



Er:YAG laser application in caries removal and cavity preparation in children: a meta-analysis

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Received: 6 December 2017 / Accepted: 5 July 2018 / Published online: 12 July 2018
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Abstract

The aim of this meta-analysis was to systematically evaluate the applications of Er:YAG lasers for the removal of caries and cavity preparation in children. The meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and was conducted with data extracted from seven relevant randomized controlled trials (RCTs) published from 1997 to July 2017. The data heterogeneity of each study was assessed by a Q test. We used the heterogeneity results to calculate the standard mean difference (SMD) or relative risk (RR) and 95% confidence interval (95% CI) using STATA version 10.0. The publication bias was evaluated using Begger's test. There were seven randomized controlled trials included in this study. The analysis results indicate that compared to the conventional mechanical method, more time was needed for Er:YAG laser treatment (SMD 1.945, 95%CI 0.942 to 2.948). However, the pain reported by patients was reduced with Er:YAG laser treatment (SMD -1.013, 95%CI -1.892 to -0.196). There were no significant differences between the groups in the complete retention rate (RR 1.021, 95%CI 0.963 to 1.114), the marginal discoloration (RR 1.638, 95% CI 0.240 to 11.986) and the marginal adaptation (RR 1.480, 95%CI 0.257 to 8.515). In conclusion, our data indicate that the time required for Er:YAG laser treatment was longer than that for the conventional mechanical method, but there was less pain associated with the Er:YAG laser treatment. There were no significant differences in the complete retention rate, marginal discoloration, and marginal adaptation between the two groups.

Keywords Meta-analysis · Er:YAG laser · Conventional mechanical method · Dental caries · Children

Introduction

Children may find frightening to visit the dentist and feel pain when caries treated with a conventional mechanical handpiece. The instruments can create noise and vibrations, which lead to discomfort and dental fear [1]. It has been shown that the incidence of dental fear in children approaches 70% [2]. Dental fear includes anxiety, crying, escape, and

even refusal of dental treatment, which may result in treatment failure. The use of an Er:YAG laser to remove caries and prepare the cavity may be an effective alternative to prevent children's dental fear and avoid the associated adverse effects.

The Er:YAG laser (erbium:yttrium aluminum garnet) was introduced into dentistry for the ablation of dental hard tissue [3] and was approved for caries removal and cavity preparation in 1997 by the US Food and Drug Administration [4]. The Er:YAG laser is a solid-state laser with a wavelength of 2940 nm, which coincides with the peak of water absorption. The laser can selectively cut infected enamel and dentin with precision and efficiency. Furthermore, the laser reduces the unpleasant sound and does not produce vibration or pressure during the caries removal process or cavity preparation [5, 6]; as a result, laser treatment is preferred by most patients, especially children [7, 8]. Previous studies have shown the Er:YAG laser has been widely used in pediatric dentistry and yielded promising results [9, 10]; there are also studies indicating the opposite results [11]. Thus, the effectiveness of the Er:YAG laser used to remove caries and prepare cavity is unclear.

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This meta-analysis systematically evaluated the effectiveness of the Er:YAG laser for the removal of dental caries and cavity preparation in children and will guide the clinical dental application of Er:YAG lasers.

Materials and methods

Focused question

This meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [12]. The question addressed in accordance with the Participants, Interventions, Control, Outcome, Study design (PICOS) principle was—What is the clinical efficacy of the Er:YAG laser for caries removal and cavity preparation in children compared to that of the conventional mechanical method?

- (P) Participants: Child patients diagnosed with dental decay (included primary teeth or permanent teeth)
- (I) Interventions: The use of Er:YAG laser for caries removal and cavity preparation
- (C) Control interventions: The use of traditional mechanical method for caries removal and cavity preparation
- (O) Outcomes: Operation time, reported pain, complete restoration retention, marginal discoloration, marginal adaptation, and secondary caries
- (S) Study design: Randomized Controlled Trial (RCT)

Search strategy

The following databases were searched (from 1997 to July 2017): PubMed, MEDLINE, Cochrane library, OVID Technologies, Science Direct, China National Knowledge Infrastructure (CNKI), China Biology Medicine (CBM), VIP, Wan fang.

The complete search strategy was performed using the following Boolean phrases:

Er:YAG laser AND (caries OR dental caries OR teeth decay) AND cavity preparation AND (children OR childhood OR primary teeth OR deciduous teeth).

