# Er,Cr:YSGG apical resection and microleakage evaluation

## An in vitro Study

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**_Periapical surgery is a common procedure** used in endodontics to resolve treatment failures when root end access is impossible and apical resection may be approached using different methods. The aim of this study was to assess the root end cutting efficiency of an Er,Cr:YSGG laser, its capability to prepare a retrograde cavity and value the microleakage of the retro-filled cavities and to compare with conventional bur methodologies. 24 human single rooted teeth were endodontically prepared and root canals were filled with a warm gutta-percha technique. Samples were randomly divided into two groups and retrograde cavities were prepared as follows:

_Group 1: Er,Cr:YSGG sapphire tip (diameter 0.6 mm), frequency 10 Hz, output power 300 mJ, air-water ratio 32 %/43 %, theoretical fluence 106 J/cm$^2$.

_Group 2: micromotor handpiece plus burs and air-water coolant

Retrograde cavities were sealed with a ZOE modified cement and microleakage was assessed using a methylene blue dye penetration method and valuated in millimetres. Microleakage values ranged from 1.05 to 2.85 mm for the group 1 (mean range 2.2 mm, standard deviation 0.79) and from 1.05 mm to 4.65 mm (mean range 2.45 mm, standard deviation 1.07) for the group 2. Statistical analysis of the results was performed using a Mann-Whitney U test for independent samples. No statistical significant differences were found ($p = 0.6999$).

## _Introduction

Periapical surgery is a common procedure used in endodontics to solve treatment failure when root end access is impossible. Eliminating the periapical inflammatory tissues plus sealing the apical terminus of the root canal system are the main objectives. Moreover, root end preparation must preserve the morphology of the root canal and apical cavities may be shaped easily, precisely and safely. Generally these goals are reached by the way of mechanical instruments: root end cavities are prepared by means of small rounds or inverted cone burs in a micro handpiece or more recently by ultrasonic retro-tips.

Clinically, healing process depends on multiple criteria and retro-filling materials takes part in the healing process particularly for what regards the marginal adaptation (microleakage problems) and the biological compatibility.

Er,Cr:YSGG laser demonstrated the capability to cut enamel, dentine and generally hard tissues, due to its high absorption level in water and hydroxyapatite. Not much is known for what regards its possible applications in apical surgery.

Subsequently, the aim of this study was to assess the root end cutting efficiency of this wavelength (2,780 nm), its capability to prepare an apical root end cavity and to value the microleakage of those filled cavities comparing those results with a conventional bur method.

## _Material and Methods

Twenty four human single rooted teeth, freshly extracted for orthodontic or periodontal reasons, presenting straight root canals, were selected and ran-

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domly assessed to two groups. Collecting these samples conformed to a protocol that satisfied the ethical standards as described by the "Centre Hospitalier Universitaire de Nice". Teeth where kept from patients who consented orally to their use for research purposes. Access cavities were conventionally prepared. The root canals length of each sample was determined by introducing a 10/100 K file until it slightly surpassed the apical foramen. The working length was corrected by pulling back while viewing the apical region under a stereo microscope (VMZ, Japan, original magnification x4). The length of the root canals ranged from 17mm to 20 mm. Only root canals that were enlarged to a Master apical file of size #35 were used in this study. A continuous irrigation of 2.5 % sodium hypochlorite was used during the enlarging procedure. A final irrigation of 11 % citric acid was used before drying the root canals (sterile paper points). Root canal fillings were assessed using a warm gutta-percha technique (Obtura System, analytic technology, USA) plus a sealer (Pup canal sealer, Kerr). X-rays (mesio-distal plus vestibulo-buccal views) served to control the quality (density, marginal adaptation, length) of root canal fillings. Access cavities were filled using a ZOE modified cement (IRM, DeTrey, USA).

Samples were then randomly divided into two groups: the laser group and the mechanical bur group. In the laser group (group 1) root apices were resected using a Er,Cr:YSGG laser (Biolase, Waterlase, USA) plus copious air-water coolant (ratio: 32 %/43 %). The laser beam was collimated through a flat-end cylindrical tip (sapphire tip, diameter 0.6 mm, length 12 mm, surface 0.002826 cm$^2$, working distance 1.5 mm). Frequency was fixed to 10 Hz and the output power fixed to 300 mJ that corresponds to a theoretical fluence of 106 J/cm$^2$. Root apex cavities were prepared for the retrograde root canal filling using the Er,Cr:YSGG laser beam, eliminating the gutta-percha excess and finishing the dentine walls.

In the bur group (group 2), root apices were resected using a micromotor handpiece (WH 999A200) plus water-air spray as a coolant and a H-390-016 Komet bur (Komet, Germany). Root end cavities were prepared using a H-1008 bur (Komet, Germany) and filled in the same conditions as described for the group 1. All retro-cavities were filled with a ZOE modified cement (Super EBA cement®, Stailine, Staident Middlesex, UK).

