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Antimicrobial Efficacy of Sodium Hypochlorite and Er, Cr: YSGG Laser against E Faecalis Biofilm - A Systematic Review

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Abstract

Background*:** The complexity of the root canal system makes it difficult to completely disinfect is the leading cause for endodontic retreatment. Sodium hypochlorite (NaOCl) is the traditionally used irrigation solution and has improved its efficacy with various adjuncts. The use of lasers in disinfecting the canal system has come into prominence in recent years. ***Aim: To assess the efficacy of sodium hypochlorite and Er, Cr: YSGG laser against *E faecalis* biofilm. ***Methodology*:** A systematic search was conducted using a search strategy in PubMed and Google scholar for studies published between 1st January 2011 and 21st March 2022. Hand searching of relevant articles in Institutional library was also performed. Comparative in vitro studies in English language or articles in other languages which had a possibility of translation into English comparing sodium hypochlorite and Er, Cr: YSGG laser for irrigation against *E faecalis* biofilm were included in the review whereas, studies comparing efficacy against biofilm other than *E faecalis*, comparison with other laser activated intracanal irrigation, data reported through letter to editors, short communications and conference proceedings were excluded from the review. ***Results*:** A preliminary search yielded a total of 67 studies of which seven articles giving 11 estimates were included for qualitative synthesis. Data on colony forming units for both the groups (sodium hypochlorite and Er, Cr: YSGG laser) was extracted. Overall, four studies presented significant difference in the effectiveness of sodium hypochlorite and Er, Cr: YSGG laser whereas three studies presented with no difference among the two groups. ***Conclusion*:** Irrigation of root canal by sodium hypochlorite and Er, Cr: YSGG laser activation both prove to be effective in reducing the *E faecalis* colony forming units. However, it is difficult to provide a conclusive statement on the superiority of Er, Cr: YSGG laser activated irrigation over sodium hypochlorite solution as half of the studies gave contrasting results. Future studies with larger sample size on complex anatomical root structure are recommended.

Keywords: Biofilm, Er, Cr: YSGG laser, E faecalis, Sodium hypochlorite.

INTRODUCTION

The success of root canal therapy depends on complete removal of necrotic pulpal tissue and eradication of bacterial and microbial toxins from the root canal. This is accomplished by a series of procedures that involve the debridement of the pulpal tissue by mechanical means, use of irrigating solution in between instrumentation, disinfection of the root canals by antibacterial solutions followed by dressing of root canal by intracanal medicament between the appointments [1]. Though all these steps contribute to making the canal free from bacteria, the one which contributes most to bacterial reduction ischemomechanical debridement. In case of single or multi-rooted teeth with a straight canal, the elimination of bacteria proves adequate which may be difficult with curved or complex structured canals [2].

Failure of root canal treatment can be due to reinfection of the canal with bacteria, persistence of bacteria in the canals or its regrowth in the canal system [3]. Accessory or lateral canals do not permit instrumentation due to their anatomy and inaccessibility. In such cases, the only way to rely on complete debridement is through chemical disinfection. The irrigating solution flushes out debris and dissolves inorganic and organic tissues. Irrigants used for disinfection are NaOCl, chlorhexidine, MTAD, phototherapic agents, apple vinegar, Propolis, castor oil detergent and essential oil [4, 5].

NaOCl remains the most extensively used among the irrigants.ts antibacterial propertydissolves organic tissues present within the root canal. It is available is concentrations ranging from 0.5% to 6%. Higher concentrations increasethe antibacterial efficacy, especially against Enterococcus faecalis (*E faecalis*) [6]. It has a disadvantage in that at higher concentration it fails to distinguish between necrotic pulpal tissue and healthy periodontium. Thus, if the solution extrudes through the apical foramen into the periapical area, it dissolves surrounding tissues [7]. Additionally, it reduces mechanical resistance of intracanal dentin due to deterioration of proteoglycans and collagen [8].

