

Cleansing efficiency of the new endodontic tip of Lite Touch Er:YAG laser – a SEM study

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The Er:YAG laser-assisted endodontics has a long-standing history since the late 1990s. The materials for the endodontic tips manufacturing, their design and the parameters used however varied significantly in time. The current article is addressing the new flexible tip developed by Light Instruments Ltd. for endodontic use and is focused on evaluation of its cleansing efficiency and morphological changes in the root canal. In this pilot study 11 extracted single-rooted teeth were used. After shaping with ProTaper™ F3 Ni-Ti files an Er:YAG laser-activated irrigation was performed with 17% EDTA irrigation for 60 second with flexible endodontic tip inserted in the root canal 4 mm coronally from apical foramen. The SEM study demonstrates that the new endodontic tip is effective in smear layer elimination of all root canal segments, and can be adjusted successfully in the endodontic therapy.

Key words: Er:YAG, laser tip, cleansing, SEM

Introduction

The Er:YAG laser's use in endodontics emerged after its 1997 FDA approval for hard tissue procedures, with the first clinical applications and development of endodontic-specific devices occurring in the late 1990s [10]. Following FDA approval and further researches, specialized flexible fibers and specific endodontic tips were developed for the Er:YAG laser, making it feasible for clinical use in endodontics [3, 5, 10]. Clinical studies and commercialization of Er:YAG lasers increased after 2000, demonstrating its advantages in endodontic procedures, such as improving cleaning and disinfection of root canals using different techniques all based on same phenomenon - photoacoustic activation including cavitation, shock waves and fluid streaming [10]. Techniques like

PIPS (Photon-Induced Photoacoustic Streaming), SWEEPS (Shock Wave-Enhanced Emission Photoacoustic Streaming) and LT-IPI (Lite Touch-Induced Photomechanical Irrigation) use low-energy laser pulses to agitate the irrigants and to detach debris, biofilm and vital pulpal remnants from the main root canal, dentinal tubules, cul-de-sac and lateral canals, leading to superior debridement, disinfection and a better healing environment [2, 3, 4, 5, 6, 10]. Despite the existence of sound evidences for the benefits of laser-activated endodontic irrigation, the manufacturers continue to launch on the market new endodontic tips with improved design. The clinical implementation of any new tip requires a complete and thorough study of its characteristics, and in the context of endodontic irrigation - its cleansing efficiency, which is crucial for the endodontic therapy success.

The current article addresses the new flexible quartz tip developed by Light Instruments Ltd. for endodontic use and is focused on the morphological effects in the root canal after its use evaluated by scanning electron microscopy.

Materials and Methods

Tooth Samples

Eleven single-rooted human teeth extracted for periodontal reasons were used in this in vitro study. Root canal preparation was carried out using ProTaper™ (Dentsply Maillefer, Baillaigues, Switzerland) F3 Ni-Ti files accomplished with 2.5% NaOCl irrigation. At the end of the mechanical shaping, each root canal was finally irrigated with 17% EDTA using Er:YAG laser (LiteTouch™, Light Instruments, Israel) equipped with a cylindrical quartz fiber tip (25mm, 440 μm). Energy was set to 0.4 W (40 mJ, 10 Hz) for 60 seconds (**Fig. 1A**). The water/air spray of the laser was turned off and the irrigation solution (17% EDTA) was injected constantly during irradiation (**Fig. 1B**). The laser tip was inserted 4 mm coronally from apical foramen and moved up and down during the procedure. After this final irrigation, two longitudinal cuts were made with a high-speed bur and the teeth were split in half for further evaluation by SEM.

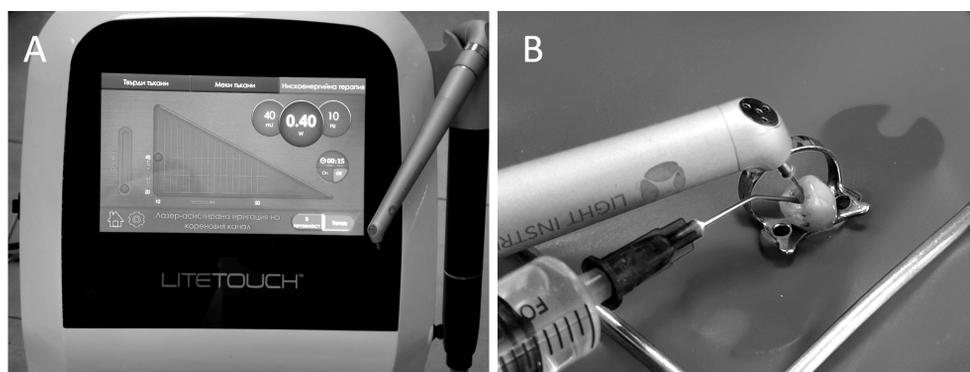


Fig. 1. The laser settings used for irrigant activation are 0.4 W (40 mJ/10 Hz) without water/air spray (A). The irrigant (17% EDTA) is constantly delivered during the irradiation (B).

