Systematic Review and Meta-Analysis

Medicine

OPEN

Effect of erbium family laser etching on shear bond strength of enamel surfaces

A meta-analysis-PRISMA

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Abstract

Background: Recently, laser etching has appealed to people's attention. It is meaningful to compare the effect of erbium-doped yttrium-aluminum-garnet (Er:YAG) and erbium-chromium; yttrium-scandium-gallium-garnet (Er,Cr:YSSG) laser etching parameters with acid etching on bond strength of enamel surfaces. As far as we know, there still remains no related meta-analysis. To evaluate the efficacy of Er:YAG and Er,Cr:YSSG lasers etching on shear bond strength (SBS) of brackets bonded to enamel. The meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, conducted with literature search.

Methods: Twelve relevant randomized controlled trials (RCTs) were included.

Results: The pooled analysis of SBS showed that there were no significant differences between erbium family lasers and acid etching. In the mass, we noticed they did not achieve statistical significance in the lasers etching and acid etching. However, pooled analysis of 5 studies showed the SBS bonding to enamel was lower in Er,Cr:YAG laser group compared with acid group. As a whole, there were statistical significance between erbium lasers groups and acid etching group in adhesive remnant index (ARI) aspects, which less adhesives remained can reduce damage to enamel. With regard to the rate of teeth with ARI score ≤ 2, the results in Er:YAG laser etching group were obviously higher than acid etching group.

Conclusion: Our data indicated that erbium lasers may be considered bonding of brackets to enamel instead of acid etching bonding to enamel.

Abbreviations: ARI = adhesive remnant index, CI = confidence interval, Er,Cr:YSSG = erbium-chromium; yttrium-scandium-gallium-garnet, Er:YAG = erbium-doped yttrium-aluminum-garnet, OR = odds ratio, RCTs = randomized controlled trials, SBS = shear bond strength, SMD = standardized mean difference.

Keywords: Cr:YSSG, enamel, Er, Er:YAG, meta-analysis, SBS

1. Introduction

Proper bonding strength can not only increase the success rate but also reduce the damage to enamel when they were separated. The ideal bonding in orthodontic practice depends on the procedures used in the process of bonding. Therefore, continuous improvement in procedures of bonding can decrease cost, reduce the failure and minimize damage to enamel in orthodontic practice.[1] The fundamentals of bonding are acid etching of enamel, followed by polymerization of adhesive resin, which is penetrated into the micro porosity created in the etched enamel areas.[2,3] Of the process, it is vital to obtain excellent shear bond strength (SBS) in the successful treatment.

So far, several different procedures for bonding to enamel have been developed, which are extended acid etching,[4,5] micro-abrasion for acid etching,[6,7] air abrading,[8] proposed adhesion promoters[9,10] and self-etching primers.[3,11–13] Among these procedures, acid etching is a conventional method to enamel conditioning.[14–17] However, using acid etching technique, the enamel surface becomes prone to acid attack if it is not completely filled with adhesive.[18,19] Besides, acid etching technique increases the caries susceptibility of the enamel, increases enamel demineralization[1,20,21] and results in dissolution of the enamel subsurface.[22,23]

In the past several decades, many studies have focused on finding alternative methods to acid etching technique which is less damage for teeth structure and has optimum SBS.[14,24–26] Recently,

This study is funded by Jinan Municipal Health and Construction Commission science and technology innovation development plan (2019-2-45) and Jinan science and technology innovation development plan (202019006).

The authors have no conflicts of interest to disclose.

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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How to cite this article: Jiang T, Gong Q, Liu Y, Zhang P-P, Zhang L. Effect of erbium family laser etching on shear bond strength of enamel surfaces: A meta-analysis-PRISMA. Medicine 2022;101:40(e30990).

Received: 1 September 2021 / Received in final form: 1 September 2022 / Accepted: 6 September 2022

http://dx.doi.org/10.1097/MD.0000000000030990

laser etching has appealed to people's attention. Laser etching is not only painless but also no vibration or heat. Among the various laser types used in dentistry, the erbium laser is the most recommended. Erbium family lasers including erbium-doped: yttrium-aluminum-garnet (Er:YAG) and erbium-chromium; yttrium-scandium-gallium-garnet (Er,Cr:YSSG) with two different wavelengths have been widely used for enamel surface conditioning in adhesive procedures.[27–32] The Er:YAG laser emits a wavelength of 2.94 μm and Er,Cr:YSSG laser emits a wavelength of 2.78 μm, which coincide with the maximum absorption in water and hydroxyapatite. For this reason, they can be used as an etching adhesive in the treatment of teeth enamel.

