



# Endodontic retreatment of curved root canals using the dual wavelength erbium, chromium:yttrium, scandium, gallium, garnet, and diode 940-nm lasers and the XP-Endoshaper/finisher technique

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Received: 19 January 2020 / Accepted: 24 September 2020 / Published online: 8 October 2020  
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## Abstract

**Purpose** The aim of this quantitative study was to compare between a dual-wavelength laser (Er,Cr:YSGG, diode 940 nm) to the XP-Endoshaper/finisher combined with ethylenediaminetetraacetic acid (EDTA) 17% technique in removing secondary smear layer created during endodontic retreatment of curved canals.

**Methods** Twenty-four human curved root canals were endodontically prepared and filled with AH-sealer and Reciproc® Gutta percha cones. The fillings were removed after 6 weeks, and the samples were randomly divided into 3 groups: A, negative control: irrigated with distilled water; B, XP-Endoshaper/finisher with EDTA 17%; and C Er,Cr:YSGG (2 W, 20 Hz, 50 μs) and diode 940 nm (2 W, 50% duty cycle). The canals were split longitudinally, and a laser scanning microscope (VK-X100K, VK-X200K, Keyence, Osaka, Japan) was used to capture images with the magnification of × 1000 from the canals. The images were scored by three blinded dentists using the Hülsmann scoring system, and a statistical analysis was carried out.

**Results** A significant difference between the apical regions of groups B and C ( $p = 0.0010$ ) was observed, with group C showing a cleaner apical region. However, this difference is cancelled out when comparing all areas of the canals ( $t = 1.43$ ,  $df 21$   $p = 0.1663$ ).

**Conclusion** Within the limitations of this study, it can be concluded that a dual laser wavelength protocol (Er,Cr:YSGG (2 W, 20 Hz, 50 μs) and diode 940 nm (2 W, 50% duty cycle) may be positive in removing the secondary smear layer formed during endodontic retreatment cases of curved root canals.

**Keywords** Dental lasers · Er,Cr:YSGG · Diode 940 nm · Endodontic retreatment · Curved canals · Sealer removal

## Introduction

Studies have reported that the success rate of endodontic retreatment lies at 74% [1]. This has been associated with one or more factors, including inadequate canal debridement, inadequate obturation, and complicated canal anatomy, all in turn result in the persistence of bacterial infection inside the root canal [2–4]. Traditionally, endodontic retreatment is

performed by first removing the obturating material and sealer, followed by repeated canal preparation and irrigation with a suitable antimicrobial solution such as NaOCl, which is reported to remove bacteria and promote healing in retreatment cases [5]. Another widely used endodontic irrigant is ethylenediaminetetraacetic acid (EDTA) which is capable of removing the inorganic component of the smear layer [6]. Following canal irrigation, the placement of intracanal medication such as calcium hydroxide is the traditional method used to combat the infective bacteria [7, 8]. However, it has been reported that calcium hydroxide dressing is not reliable in all cases, most importantly due to the varied root canal anatomy, in addition to the presence of bacteria inside dentinal tubules [9], and this may lead to reinfection and failed root canal treatment.

During endodontic retreatment cases, the obturating material is traditionally removed mechanically and the canal irrigated with the same endodontic treatment disinfecting

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irrigations such as NaOCl [10]. Different studies focusing on root canal retreatment concluded that rotary instruments are more effective in removing the obturating material than hand files [11, 12]. Other studies found no significant difference in removing gutta percha using different rotary systems [13, 14]. Moreover, a study found that the absence of the endodontic smear layer resulted in a more effective removal of calcium hydroxide, which is found in some sealing materials, from straight root canals using traditional irrigation methods and rotary instruments [15]. Furthermore, EDTA has been reported to be capable of removing endodontic sealer to a certain degree [16].

