to −0.56), and no significant differences were found in bond failure rates (risk ratio [RR]: 1.54; 95% Cis: 0.27 to 8.89) and adhesive remnant index (ARI) (MD: −0.50; 95% CIs: −1.14 to 0.14) between them. Qualitative analysis showed that flash-free might have a positive effect on enamel demineralization compared to APC but the quantity of plaque did not differ between them.

Conclusions: The flash-free bonding system significantly reduced bonding time and it had comparable bond failure rates with APC. So far, there is not enough evidence to support its positive effect on reducing enamel demineralization and the pathogenic bacteria around brackets. In summary, flash-free might be a better choice for clinical bracket bonding. (*Angle Orthod.* 2022;92:691–699.)

KEY WORDS: Flash-free; Bracket bonding; Adhesives; Bonding performance

INTRODUCTION

Malocclusion is a highly prevalent public oral health problem[1] that is mainly solved through orthodontic treatment. Currently, fixed appliance therapy is still one of the most efficient orthodontic treatments. Brackets play an important role in this process and are bonded to teeth with adhesive. Adhesive is important for a high-quality bond between brackets and teeth for the entire length of treatment. The history of adhesive dentistry for enamel bonding began with Newman,[2] who first succeeded in bonding plastic attachments to the surface of teeth using an epoxy adhesive. It developed quickly in orthodontics.[3] Currently, a wide variety of resins and cements, self-cured or light-cured, are available to orthodontists. Compared to chemically cured adhesives, light-cured adhesives have a nearly unlimited working time for accurate bracket placement, which can be classified as adhesive precoated (APC) and operator coated (OPC) bonding systems, with APC offering easier and faster bonding than OPC.[4]

[a] Graduate Student, Chongqing Key Laboratory of Oral Diseases and Biomedical Sciences, Chongqing, China.
[b] Dentist, Stomatological Hospital of Chongqing Medical University, Chongqing, China.
[c] Dentist, Chongqing Municipal Key Laboratory of Oral Biomedical Engineering of Higher Education, Chongqing, China.
[d] Graduate Student, Stomatological Hospital of Chongqing Medical University, Chongqing, China.
[e] Dentist, The Third Affiliated Hospital of Chongqing Medical University, Chongqing, China.
[f] Postdoctoral Student, Chongqing Municipal Key Laboratory of Oral Biomedical Engineering of Higher Education, Chongqing, China.
[g] Professor, Stomatological Hospital of Chongqing Medical University, Chongqing, China.
Corresponding author: Dr Jinlin Song, Stomatological Hospital of Chongqing Medical University, No 426, North Songshi Road, Chongqing 401147, China
(e-mail: songjinlin@hospital.cqmu.edu.cn)

Accepted: April 2022. Submitted: December 2021.
Published Online: July 14, 2022

The APC bonding system (3M Unitek, Monrovia, CA, USA) was first introduced in 1991, followed by APC II and APC PLUS bonding systems with modified composition and better performance.[5] However, the problem of the flash (the excess adhesive around the bracket after positioning) had still not been solved. Careful and complete removal of the flash is time-consuming, as any extraneous flash may cause plaque accumulation,[6] progression of periodontal inflammation, and white spot lesions, ultimately affecting the esthetic outcome of orthodontic treatment.[7]

To solve this problem, flash-free technology was introduced[8] (3M Unitek) in 2013, with advantages claimed by the manufacturer: elimination of the excess flash clearing procedure when positioning the bracket and reduced bond failure rates.[9] Its most pronounced "flash-free" feature is based on a nonwoven, polypropylene fiber material soaked by a low-viscosity resin.[10] Once the bracket is placed, the compressible material lets the resin spread out and conform to the tooth surface, making uniform and consistent contact, without any flash to clean,[11] which was expected to significantly decrease chair time and plaque accumulation.

Mohamed et al.[12] systematically compared the bonding performance of APC and OPC bonding systems. As a new generation of bonding systems that evolved from APC, flash-free experienced more modifications of structure and composition than APC. Multiple studies[5,8–11] have compared the performance of flash-free and conventional adhesives but controversy still exists about its actual clinical bonding performance. Therefore, a systematic review was needed to make a comprehensive comparison of flash-free and conventional bonding systems and to provide up-to-date evidence for clinical practice.

METHODS

Registration and Protocol

The protocol for this systematic review was registered on the National Institutes of Health Research Database under the registration number CRD42020171507. The review is reported according to the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-analyses).[13]

Eligibility Criteria

Inclusion criteria. The inclusion criteria were specified using the PICOS approach:

1. Participants: Patients undergoing treatment with fixed orthodontic appliances were included.
2. Intervention: Flash-free bonding system
3. Control: Conventional bonding systems, including APC and OPC bonding systems
4. Outcome measures: Bonding time; clinical bond failure rates; enamel demineralization and periodontal status; adhesive remnant index (ARI) scores
5. Study design: Randomized controlled clinical trials (RCTs). No language or year of publication restrictions were applied.