At present, more and more researches of Er:YAG and Er,Cr:YSSG etching on SBS of enamel surfaces is emerging. It is meaningful to compare the effect of Er:YAG and Er,Cr:YSSG laser etching parameters with acid etching on bond strength of enamel surfaces. As far as we know, there still remains no related meta-analysis. Hence, we performed this meta-analysis and analyzed SBS values and adhesive remnant index (ARI) score simultaneously to provide a guideline for clinical dental application safety and efficiency of Er:YAG laser and Er,Cr:YSSG laser treatment to gain an optimal response.

2. Materials and Methods

The present meta-analysis was conducted according to the guidelines of the Cochrane Collaboration[33] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[34] This study did not involve human or animal specimens. Therefore, ethical approval was not necessary.

2.1. Search strategy

The following databases were searched from their earliest records until July 2019: Pubmed, EBSCO, Cochrane library, China National Knowledge Infrastructure, Wanfang databases. To minimize the potential reviewer bias, the study selection process was performed by two reviewers independently in two phases. The databases were searched using the following search strategy: (Er) AND (dentin odds ratio [OR] dentin OR dentinal OR enamel OR "dental enamel" OR "tooth enamel" OR "the enamel") AND ("adhesive strength" OR "bond strength" OR "bonding strength" OR "adhesion strength").

2.2. Inclusion and exclusion criteria

Studies were considered suitable for inclusion in the meta-analysis according to the following criteria (A): A1. The studies were randomized controlled trials (RCT); A2. The studies were limited to human subjects; A3. Studies about SBS of enamel are evaluated; A4. Studies comparing Er:YAG laser or Er,Cr:YSSG laser with phosphoric acid; A5. The range of laser parameters is 1~1.5 W, 100~120 mJ, 10~20 Hz, wavelength 2.94 μm for Er:YAG laser and 1~1.5 W, wavelength 2.78 μm for Er,Cr:YSSG laser.

The exclusion criteria were as following (B): B1. The repeated published literature. B2. Data of SBS values are not reported as mean ± SD. B3. Studies are of insufficient information of laser devices and energy settings. B4. No power description of the parameters. B5. Studies did not contain SBS or ARI on enamel surfaces. B6.The subjects were not human teeth.

