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An Evaluation on the use of Photon-Induced Photoacoustic Streaming in Root Canal Treatment

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ABSTRACT

Introduction: The main purpose of endodontic treatment is to retain the involved teeth in the oral cavity for as long as possible by the prevention and elimination of infection in the root canal system. Irrigation of the root canal after instrumentation is a fundamental component of endodontic treatment success. It is mainly aimed to achieve debridement, smear layer removal, and disinfection of the entire root canal system. Recently, Photon Induced Photoacoustic Streaming (PIPS), which is an activation technique based on the using of Er:YAG (2.940nm) laser equipped with PIPS tip at sub-ablative energy levels, has been used to achieve this goal.

Objective: Evaluate the ability of PIPS technique in removing smear layer and remnants.

Material and Method: Review and summarize studies evaluated the effect of PIPS in root canal treatment.

Results: Several in-vitro studies has been evaluated the evidence to support the benefit of PIPS technique over the traditional and other laser agitation techniques as an efficient method regarding removal of smear layer, remnants disinfection of root canal system and its benefits in other procedures.

Conclusion: Photon induced photoacoustic streaming in in-vitro studies seems to show better smear layer removal at coronal and middle thirds of root canal but not at the apical third, it has no superior effects compared with the other activation technique of endodontic solution.

Key Words: Endodontics, Erbium: YAG, Lasers, PIPS, Smear layer

INTRODUCTION

Removal of tissue remnant and smear layer produced by root canal preparation, in addition to the disinfection of root canal system, represent a key role of successful endodontic treatment. [1]

Traditionally, this goal is achieved by a sequence of procedures aimed at treatment of the infected root canal and its three-dimensional tubular network, starting with good, effective diagnosis and evaluation of the case, followed by traditional mechanical root canal enlargement by means of rotary instruments, removal of infected pulp tissue, smear layer (SL), disinfecting of the root canal by chemical disinfection agents and filling with biocompatible materials. [2, 3]

Since the invention of the laser and the first research on using CO2 in endodontics by Weichman and Johnson in 1971,[4] a considerable number of studies and experiments have been conducted to evaluate and investigate the benefit of lasers as an adjunct to root canal treatment.[5, 6] The clinical use of lasers in root canal treatment was introduced by the development of the new delivery systems of lasers including thin and flexible fibers and endodontic tips in the late 1990s.[7] This adjunctive application is primarily aimed to eradicates bacteria and their toxins and remove the pulpal tissue remnant and SL from the root canal.[8]

Photon-induced photoacoustic streaming, a specific Laser-activated irrigation (LAI) technique, is based on the radial firing stripped tip with a laser of subablative evaporated at very low energies of 20 mJ at 15 Hz for an average power of 0.3 W at 50 µs impulses of the Er:YAG 2940nm.[9] The impulses create an interaction of water molecules with peak powers of 400 W.[10] This creates an expansion and successive

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shock waves lead to the formation of a very powerful streaming of the fluid located inside the root canal, with no rising of temperature.[11] The authors also stated that the energy conversion efficacy is larger when a conical fiber tip is used, with higher pulse energy and lower pulse duration.[12]

The newly designed radical quartz tip of 400µm diameter and 12mm long PIPS tip, stripped 3mm at its distal end, is not required to be placed inside the canal system itself but rather in the pulp chamber only. This reduces the need for using larger files and rotary instruments to create larger canal shapes to open the system Divito et al. 2012.[13]

The objective of this study was to evaluate the ability of PIPS (Photon Induced Photoacoustic Streaming) technique in removing smear layer and remnants from root canals.

MATERIALS AND METHOD

Methods and Study design; A literature search conducted for the electronic database for the articles that addressed the effective of use of PIPS technique in root canal treatment.

The searching keywords were; Endodontics, Er:YAG laser, Photon-induced photoacoustic streaming (PIPS), and the combination of PIPS with the other keywords.

Primarily, titles and abstracts resulting from the electronic searches were screened. Thereafter, full-text articles were examined and selected according to the inclusion criteria. The reference lists of potentially included articles were also searched.

RESULTS AND DISCUSSION

Several studies were evaluated to define the benefit of using Photon-induced photoacoustic streaming (PIPS) in root canal treatment were these studies compared this technique to the traditional methods (Table 1).

The PIPS technique was introduced by Olivi et al.[13] as a revolutionary technique that eliminates the need of over enlarging the root canal size as the tip is not introduced into the canals according to the treatment protocol. Later in 2011 and 2012, Divito et al.[14,15] conducted two in-vitro studies considering an apical root canals enlargement of ISO 20/0.06. They have studied the effect of different repetition rates of 10Hz and 15Hz.Their results showed that using of PIPs technique with these parameters to activate 17% EDTA for 20s and 40s has significantly removed SL. Furthermore, SEM magnification at 20,000X exposed higher opened dentinal tubules. One of the most significant findings of their work is the measurement of the temperature rise during irradiation. Thermocouples were utilized to conduct the temperature measurements which were found to be 1.2^{o}C and 1.5^{o}Cfor irradiation times of 20s and 40s, respectively.