Exclusion criteria.

1. Absence of a control group
2. Studies reporting no outcomes mentioned already
3. Registered protocols with no published results
4. Reviews, abstracts, book chapters, commentaries, letters, conference proceedings

Table 1. Database Search Strategy

Database	Search Strategy/Keywords	Results
Cochrane	(flash-free OR flash free OR "flash free") AND (bracket OR brackets OR dental bonding OR fixed appliances) Search: Title/abstract/keywords	18
Pubmed	(("Dental Bonding" [MeSH] OR "Dental Cements" [MeSH]) OR ("Orthodontic Brackets" [MeSH] OR "Orthodontic Appliances" [MeSH])) AND (flash-free [all fields] OR flash free [all fields] OR " flash free" [all fields])	40
Embase	('Dental Bonding'/exp OR 'Tooth Cement'/exp OR 'Orthodontic Device'/exp OR 'Orthodontic Bracket '/exp) AND ('flash-free' OR 'flash free')	14
Web of Science	(Dental bonding OR Dental cements OR Orthodontic adhesives OR Orthodontic brackets) AND (flash-free OR flash free OR " flash free") Search: Topic	71

Information Sources, Search Strategy, Study Selection

A search of relevant literature was conducted by two reviewers (HW and GF) independently in the Cochrane Library, PubMed, Web of Science, and Embase databases from the earliest available date to November 20, 2021. Related orthodontic and adhesive journals and the reference list in each retrieved study were manually searched for additional relevant studies. In addition, gray literature was searched in the National Research Register, and Open Grey with the term "flash-free." Specific search strategies for each database are presented in Table 1.

The eligibility of identified studies was initially checked by screening their titles and abstracts in Endnote. Potentially eligible articles were read in full text and judged against the inclusion/exclusion criteria for a final judgment by the two authors (HW and GF).

Any disagreements about study inclusion were resolved through discussion.

Data Collection Process and Data Items

The data extraction process was conducted independently by the two authors (HW and GF) with standardized sheets in Word. Any disagreements were resolved through discussion. When any problems arose, the study investigators were contacted for additional details (every 2 weeks for 2 months).

Information collected from the included studies consisted of publication details, participants, control groups, outcomes measured, study design, enamel pretreatment, and study duration.

Study Risk of Bias Assessment

The Cochrane scale was employed (RoB 2.0 tool).[14] The risk of bias was considered low, some concerns, or high for each assessed criterion. The assessment was conducted independently by the two authors (HW and GF), and disagreements were resolved through discussion. When agreements could not be reached through discussion, a third author's opinion (JS) was considered.

Effect Measures and Synthesis Methods

If it was considered not appropriate to make a quantitative synthesis of studies, a qualitative synthesis was performed. As the bracket bonding in studies was performed by different operators with inevitable methodological differences, a priori choice of a random-effects model was reasonable to account for between-study variance. To conduct the meta-analyses, for continuous data, the means with their corresponding standard deviations (SD) and sample sizes of each outcome were statistically pooled to calculate the mean difference (MD) with corresponding 95% confidence intervals (CI) using the inverse variance method. For dichotomous data, the number of events and the sample sizes were pooled together to calculate the risk ratio (RR) with corresponding 95% CIs using the inverse variance method. Heterogeneity across studies was assessed with the I^2 statistic.

Sensitivity analysis was conducted to evaluate the robustness of the overall results by the one study removal method. The sensitivity analysis and meta-analysis were implemented by Review Manager 5.3 (Cochrane Collaboration).

Reporting Bias Assessment

The Egger test and Begg test were used to assess publication bias.

Certainty Assessment

The certainty of evidence of each outcome was appraised using GRADEpro Guideline Development Tool[15] according to the study design, risk of bias, inconsistency, indirectness, imprecision, and other considerations. The assessment was conducted independently by the two authors (HW and GF), and disagreements were resolved through discussion.

RESULTS

Study Selection and Characteristics

The database search identified 143 articles, and no articles were identified through additional sources. After the removal of duplicates, 78 articles were reviewed with titles and abstracts, and 55 of them were excluded. The remaining 23 articles were regarded as potentially eligible. After reading the full texts, 17 studies were excluded and six studies were finally included in the review (Figure 1).