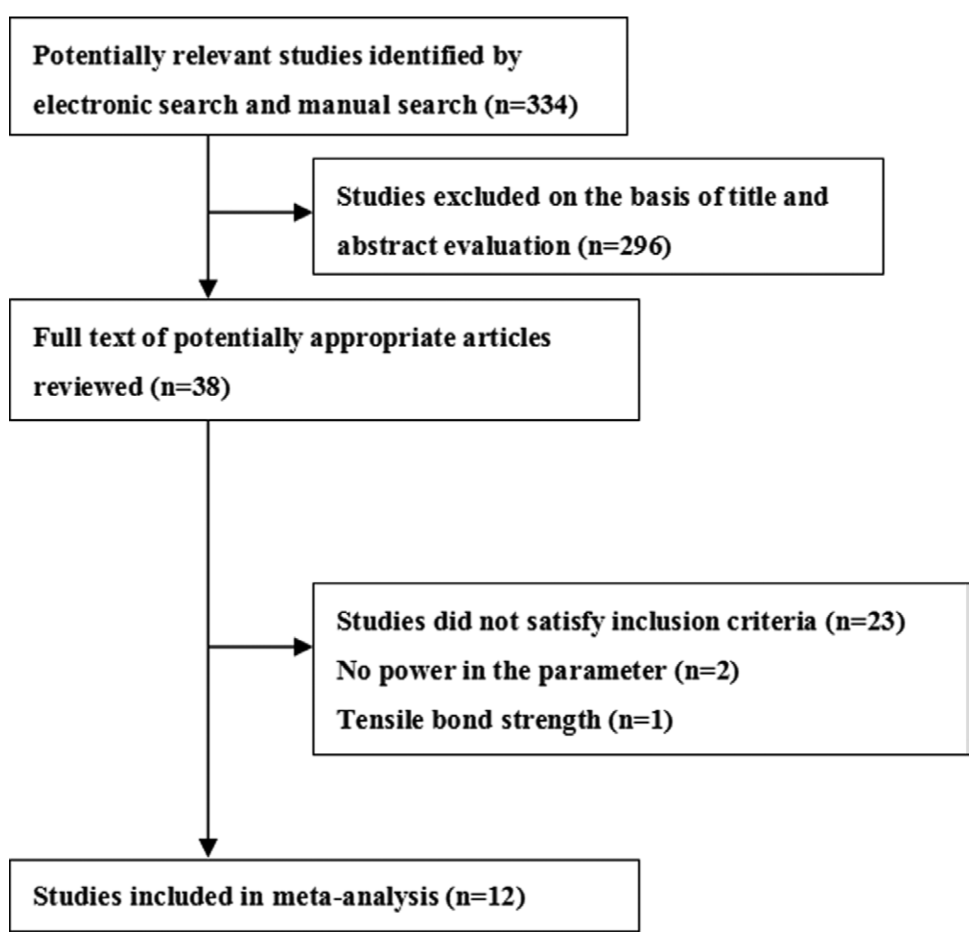

Figure 1. Flowchart of studies included in meta-analysis.

2.3. Data extraction and outcome measurements

Data was collected by two authors respectively. The extracted data included: first author, year of publication, sample size (number of teeth), study design, inclusion criteria, laser type, laser parameters, SBS values, ARI scores, study type.

2.4. Quality assessment

The quality of all selected studies was assessed via the modified Jadad scale.[35] Two evaluators completed this task independently. If there was any disagreement, they would consult with each other to reach an agreement. The modified Jadad scale evaluated the included studies from 4 aspects as follows: random, allocation, blind and drop-out. As a whole, score 1~3 were classified as low-quality literature and 4~7 were classified as high-quality literature.

2.5. Statistical analyses

SBS was tested by a chisel edge, installed on the crosshead of universal testing. ARI scores were determined to evaluate amount of adhesive residue in the site of debonding, which shows that less residue and less damage to enamel. The scoring was based on the criteria established by Artun and Bergland.[36] In the meta-analysis, we calculated the proportion of teeth with ARI score 0~2 which means that part of an adhesive is retained or on the enamel.

SBS bonded to enamel is continuous variables. All the SBS values were calculated as standardized mean difference (SMD) and 95% confidence interval (CI). The rate of ARI data belongs to a binary variable and the index of factor is the odds ratio (OR). When heterogeneity is not obvious ($P > .1$, $I^2 \leq 50\%$), we select a fixed effect model.[37] On the contrary ($P \leq .1$, $I^2 > 50\%$), we select a random effect model.[38] We also carried out a subgroup analysis according to the laser type, Er:YAG laser group and Er,Cr:YSSG laser group. Funnel plots[39] and Egger test[40] were performed to evaluate the publication bias. When the results are $P < .05$, the difference is statistically significant. Both of them used the STATA software version 15.0 for meta-analysis.

3. Results

3.1. Study identification and selection

The flowchart of the screening process for included studies in the meta-analysis is shown in Figure 1. We identified 334 potentially relevant studies through electronic search and manual search. 296 Studies were excluded on the basis of title as well as an abstract evaluation, and 38 studies were obtained by the full text of potentially appropriate articles reviewed. Among the 38 studies, 26 studies are excluded according to parameters and blank control type and finally 12 studies were included in the meta-analysis consisting of a number of teeth (Table 1).

3.2. Quality assessment

In this meta-analysis, eleven studies considered to be high quality with Jadad score ≥4,[35] and 1 study was considered to be low quality with Jadad score <4 so that it (Table 2).

Table 1

Characteristics of the included studies.

