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Effects of laser therapy on disinfection and root canal filling in teeth with fixed orthodontic treatment

SUMMARY

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INTRODUCTION

The correlation between the presence of dento-maxillary anomalies and endodontic therapy has been highlighted by numerous researchers. Moreover, the significant number of patients with dento-maxillary anomalies accompanied by early or late-occurring dental, pulpal, or periodontal changes during orthodontic treatment represents a field with multiple research avenues

The essential conditions for successful endodontic treatment are the chemomechanical removal of pulp tissue remnants and microorganisms from the root canal system. Root canal preparation is performed either manually or with rotary instruments, using various techniques. The introduction of rotary instruments has reduced the reliance on conventional manual endodontic files. These rotary files are made of nickel-titanium alloy, which provides enhanced flexibility. Irrigation of the root canals is mandatory during their preparation.

However, neither manual nor rotary instrumentation systems can fully address secondary canals, which may lead to complications in the apical periodontium due to incomplete root canal fillings. For this reason, root canal irrigation—combined with the use of antiseptic solutions and laser irradiation—effectively eliminates microbial flora and promotes three-

dimensional root canal obturation. The most commonly used irrigation solutions are sodium hypochlorite (considered the gold standard in endodontic treatment), hydrogen peroxide, EDTA solution, and chlorhexidine.

The 940 nm diode laser can be used as an adjunct for root canal disinfection, as it generates limited cavitation in the aqueous medium around the fiber tip during irrigation. Combining laser therapy with irrigation solutions is an effective method for reducing postoperative pain. Laser therapy can alleviate inflammation-related pain by dose-dependently decreasing levels of prostaglandin E2, prostaglandin-endoperoxide synthase 2, and interleukin-1 beta.

The fundamental working hypothesis of this thesis is based on the assumption that the use of lasers in root canal disinfection is an essential condition for ensuring effective sterilization of the periapical area, thereby preventing reinfection and the need for endodontic retreatment. It is postulated that relying solely on classical disinfectants such as EDTA, chlorhexidine, or hypochlorite may contribute to microbial flora imbalances and activation of local metabolic mechanisms, representing a risk factor for the development of chronic apical periodontitis.

The diode laser activates the fluid and enhances the efficacy of the chelating agent, as well as the removal of the smear layer. When used alongside chemical disinfectants such as NaOCl and EDTA, it amplifies the decontamination effect.

CURRENT STATE OF KNOWLEDGE

1. Structure of Dental Pulp

The dental pulp is a specialized loose connective tissue with a gelatinous appearance, pink coloration, and soft consistency that adheres to the dentinal walls. It occupies the pulp chamber, replicating the tooth's shape.The dental pulp is surrounded by dentin, a mineralized tissue that provides both protection and spatial support. The pulp tissue communicates with the periodontium and the rest of the organism through the apical foramen and accessory canals.

The characteristic cell of dental pulp, the odontoblast, has dentin production as its primary function. Morphologically, it shows topographic differentiations: in the coronal pulp, odontoblasts are numerous, columnar in shape, with an average height of 25 micrometers and diameter of 5-7 micrometers. The main functions of odontoblasts include dentinogenesis, synthesis of collagen, proteoglycans and glycoproteins, and secretion of phosphoproteins, alkaline and acid phosphatases.

The fibroblast is the most numerous cell type, occupying the entire pulp territory, with higher density in the coronal pulp. Pulpal fibroblasts have a fusiform shape with multiple extensions, featuring clear, homogeneous cytoplasm and pale nuclei. All organelles involved in synthetic processes are well-developed (endoplasmic reticulum, Golgi apparatus).

Secreted by pulp fibroblasts, the ground substance forms a gelatinous matrix that comprises the bulk of the dental pulp and fills the intercellular spaces.

Collagen fibers are a major constituent of the pulp. These fibers form a wide reticular network that provides structural support to other pulp components.

The interstitial fluid is a plasma transudate with a composition similar to blood plasma, differing primarily in its lower protein content, variable water volume, electrolyte and glucose levels, and its capacity to store or release these compounds in specific physiological and pathological states.

2.**Dental Pulp Inflammation: Fundamental Principles of Endodontic Therapy**

Dental pulp inflammation frequently occurs both due to the spread of infection from dental caries through dentinal tubules toward the pulp and as a result of microtraumas caused by orthodontic forces. The effects of orthodontic treatment on dental pulp should not be overlooked by clinicians. Alterations in pulp physiology arise in response to external stimuli of increased intensity. Studies have shown that from the onset of orthodontic treatment, there is a reduction in pulp tissue oxygenation. Furthermore, in vivo research on mice has demonstrated an initial decrease in blood flow during the early phase of orthodontic tooth movement.