Based on their absorption spectrum, different lasers strike different targets. Erbium lasers which are absorbed in water and hydroxyapatite are capable of ablating dental hard tissues [17]. Several studies using different Er,Cr:YSGG settings endorsed the use of a the 2780-nm wavelength in removing remove the endodontic smear layer created during root canal treatment of straight canals [18–21]. Additionally, diode lasers emitting photons on the wavelength of 940 nm has been shown the ability to target bacteria located deep within the dental hard tissues by penetrating the latter [22]. Recent research has investigated the possibility of applying both wavelengths in an alternating mode to remove both organic and inorganic smear layer components, as well as removing the deeply embedded bacteria. Those studies have shown positive results in removing the endodontic smear layer from straight root canals [23]. Additionally, a recent study [24] reported positive smear layer removal results using a new dual wavelength Er,Cr:YSGG and diode 940 nm laser protocol during root canal treatment of curved root canals. The safety of those setting on the root surface, periodontal tissues, and the surrounding bone has also been reported [25]. No publications assessing the ability of the dual wavelength laser Er,Cr:YSGG and diode 940 nm laser in cleaning and disinfecting curved root canals in retreatment cases were found in the literature.

In our present study, we aim to investigate the effectiveness of the dual wavelength laser Er,Cr:YSGG and diode 940 nm in removing the endodontic sealer remnant and uncovering the dentinal tubules in curved canals in comparison with the XP-Endoshaper and XP-Endofinisher coupled with 17% EDTA.

## Materials and methods

After consulting the statistical department at the RWTH Uniklinik—Aachen university and based on the outcome of the first part of our study [24], the number of samples was determined to be 24 human curved root canals. Teeth extracted due to periodontal reasons were collected, and the Patients' consent to use the teeth in our study was

obtained. To ensure standardization, the crowns were dissected using a diamond saw and the root lengths were set to 10 mm. All canals were prepared using the Reciproc® system (Reciproc®, VDW GmbH, Munich, Germany) and obturated with AH Plus® sealer (DENTSPLY Maillefer, USA) and Reciproc® Gutta percha cones. All teeth were stored in thymol solution for 6 weeks to allow the sealer and gutta percha to bind with the canal walls. The fillings were then removed using manual hedstrom files ISO 25, and the canals were recapitulated with R25 Reciproc® system to create a secondary smear layer. The roots were then longitudinally split using a diamond saw, and the mean canal curvature was  $22^\circ \pm 6^\circ$ . The samples were divided into three groups ( $n = 8$ ) as shown in Table 1.

Group A: served as the negative control group; the canals were irrigated with distilled water before obturation and after removing the gutta percha and reciprocating the canal.

Group B: XP-Endoshaper with distilled water, and XP-Endofinisher with EDTA 17%: the XP-Endoshaper was applied with distilled water and activated inside the canal for 60 s with a speed of 800 rpm while being moved in an apical-coronal direction. The XP-Endofinisher tip was then applied at 800 rpm for 60 s using EDTA 17% as an irrigating solution; the XP-Endofinisher tip was applied in a continuous movement along the axes of the canal. This treatment was applied pre-obturation and after removing the gutta percha cones and reciprocation.

Group C: dual wavelength laser treatment: Using the RFT2 tip, each canal was treated for 1 laser cycle with a speed of 1 mm/s. The settings applied were Er,Cr:YSGG (2 W, 50  $\mu$ s, 20 Hz, water 80%, air 30%) and diode 940 nm laser (2 W, 50% duty cycle) [24]. Each sample received this treatment once before obturation and once after removing the gutta percha and reciprocation.

All procedures were performed in a water bath set to 37 °C to mimic the human body temperature. Afterwards, the root canals were split longitudinally in half and examined under the 3D scanning laser microscope (VK-X100K, VK-X200K, Keyence, Osaka, Japan). Images were taken from the cervical, middle, and apical third of the canals, and the images were scored by three blinded dentists using a scoring system originally described by the Hülsmann et al. [26] as follows:

- Score 1: clean canals with all dentinal tubules uncovered and no trace of smear layer
- Score 2: most of the dentinal tubules are visible; few areas are covered with smear layer
- Score 3: canal covered with a smooth homogeneous smear layer, few visible dentinal tubules
- Score 4: canal entirely covered with a smooth homogeneous smear layer, no visible dentinal tubules
- Score 5: unclean canal covered with a heavy non-homogeneous smear layer