The main characteristics of the selected studies are presented in Table 2. The studies included were published from 2018 to 2020.[16–21] All of them were randomized controlled trials. Among the studies included, one study made a comparison between flash-free and OPC,[21] while the others made comparisons between flash-free and APC.[16–20] Two studies compared the bonding time and adhesive remnant index (ARI),[16,18] three reported bracket failure rates[6–18] and three[19–21] reported enamel demineralization and periodontal status. The 17 excluded studies with reasons are shown in Table 3.

Risk of Bias in Studies

Three studies[16,17,19] were judged to have a low risk of bias, and the other studies[18,20,21] were judged to have some concerns because of lack of information about selection bias, performance bias, and detection bias (Table 4).

Results of Syntheses

A qualitative analysis was conducted for three studies[19–21] investigating enamel demineralization and periodontal status with methodological variation. Two studies[20,21] reported no significant differences in enamel demineralization between flash-free and conventional bonding systems, while the study by Almosa et al.[19] reported that the mean values of demineralization were significantly decreased in flash-free compared to APC. Tan et al.[21] reported that the effects of flash-free and OPC on periodontal health did not differ from each other, while Yetkiner et al.[20] reported that, though the quantity of plaque around flash-free and APC did not

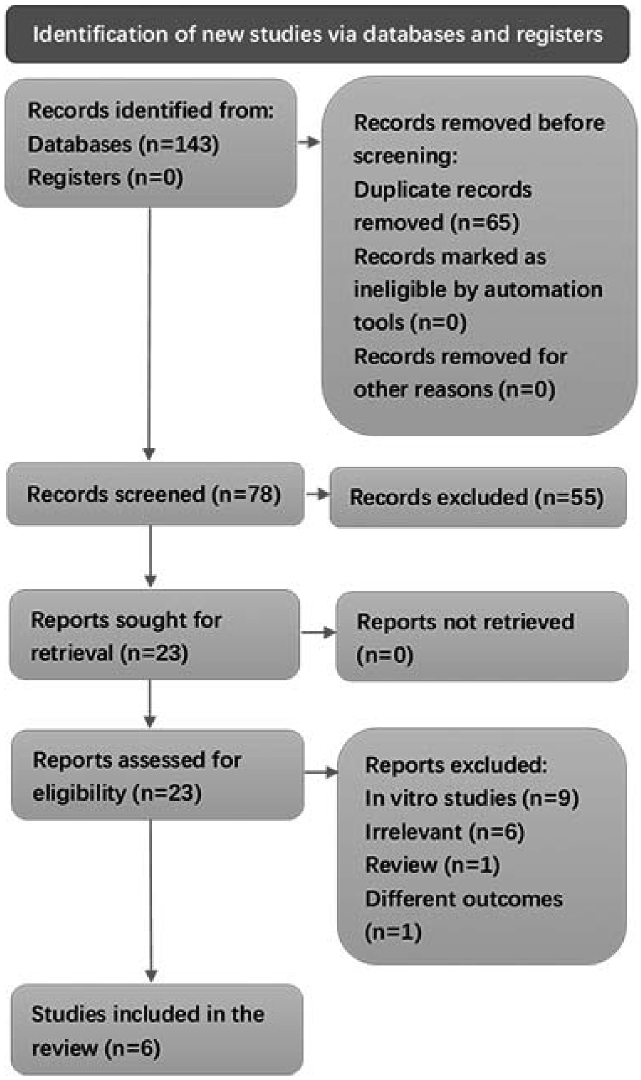

Figure 1. PRISMA flow diagram showing the process of identifying and selecting eligible studies for the systematic review.

differ, less pathogenic bacteria were detected in the plaque around flash-free.

The meta-analysis results showed that the flash-free significantly reduced bonding time compared to APC (mean difference [MD]: −1.56; 95% CI: −2.56 to −0.56; $P = .002$, Figure 2), and no significant difference was found in failure rates (RR: 1.54; 95% CI: 0.27 to 8.89; $P = .63$, Figure 3) and ARI (MD: −0.50; 95% CI: −1.14 to 0.14; $P = .13$, Figure 4) between them. The results of failure rates in two articles by Grünheid et al.[16,17] were from the same research, so only the article in 2018[16] was included in the meta-analysis of failure rates.

Substantial heterogeneity existed among the studies included in the meta-analyses of bonding time and failure rates. However, the studies presented a consistent direction of effect in the meta-analyses. Subgroup analyses and sensitivity analyses could not be performed because only two studies were included in each meta-analysis.

Reporting Biases

Publication bias was not estimated because of the limited number of studies included in the meta-analysis. No selective reporting was found within studies.