Root canal preparation is performed either manually or with rotary instruments using various techniques. According to specialized literature, mechanical root canal treatment consists of two stages: cleaning (which involves removal of radicular pulp, organic debris, and altered dentin) and shaping (preparing the canal to achieve a form that allows for a tight, three-dimensional root canal obturation).

During root canal instrumentation in endodontic treatments, a smear layer (SL) is produced. This layer contains both organic and inorganic components, forming a 1-2 μm thick coating on the canal walls and at the entrance of dentinal tubules where it creates dentinal plugs, extending to a depth of 40 μm. The smear layer consists of small inorganic particles of calcified tissue and organic matter (vital or necrotic pulp residues, odontoblastic processes, bacteria, and erythrocytes).

Root canal irrigation is essential for achieving disinfection that cannot be accomplished through mechanical instrumentation alone. The purpose of irrigation in non-instrumented areas is to remove all tissues covering mineralized dentin. Since biofilm, pulp remnants, and predentin are organic materials, NaOCl serves as the key irrigant for cleaning non-instrumented root canal zones. Alternating between NaOCl and EDTA during instrumentation is a common clinical practice.

Root canal obturation represents the final stage of endodontic therapy, aiming to seal the root canal with non-resorbable, histocompatible filling materials possessing antimicrobial properties. This ensures periapical space integrity and long-term tooth preservation in the dental arch.

3. The Use of Laser in Endodontic Treatment

The use of high-power lasers in endodontics offers the advantage of reaching areas inaccessible to instruments and chemical agents. Currently, there are two primary methods for laser-assisted root canal cleaning and disinfection.

The Nd:YAG laser (1064 nm) is the most commonly used wavelength in endodontics. When root canal walls are irradiated with an Nd:YAG laser, it induces vitrification, melting, and evaporation of the smear layer. All wavelengths exhibit strong bactericidal effects due to thermal action. Regardless of the wavelength or degree of dentinal wall penetration, lasers induce significant structural changes in bacterial cells.

PERSONAL RESEARCH

I Statistical Studies on the Prevalence of Laser Use in Endodontics: Evaluation Survey

The first part of my personal research is a descriptive study conducted between April-June 2023. A self-designed 14-question questionnaire was distributed online to the Faculty of Dental Medicine at "George Emil Palade" University of Medicine, Pharmacy, Science and Technology in Târgu Mureș and to the Mureș County College of Dentists. The questionnaire was statistically validated.

Participants were informed about the research purpose, data confidentiality, and that results would be used exclusively for scientific purposes. Clear instructions were provided for questionnaire completion. Collected data was recorded in databases using Excel**.**

Results of our retrospective study highlight current trends in Romanian endodontic practice, emphasizing the level of modern technology integration and variations according to professional training. Responses from participating dentists are subjective and may deviate from objective clinical facts, but provide feedback about modern therapeutic techniques in this rapidly developing specialty - Endodontics.

Most study participants were aware of the advantages of using diode lasers for root canal sterilization during endodontic treatments, in periodontal therapy, surgical wound healing, or oral lesions, but didn't know which wavelength is most recommended. Classical antiseptics were used much more frequently than diode lasers for infected root canal sterilization, with hydrogen peroxide being the most common, followed by EDTA.

Practitioners with 5-10 years of experience in dental medicine, particularly Endodontics specialists, perform endodontic treatments according to current standards, employing rubber dam isolation, rotary systems for root canal instrumentation, and appropriate irrigation protocols.

There remains a significant need for dental education regarding laser applications and awareness of their advantages in clinical practice. The current primary limitation is the requirement for more accessible laser equipment.

II. The second study is entitled:Effects of Orthodontic Tooth Movement on the Periapical Health of Endodontically Treated Teeth and aims to evaluate the periapical region of teeth that underwent endodontic treatment with Er,Cr:YSGG laser and EDTA during fixed orthodontic appliance therapy.

The study analyzed 32 teeth from 25 patients aged 20-30 years using CBCT imaging. All endodontic treatments employed a disinfection protocol combining EDTA and 5.25% NaOCl with Er,Cr:YSGG laser-activated irrigation.

Orthodontic therapy was performed at the Orthodontics Department of the Faculty of Dental Medicine, UMFST "George Emil Palade", utilizing the MBT technique (0.022 prescription) with metal brackets and molar bands.
In all endodontic treatments, EDTA and 5.25% NaOCl were used in combination with laser (LAI), which activates the fluid and increases the effectiveness of the chelating agent and removal of the smear layer. The total sample included endodontically compromised teeth that underwent endodontic treatment during orthodontic treatment, which remained intact after the orthodontic process without requiring retreatment. The evaluation was done using CBCT. The CBCT investigation was performed after the root canal treatment, which occurred during orthodontic treatment, as well as in the first month after completing the orthodontic treatment.