First author (yr of publication)	Study design	Number of teeth	Inclusion criteria	Intervention	Laser type	ERL parameters
M.H. Hosseini[23]	RCT	15 human premolars	Human subjects; shear bond strength of enamel; take phosphoric acid as control.	Test: laser Control: 37% phosphoric acid	Er:YAG	Wavelength 2.94 μm, frequency 10 Hz, output power of 1 W, energy of 100 mJ.
Cahide Aglarci[1]	RCT	17 human premolars	Human subjects; shear bond strength of enamel; take phosphoric acid as control.	Test: laser Control: 37% phosphoric acid	Er:YAG	Wavelength 2.94 μm, frequency 10 Hz, output power of 1.2 W, energy of 120 mJ.
R Nalçaci[3]	Not RCT	16 human premolars	Human subjects; shear bond strength of enamel; take phosphoric acid as control.	Test: laser Control: 37% phosphoric acid	Er:YAG	Wavelength 2.94 μm, frequency 10 Hz, output power of 1.2 W, energy of 120 mJ.
Hilal Yilanci[18]	RCT	20 premolar teeth	RCT; human subjects; shear bond strength of enamel; take phosphoric acid as control.	Test: laser Control: 37% phosphoric acid	Er:YAG	Wavelength 2.94 μm, frequency 10 Hz, output power of 1 W, energy of 100 mJ.
Radwa A. Sallam[14]	RCT	20 human premolars	RCT; human subjects; shear bond strength of enamel; take phosphoric acid as control.	Test: laser Control: 37% phosphoric acid	Er:YAG	Wavelength 2.94 μm, frequency 15 Hz, output power of 1.5 W, energy of 100 mJ.
Serkan Sağır[41]	RCT	12 premolars	RCT; human subjects; shear bond strength of enamel; take phosphoric acid as control.	Test: laser Control: 37% phosphoric acid	Er:YAG	Wavelength 2.94 μm, frequency 10 Hz, output power of 1.2 W, energy of 120 mJ. 100 μs. MSP.
Shiva Alavi[15]	RCT	15 non-carious human premolars	RCT; human subjects; shear bond strength of enamel; take phosphoric acid as control.	Test: laser Control: 37% phosphoric acid	Er:YAG	Wavelength 2.94 μm, frequency 20 Hz, energy of 100 mJ.
S. Dilip[44]	RCT	15 premolars	RCT; human subjects; shear bond strength of enamel; take phosphoric acid as control.	Test: laser Control: 37% phosphoric acid	Er,Cr:YSSG	Wavelength 2.78 μm, 1W 10 s.
Emine Göncü Başaran[43]	RCT	10 maxillary central incisors	RCT; human subjects; shear bond strength of enamel; take phosphoric acid as control.	Test: laser Control: 38% phosphoric acid	Er,Cr:YSSG	Wavelength 2.78 μm, 1 W
Törün Özer[42]	RCT	15 molars	RCT; human subjects; shear bond strength of enamel; take phosphoric acid as control.	Test: laser Control: 37% phosphoric acid	Er,Cr:YSSG	Wavelength 2.78 μm, 1.5 W
Serdar Usümez	RCT	20 premolars	RCT; human subjects; shear bond strength of enamel; take phosphoric acid as control.	Test: laser Control: 37% phosphoric acid	Er,Cr:YSSG	Wavelength 2.78 μm, 1 W
Ildem Ustunkol[45]	RCT	15 sound human third molars	RCT; human subjects; shearbond strength of enamel; take phosphoric acid as control.	Test: laser Control: 35% phosphoric acid	Er,Cr:YSSG	Wavelength 2.78 μm, 1.25W, 20Hz, a pulse duration of 140 μs

Er,Cr:YSSG = erbium-chromium; yttrium-scandium-gallium-garnet, Er:YAG = erbium-doped yttrium-aluminum-garnet, RCT = randomized controlled trial.

Table 2

Quality evaluation of the included trials.

Author	Time	Random	Allocation	Blind	Drop-out	Jadad score
M.H. Hosseini	2012	Randomization	Describe	No description	No drop-out	5
Cahide Aglarci	2016	Randomization	No description	No description	No drop-out	4
R Nalçaci	2017	No description	No description	No description	No drop-out	1
Hilal Yilanci	2017	Randomization	No description	No description	No drop-out	5
Radwa A. Sallam	2018	Randomization	Describe	Describe	No drop-out	7
Serkan Sag˘ir	2013	Randomization	Describe	Describe	No drop-out	6
Shiva Alavi	2013	Randomization	No description	Describe	No drop-out	6
S. Dilip	2018	Randomization	No description	No description	No drop-out	5
Emine Göncü Başaran	2009	Randomization	No description	No description	No drop-out	5
Törün Özer	2006	Randomization	No description	No description	No drop-out	5
Serdar Usümez	2002	Randomization	No description	No description	No drop-out	5
Ildem Ustunkol	2003	Randomization	Describe	No description	No drop-out	6