Certainty of Evidence

Low-to-moderate certainty of evidence for the outcomes is expected. Evidence was mainly downgraded because of shortcomings in the risk of bias and inconsistency of some studies (Table 5).

DISCUSSION

Summary of Evidence

The problem of flash has been a challenge concerning orthodontists for a long time. Careful and complete removal of flash is time-consuming and any flash left may cause the development of enamel demineralization and periodontal inflammation with increased plaque accumulation.[6] The flash-free bonding system was claimed to solve this problem well. However, its actual bonding performance was questioned because of the modifications in its structure and constituents.[22] Thus, this review and meta-analysis was conducted to compare flash-free with conventional bonding systems comprehensively. The review included six studies,[16–21] all of which were RCTs. A critical appraisal of the trials using the Cochrane RoB 2.0 tool found that three studies[18,20,21] were judged to have some concerns. The overall assessment of the evidence was rated as low to moderate according to Grade due to limitations in risk of bias and inconsistency.

According to the results of meta-analysis, flash-free was superior to the APC bonding system in requiring less bonding time. This result was expected since the procedure of excess adhesive removal was eliminated in the flash-free bracket bonding process and, although the elimination of this procedure saves only a few seconds per tooth, it makes sense in clinic because cumulative time savings add up to significant differences when considering a full-mouth application.[17] Bracket bonding is probably the longest appointment during orthodontic treatment and reduced chair time can make work more efficient and improve patient satisfaction.[16]

Bond strength performance is one of the most important characteristics of an adhesive, which could be evaluated by clinical bond failure rates. Some considered that the nonwoven mesh at the bracket

Table 2. Main Characteristics of Included Clinical Studies

Study	Type of Study and Study Design	Participants	Enamel Pretreatment	Control	Outcomes	Results	Duration of Study
Grünheid et al., 2018	Split-mouth RCT	42 patients presenting for comprehensive orthodontic treatment	Teeth were polished using a fluoride-free prophylaxis paste on a rubber cup, etched with 35% orthophosphoric acid for 30 s, primed using a light-cure adhesive primer (Transbond XT Light Cure Ad-hesive Primer; 3M Unitek).	APCII Adhesive Coated Appliance System	Bonding time; failure rate within one year; ARI	Flash-free adhesive may result in bonding time savings of approximately one-third compared with the conventional adhesive. With regard to bracket survival, a statistically significant difference was not found.	1 y
Grünheid et al., 2019	Split-mouth RCT	42 patients presenting for comprehensive orthodontic treatment	Teeth were polished with a fluoride-free prophylaxis paste, etched with 35% orthophosphoric acid for 30 s, and primed using a light-cure adhesive primer (Transbond XT Light Cure Ad-hesive Primer; 3M Unitek).	APCII Adhesive Coated Appliance System	Bracket failure rate for the entire treatment	Bracket survival with the flash-free adhesive was equivalent to the conventional adhesive. Adhesive removal was significantly faster when using the flash-free.	32 mo
Tumoglu et al., 2019	Split-mouth RCT	33 patients required fixed orthodontic therapy without extractions	Buccal surfaces of the teeth were pumiced, teeth were etched with the use of 37% phosphoric acid etchant for 30 s. After the etching protocol, a thin uniform coat of primer (Transbond XT Primer; 3M Unitek)	Adhesive Precoated Plus bracket systems	Bracket bonding time; bracket failure rates over 6 mo; ARI	Flash-free bonding system can reduce the bonding time without increasing bracket failure rate.	6 mo
Almosa et al., 2019	Parallel RCT	20 patients with at least 2 premolars indicated for extraction for orthodontic treatment	Each tooth was cleaned with fine pumice and rubber cup for 10 s. A 35% phosphoric acid etch was applied on the enamel surfaces for 30 s. A thin layer of bonding agent was coated on the etched surface with a disposable brush	APC Plus Adhesive Ceramic Brackets	Enamel demineralization depth	The enamel demineralization around Flash-Free adhesive bracket system was significantly less than that of APC plus Adhesive bracket system	4 wk
Yetkiner et al., 2019	Split-mouth RCT	50 adolescents screened for orthodontic treatment	Not reported	Clarity advanced APC II	Plague accumulation; enamel demineralization; periodontal biomarker and pathogen levels	The quantity of plaque on adhesive flash-free brackets and conventional brackets did not differ, but the constituents of plaque differed, with less pathogenic bacteria detected around adhesive flash-free brackets.	Entire orthodontic treatment
Tan et al., 2020	Split-mouth RCT	30 patients with the need for orthodontic treatment	37% phosphoric acid was used for enamel etching, Transbond XT Primer (3M Unitek, Monrovia, Calif) was applied to the etched enamel	Conventional ceramic brackets with Transbond XT Light Cure Adhesive	Demineralization Measurements; Periodontal Measurements	The effects of flash-free and conventional brackets on enamel demineralization and periodontal health did not differ from each other.	6 mo