Scanning Electron Microscopy (SEM)

All samples were desiccated and fixed on stubs and then coated with gold using an JEOL JFC 1200fine coater (Tokio, Japan). Images were collected on an JEOL JSM 6390 (Tokio, Japan) with acceleration voltage of 20 kV. The morphological effects of the laser-assisted irrigation were examined at a magnification of 600X for all three portions of each root canal. The scoring of the smear layer was done according to the modified criteria given by Tomov et al. [1]:

- Score 1** – Complete absence of a smear layer and open dentinal tubuli free of debris.
- Score 2** – Presence of a smear layer only in dentinal tubules orifices (>50% are visible).
- Score 3** – Presence of a thin homogeneous smear layer covering the canal wall with a few dentinal tubules open (<50% are visible).
- Score 4** – A thick smear layer covering completely the canal wall. The dentinal tubules are filled with debris and their contours are not clear.
- Score 5** – The entire canal wall is covered by a heavy smear layer with no visible dentinal tubules.

A single-blind evaluation of the SEM micrographs was carried out by two examiners (G.T. and K.G.) according to this scoring system. Data was analyzed using SPSS software, version 16. Friedman and Wilcoxon tests were applied for the comparison of smear layer removal between the three regions. Additional pictures of other artefacts were done at different magnifications.

Results

The results obtained from this study are summarized in **Table 1**. The smear layer removal was greater in the coronal and middle regions than the apical region of the root canal ($P=0.003$ and $P=0.02$, respectively) with no differences between the coronal and middle regions ($P=0.09$).

Table 1. Mean amounts of smear layer by regions

Regions	Mean±SD
Coronal portion	1.62±1.94
Middle portion	2.37±1.70
Apical portion	3.43±1.38

The morphological analysis of the microphotographs revealed that the coronal and the middle portion of the root canal are almost completely free of smear layer and the majority of the dentinal tubules are visible and clean – scores 1 and 2 (**Fig. 2A, B**). In the apical portion some areas are partially covered with thin smear layer and not all dentinal tubules are clean – scores 2 and 3 (**Fig. 2C**).

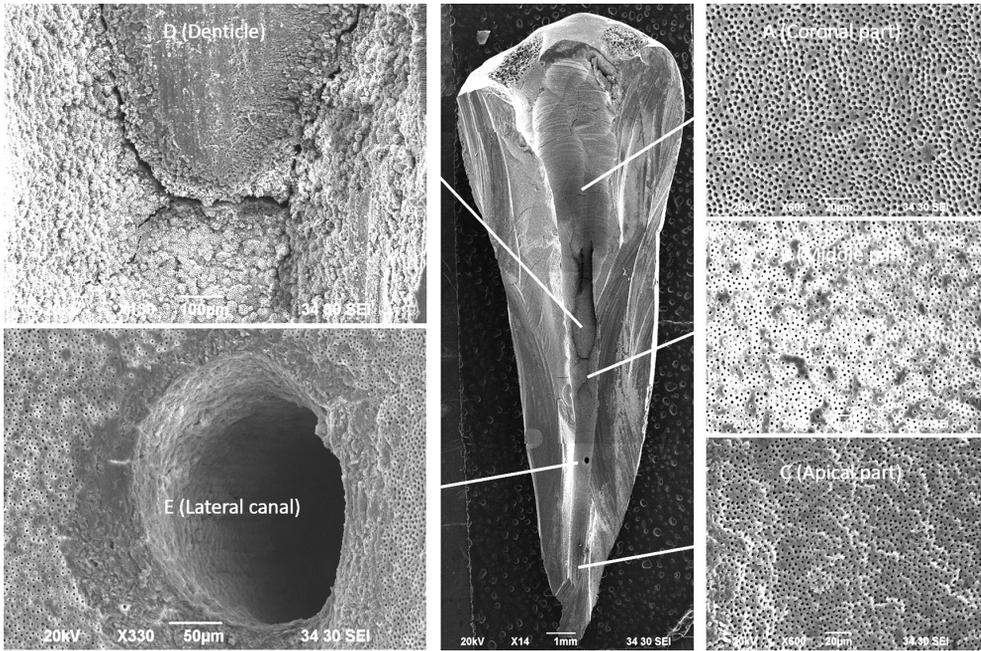


Fig. 2. SEM evaluation at magnification $X 600$ revealed lack of smear layer after Er:YAG laser-assisted irrigation with 17% EDTA for 60 seconds. The coronal (A) and the middle (B) are clean with open dentinal tubules. In the apical portion (C) some dentinal tubules are covered with thin smear layer. Additional observations showed specific root canal artifacts like impacted denticle (D) and lateral canal (E), both clean and free of debris.

The additional observations revealed different structures and root canal artifacts like impacted denticle (**Fig. 2D**) and lateral canal (**Fig. 2E**), both clean and free of debris.

Discussion

The laser-assisted irrigation is based on delivering the laser beam through a tip into the root canal filled with liquid. The energy of the Er:YAG laser is highly absorptive in water at between 1–3 μm penetration depth [10], resulting in formation of cavitation bubbles that create shock waves in proximity to canal walls during their collapses and generating shear flows capable of removing debris from the dentinal surface [10]. Additionally, due to the emitted shock waves in proximity to the canal walls, they encounter the root canal wall at supersonic speed with energy efficient enough for optimal cleaning and disinfecting the root canal system.

