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Gingival melanin depigmentation by Er:YAG laser: A literature review

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ABSTRACT

Laser ablation is recently suggested as a most effective and reliable technique for depigmentation of melanin hyperpigmented gingiva. To date, different lasers have been used for gingival depigmentation (CO_2, diode, Nd:YAG, Er:YAG and Er,Cr:YSGG lasers). The use of Er:YAG laser for depigmentation of melanin hyperpigmented gingiva has gained increasing importance in recent years. The purpose of this study was to report removal of gingival melanin pigmentation using an Er:YAG laser in a literature review. The main outcomes, such as improvement of signs (clinical parameters of bleeding, erythema, swelling and wound healing), symptoms (pain) and melanin recurrence/repigmentation were measured. The literature demonstrated that depigmentation of gingival melanin pigmentation can be performed safely and effectively by Er:YAG laser resulting in healing and an esthetically significant improvement of gingival discoloration. Thus, Er:YAG laser seems to be safe and useful in melanin depigmentation procedure. However, the main issue in giving the final conclusion of the optimal Er:YAG laser use in melanin depigmentation is that, to date, studies are offering completely discrepant Er:YAG laser procedure protocols (complex settings of laser parameters), and different criteria for the assessment of depigmentation and repigmentation (recurrence), thus hampering the comparison of the results. Therefore, further studies are necessary to give an optimal recommendation on the use of Er:YAG laser in gingival melanin hyperpigmentation.

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Introduction

Normal physiologic color of gingiva is coral or salmon pink, with physiological variations that depend upon the degree of vascularization, epithelial thickness, the thickness of keratinized layer and the amount of melanin pigment. The excessive deposition of melanin by active melanocytes, located mainly in the basal and suprabasal cell layer of the oral epithelium, can cause dark colored areas that occur most frequently in the gingiva, known as melanin hyperpigmentation/„black gums“ (1–6). Melanin hyperpigmentation/MH is known to be associated with various etiological factors, such as: drugs, heavy metal ingestions/poisonings, genetics, endocrine disturbances (Addison's disease, Albright and Nelson's syndrome, acromegaly), and exposure to UV rays, inflammation, benign and malignant lesions, cultural intentional tattooing and smoking (1–6). It can be also caused by some pathologic conditions, such as malignant melanoma, Kaposi's sarcoma, Peutz Jeghers syndrome, trauma, hemochromatosis, and chronic pulmonary disease (7). Therefore, a detailed medical history of the patient and further histopathological examination is crucial in determining whether the MH cause is physiological or pathological.

Although clinically MH is not a medical problem or a disease, the demand for cosmetic corrections is on the increase, mainly by fair-skinned people and when MH is located on the anterior labial gingiva (2–5).This problem is aggravated in patients with a "gummy smile" or excessive gingival display while smiling (2–7). Gingival depigmentation is a periodontal surgical procedure, whereby the gingival hyperpigmentation is removed or reduced with different treatment methods, such as bur abrasion, scraping with scalpel, partial thickness flap, gingivectomy, cryotherapy, electrosurgery, free gingival autografting, chemical methods, subepithelial connective tissue graft, lasers and combination techniques (1–4). Even though selection of a technique is mainly based on clinical experience and individual preferences, most authors recognize laser ablation as the most effective, pleasant and reliable technique for depigmentation of gingiva (1–4).

Lasers can cut, ablate and reshape gingiva easily, further promoting hemostasis, leaving surgical area mostly bloodless and visible (2–4). To date, various lasers have been used for gingival depigmentation, including carbon dioxide (CO_2, wavelength: 10600 nm), semiconductor diode (wavelengths: 810–980 nm), neodymium doped:yttrium aluminum garnet (Nd:YAG,wavelength: 1064 nm), erbium doped:yttrium aluminum garnet (Er:YAG, wavelength: 2940 nm) and erbium and chromium doped:yttrium scandium gallium garnet (Er,Cr:

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YSGG, wavelength: 2780 nm) lasers (1–4). In the case of laser depigmentation, the ability of melanin-containing melanocytes to absorb the laser light is dependent on the wavelength of the apatite and water (6). The use of Er:YAG laser for depigmentation of melanin hyperpigmented gingiva has gained increasing importance in recent years (1–4). Due to the specific wavelength of the Er:YAG laser, it has a demonstrated high absorption by water, minimizing the thermal denature of the laser-treated tissue and leading to early wound healing following irradiation (7,8). Most authors recognize the importance of use of microscope (microsurgery) or magnifying glass during Er:YAG laser ablation as a way to remove as much melanocites as possible (8).