[a] APC indicates adhesive precoated; ARI, adhesive remnant index; RCT, randomized controlled trial.

base, as a new design feature of the flash-free system, had a lower material density and might affect the overall bond strength of the adhesive.[11] However, according to the results of meta-analysis, no statistically significant difference in bond failure rates was found between flash-free and APC. Additionally, the bond failure rate values of flash-free reported by the two studies were both clinically acceptable. These results indicated that flash-free probably had comparable bond strength to APC. This was consistent with

Table 3. 17 Excluded Studies With Reasons at the Full-Text Phase

Title	Author and Year of Publication	Reason of Exclusion
Effect of surface treatments and flash-free adhesive on the shear bond strength of ceramic orthodontic brackets to CAD/CAM provisional materials	Soliman et al., 2022	Irrelevant
Effect of a single-component ceramic conditioner on shear bond strength of precoated brackets to different CAD/CAM materials	González et al., 2021	Irrelevant
Enamel around orthodontic brackets coated with flash-free and conventional adhesives	ElSherifa et al., 2020	In vitro study
Effects of adhesive flash-free brackets on debonding pain and time: a randomized split-mouth clinical trial	Çokakoğlu et al., 2020	Different outcomes
Shear bond strength of a flash-free orthodontic adhesive system after thermal aging procedure.	González et al., 2019	In vitro study
Particulate production during debonding of fixed appliances: laboratory investigation and randomized clinical trial to assess the effect of using flash-free ceramic brackets.	Vig et al., 2019	Irrelevant
Comparison of adhesive seal morphology between APC™ PLUS and APC™ Flash-Free Adhesive coated brackets	Jung et al., 2018	Irrelevant
Bond strength of pre-coated flash-free adhesive ceramic brackets. An in vitro comparative study on the second mandibular premolars.	Marc et al., 2018	In vitro study
Shear bond strength and excess adhesive surface topography of different bonding systems after thermocycling: a comparative in-vitro study	Dheyaa et al., 2018	In vitro study
Flash-free orthodontic adhesive system compared with the conventional direct bonding method	Szuhanek et al., 2018	In vitro study
Shear bond strength of orthodontic brackets with APC™ flash-free adhesive: An in-vitro study	Almoammar et al., 2017	In vitro study
Shear bond strength of ceramic brackets with different base designs: comparative in-vitro study	Ansari et al., 2016	Irrelevant
Microleakage under ceramic flash-free orthodontic brackets after thermal cycling	Kim et al., 2016	irrelevant
A new flash-free orthodontic adhesive system: a first clinical and stereomicroscopic study	Foersch et al., 2016	In vitro study
Current state of knowledge and clinical management of the APC(TM) flash-free adhesive coated appliance system	Jaeger et al., 2016	Review
Comparison of shear bond strength and bonding time of a novel flash-free bonding system	Lee et al., 2016	In vitro study
Debonding and adhesive remnant cleanup: an in vitro comparison of bond quality, adhesive remnant cleanup, and orthodontic acceptance of a flash-free product	Grünheid et al., 2015	In vitro study

the results of direct measurements of shear bond strength in vitro, which displayed no significant difference between flash-free and conventional bonding systems.[5,8,9,23]

It is noteworthy that substantial heterogeneity existed among the studies included in the meta-analyses of bonding time and failure rates. According to the Cochrane handbook,[14] the included articles will inevitably differ in a meta-analysis, especially in experimental methodology. Any kind of variation between studies in a meta-analysis is called heterogeneity. Considering the methodological differences among the studies in the meta-analyses, such heterogeneity was inevitable. However, despite considerable heterogeneity, all studies included showed a consistent direction of effect in the meta-analysis that, to some extent, supported the conclusion. Existing heterogeneity is a reminder that the results should be treated with caution, and further well-designed research with methodological rigor is deemed necessary in the future.