Inclusion criteria

There were two reviewers who identified and selected potentially relevant studies independently by reading titles and abstracts. The reviewers selected articles based on the following study inclusion criteria: (1) investigates the clinical effectiveness of the Er:YAG laser compared to conventional mechanical method, (2) is a randomized controlled trial, and (3) drop-out rate < 20%.

Exclusion criteria

The full-text publications of all possible eligible studies were reviewed based on the following exclusion criteria: (1) repeated published literature; (2) a lecture, conference report, dissertation or review; and (3) there was no sufficient data to calculate standard mean difference (*SMD*) or relative risk (*RR*) and 95% confidence interval (95%*CI*). All disagreements were solved through discussion or with the assistance of a third professor.

Data extraction

The following information was extracted from each included study: the first author, year of publication, study design, number of patients, age of patients, type of teeth, and control group.

Assessment of quality of all included research

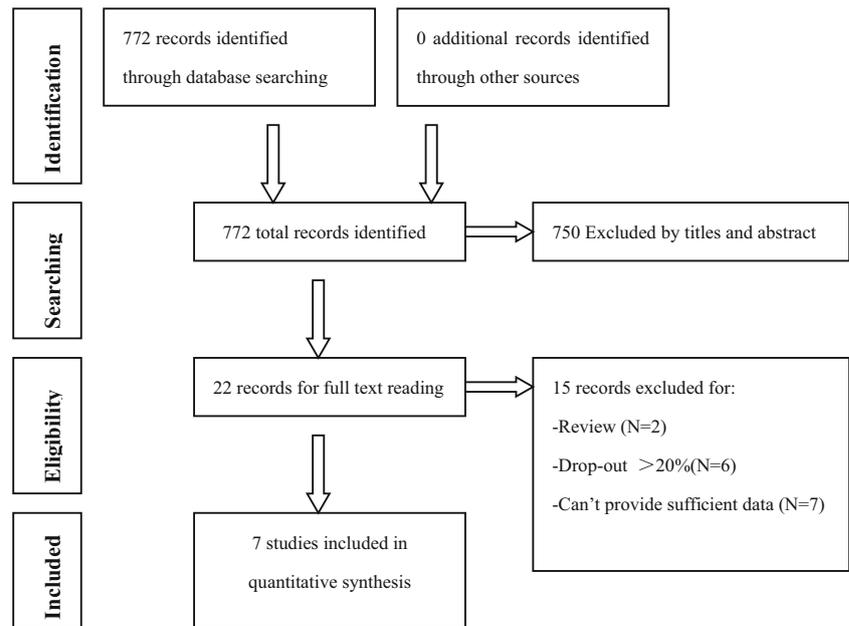
The reviewers assessed the quality of all the included research using the modified Jadad scale [13]. In the modified Jadad scale, the maximum quality score is 7 points, and a quality score ≥ 4 is considered high quality for randomized controlled trials. A score < 4 is considered to be low quality.

Statistical analysis

This study used STATA version 10.0 software (STATA Corporation, College Station, TX, USA) to conduct the meta-analysis. A *Q* test was conducted to assess the heterogeneity of each study. The heterogeneity results were used to determine if the Mantel-Haenszel fixed effects model ($P \geq 0.1$) or the DerSimonian Laird random effects model ($P < 0.1$) [14, 15] was used for the calculation of pooled standard mean difference (*SMD*) or relative risk (*RR*) and 95% confidence interval (95%*CI*). Begger's test was used to assess publication bias with a $P < 0.1$ indicating statistical significance. All *P* values were two-sided. The meta-analysis was performed with the longest follow-up period of each index.

Results

There were 772 potential studies initially identified. The inclusion criteria were used to exclude 750 studies because they were repeated, not *RCT* or not clinical studies. The 22 remaining studies were retrieved in full-text for more detailed information. After reading the full-text, an additional 15 studies were excluded because there was insufficient data, or the drop-out rate was > 20%. Therefore, only seven research articles were included in the final meta-analysis [16–22]. The flow diagram of the study selection process is shown in Fig. 1. The characteristics of all eligible research studies extracted are also shown (Table 1).

Fig. 1 Flow chart of the process of study selection

Quality assessment

The quality of all included research studies was assessed using the modified Jadad scale [13]. In this meta-analysis, four studies scored >4 and were considered to be high quality, and three studies scored <4 and were considered low quality (Table 2).