3.3. Meta-analysis of SBS

Erbium family lasers showed similar SBS to acid etching (SMD = –0.52, 95% CI range: –1.11–0.06, $P > .05$) via based on 12 studies all of the above (Fig. 2). For the pooled analysis of SBS of 7 studies, there was no significant difference between Er:YAG laser group and acid etching group on enamel (SMD = 0.10, 95% CI range: –0.46–0.67, $P > .05$).[1,3,14,15,18,23,41] For Er,Cr:YAG laser, pooled analysis of 5 studies[21,42–45] showed that the SBS bonding to enamel was lower in Er,Cr:YAG laser group compared with acid group(SMD = –1.48, 95% CI range: –2.44 to –0.52, $P < .05$). There were some evidence (I^2 = 86.0%) of heterogeneity. Random effect model was used for the meta-analysis of SBS values.

3.4. Meta-analysis of ARI scores

Overall, the rate of teeth with ARI score ≤2 in the erbium family lasers was higher than that in the acid etching group (OR = 6.20, 95% CI range: 2.62–14.67, $P < .05$, 93.14% vs 68.63%) (Fig. 3), which indicated that less adhesives remain on the enamel surfaces in the laser irradiated groups and reduce enamel loss during cleaning after the debonding procedure. ARI scores are used to evaluate residual adhesive conditions on