ARI was evaluated to compare the bonding performance of flash-free with conventional adhesives comprehensively. Though not precise, ARI can give a rough indication of where bond failure happens. According to the results of meta-analysis, no differences in ARI were found between flash-free and APC on brackets that failed clinically. This suggested that bond

Table 4. Risk of Bias of the Included Studies

Study	Bias Arising From the Randomization	Bias Due to the Deviations From Intended Interventions	Bias Due to Missing Outcome Data	Bias in Measurement of Outcome	Bias in Selection of the Reported Result	Overall Risk-of-Bias Judgment
Almosa et al., 2019	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias
Grünheid et al., 2018	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias
Grünheid et al., 2019	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias
Tan et al., 2020	Some concerns	Some concerns	Low risk of bias	Some concerns	Low risk of bias	Some concerns
Tumoglu et al., 2019	Some concerns	Some concerns	Low risk of bias	Some concerns	Low risk of bias	Some concerns
Yetkiner et al., 2019	Low risk of bias	Some concerns	Low risk of bias	Some concerns	Low risk of bias	Some concerns

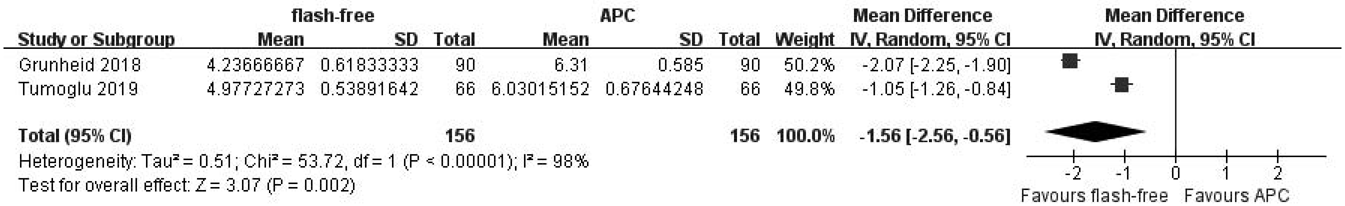

Figure 2. Meta-analysis of clinical bonding time comparing flash-free and APC bonding systems.

failures of flash-free did not happen more frequently at the bracket-adhesive interface than APC, which further demonstrated that the nonwoven mesh at the bracket base did not weaken the bond strength of flash-free. In summary, the available evidence suggested that the novel mesh structure in flash-free might not have a negative influence on bond strength and that the clinical bond failure rates of the flash-free and APC were not significantly different.

The study by Almosa et al. found that enamel demineralization around the flash-free brackets was significantly reduced compared with that of the APC.[19] However, the studies by Tan et al.[21] and Yetkiner et al.[20] reported that no significant differences of demineralization were found between flash-free and conventional adhesives; however, they only made an estimation of demineralization degree using relatively rough methods,[20,21] while Almosa et al.[19] sectioned the teeth and measured the demineralization depth accurately under scanning electron microscope (SEM), which may be considered more reliable. Less demineralization of flash-free adhesive could be attributed to the presence of less excess adhesive on smooth surfaces. A previous study reported that flash-free had significantly lower excess adhesive measurements than APC.[10] Additionally, further in vitro examination by SEM described that the excess adhesive of flash-free displayed a smooth, nontextured surface, with the adhesive spreading out and conforming to the enamel surface, while APC and OPC presented a ruffled surface with a more irregular transition from adhesive to enamel.[11]

Tan et al.[21] reported that the effects of flash-free and OPC on periodontal health were not different from each other. However, Yetkiner et al.[20] reported that, although the quantity of plaque on flash-free and conventional brackets was not different, the constituents of plaque differed, with less pathogenic bacteria detected around flash-free brackets.

Limitations

The main limitation of this review was the small number of studies included. This was probably due to the fact that the flash-free bonding system is a novel adhesive product and lacks a large number of original studies, which is a problem that all meta-analyses concerning new materials face.

Though three included studies[8,20,21] reported the same outcome for enamel demineralization, meta-analysis of them could not be conducted because of their methodological and outcome measurement differences. Tan et al.[21] and Yetkiner et al.[20] detected demineralization with the DIAGNOdent Pen (Kavo, Biberach, Germany) or quantitative light-induced fluorescence imaging,[20,21] while Almosa et al.[19] measured the demineralization depth under SEM.

For risk-of-bias assessment, three studies[18,20,21] were judged to have some concerns because of lack of information in bias arising from randomization, bias due to deviations from intended interventions, and bias in measurement of outcome. Thus, it is critical that future RCTs have more uniform study designs and methodological rigor.