Meta-analysis results

The procedure time was assessed in five *RCTs*, and the *Q* test analysis showed heterogeneity among these studies ($\chi^2 = 70.50$, $P < 0.001$, $I^2 = 94.3\%$). The meta-analysis result using a random effects model indicated that the time required by the Er:YAG laser was longer (*SMD* 1.945, 95%*CI* 0.942 to 2.948, $P < 0.001$) than that of the conventional mechanical method (Fig. 2).

The pain score was assessed in five *RCTs*, and the *Q* test showed that there was heterogeneity ($\chi^2 = 45.02$, $P < 0.001$, $I^2 = 93.3\%$). The meta-analysis result of our random effects

model suggested the pain caused by the Er:YAG laser was less (*SMD* -1.013 , 95%*CI* -1.829 to -0.791 , $P < 0.001$) than the pain reported from the conventional mechanical method (Fig. 3).

The complete retention result was assessed in four *RCTs*, and the *Q* test showed there was no heterogeneity ($\chi^2 = 1.410$, $P = 0.495$, $I^2 = 41.8\%$). The meta-analysis result of a fixed effects model showed that there were no significant differences (*RR* = 1.011, 95%*CI* 0.937 to 1.091, $P = 0.783$) for the complete retention of restoration using the Er:YAG laser and conventional mechanical method (Fig. 4).

The marginal discoloration result was assessed in three *RCTs*, and a *Q* test showed there was no heterogeneity ($\chi^2 = 0.280$, $P = 0.594$, $I^2 = 0.00\%$). The meta-analysis result of the fixed effects model showed that there were no significant differences (*RR* 1.638, 95%*CI* 0.224 to 11.986, $P = 0.627$) in the marginal discoloration of restoration for the Er:YAG laser and conventional mechanical methods (Fig. 5).

Table 1 Main characteristics of all studies included in the meta-analysis

| First author | Publication year | Age | Study design | n | Type of tooth | Case | Control |
|--------------|------------------|---------------|----------------|-------|----------------------------------|--------|---------|
| Liu JF | 2006 | 3.3–12 | Split-mouth | 40 | Primary teeth | Er:YAG | Bur |
| Valerio RA | 2016 | 6–10 | Split-mouth | 29 | Primary teeth | Er:YAG | Bur |
| GV G | 2015 | 6–16 | Split-mouth | 58 | Permanent teeth | Er:YAG | Bur |
| Lv X | 2015 | 4–14 | Split-mouth | 31/30 | Primary (26%) Permanent (74%) | Er:YAG | Bur |
| Xu Y | 2015 | 7.3 \pm 2.1 | Practice-based | 75 | Primary teeth | Er:YAG | Bur |
| Wei Y | 2016 | 4.9–10.4 | Practice-based | 41 | Primary teeth | Er:YAG | Bur |
| Zhang S | 2013 | 3–15 | Split-mouth | 53 | Primary and Permanent | Er:YAG | Bur |

Table 2 Quality evaluation of the included trials

| Author | Time | Random | Allocation | Blind | Drop-out | Jadad score |
|------------|------|----------------|----------------|----------------|-------------|-------------|
| Liu JF | 2006 | Randomization | Describe | No description | No drop-out | 6 |
| Valerio RA | 2016 | Randomization | Describe | Describe | No drop-out | 7 |
| GV G | 2015 | No description | No description | Describe | No drop-out | 3 |
| Lv X | 2015 | Randomization | No description | Describe | No drop-out | 5 |
| Xu Y | 2015 | No description | No description | Describe | No mention | 2 |
| Wei Y | 2016 | No description | No description | Describe | No drop-out | 3 |
| Zhang S | 2013 | Randomization | Describe | Describe | No drop-out | 6 |

The marginal adaptation result was assessed in three RCTs, and the Q test showed there was no heterogeneity ($x^2 = 0.160$, $P = 0.692$, $I^2 = 0.00\%$). The meta-analysis result of the fixed effects model showed that there were no significant differences ($RR = 1.480$, $95\%CI$ 0.257 to 8.515, $P = 0.661$) in the marginal adaptation of restoration for the Er:YAG laser and conventional mechanical method (Fig. 6).

There were insufficient data to perform a meta-analysis of secondary caries results.