However, the application of these physical principles depends on many factors including the design of the “delivery system” i.e. the endodontic tip. The endodontic portfolio of Light Instruments has been enriched in the past ten years with 3 available modalities at the moment – conical sapphire tip ($17\pm 0.1\text{mm}$, $400\pm 0.2\mu\text{m}$), conical metal side-firing spiral tip (25mm , $300\mu\text{m}$) and the newly developed cylindrical quartz fiber tip (25mm , $440\text{-}\mu\text{m}$) (**Fig. 3A, B, C**). The first two endodontic tips are studied both

experimentally and clinically [2, 6, 7, 8, 9]. Their advantages and limitations are also well known. The conical sapphire tip is usually inserted into the coronal third or even into the pulp chamber in completely straight canals, with the beam activating the irrigant in all its volume. [2] In curved canals however, the generated shock waves encounter resistance at the canal curvature and the residual photoacoustic effects apically are insufficient for good cleaning [9]. The reported clinical effectiveness in the literature is referred only to straight root canal cases [2, 7]. The limitations of the sapphire tip were overcome with the introduction of so-called side-firing tip by A. Stabholz. It demonstrates good cleansing effectiveness but requires significant enlargement of the root canal [8, 9] (**Fig. 3D**). The use in a very curved canals is also problematic.

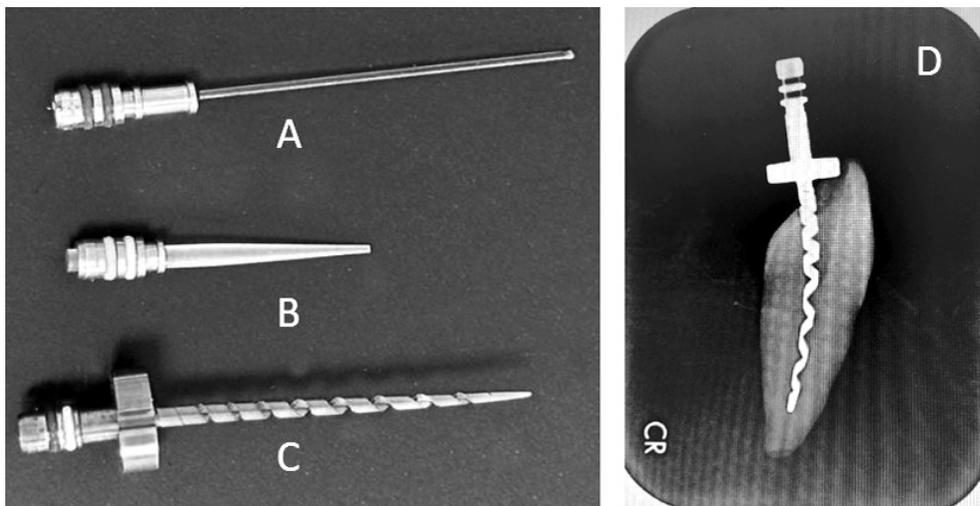


Fig. 3. The available endodontic tips - cylindrical quartz fiber tip (A), Endo tip LIFG4001A (B) and Sapphire tip AS7075X (C) revealed different designs that interfere with their effectiveness. X-ray of the Endo tip LIFG4001A inserted into root canal (D).

To address all these limitations Light Instruments designed new plastic quartz fiber tip which was subject of the current study where both the cleansing abilities and the morphological effects of 17% EDTA together with laser irradiation were evaluated in vitro on a root dentin. Intact teeth were used to simulate the clinical reality as closely as possible. Our previous study revealed that prolonged exposition on EDTA might provoke severe demineralization of the root dentin [11] and that is why the irrigation time and irrigant volume were limited to 1 minute and 10 ml respectively, to minimize potential changes in the dentin's microhardness, permeability, and solubility characteristics.

The energy used was also different from the previously reported studies. In contrast to Bibova N. (0.5 W:50 mJ/10 Hz) and Sahar-Helft S. (1.5 W:150 mJ/10 Hz) in this experiment a lower energy (0.4 W:40 mJ/10 Hz) was used for the same time of activation achieving comparable cleansing effectiveness [2, 7]. The position of the laser tip inside of the root canal is also important. When using fiber tip along the root canal, the clinicians have to consider the possibility for occurring apical extrusion of the irrigant during laser activation [2, 11]. Therefore, in this in vitro study the laser tip was inserted 4 mm coronally from apical foramen and moved up and down during the procedure.

The results obtained are in essence close to the effectiveness reported by other authors [2, 3, 7]. The main differences are the lower energy used and the ability of this flexible tip to be used in narrow and curved root canals.

Conclusion

Since the physical principles behind Er:YAG laser-activated irrigation are essentially the same, the aspiration of manufacturers and clinicians is to have an endodontic tip that is both effective and safe. This in vitro SEM study demonstrates that the new flexible quartz fiber tip met these requirements and can be adjusted successfully for endodontic therapy. However, additional clinical research with multiple patients is required to verify this modality as a routine.

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