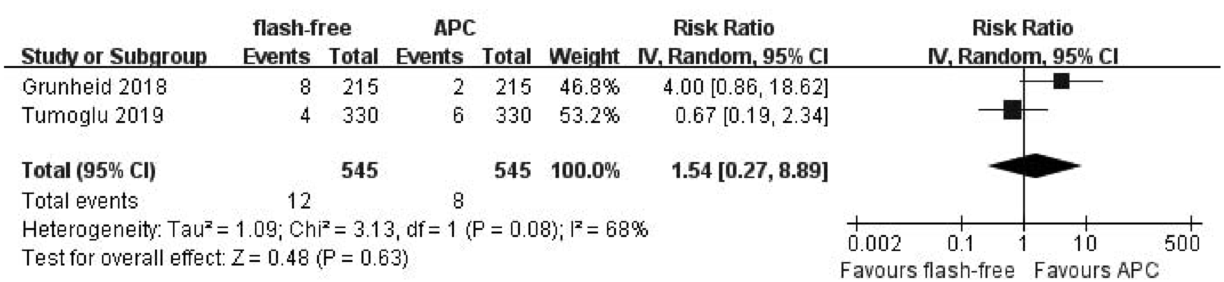

Figure 3. Meta-analysis of clinical bond failure rates comparing flash-free and APC bonding systems.

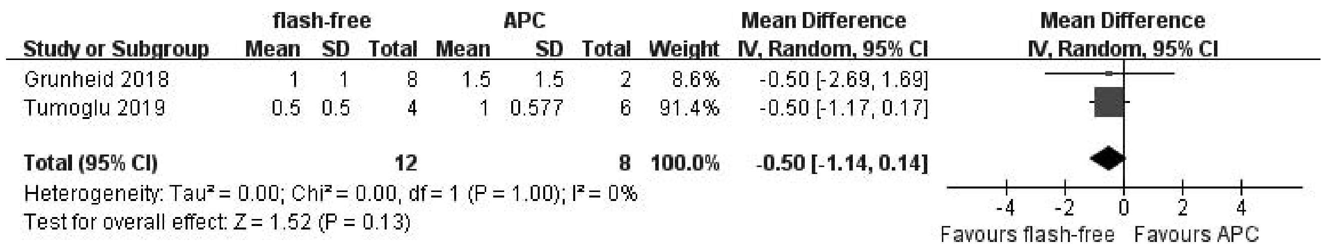

Figure 4. Meta-analysis of ARI scores comparing flash-free and APC bonding systems.

Table 5. GRADE Assessment for Certainty of Evidence[a]

Certainty Assessment							№ of Patients		Effect			
No of Studies	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other Considerations	Flash-free	APC	Relative (95% CI)	Absolute (95% CI)	Certainty	Importance
Bonding time												
2	randomized trials	serious[b]	not serious	not serious	not serious	none	156	156	-	MD 1.56 lower (2.56 lower to 0.56 lower)	⊕⊕⊕○ Moderate	CRITICAL
Bond failure rates												
2	randomized trials	serious[b]	not serious	not serious	not serious	none	12/545 (2.2%)	8/545 (1.5%)	OR 1.56 (0.26 to 9.40)	8 more per 1,000 (from 11 fewer to 108 more)	⊕⊕⊕○ Moderate	CRITICAL
ARI												
2	randomized trials	serious[b]	not serious	not serious	not serious	none	12	8	-	MD 0.5 lower (1.14 lower to 0.14 higher)	⊕⊕⊕○ Moderate	CRITICAL
Enamel demineralization												
3	randomized trials	serious[c]	serious[d]	not serious	not serious	none	Two studies reported that no significant differences of enamel demineralization existed between flash-free and conventional bonding systems, while one study reported that the demineralization values of flash-free were significant lower than those of APC bonding system.				⊕⊕○○ Low	CRITICAL
Periodontal status												
2	randomized trials	serious[c]	not serious	not serious	not serious	none	The two studies both reported that no significant difference of periodontal status was found between flash-free and conventional bonding systems.				⊕⊕⊕○ Moderate	CRITICAL

[a] CI indicates confidence interval; MD, mean difference; OR, odds ratio.
[b] The study by Tumoglu et al. exhibited some concerns in Risk of bias evaluation.
[c] The studies by Yetkiner et al. and Tan et al. exhibited some concerns in Risk of bias evaluation.
[d] The study by Almosa et al. presented inconsistent results with the studies by Yetkiner et al. and Tan et al.

CONCLUSIONS

- Based on the evidence available, the flash-free bonding system required less bonding time than APC, and no significant differences were found in bond failure rates and ARI.
- There is currently not enough evidence to support a positive effect of flash-free on reducing enamel demineralization and the pathogenic bacteria around brackets. In summary, flash-free might be a better option for clinical bracket bonding than APC or OPC.
- More clinical trials with standardized methodology are needed to further evaluate the performance of flash-free in the future.

ACKNOWLEDGMENTS

This project was supported by Chongqing Graduate Tutor Team (dstd201903).