Discussion

There are numerous studies evaluating the use of the Er:YAG laser for caries removal and cavity preparation in pediatric dentistry up to now. The Er:YAG laser is known as an alternative to the traditional handpiece in caries treatment. However, the data have not been systematically evaluated. This meta-analysis is the first systematic evaluation of the effectiveness of the Er:YAG laser for caries removal and cavity preparation in children.

In the included seven RCTs, four of the studies have been performed with randomization, for others this is not

known. For one it is not known if there is a blinding. This may influence the objectivity and persuasion of the conclusions. Therefore, we insist on the necessity of continuing exploration in this field with the support of subsequent RCTs.

The meta-analysis refers to a statistical study that includes a large collection of results from individual researches for the purpose of integrating the findings [23]; randomized controlled trials are considered the highest-level evidence. In this meta-analysis, there were four high quality studies among the seven fully evaluated studies. Studies were designed using a split-mouth comparison, and all procedures were performed by a single physician to reduce the error variance and improve the statistical power. The results of the Begger's test indicated there was no publication bias in any of the research included in this meta-analysis. Furthermore, we selected the appropriate analysis model based on previous Q test heterogeneity assessment results. Therefore, this meta-analysis is reliable.

The results of this meta-analysis showed that the average time used by the Er:YAG laser was longer than that of the conventional mechanical method. Aoki et al. [24]

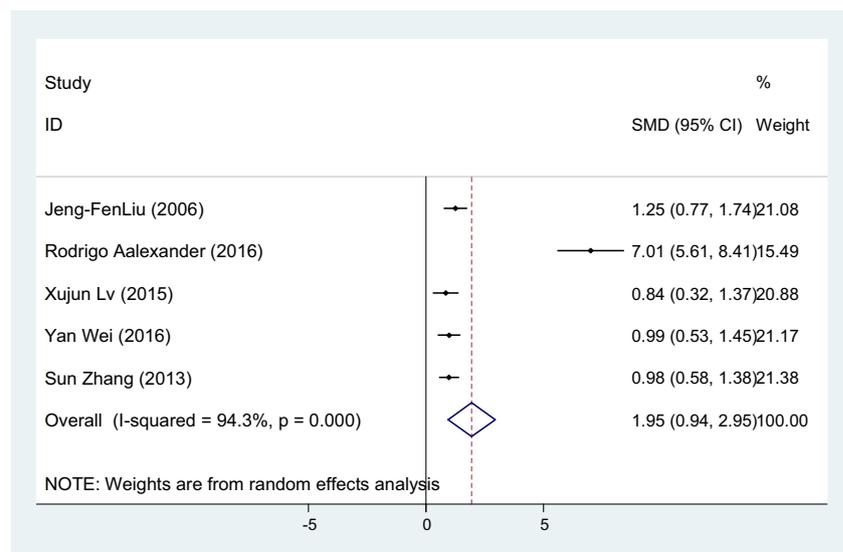
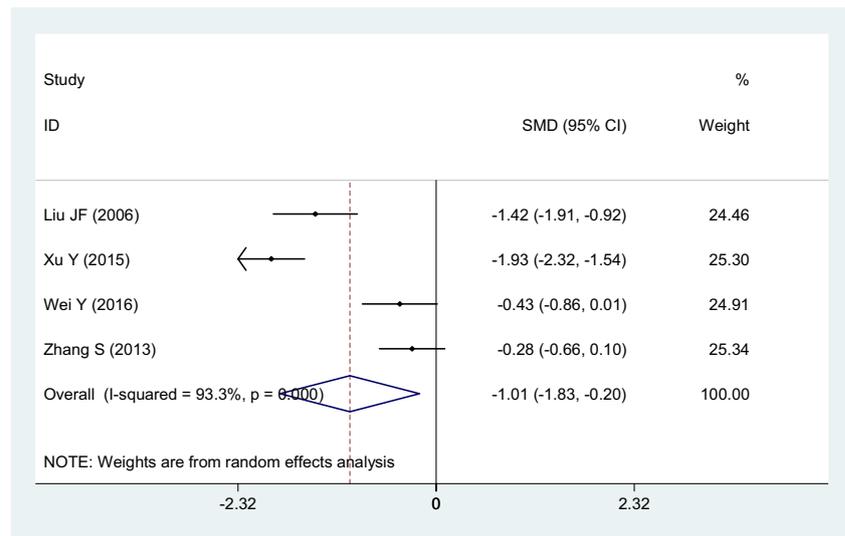
Fig. 2 Forest plots of comparison of Er:YAG laser versus control group about working time