In addition, recently it has been mentioned that beneficial effects of Er:YAG laser in gingival melanin depigmentation can be partly explained by the effects of low-level laser therapy/LLLT (9). LLLT is defined as a certain amount of energy that simultaneously penetrates or scatters into the surrounding or underlying tissues during high-level laser irradiation, causing the least thermal damage due to bactericidal effect and the generation of reactive oxygen species at the target tissue (9,10). That phenomenon is also known as laser therapy/photobiomodulation (PBM), and it causes efficient activation of biological response, which in turn helps the promotion of wound healing/regeneration (9–11).

The purpose of this study was to report removal of gingival melanin pigmentation using an Er:YAG laser in a literature review.

Materials and methods

Search strategy

The studies published until 31. December 2016 were obtained from the Medline/PubMed, Science Direct and Cochrane Library of the Cochrane Collaboration (CENTRAL) online databases, using following search terms: “melanin hyperpigmentation” AND “Er:YAG laser”, “Er:YAG laser” AND “gingival melanin depigmentation” and “gingival melanin” AND “Er:YAG laser”. Screening and study selecting process was performed independently by two authors (V. P. and S. M) to avoid a potential reviewer bias. Further, the references of all selected articles were scanned. The online databases’ search initially identified 13 publications. On the basis of title and abstract evaluation, authors agreed by discussion to exclude 2 publications. Remaining publications in full-text format (relevant or possibly-relevant) were retrieved for more detailed analysis.

Study inclusion and exclusion criteria

Selected publications were further analyzed according to the following inclusion criteria:

(1) Publication in an international peer reviewed literature
(2) English language publications
(3) Comparative and randomized clinical studies involving human adult subjects (age ≥ 18 years)
(4) Presence of at least five patients in test group

Studies that fulfilled the inclusion criteria were further analyzed according to the following exclusion criteria:

(1) Not sufficient information on laser parameters’ settings
(2) No outcome of interest
(3) Duplicate studies

A total of seven selected studies met the required selection criteria. The main outcomes, such as improvement of signs (clinical parameters of bleeding, erythema, swelling and wound healing), symptoms (pain) and melanin recurrence/repigmentation were measured. In the case of comparative studies overall patients’ preference was also recorded.

The present review attempts to systematically evaluate the available literature on efficacy of Er:YAG laser in melanin depigmentation. At the same time, it should be mentioned that due to extreme heterogeneity of the selected studies (study design, Er:YAG laser parameters, observation period…) the meta-analysis could not be performed.

Results

Evaluating of signs/clinical parameters following Er:YAG laser

Bleeding

Even though gingiva displays a very unique and complex topography, Er:YAG laser has been proven to be a tool of choice when it comes to precise cut and ablation of gingiva. In the selected studies, bleeding was easily measured as: 1-none, 2-slight, 3-moderate, and 4-severe. Even though Er:YAG laser is not considered a laser of choice when ideal haemostasis is desired, all authors agreed that score 1 was successfully achieved by instant coagulation and occludation of the small blood vessels (up to 0.5 mm diameter). Regarding the comparative studies (Er:YAG laser compared to the diode laser), higher bleeding score was observed following Er:YAG laser irradiation (6,12). It can be partially explained by the lower haemostatic effect of the Er:YAG laser compared to diode lasers. Diode lasers pass through water and penetrate much deeper into the soft tissue unlike Er:YAG, that neither penetrate deeply nor cause sustained heat to provide rapid vessel shrinkage (especially vessels more than 0.5 mm in diameter). Also, diode lasers’ wavelength lies within the spectrum absorbed by haemoglobin. These authors (6,12) suggested an overall subjective preference of the diode than Er:YAG laser by patients (as measured by questionnaires).