REFERENCES

1. Tristão SKPC, Magno MB, Pintor AVB, et al. Is there a relationship between malocclusion and bullying? A systematic review. *Prog Orthod*. 2020;21(1):1–13.
2. Newman G. Epoxy adhesives for orthodontic attachments: progress report. *Am J Orthod*. 1965;51(12):901–912.
3. Alakttash A, Fawzi M, Bearn D. Adhesive precoated bracket systems and operator coated bracket systems: Is there any difference? A systematic review and meta-analysis. *Angle Orthod*. 2019;89(3):495–504.
4. Eliades T. Orthodontic materials research and applications: part 1. Current status and projected future developments in

bonding and adhesives. *Am J Orthod Dentofacial Orthop*. 2006;130(4):445–451.

5. González-Serrano C, Baena E, Fuentes M, et al. Shear bond strength of a flash-free orthodontic adhesive system after thermal aging procedure. *J Clin Exp Dent*. 2019;11(8):e679.
6. Gwinnett A, Ceen R. Plaque distribution on bonded brackets: a scanning microscope study. *Am J Orthod*. 1979;75(6): 667–677.
7. Maxfield BJ, Hamdan AM, Tüfekçi E, Shroff B, Best AM, Lindauer SJ. Development of white spot lesions during orthodontic treatment: perceptions of patients, parents, orthodontists, and general dentists. *Am J Orthod Dentofacial Orthop*. 2012;141(3):337–344.
8. Almoammar KA, Alkofide E, Alkhathlan A, Alateeq Y, Alqahtani A, Alshaafi MM. Shear bond strength of orthodontic brackets with APC™ flash-free adhesive: An in-vitro study. Article. *J Biometer Tissue Eng*. 2017;7(8):671–677.
9. Marc M-G, Bazert C, Attal J-P. Bond strength of pre-coated flash-free adhesive ceramic brackets. An in vitro comparative study on the second mandibular premolars. *Int Orthod*. 2018;16(3):425–439.
10. Foersch M, Schuster C, Rahimi RK, Wehrbein H, Jacobs C. A new flash-free orthodontic adhesive system: a first clinical and stereomicroscopic study. *Angle Orthod*. 2016;86(2): 260–264.
11. Gruenheid T, Sudit GN, Larson BE. Debonding and adhesive remnant cleanup: an in vitro comparison of bond quality, adhesive remnant cleanup, and orthodontic acceptance of a flash-free product. *Eur J Orthod*. 2015;37(5):497–502.
12. Alakttash AM, Fawzi M, Bearn D. Adhesive precoated bracket systems and operator coated bracket systems: is there any difference? *Angle Orthod*. 2019;89(3):495–504.
13. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71.
14. Shuster JJ. Cochrane handbook for systematic reviews for interventions. *Res Synthes Methods*. 2011;2(2):126–130.
15. Schünemann H, Brozek J, Guyatt G, Oxman A, eds. *GRADE Handbook for Grading Quality of Evidence and Strength of Recommendations*. The GRADE Working Group; 2013.
16. Grünheid T, Larson B. Comparative assessment of bonding time and 1-year bracket survival using flash-free and conventional adhesives for orthodontic bracket bonding: a split-mouth randomized controlled clinical trial. *Am J Orthod Dentofacial Orthop*. 2018;154(5):621–628.
17. Grünheid T, Larson B. A comparative assessment of bracket survival and adhesive removal time using flash-free or conventional adhesive for orthodontic bracket bonding: a split-mouth randomized controlled clinical trial. *Angle Orthod*. 2019;89(2):299–305.
18. Tümoğlu M, Akkurt A. Comparison of clinical bond failure rates and bonding times between two adhesive precoated bracket systems. *Am J Orthod Dentofacial Orthop*. 2019; 155(4):523–528.
19. Almosa NA, Alqasir AM, Aldekhayyil MA, Aljelayel A, Aldosari MA. Enamel demineralization around two different orthodontic bracket adhesive systems: an in vivo study. *Saudi Dent J*. 2019;31(1):99–104.
20. Yetkiner E, Gürlek Ö, Işık A, Lappin D, Buduneli N. Do adhesive flash-free brackets affect bacterial plaque in patients with adequate oral hygiene? A randomised controlled clinical and microbiological assessment. *Oral Health Prev Dent*. 2019;17(6):533–539.
21. Tan A, Çokakoğlu S. Effects of adhesive flash-free brackets on enamel demineralization and periodontal status. *Angle Orthod*. 2020; 90(3):339–346.
22. ElSherifa M, Shamaa M, Montasser M. Enamel around orthodontic brackets coated with flash-free and conventional adhesives. *J Orofacial Orthop*. 2020;81(6):419–426.
23. Lee M, Kanavakis G. Comparison of shear bond strength and bonding time of a novel flash-free bonding system. *Angle Orthod*; 86(2):265–270.