E faecalis has an ability to adapt to harsh environments which ensures that it is present even in the canals devoid of nutrients and the ones that are inaccessible to instrumentation. Unlike other bacteria, *E faecalis* can invade and colonize dentinal tubules, thereby resisting efforts of antimicrobial agents [9, 10].

Lasers have been increasingly employed as an adjunct in irrigating root canals. Literature reports the use of different lasers like CO_2, Nd: YAG, Er: YAG, Er, Cr: YSGG which remove smear layer along with intracanal debris [11]. Lasers have proved to be effective in disinfecting areas of the canals that cannot be reached by irrigating solutions alone. With variations in wavelength, the lasers provide different levels of efficacy against the intracanal bacteria. Erbium lasers have limited harmful effect on the dental tissues in spite of its heat generation while providing a satisfactory outcome [11]. Combination of NaOCl of appropriate concentration with activation using lasers of suitable wavelengths has been used in many studies without conclusive evidence on the superiority of one over the other. In light of this, the present systematic review was conducted with an aim to answer the focused question 'What is the efficacy of sodium hypochlorite intracanal irrigation and Er, Cr: YSGG laser activation against *E faecalis*?'

METHODOLOGY

Literature Search

A systematic search was conducted in PubMed database and Google scholar search engine. Search terms relevant to the topics were selected with the help of MeSH library (Table 1). Free text terms were also used and appropriate search strategy was framed using Boolean operators to obtain relevant articles through the database (Table 2). Filters were set for article type at clinical trial, clinical study, randomized controlled trials and human species with best match option. Additional to the search strategy, the articles were also selected by searching cross references of the selected studies, hand searching of relevant articles from speciality journals available in the institutional library and through grey literature.

Table no 1: Search terms (MeSH and free text terms) used for forming a search strategy

Primary keyword	Secondary keywords
Root canal therapy(P)	Root canal, Extracted teeth
Er Cr: YSGG laser (I)	erbium, chromium-doped yttrium, scandium, gallium and garnet, Dry irradiation, Laser activated irrigation
Sodium hypochlorite (C)	Hypochlorite, Sodium, Sodium Hypochlorite (Solution), Clorox Antiformin
Antimicrobial efficacy (O)	Outcome, Treatment, Treatment Efficacy, Antimicrobial, Enterococcus faecalis, Gram positive, E fecalis biofilm

Table no 2: Search strategy used for retrievingarticles

Sr. No.	Search strategy	Articles in hits	Articles selected
1	enterococcus faecalis biofilm AND Er Cr YSGG laser AND Sodium hypochlorite AND antimicrobial efficacy	3	3
2	E-faecalis AND Er, Cr: YSGG laser AND sodium hypochlorite AND antimicrobial efficacy	5	5
3	Er, Cr: YSGG laser AND sodium hypochlorite AND irrigation AND antimicrobial efficacy AND root canal	13	11
4	Er, Cr: YSGG laser irradiation AND sodium hypochlorite AND root canal	7	6
5	Er, Cr: YSGG laser AND NaOCl [tiab] AND Enterococcus faecalis[tiab]	12	10
6	Er, Cr: YSGG laser AND NaOCl [tiab] AND Enterococcus faecalis[tiab] AND in-vitro	5	5
7	Er, Cr: YSGG laser AND NaOCl [tiab] AND Enterococcus faecalis [tiab] AND antibacterial	6	5
8	(Er, Cr: YSGG laser OR laser activated irrigation) AND (Sodium hypochlorite OR antiformin OR clorox) AND Enterococcus faecalis[tiab] AND antibacterial AND root canal AND in-vitro	16	3
9	**Total**	**67**	**48**

Eligibility Criteria

All in-vitro studies comparing NaOCl with Er, Cr: YSGG activation in intracanal irrigation and assessing efficacy against *E faecalis* were eligible for the review. With respect to language, articles published in English language or in other languages where translation to English was possible were included. The time period of publication for inclusion was kept from the studies published between 1st January 2011 and 31st March 2022. Studies reporting efficacy of NaOCl and Er, Cr: YSGG activated irrigation against mixed species with no segregation of data for *E faecalis*, done in extracted teeth other than human, comparing NaOCl with lasers other than Er, Cr: YSGG, data reported through letters to the editor, short communications, patents and conference proceedings were excluded from this systematic review.