Wound healing

Laser can ablate soft tissues precisely (by various delicate contact tips) and wound healing is demonstrated to be favorable due to the minimal thermal alteration of the treated surface. The majority of the authors evaluated wound healing by the following score: 0-tissue defect or necrosis, 1-ulcer, 2-incomplete or partial epithelization, and 3-complete epithelization. All of the authors agreed that Er:YAG laser demonstrated score 3 (complete epithelization) in the treated sites due to the formation of the protein coagulum immediately after surgery, and a thin layer of fibrin that covered parts of the treated sites (5,6,13). During the first week, exfoliation of fibrin layer was observed and complete re-epithelialization occurred. Gingiva has a healthy appearance without any infection, swelling and scarring. After the second week, translucent and nonkeratinized epithelium was seen, and the gingival color, compared to the neighboring untreated gingiva was reddish. At week four, the gingiva was same as the normal untreated gingiva (5,6,13). The similar results were obtained by this research group (Figures 1 and 2). While some comparative studies (Er:YAG vs diode laser) revealed no difference between groups regarding wound healing (14), some of the authors mentioned prolonged healing and higher injury score following Er:YAG laser when compared to diode (14). The authors explained this difference in wound healing by the fact that these laser

Figure 1. Case presentation of Er:YAG laser melanin depigmentation. a) Male, 28 years old. Generalized severe melanin hyperpigmentation in the upper arch, on the first visit, b) Er:YAG laser microsurgery for melanin depigmentation. The use of surgical microscope facilitates the thorough detection and near-complete elimination of small areas of remaining pigmentation, as well as careful irradiation of the delicate area of the gingival margin and papilla, c) During irradiation with local anesthesia, 40 mJ/pulse at tip end (70 mJ/pulse on the control panel) and 30 Hz under water spray in oblique contact mode using an 80 degree curved contact tip, d) immediately after Er:YAG laser melanin depigmentation, no severe thermal injuries such as carbonization and severe coagulation of the gingival tissue, e) 1 week postoperatively, ablated gingiva showed fast epithelialization with a healthy appearance, f) 4 weeks postoperatively, complete healing was observed without recurrences or gingival recessions or deformities (Case details from Akira Aoki).

Figure 2. Melanin hyperpigmentation of upper arch. a) Before and b) 4 weeks after Er:YAG laser irradiation

types have completely different absorption coefficients and suggested an overall subjective preference of the diode laser by patients, as measured by questionnaires (14). When Er:YAG laser was compared to CO_2 laser (15,17), CO_2 laser demonstrated carbonization, prolonged wound healing and scarring due to its specific wavelength. Therefore, Er:YAG laser was suggested as more pleasant and with better aesthetic results (11,15). Hemostatic effects and enhanced wound healing following Er:YAG laser irradiation can be partly explained by LLLT effects (8–11).

Evaluating the pain following Er:YAG laser

All articles used visual analogue scale (VAS) score for pain assessment. Pain assessment was used using 10-cm (100 mm) horizontal continuous scale marked “no pain” on the left and “maximum pain” on the right side of the scale. The scores were as follows: no pain (0), slight pain (0.1–3.0 mm), moderate pain (3.1–6.0 mm), and severe pain (6.1–10 mm). Only, Simşek Kaya et al. (12) used a self-administered modified version of Melzack’s McGill Pain Questionnaire (1-not at all; 2-mild; 3-moderate; 4-severe; 5-very severe). Er:YAG laser treatment mostly required topical anesthesia only (5,6,15) and local anesthesia upon patients request (6,14), while in some cases anesthesia was not applied at all (12,13,17) (Table 1). None of the patients experienced severe pain, just mild itching, minimal or mild pain during the treatment and none reported using postoperative painkillers. VAS for Er:YAG laser treated sites demonstrated the least amount of pain during and after operation (0.1–3.0). In comparative studies, when Er:YAG laser was compared to diode laser (12,14), no significant difference was observed. Both laser treatment groups had overall mild pain recorded (average pain scores were 1.4 for diode and 1.5 for Er:YAG laser). Pain sensations were especailly increased when consuming acidic, salty or hot foods on the day of the irradiation. Hegde (15) measured the pain for three techniques (surgical stripping/Er:YAG laser/CO_2 laser). One day after the operation, a significantly lower amount of pain following Er:YAG laser in comparison with surgical stripping and CO_2 laser was demonstrated (at the same time, no significant differences were noted among surgical stripping and CO_2 laser). The same result was demonstrated by Kishore et al. (17), who reported that VAS showed that most of the Er:YAG treated sites had slight pain whereas CO_2 laser treated patients reported slight to moderate pain and two patients complained of severe pain (6.1–10). When pain was considered Er:YAG outscored CO_2 laser.