Fig. 3 Forest plots of comparison of Er:YAG laser versus control group about pain



found that using the Er:YAG laser required threefold longer time than that of the traditional mechanical treatment to prepare cavities; Celiberti et al. reported that the laser needed almost 2.5 times longer time than that of a traditional handpiece to prepare cavities of similar size [25]. Zhang S et al. found that the time taken to remove carious enamel with the Er:YAG laser was slightly longer than that of a conventional handpiece; however, the time to cut dentin with the Er:YAG laser was similar to that with the traditional mechanical treatment [22], which was in accordance with Shigetani et al. [26]. It was difficult to accurately determine how much additional time was needed for the Er:YAG laser relative to the conventional handpiece. The time issue was prone to subjectivity and is very dependent on cavity size and operator's experience. Moreover, studies have shown that although the Er:YAG laser working time was longer, most children

preferred the Er:YAG laser due to the reduced pain and increased overall comfort [27, 28].

Our results indicate that the pain caused by the Er:YAG laser was reduced compared to that of the conventional mechanical method. Children have lower levels of concentration and self-control compared to adults, and it is difficult for them to cooperate with clinical practice. Additionally, the conventional burs will produce noise and vibration during dental treatments. These differences may result in children's dental fear [27]. Thus, the Er:YAG laser has advantages during treatment in pediatric dentistry.

This meta-analysis evaluated the complete retention rate, marginal discoloration and marginal adaptation of restoration. The results indicated there were no significant differences between the two groups. Previous in vitro studies [11, 29–31] showed the Er:YAG laser irradiation decreased the risk of thermally induced pulp injury in cases with exposed dental

Fig. 4 Forest plots of comparison of Er:YAG laser versus control group about complete retention

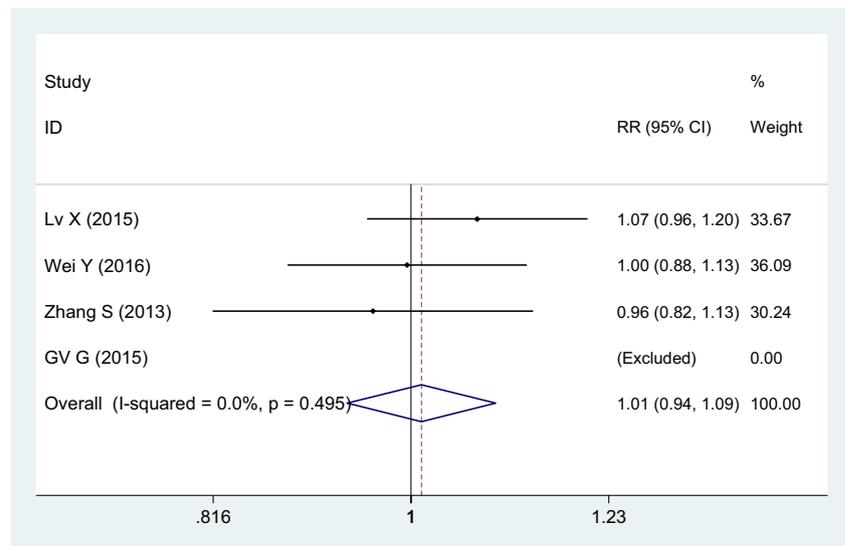
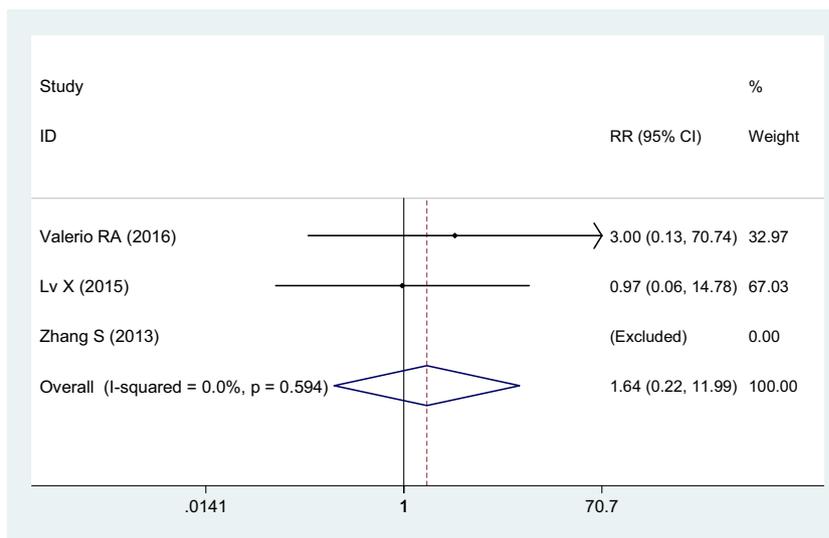