**Table 1** The pre- and post-obturation procedures of the three study groups A, B, and C

Group	Pre-obturation treatment	Post-obturation treatment
A	Irrigated with distilled water	Irrigated with distilled water
B	XP-Endoshaper/finisher 17% EDTA <sup>†</sup> irrigation	XP-Endoshaper/finisher 17% EDTA <sup>†</sup> irrigation
C	Er,Cr:YSGG <sup>‡</sup> : 2 (W), 20 (Hz), 50 (μs), 80% Water, 30% Air diode 940 nm: 2 (W), 50% duty cycle	Er,Cr:YSGG <sup>‡</sup> : 2 (W), 20 (Hz), 50 (μs), 80% Water, 30% Air diode 940 nm: 2 (W), 50% duty cycle

<sup>†</sup> Ethylenediaminetetraacetic acid

<sup>‡</sup> Erbium, chromium, yttrium, aluminium, scandium, gallium, garnet

## Statistical analysis

Hülsmann scores were described by mean and standard deviation statistical values. A linear mixed effects model was fitted to the response variable Hülsmann score with random intercept by sample within group and area, and random intercept and dentist by sample within group. The fixed effects were area, dentist, group, and the corresponding two-way interactions. We used linear contrast to assess differences for specific questions. The significance level was set to 5%. SAS statistical software was used for computations, and proc mixed was used for the model fitting.

## Results

### Microscopic results

Figure 1a, b, c is a representation of the control group A in the cervical, middle, and apical thirds, respectively. The canal walls show a heavy, non-homogeneous smear layer with no detectible dentinal tubules. All parts of the canal were given score 5 by the 3 dentists. Figure 2a, b, c is a sample image taken from group B, treated with the XP-Endoshaper and XP-Endofinisher coupled with 17% EDTA, the canal shows very clean cervical and middle thirds and no trace of smear layer, and a relatively clean apical third with some smear layer remnants. The apical third was given Hülsmann scores between 1 and 3, while one apical third received a score 4. The results of

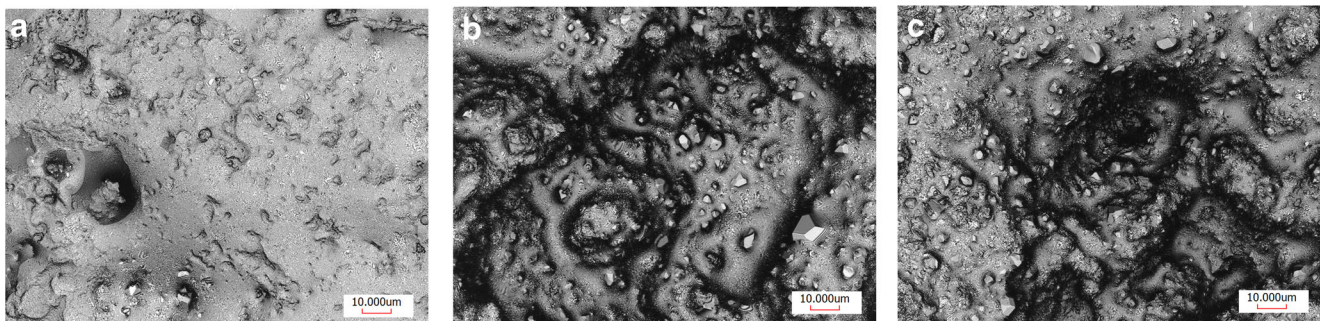
the laser group C are shown in (Fig. 3a, b, c); the dentinal tubules are exposed in all three thirds of the canal, with a few traces of smear layer in the apical third. In this group, the Hülsmann scores ranged between 1 and 2, and only one apical third received score 3, indicated a homogeneous smear layer covering the walls with a few visible dentinal tubules.