Even though they used an irrigant of 17% EDTA in the experiments, they compared their finding against conventional needle irrigation with saline. This is an obvious omission, and consequently, their results are questionable.

The same great results were also achieved by using a combination of NaOCl and 17% EDTA as compared to using SNI technique.[16] That is, the volume increase of canals treated with PIPS was found to be 2.6 times greater than that treated with SNI.

The activation of 17% EDTA with PIPS, as compared to other activating techniques, showed 0% remaining $Ca(HO)_2$ in canals of PIPS group, with significant superior effectiveness to SI ($p<0.001$), UI ($p=0.046$) and NI ($p<0.001$).[17] Similarly, the activation of 3% NaOCl revealed the same greater removal efficacy of $Ca(HO)_2$ from the main canal and isthmus of both PIPS and USI groups.[18]

A significantly greater amount of filling material removed at coronal and middle thirds ($p<0.05$) but no significant difference observed at apical thirds ($p>0.05$) when PIPS used to activate 3%NaOCl compared to USI group.[19] PIPS with 1% NaOCl removed antibiotic paste with significantly different ($p<0.006$) than that of other irrigation methods.

However, utilizing PIPs for debridement (SL, filling materials, and medications removal) has been reported to show less effectiveness comparing to LAI using Er:YAG laser utilized by flat endodontic fiber.[19,20] The authors found out that the use of Er:YAG with flat fiber positioned 3mm short working length (WL) (activating 5% NaOCl followed by 17% EDTA for 60s cycle of each irrigant) removed 13% filling material versus 4% with PIPS and 3% with Nd:YAG laser.[18] Flat endodontic fiber also displayed the least SL scores at middle thirds of root canals when tip placed 1mm short WL. PIPS in the same study showed the least SL scores at coronal third, while the least SL scores at apical thirds recorded in groups of ANP method.[21] Comparable results achieved by using of QMix as irrigant, as well.[22]

Considering the tissue dissolution ability, the 5.25% NaOCl activated using Er:YAG laser with flat tip showed the best results ($p<0.05$).[17] The lack of effectiveness of PIPS technique as compared to LAI using Er:YAG can be attributed to the effect of the position of laser tip. The results of Meire et al.[23] supported this conclusion where they found that the greater debris removal from artificially created groove achieved when the tip held next to the groove rather than the pulp chamber as well as when using shorter pulse length and lower frequencies. Also, no significant effect observed neither with different fiber diameters (300, 400 or 600µm) nor with tip shapes (conical or flat end). To conclude, it should be addressed that no treatment group used in the articles has successfully removed the SL at apical thirds of the root canal. Even though PIPS groups eliminate the need of over enlargement of the root canal, they showed less effectiveness regarding the cleaning of the apical third.

CONCLUSION

A comprehensive review of using of photon-induced photoacoustic streaming in endodontics has been conducted. A number of 36 research articles have been included in the review. The articles were classified according to the Smear Layer (SL) removal and retreatment properties, root canal system disinfection, and other treatment properties. Regarding SL removal, PIPS showed greater SL removal at the coronal thirds of root canal, while it produced less results at the apical thirds. On the other hand, the examination of its of disinfection ability revealed that it well sterilizes main canal with tendency to disinfect deep dentine layers at 500µm when high energies used. Some articles assessed PIPS effect on bond strength of filling materials and sealers to canal dentine wall. The results were inconsistent, and consequently a conclusion cannot be drown.

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Table 1: Studies investigating the efficacy of PIPS for smear layer removal and treatment procedures (Variants; comparison group, irrigants used and evaluation methods).

Procedures		Studies %
Comparison groups	CI	56.25%
	PUI	43.75%
	ANP	6.25%
	EA	31.25%
	Other laser	31.25%
Irrigant used	17% EDTA	43.75%
	NaOCL	62.50%
	Q Mix	6.25%
	DW	25.00%
Evaluation methods	SEM	62.50%
	OPMI	6.25%
	Micro-CT	31.25%
	Pixel count of $Ca(OH)_2$	6.25%
	Percentage of weight loss	6.25%
	Stereomicro-scope	6.25%

CI, Conventional irrigation; SEM, scanning electron microscope; EDTA, Ethylenediaminetetraacetic acid; NaOCl, sodium hypochlorite; CHX, chlohexidine gluconate; PUI, passive ultrasonic irrigation; ANP, apical negative pressure; DW, distilled water; EA, Endo-activator,OPMI; operating microscope .