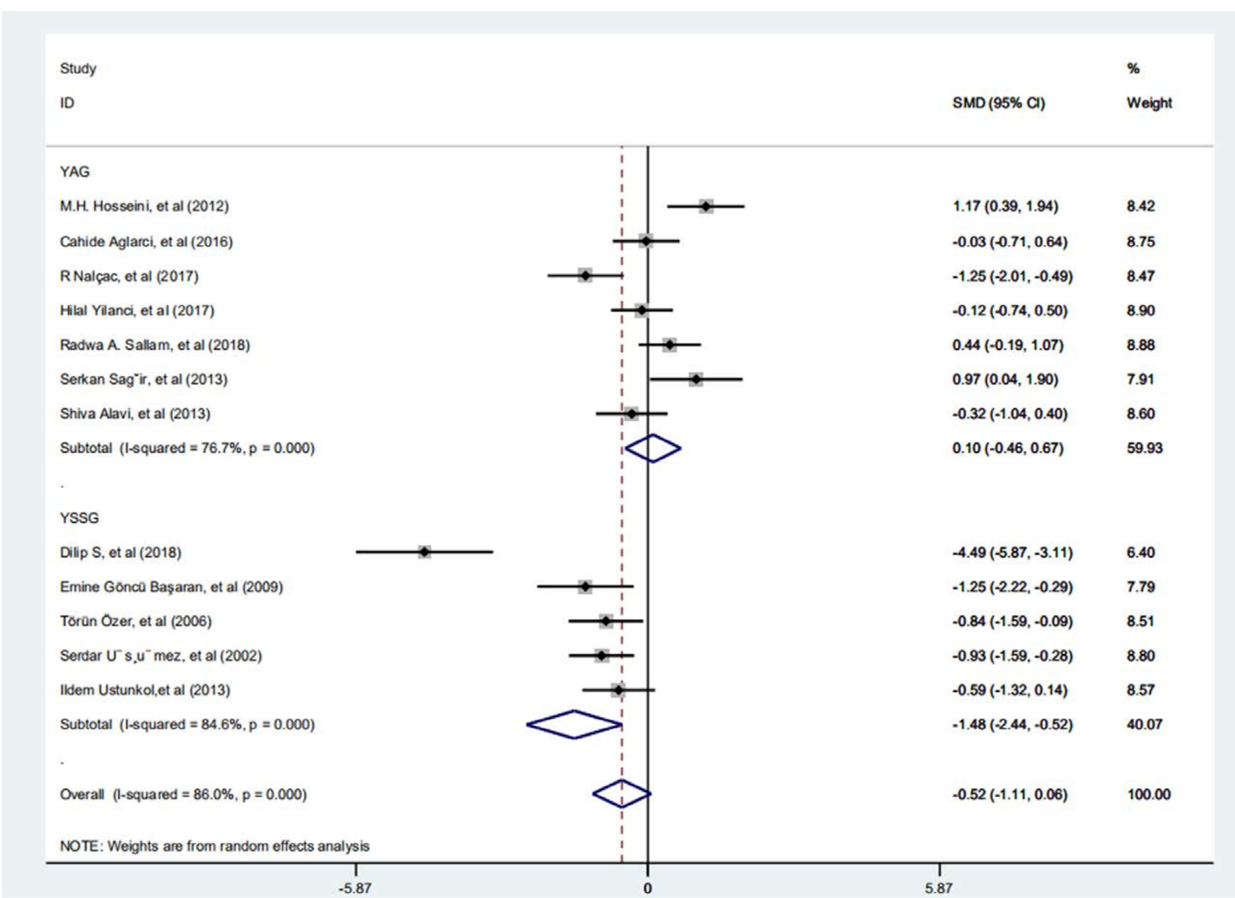

Figure 2. Forest plot for SBS for Er:YAG/Er,Cr:YSSG laser compared to acid etching. Er,Cr:YSSG = erbium-chromium; yttrium-scandium-gallium-garnet, Er:YAG = erbium-doped yttrium-aluminum-garnet, SBS = shear bond strength.