### Statistical results

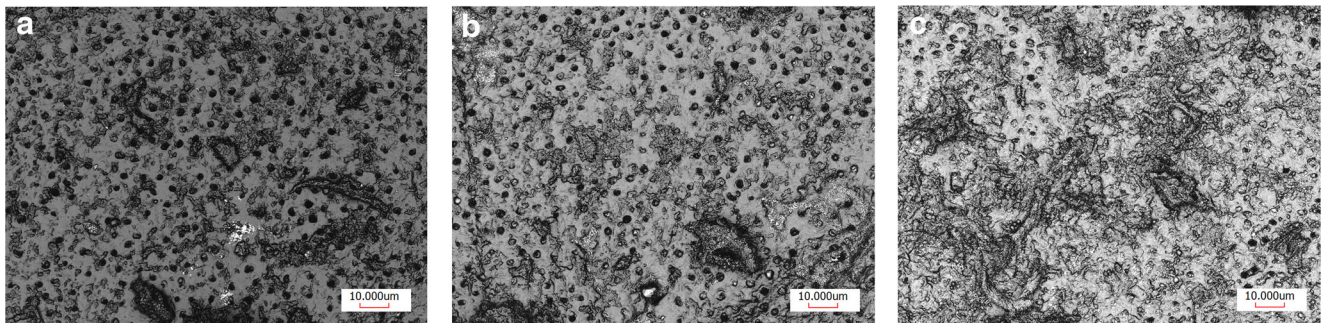
Table 2 exhibits the statistical results of the three study groups. The *p* value was set to ( $p < 0.0001$ ). There were no significant differences related to the score givers; however, significant differences between areas ( $F = 19.91$ ,  $p < 0.0001$ ), groups ( $F = 454.81$ ,  $p < 0.0001$ , and groups differ within areas ( $F = 10.67$ ,  $p < 0.0001$ ) were observed. Regarding the overall cleanliness of the canals, the laser group C was slightly more homogeneous across all areas than the group of the XP-Endoshaper and finisher group B. A statistically significant difference between both groups B and C was observed in the apical region ( $p = 0.0010$ ). In this region, the apical third group C received a Hülsmann score of 2.0000, whereas the same area in group B was scored with 2.7500.

## Discussion

This study is a quantitative investigation of the effectiveness of the dual wavelength laser Er,Cr:YSGG and diode 940 nm laser in removing the smear layer created during endodontic



**Fig. 1** a, b, c The cervical, middle, and apical regions of the control group A, respectively



**Fig. 2** a, b, c The cervical, middle, and apical regions of the XP-Endoshaper and XP-Endofinisher group, respectively

retreatment of curved root canals, which contains dentin debris and AH-plus sealer remnants, and exposing the dentinal tubules. We compared the results of group C where the laser was used to those of group B, treated with EDTA 17% activated with the XP-Endoshaper and XP-Endofinisher tips. Our in vitro experiment revealed clean canals in the cervical and middle thirds of both groups B and C, with a significantly cleaner apical third in group C.

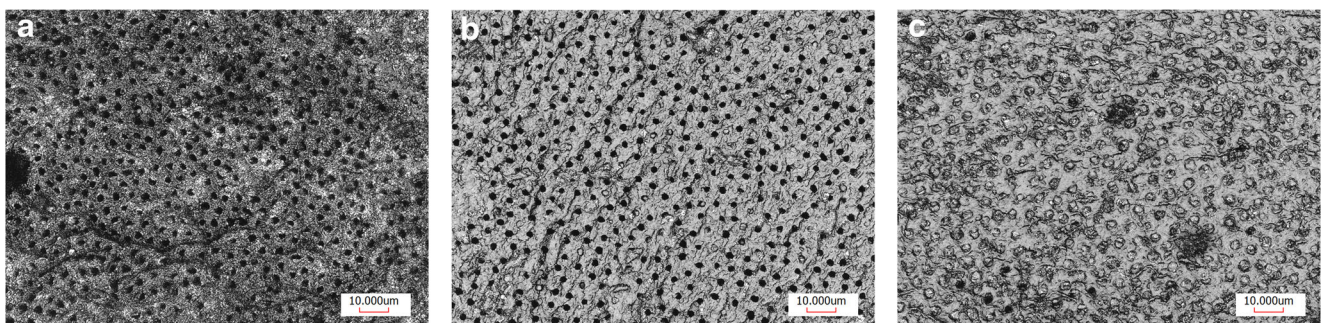
Removing the endodontic obturating material is an important factor in determining the success or failure of root canal retreatment procedures [27]. Previous studies affirmed the positive cleaning ability of rotary instruments in removing the endodontic gutta percha [28, 29], which agrees with the results of our study. However, it has been observed that using rotary instruments alone to remove the obturating material will not expose the dentinal tubules [30]. In our study, we focused on extensively re-instrumenting the canals with the Reciproc® files which resulted in creating a new smear layer observed heavily in the control group A, agreeing with Latheef et al. [30].