Fig. 5 Forest plots of comparison of Er:YAG laser versus control group about marginal discoloration



tubules and microcracks or rough and scaly surfaces. The laser can also increase tooth acid resistance. These results could have remarkable clinical implications for the application of the Er:YAG laser.

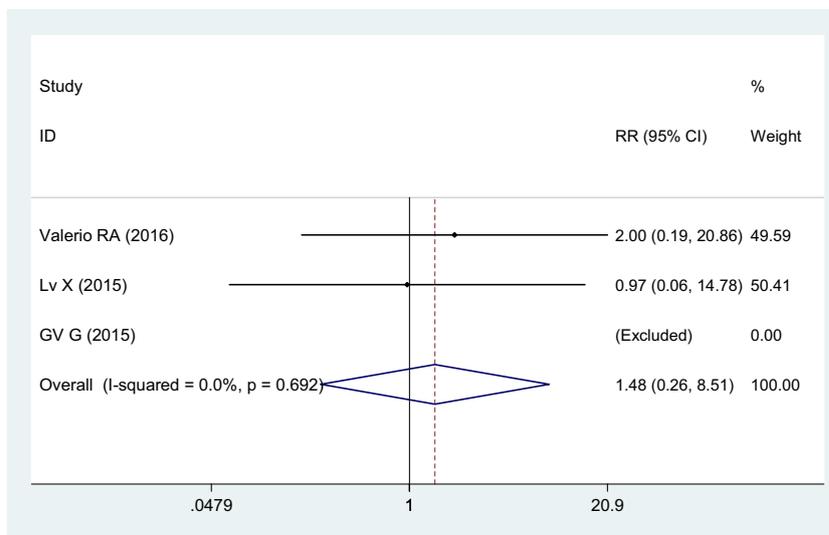
The meta-analysis of secondary caries was not performed due to insufficient data. However, there were studies related to secondary caries. Valerio et al. and Zhegova et al. demonstrated that there were no significant differences in secondary caries between the Er:YAG laser and bur group [17, 18]. Additionally, in vitro studies examining differences of microleakage between the Er:YAG laser and the bur method showed no statistically significant differences [31–34]. Conversely, Tuna et al. [35] reported that Er:YAG laser-prepared cavities showed a higher degree of leakage than those of conventionally bur-prepared cavities. The findings were consistent with several prior studies [36–38]. Although the examination of secondary caries

was a main criterion evaluated in the application of Er:YAG laser, our findings indicate that additional studies focused on secondary caries are needed.

Limitations of the meta-analysis

There are several limitations to this study. First, (1) there were a limited number of studies that meet the inclusion criteria, which is a substantial limitation of the meta-analysis. (2) The description of randomized design is simple in several studies, and this can affect the quality. (3) There was high loss to follow-up. (4) There were a small number of studies with data on secondary caries. These findings suggest it is necessary to improve the quantity and quality of related randomized controlled trials to better guide clinical practice.

Fig. 6 Forest plots of comparison of Er:YAG laser versus control group about marginal adaptation



Conclusions

- (1) The operation time of the Er:YAG laser treatment is longer than the conventional mechanical method;
- (2) The pain produced by the Er:YAG laser is reduced compared to the conventional mechanical method;
- (3) There are no statistical differences in complete restoration retention, marginal discoloration and marginal adaptation between the Er:YAG laser and conventional mechanical method.

Compliance with ethical standards

The study was approved by the Research Ethics Committee of Stomatological Hospital, Hebei Medical University. This was a meta-analysis so an informed consent was not required. This article does not contain any studies with human participants or animals.

Conflict of interest The authors declare that they have no conflict of interest.

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