Study Selection

Two authors (RJ & SSR) independently conducted the screening process. Stage 1involved screening of the articles based on titles. At stage 2, the included articles were read for abstract followed by exclusion of irrelevant abstracts. At Stage 3, the remaining articles were perused and a final decision for their inclusion/exclusion was made.

Data Extraction

A standardized data extraction form was prepared in Microsoft Excel and named as a pilot data sheet. Initially, data was extracted for two articles and was discussed with the third author. After consensus, data for all other articles was extracted. The sheet included information on author's name, publication year, study design, specimen used, intervention details, control details, sample size in intervention and control group, outcome data before and after intervention (colony forming units, smear layer score before irrigation with sodium hypochlorite or activation with laser), inference from the author and an overall remark for the study (Fig 1).

Intervention (sample size)	Control (sample size)	Before (I)	Before (C)	After (I)	After (C)	Inference	Remark (if any)
20	20	2.30 x 10	4.38 x 10	9.10 x 10	2.09 x 10	99.9% for laser and 99.8% reduction in colony forming units from baseline to after intervention (significant reduction) Significant difference between NaOCl and Er,Cr:YSGG activated group	Complete elimination of E-faecalis did not result
16	16	Not reported	Not reported	4.8 ± 2.2	6.8 ± 2.2	No significant difference in colony forming unit was present between NaOCl and Er,Cr:YSGG activated group	High cost of laser unit, unit is cumbersome for dentist
16	16	Not reported	Not reported	4.2 ± 2.2	4.8 ± 2.2	No significant difference in colony forming unit was present between NaOCl and Er,Cr:YSGG activated group	High cost of laser unit, unit is cumbersome for dentist
10	10	Not reported	Not reported	1.7 ± 0.65	4.4 ± 0.50	Significant difference in smear layer scores was present in coronal third between NaOCl and Er,Cr:YSGG activated group	Only straight canals were assessed
10	10	Not reported	Not reported	2.0 ± 0.73	4.8 ± 0.41	Significant difference in smear layer scores was present in middle third between NaOCl and Er,Cr:YSGG activated group	Only straight canals were assessed
10	10	Not reported	Not reported	3.3 ± 0.55	4.9 ± 0.27	Significant difference in smear layer scores was present in apical third between NaOCl and Er,Cr:YSGG activated group	Only straight canals were assessed
10	20	Not reported	Not reported	0.85 ± 0.07	0.51 ± 0.02	Significant difference in proportion of dead E-faecalis cell volume was present between NaOCl and Er,Cr:YSGG activated group	–
10	20	Not reported	Not reported	0.73 ± 0.08	0.36 ± 0.05	Significant difference in proportion of dead E-faecalis cell volume was present between NaOCl and Er,Cr:YSGG activated group	–
15	15	5.6 ± 0.51	5.85 ±0.94	1.22 ± 0.78	1.49 ± 1.07	99.99% for laser and 99.68% reduction in colony forming units from baseline to after intervention (significant reduction) No significant difference in colony forming unit was present between NaOCl and Er,Cr:YSGG activated group	Complete elimination of E-faecalis did not result
15	15	Not reported	Not reported	1.33 ± 3.52	39.33 ± 53.65	Significant difference in colony forming unit was present between NaOCl and Er,Cr:YSGG activated group	–
25	25	100±0	100±0	2±10	0±0	100% reduction in colony forming units from for both the groups from baseline to after intervention No significant difference in colony forming unit was present between NaOCl and Er,Cr:YSGG activated group	–

Figure 1: Data extraction table

RESULTS

The articles included and excluded in each step of this review are presented in Figure 2 through a PRISMA 2020 guidelines flowchart. Initial search in PubMed database yielded a total of 67 articles. No relevant articles were retrieved through Google search. After screening of studies based on titles, 48 studies were included and checked for duplicate removal. Of these, 25 articles were found to be duplicates that got reflected in different search strategies and were thus excluded. Abstract of the remaining 23 articles was read and 15 articles further considered for full-text read. After reading full text, 7 articles were excluded; the reasons being: 3 articles did not have a comparison group of interest, 2 articles assessed the efficacy against mixed species and did not provide a separate data for *E faecalis*, 2 articles did not present the data in a standard format but rather presented in graphs which was not possible to read and extract the data. Finally, 7 articles giving eleven estimates were included for qualitative synthesis.