Microleakage was assessed using a methylene blue dye penetration method. Each tooth was covered with two coats of an acid-resistant varnish (V33, Domblans, France) to within 0.5 mm of the apex. The root-ends were immersed in a 0.5 % aqueous solution of methylene blue for 24 hours. They were then rinsed thoroughly in distilled water, the varnish was removed and the teeth were embedded in clear epoxide resin (Buehler® Ltd.). They were sectioned transversally from the apex to the crown (0.3 mm thick slices) with a slowly rotating diamond blade (0.3 mm thickness) under running water (Isomet Low Speed Saw, Buehler® Ltd.). Digitalized images (Color video camera CCD-IRIS, Sony, Tokyo, Japan; Lens macro 50 mm, Olympus, Tokyo, Japan) of the slices were collected from an optical microscope (original magnification x 5) using an image analysis system (Visilog 5.3 program, Noesis Vision, St-Laurent, PQ, Canada) and the microleakage was observed on blind coded samples and quantified as follows. Each slice being 0.3 mm thickness, when the methylene blue is observed on the apical surface and becomes invisible on the coronal surface, the result is quantified at 0.3/2 = 0.15 mm. If the methylene blue is visible on the coronal surface of one slice and becomes invisible on the apical surface of the successive slice, the methylene blue is considered to disappear in the thickness of the eliminated slice (diamond blade thickness). Then, a 0.15 mm value is attributed and added to the last visible valuation. Statistical analysis of the results was performed using the non-parametric Mann-Whitney U test for independent samples.

## _Results

They are expressed in table 1 and figure 1. In group 1 (laser) values ranged from 1.05 mm to 2.85 mm (mean range = 2.2 mm, standard deviation = 0.79 mm). In Group 2 (bur) values ranged from 1.05 mm to 4.65 mm (mean range = 2.45 mm, standard deviation = 1.07). Statistical expression of the results (Mann-Whitney U test) demonstrate there are no significant differences ($p = 0.6999$).

## _Discussion

Bacterial contamination of root canals is considered the main etiologic factor of periapical pathologies. The total elimination of debris and obtaining a sterile root canal system seems very difficult. Most of failures in root canal treatments are attributed to insufficient cleaning and bacterial decontamination. Some bacteria, such as Enterococcus faecalis[1] are isolated from leakages observed between the dentinal walls and root canal filling materials or inside the dentinal tubules. Retreatment is indicated once the endodontic treatment fails and is attribuable to inadequencies in cleaning, shaping and obturating the root canal system. Reinfection may occurs due to wrong fillings or iatrogenic events such as lost of coronal seal. But retreatment may be impossible due to specific conditions such as broken instruments and generally impossibility to reach the apical region of the root canal. Then, apical surgery is indicated when teeth respond poorly to re-treatment or when, generally, they cannot be treated appropriately by conventional means.

The first wavelength to be used in apical surgery ($CO_2$ laser) was performed in order to seal the apical foramen of extracted teeth.[2, 3] This wavelength was used also in order to improve haemostasis and visualize perfectly the operative field and, at the same

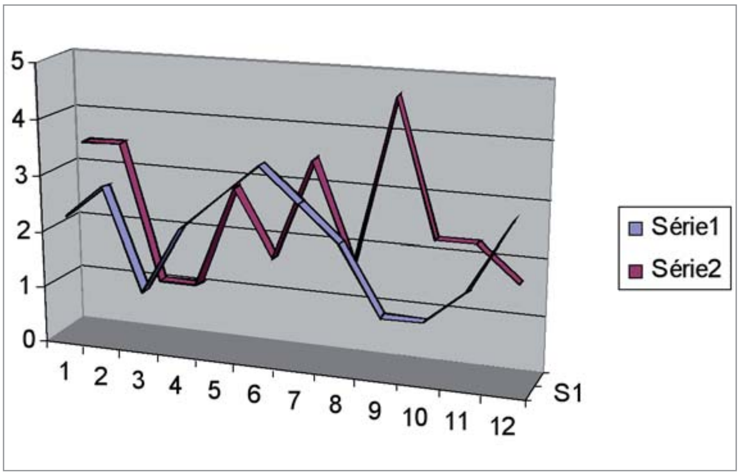


**Table and figure1:** Microleakage infiltration (in mm). (series 1 = Er,Cr:YSGG laser; series 2= bur)

| Mean degree of pain over 6 months (n = 25) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Laser** | 2.25 | 2.85 | 1.05 | 2.25 | 2.85 | 3.45 | 2.85 | 2.25 | 1.05 | 1.05 | 1.65 | 2.85 |
| **Bur** | 3.45 | 3.45 | 1.05 | 1.05 | 2.85 | 1.65 | 3.45 | 1.65 | 4.65 | 2.25 | 2.25 | 1.65 |