The Probability of Root canal Infection index (PRI) was assessed for the studied teeth as described by Reit & Grondahl [37], considering periapical bone destruction as absent, uncertain or present. Changes in PRI scores during and after orthodontic treatment were analyzed using multinomial logistic regression and generalized estimating equations to account for score correlations.

Results show that the percentage of teeth exhibiting periapical bone destruction, as assessed by PRI, was significantly higher following orthodontic treatment (Table II). Specifically, the post-treatment and during-treatment odds ratios for present versus absent bone destruction and present versus uncertain were 1.67 (90% CI: 1.16-2.49, P=0.008) and 1.77 (90% CI: 1.11-2.85, P=0.031), respectively. Teeth with inadequate endodontic treatment demonstrated a higher risk of post-orthodontic periapical bone destruction compared to properly treated teeth.

The Er,Cr:YSGG laser, when combined with EDTA and NaOCl, effectively enhances endodontic outcomes by removing the smear layer and reducing bacterial presence, although high NaOCl concentrations may compromise root dentin strength. High-quality endodontic treatment prior to orthodontic procedures and the application of light forces - particularly in adult patients with root pathology - are essential to minimize complication risks.

III**.** The third study in the personal research section, entitled: The Influence of Laser Therapy on Periapical Lesion Healing Following Endodontic Treatment, explores the correlation between bone density after root canal obturation and the diagnostic accuracy of cone-beam computed tomography (CBCT). It also aims to assess the impact of laser-assisted disinfection combined with EDTA irrigation on periapical healing, as evaluated through CBCT imaging at various time intervals (6 months, 1 year, 2 years, 2.5 years) and bone density levels (D1-D5).

This retrospective study aimed to evaluate periapical lesion healing following non-surgical endodontic therapy using cone-beam computed tomography (CBCT) at multiple post-treatment intervals. The study included 60 patients aged 30-60 years, divided into two distinct

groups based on the disinfection protocol used during endodontic treatment, to determine the impact of laser-assisted disinfection on periapical healing. The experimental group (n = 30) received endodontic irrigation with ethylenediaminetetraacetic acid (EDTA) combined with Er,Cr:YSGG laser disinfection. The control group (n = 30) underwent conventional chemical irrigation (without laser).

CBCT imaging was performed using the PaX-Uni3D system (TVAPANO04, VATECH) to assess periapical lesion healing at various intervals: baseline (pre-treatment), 6 months, 1 year, 2 years, and 2.5 years post-treatment.

Results demonstrated at 6 months that the experimental group showed significantly greater lesion size reduction than the control group, with statistically significant differences observed at each subsequent interval ($p < 0.05$). By 2.5 years, the experimental group achieved a mean lesion size of 0.85 ± 0.32 mm, compared to 1.92 ± 0.56 mm in the control group ($p = 0.002$), indicating the sustained and superior long-term efficacy of the combined Laser+EDTA protocol.

Time frame	**Experimental group (Laser + EDTA)**	**Control group**	**p-value (Significance)**
Baseline	6,42 ± 1,23 mm	6,51 ± 1,18 mm	0,812 (NS)
6 months	4,21 ± 0,98 mm	5,13 ± 1,02 mm	**0,041 (S)**
1 year	2,85 ± 0,82 mm	4,02 ± 1,01 mm	**0,008 (S)**
2 years	1,49 ± 0,64 mm	2,83 ± 0,88 mm	**0,003 (S)**
2,5 years	0,85 ± 0,32 mm	1,92 ± 0,56 mm	**0,002 (S)**

Table 1. Periapical healing outcomes

Healing progression in the control group was significantly slower, particularly in low-density bone (D4-D5), suggesting that laser therapy adjuncts optimize the natural healing process. CBCT imaging plays an essential role in endodontic protocols, especially for chronic lesions and compromised bone (Fig. 1).

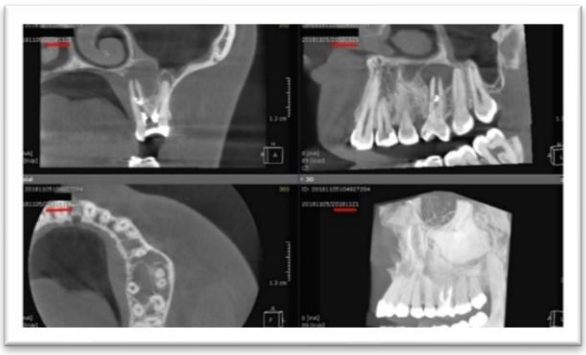

Fig. 1. CBCT (maxillary cystic lesion and healing outcome)