DISCUSSION

The use of lasers in Endodontics was first reported by Weichman and Johnson in the year 1971 [11]. They made an attempt to seal the apical foramen of extracted teeth using carbon dioxide laser. The actual use of lasers in dentistry for clinical applications started in the late 90s [12]. With constant improvements, newer type of delivery systems that included flexible and thin

fibres along with endodontic tips were developed. Lasers are now used in pulpotomy, pulp capping, apical surgery, endodontic retreatment, obturation along with disinfection and cleaning of root canals [13]. The traditionally followed treatment plans in endodontic canal instrumentation fail to provide adequate disinfection. The accessory canals, curvatures and varied canal morphology still remain a challenge for dentists. Irrigating solutions help in reaching and flushing out debris from the areas where instrumentation is not adequate.

The conventional NaOCl solution ionizes into Na^+ and OCl^- when in contact with the water. This establishes equilibrium with hypochlorous acid thereby affecting the vitality of the microbial cells [14]. NaOCl with different concentrations have proved to be effective in disinfecting root canals. The higher the concentration, greater is the risk of NaOCl toxicity during apical flow beyond the root apex [15]. On the other hand, lasers are proving to be as effective as root canal irrigants in eliminating the microorganisms without the attendant complications [16].

Based on the eligibility criteria, seven studies were considered for qualitative synthesis. All the included studies reported efficacy of sodium hypochlorite and Er, Cr: YSGG laser against *E faecalis* in single rooted extracted human teeth, either premolars or incisors. The specimens in these studies were first prepared by cleaning and shaping of the root canal followed by sterilizing the prepared teeth. The prepared teeth were then inoculated with *E faecalis* for a specific period of time. These samples were distributed into various treatment groups with one group comprising irrigation of root canal with sodium hypochlorite and the other group with Er, Cr: YSGG laser activation.