A study reported that the XP-Endoshaper and XP-Endofinisher are capable of partially removing residual root canal obturating materials from straight root canals [31]. Another study reported an improvement in removing the obturating material from curved root canals [32] when applying the XP-Endofinisher tips after removal with rotary systems; the authors however did not specify whether the sealer was completely removed and the dentinal tubules were fully exposed.

Positive results have been reported regarding the debridement effect of different Er,Cr:YSGG laser setting combinations in straight root canals [18, 19, 33]. Additionally, it has been shown that the combined use of the Er,Cr:YSGG and diode 940 nm lasers provide an effective and safe method in removing the smear layer and simultaneously disinfecting straight canals [23, 34, 35]. The lasers settings tested in the present study have previously shown positive outcomes in removing the dental smear layer from curved root canals in endodontic treatment cases [24]. However, no study has been found regarding the effect of the alternate application of these wavelengths in dental retreatment investigations.

Furthermore, it seems that most endodontic laser studies continue to focus their attention on the effect of lasers in straight canals, even though around 84% of root canals have a certain degree of curvature [36]. In terms of the laser's capability in cleaning the apical third of curved root canals, our results agree with those of Alamoudi et al. who applied the Er,Cr:YSGG laser in simulated curved canals (20° curvature) filled with red fuchsine dye. In their work, the authors described a positive dye removal from the apical region using both circular and pulling tip movements and different settings combination [37].

In addition to removing secondary smear layer and uncovering the dentinal tubules, our study focused on laser tip preservation by applying only one laser cycle per canal. However, in 4 out of 8 cases, some burnt debris and remnants were observed on the RFT2 laser tip. This could be attributed to the use of the R25 Reciproc® file, which might have been



**Fig. 3** a, b, c The cervical, middle, and apical regions of the laser group C, respectively

**Table 2** Statistical analysis comparing the overall cleanliness of the 3 groups and the apical region separately

Estimates								
Label	Estimate	Standard error	DF*	t value	Pr** >  t	Alpha	Lower	Upper
Control vs test groups	-3.2847	0.1090	21	-30.13	< 0.0001	0.05	-3.5115	-3.0580
XP vs laser	-0.1806	0.1259	21	-1.43	0.1663	0.05	-0.4424	0.08127
Control vs XP Endoshaper & finisher/apical	-2.0833	0.2127	42	-9.80	< 0.0001	0.05	-2.5126	-1.6541
Control vs laser/apical	-2.8333	0.2127	42	-13.32	< 0.0001	0.05	-3.2626	-2.4041
XP vs laser/apical	-0.7500	0.2127	42	-3.53	0.0010	0.05	-1.1792	-0.3208

\*Degrees of freedom

\*\*Probability

too narrow for the application of the RFT2 tip in severely curved canals. We believe that further canal enlargement can endanger the dentine's integrity in extremely narrow canals and would therefore recommend, in such cases, using lower laser settings for 4 cycles as done by Al-Karadaghi et al. [23]. We also noticed that the laser tip circular movement may not be applicable in all cases of curved canals due to the severe curvature and different canal anatomy and would recommend in such cases the use of a pulling movement in the apical third of the canal, as suggested by Alamoudi et al. [37].

## Conclusion

The present study reported on the effectiveness of the dual wavelength Er,Cr:YSGG and diode 940 nm lasers in removing the secondary smear layer containing dentin debris and sealer remnants from curved obturated root canals. Overall, no significant difference was observed between the laser group (Er,Cr:YSGG 2 W, 20 Hz, 50  $\mu$ s) (diode 940 nm 2 W, 50% duty cycle) and the XP-Endoshaper and XP-Endofinisher combined with EDTA 17%. However, there was a significant difference between both groups in the apical third where the laser method showed a more effective debridement. Further research is recommended to examine the microbiological effect of the suggested dual wavelength method before applying in clinical scenarios.

**Acknowledgements** All three authors confirm that they have contributed significantly to the present research and have all read and agreed on the final version of the manuscript.

**Funding** Open Access funding enabled and organized by Projekt DEAL.

## Compliance with ethical standards

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

**Ethical approval** This article does not contain any studies with human participants or animals performed by any of the authors.

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