time, to decontaminate the root apex as well as to reduce the permeability of the root surface dentin.[4] In an in vivo experiment on beagle dogs, some modifications (mini-contra-angle) did not enhance the quality of the result: the success rate following apicoectomies using this laser was not improved and failed to support the technique proposed by Miserendino.[5,6] In contradiction with those remarks and in an vitro study, Esen et al.[7] aimed to compare the degree of dye penetration (fushin) of root end cavities $CO_2$ laser, ultrasonic retrotips and rotary instruments prepared. For these authors, apical leakage in the $CO_2$ laser group was significantly less than in the other groups. In an interesting study Fayad et al.[8] investigated the effect of $CO_2$ laser irradiation on periodontal cell fibroblasts to resected root ends. Considering that the goal of endodontic surgery is to achieve periapical regeneration by bone and cementum deposition, the healing process includes the attachment of PDL fibroblasts to the resected structure. This study demonstrates there were no PDL cells attached to the laser strike areas. This absence of attachment could be attributed to the morphological changes including charred, carbonized, craters formation and melting of the hard tissues involved (dentine, cementum, bone) with subsequent solidification and re-crystallisation. This could explain why, in a 4-years in vivo study, the $CO_2$ laser did not improve the healing process.[9] This wavelength, today, is not so frequently used in apical surgery, in exception of the haemostatic effect that is yet appreciated by some dental practitioners.

Nd:YAG laser demonstrated to be effective in reducing the penetration of dyes or bacteria through resected roots, but all observations demonstrated that the permeability of the dentin was not completely prevented.[10, 11, 12] This could be linked to the fact Nd:YAG laser causes melting of dentinal surfaces ressembling the appearance of glazed interconnected droplets. Resolidification and recrystallization of the melted area, appeared to be incomplete and discontinuous. Subsequently, it is possible to postulate why the permeability of the dentine was reduced even if not completely prevented. Preparing bacterial reservoirs in the access cavities and comparing the apical seals achieved using retrograde amalgam fillings or Nd:YAG laser without apical preparation, Wong et al.[13] did not find any statistically significant differences in bacterial leakage between the laser-treated group and the retrograde amalgam group. This result could be identical as the above argumentation: N:YAG laser produces a partially non homogeneous glazed surface and leakage becomes possible.

Er:YAG as well as Er,Cr:YSGG lasers, that are two narrow wavelengths, are both highly absorbed in water and hydroxyapatite and recognized as perfectly adapted for hard tissue ablation. Using an Er:YAG laser to prepare root end cavities, Ebihara et al.[14] found no statistically significant differences in dye penetration between the laser-treated group and the ultrasonic group. These results, in accordance with our in vitro observations, are not surprising since Er:YAG or Er,Cr:YSGG lasers neither melt nor seal the dentinal tubules. Subsequently, any reduction in dentine permability should not be expected. When using Er:YAG as well as Er,Cr:YSGG lasers, smooth and clean resected surfaces devoid of charring or glazing or melting are observed.[15, 16] Using this wavelength and comparing with ultrasonic devices, Karlovic et al.[17] founded lower values of microleakage when the root ends cavities were prepared with Er:YAG laser, whatever the sealing material used. Some authors[18] tended to mix different wavelengths and in respect of the interaction laser –tissue, used an Er:YAG laser to perform osteotomy and root resection plus an Nd:YAG laser to seal the dentinal tubules and reduce the possible bacterial contamination. Moreover they applied low level laser therapy with a GaAlAs laser to enhance wound healing process. This approach is interesting and those authors observed that the clinical follow-up showed a significant decrease of radiolucent periapical lesions. No clinical signs and symptoms were reported by the patients. Effective dentine (as well as enamel and bone) cutting by means of an Er,Cr:YSGG was first demonstrated in the middle nineties[19] so that its possible use in apical resection is not a surprising application. The emitted energy may be delivered, in a first approach and clinically, in the root canal by a thin optical fiber. Thus, the potential bactericidal effect of laser irradiation (in synergy with sodium hypochlorite) may be used for disinfecting the root canal. Moreover, sapphire tips—as demonstrated in this in vitro study—are able to cut the apex and prepare the retrograde cavity to be filled.

The outcome of this in vitro study indicates that there are no statistically significant differences in the two groups in terms of microleakage. The root end resection as well as the retroapical cavities may be performed by Er,Cr:YSGG laser as a useful method. Laser apicoectomy has the potential to reduce the risk of bacterial contamination of the surgical wound and to eliminate the hazards associated with target tissues aerosols produced by rotary air driven instruments. Effectively, ablation of the tissues to be removed (dentine, cementum) is achieved by a thermo-mechanical mechanism. In this process light is absorbed by water molecules, rapidly heating a small volume. Water vaporization creates a strong subsurface pressure and leads to an explosive removal of the target tissue.[20] The explosive thermo-mechanical ablation occurs with wavelengths from 2.7 to 3 µm and leads to ejection of mineral particles with preserved mineral structure.[21] Subsequently, heating the infected tissues decontaminates it. Mineral particles produced by burs and rotative instruments are not decontaminated and may fall down in the surgical periapical cavity, compromising the healing process. Moreover, micro-cracks, have never been observed nor reported.[22] Further studies—long term and multicentric clinical investigations—should value and compare the healing process, comparing the mechanical and photo-thermo-mechanical efficiency._

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