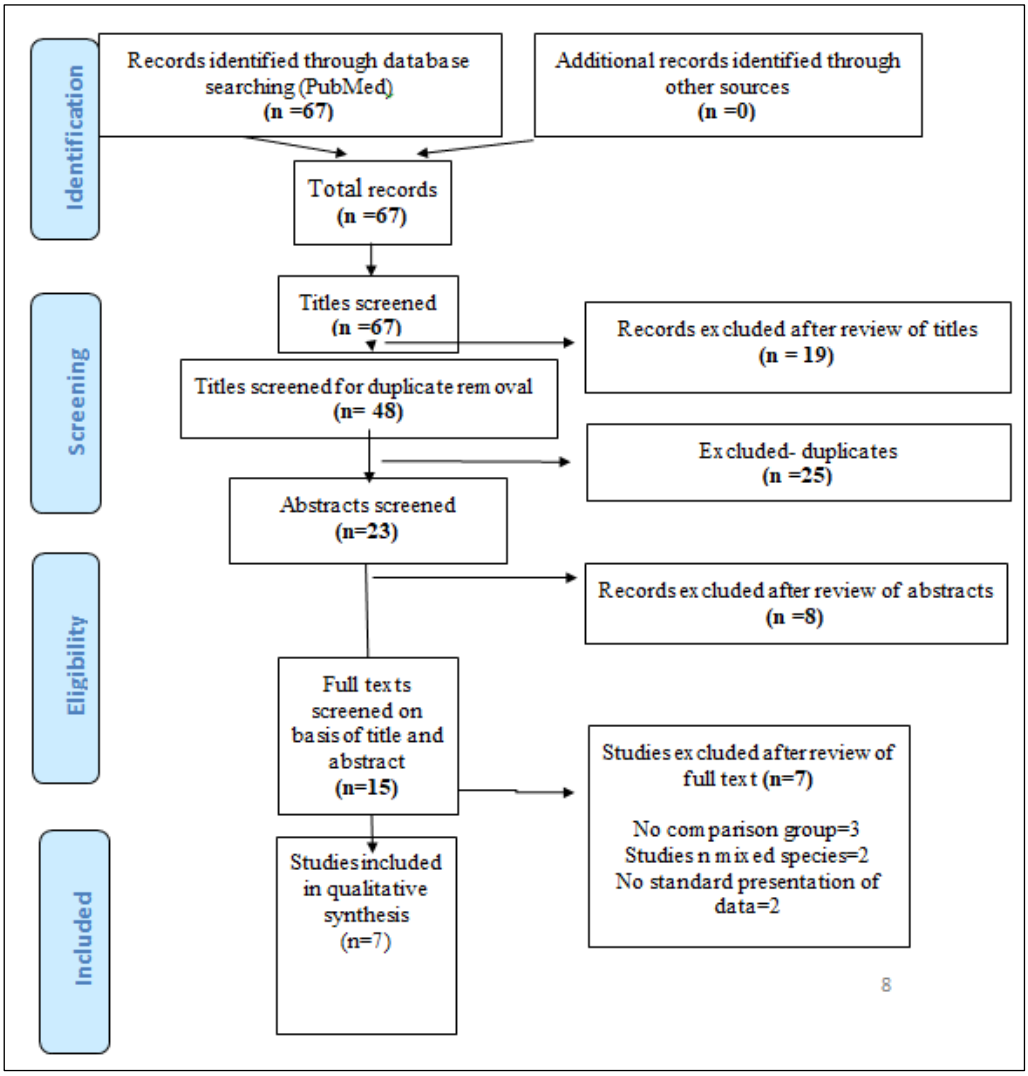

Figure 2: PRISMA Flow Chart

A variation was observed in the concentration of NaOCl used for irrigation of the root canals. 2.5% NaOCl solution was used in two studies [17] while two used 5% sodium hypochlorite solution [18, 19]. The study reported by Christo *et al.*, (2016) [14] compared the efficacy of 1% and 4% with Er, Cr: YSGG activated

irrigation of the respective concentrations. Additionally, Wang X *et al.,* in 2017 and 2018 assessed the efficacy of 5.25% sodium hypochlorite solution alone against E faecalis compared to Er, Cr: YSGG activation [20, 21].

Juric IB *et al.,* demonstrated a significant difference between NaOCl and Er,Cr:YSGG activated irrigation group with laser group being superior to NaOCl [17]. Wang X *et al.,* reported that groups with laser activation of NaOCl irrigating solution were more effective in removing smear layer than NaOCl group alone [14, 20, 21]. Maximum bacterial elimination was observed in a group with Er, Cr: YSGG + NaOCl compared to 5% NaOCl alone against *E faecalis* [22].

However, Dumani A *et al.,* inferred that Er, Cr: YSGG laser has antimicrobial effects on dentinal tubules that are infected with *E faecalis*. There was no difference between the effects of laser activated solution and solution alone [17]. In a study by Christo JE *et al.,* low powered laser activation with Er, Cr: YSGG did not improve the antibacterial effect of low concentrations of sodium hypochlorite [13]. Similarly, Suer *et al.,* too reported no significant difference in antimicrobial effect of laser irradiated activation with Er, Cr: YSGG laser when compared with NaOCl irrigating solution alone [18].