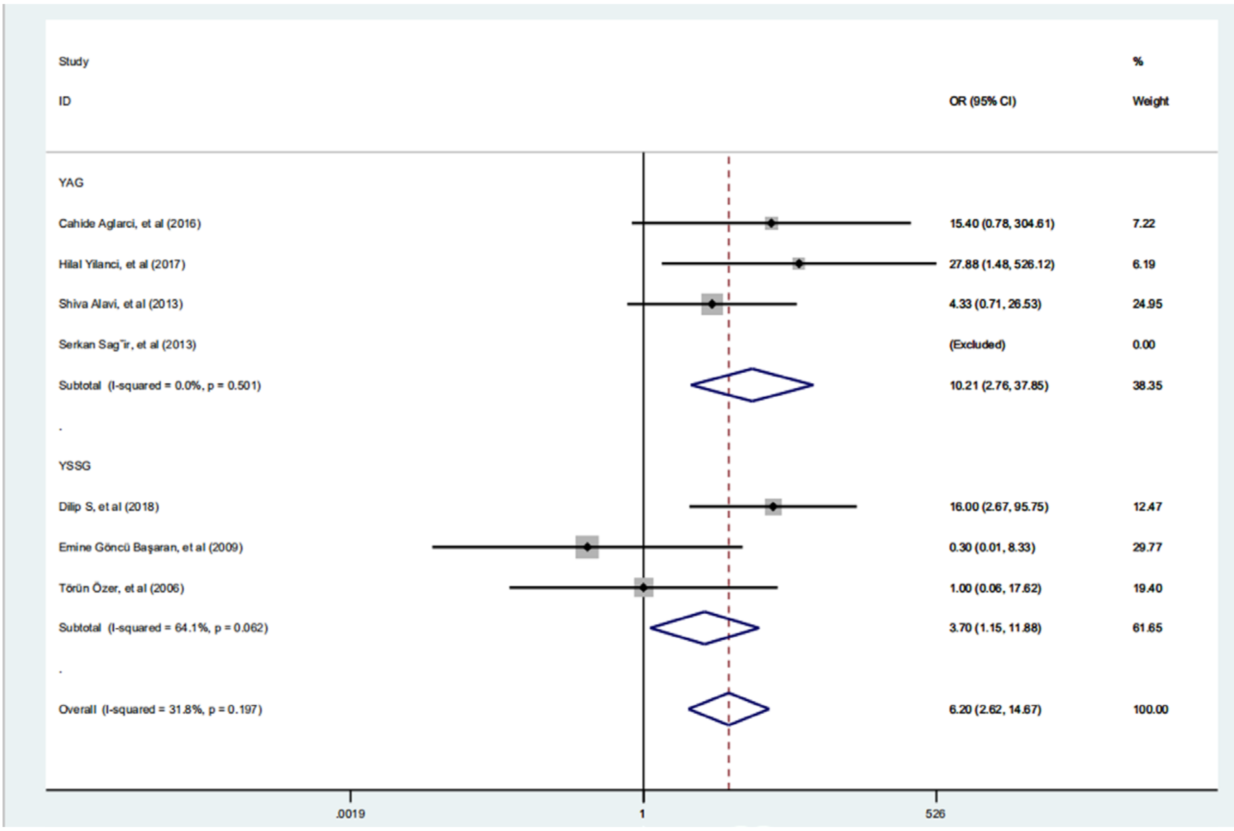

Figure 3. Forest plot for ARI for Er:YAG/Er,Cr:YSSG laser compared to acid etching. ARI = adhesive remnant index, Er,Cr:YSSG = erbium-chromium; yttrium-scandium-gallium-garnet, Er:YAG = erbium-doped yttrium-aluminum-garnet.

enamel surfaces after laser treatment. It is found that the rate of teeth with ARI score ≤2 in Er:YAG laser etching group was obviously higher than phosphoric acid etching group[1,15,18,41] of (OR = 10.21, 95% CI range: 2.76–37.85, $P < .05$, 96.77% vs 69.35%), showed that Er:YAG laser was better than acid etching for cleaning teeth after debonding. Similarly, the rate of teeth with ARI score ≤2 in Er,Cr:YSSG laser was also higher than in the acid group on enamel etching (OR = 3.70, 95% CI range: 1.15–11.88, $P < .05$, 87.5% vs 67.5%) based on 3 studies,[42–44] indicated that less adhesive left on the enamel surface. There were no significant heterogeneity ($I^2 = 31.8\%$), we choose a fixed effect model to calculate OR and 95% CI.

3.5. Publication bias

The results of Egger's linear regression tests (SBS: $P = .087$; ARI: $P = .463$) showed that there was no publication bias among the included studies.

4. Discussion

Up to now, there are a good number of studies assessing the erbium lasers etching on enamel by SBS values and ARI score index. However, the data have not been systematically assessed. To the best of our knowledge, this meta-analysis is the first systematic evaluation of the efficiency of Er:YAG and Er,Cr:YSSG lasers for which used SBS of orthodontic brackets bonded to enamel surfaces.

In this meta-analysis, we researched that the SBS of enamel surfaces did not report a significant difference between Er:YAG laser and acid group, suggesting that there was no evidence of the superior effectiveness of Er:YAG laser via comparing to acid. Compared to the acid group, SBS bonding to enamel in Er,Cr:YSSG laser group was decreased. Overall, the SBS of erbium lasers treatment were similar to acid etching. Besides, there were obvious differences about ARI score of enamel between erbium lasers and acid group. There were higher rate of teeth with ARI score ≤2 in erbium lasers irradiated group than in acid etching group, showed that less adhesive remains on the enamel and may save some chair time for cleaning teeth after debonding.

As we mentioned above, erbium laser etching on enamel had too many parameters variations. At present, no definitive conclusion could be drawn with regard to the clinical efficacy of erbium lasers in the application on SBS bonding to enamel. The lack of sample size also prevented us from obtaining unbiased and reliable results. Further RCTs are needed to confirm the most appropriate parameters etching with enamel. In addition, although erbium lasers can overcome the disadvantages of acid etching, lasers irradiated have a more expensive treatment than traditional ones.[46] This is an important issue to resolve.

Therefore, taking the cost and effectiveness into consideration, several well-designed trials with high methodological quality should be analyzed for SBS and ARI to obtain more effective and safe treatment methods. Anyway, this review will provide a scientific evidence for Er:YAG/Er,Cr:YSSG laser efficacy and safety in treatment of enamel bonding technology in the long term.

In this meta-analysis, we suggested that Er:YAG laser and Er,Cr:YSSG laser are effective when used to etch on the SBS bonded to enamel. Compared with acid technology, there was better about the rate of teeth with ARI score ≤2 in erbium lasers treatment after debonding. Nevertheless, there is still a long way to go for that Er:YAG and Er,Cr:YSSG lasers are applied to orthodontics practice widely instead of acid etching.

Author contributions

Data curation: Qi Gong.
Methodology: Ying Liu.
Project administration: Li Zhang.
Resources: Pan-Pan Zhang.
Supervision: Li Zhang.
Visualization: Li Zhang.
Writing – original draft: Tao Jiang.
Writing – review & editing: Tao Jiang.

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