Literature reports the effect of duration of laser irradiation on the microorganisms. When efficacies of lasers with different time duration of exposure were compared, it was inferred that the prolonged time exposure increased the number of dead microorganisms in the canals significantly [23]. Similarly, a variation in the duration of exposure of the NaOCl and Er, Cr: YSGG laser was also observed across the included studies. In four of the studies, the exposure was for 60 seconds. A study by Wang *et al.,* in 2018 reported efficacy with irrigation for 3 minutes [15] and another study by Dumani A *et al.,* in 2019 assessed efficacy for exposure for 2 minutes [17]. Apart from these, there were another two studies that did not report about the duration of irrigation using NaOCl solution [13, 16]. Likewise, Er, Cr: YSGG activation also demonstrated variation across the studies when used with a wavelength of 2780nm. Activation of the irrigation solution by laser for 1 minute was reported in two studies [14, 15], exposure for 20 seconds was reported in one study[12] while 40 seconds activation was reported in two studies [17, 18]. The remaining studies did not provide data of the duration of activation done for the irrigation solution [13, 16]. The efficacy was assessed by colony forming unit (CFU) counts, dead bacteria count or by smear layer scores. The data regarding irrigation was not reported in four studies [13-16], while in three studies, CFUs were assessed and they had values ranging from 2.30-100 before irrigation with laser activation and 4.38-100 after irrigation with NaOCl solution [12, 17, 18].

After irrigation with Er, Cr: YSGG activation, the CFUs reduced to a range of 2-9.10 while in the NaOCl irrigated group the range was 0-39.33. All these studies reported a significant reduction in CFUs with the use of NaOCl and Er, Cr: YSGG activation. Wang X *et al.,* in 2017 demonstrated smear layer scores in coronal, middle and apical third of the root canal [14]. The scores in the Er, Cr: YSGG activated and NaOCl solution group ranged from 1.7-3.3 and 4.4-4.9 respectively with a significant decrease post irrigation. Another study by Wang X *et al.,* in 2018 reported efficacy by demonstrating the proportion of dead *E faecalis* cell volume [15]. After irrigating the canals by Er, Cr: YSGG activation for 3 minutes, the dead *E faecalis* cell volume was reported to be 0.85 ± 0.07 whereas with NaOCl alone it was 0.51 ± 0.02. After laser activated irrigation for 60 seconds, the dead *E faecalis* cell volume was reported to be 0.73 ± 0.08 while it was 0.36 ± 0.05 in only NaOCl irrigated canals. Both the groups presented a significant increase in dead *E faecalis* cell volume post irrigation [15].

When both the treatments were compared with each other, few of the studies favoured Er, Cr: YSGG activated irrigation while few found both the irrigation techniques to be similar. A significant difference between NaOCl and Er, Cr: YSGG activated group was reported in four studies [12, 14-16]. The Er, Cr: YSGG activated irrigation was reported to be superior against *E faecalis* compared to NaOCl solution irrespective of the concentration used. No significant differences between the groups were reported in three studies [13, 16, 18]. The efficacy against *Efaecalis* between the groups was comparable. Only one study by Suer K *et al.,* in 2020[18] reported a 100% reduction in colony forming units after irrigation. These results could not provide a definite consensus on the superiority of lasers activation over the NaOCl solution.

The results of the present review are in accordance with the review reported by Dawasaz AA in 2022[24].This review assessed the efficacy of diode laser in root canal disinfection but could not provide a consensus on the laser use. This could be due to fewer number of studies included which provided inadequate evidence, partly due to smaller sample size and high heterogeneity. Similarly, Bordea IR *et al.,* in 2020 [25] reported lack of evidence due to discrepancy in the methodology, heterogeneity and standardised protocol. However, the study stated that the laser therapy with antimicrobial solution could provide a synergetic effect against intracanal microorganisms.

CONCLUSION

Within the limitations of this systematic review, it can be concluded that NaOCl in different concentrations and ER, Cr: YSGG laser activation irrespective of the duration of exposure proved to be effective in reducing the bacterial colony forming units, as well as being effective against *E faecalis*. Few

studies prove Er, Cr: YSGG laser activated NaOCl to be superior to NaOCl alone while some do not report any difference between the two disinfecting methods. Further studies with larger sample size involving multi-rooted teeth and teeth with curved canals can be thought of to provide a consensus on the effectiveness of Er, Cr: YSGG laser activated NaOCl.

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