Er:YAG laser has the least thermal damage and least tissue penetration (1μm), resulting in low tissue necrosis, and thus pain reduction. Possible explanation for the decreased pain during Er:YAG laser irradiation could be due to the protein coagulum that is formed on the wound surface (acting as a biological dressing) or due to the sealing of the ends of sensory nerves (17). Decreased pain, called “laser analgesia” can partly occur as a result of LLLT (18). Clinicaly observed analgesia was further confirmed by *in vivo* studies, wherein LLLT could decrease the firing frequency of nocioceptors, therefore causing analgesia (18).

Evaluation of melanin recurrence/repigmentation following Er:YAG laser

Even though the initial results of gingival depigmentation by Er:YAG laser are highly encouraging, the common issue is recurrence of pigmentation/repigmentation (6,13,18). Repigmentation rate is strongly influenced by ethnic (Africans, East Asians and Hispanics), genetic, hormonal factors as well as smoking (6,18,19). It is believed that repigmentation may be attributed either due to high activity of melanocytes or due to incomplete ablation of melanocytes during surgery (due to close proximity of the adjacent teeth), which starts with migration of melanocytes from the adjacent free gingiva to the treated areas (2–10). Therefore, in order to prevent the “migration effect” from residual melanocites, high attention should be given to ablate as much melanocites in the periphery as possible. Usually, slight repigmentation can be observed at 6 months post-operatively (Table 1). In our study, the available studies demonstrated that the depigmentation was achieved uniformly. Three out of seven studies reported melanin repigmentation free surfaces even at 6 months of post-op (Table 1). However, in comparative studies where Er:YAG laser was compared either with CO_2 laser or surgical stripping, the least satisfying results regarding repigmentation were on the Er:YAG laser side. The repigmentation that appeared was reported to be in the form of small dots in the interdental areas on the attached gingiva, easily measured by available indices: Dummett oral pigmentation index/DOPI for intensity of pigmentation, melanin index, melanin pigmentation index, and gingival pigmentation index for extent of pigmentation (12,19). Hegde et al. demonstrated almost 30% of the recurrence in Er:YAG laser treated sites, according to the histological evaluation (15). The changes in DOPI and Hedin indices from the baseline to 6 months were almost similar with all the techniques at six postoperative months (90.0% for surgical stripping sites, 84% for Er:YAG, and 82.7% for CO_2 laser treated sites). Similarly, when Er:YAG laser was compared to diode laser, incomplete ablation of the gingival epithelium in Er:YAG laser irradiation sites with some remaining deeper gingival mucosal injuries was reported (14). The author favorized the use of diode laser when compared with Er:YAG (14). Contrarily, Simşek Kaya et al. rated gingival depigmentation by diode and Er:YAG laser as satisfactory by patients and the operator after a follow-up (12). Further, Rosa reported a slight melanin recurrence following Er:YAG in one out of five patients, who was a smoker (6).

Conclusion

Depigmentation of gingival melanin pigmentation can be performed safely and effectively by Er:YAG laser resulting in eventful wound healing and esthetically significant improvement of gingival discoloration with no side effects or complications. Thus, Er:YAG laser seems to be safe and useful in melanin depigmentation procedure. However, the main issue in giving the final conclusion regarding the optimal use of the Er:YAG laser use in gingival melanin depigmentationis remains the fact that the available studies are mostly case

Table 1. Effects of Er:YAG laser on gingival melanin depigmentation (RCT- randomized controlled trials, LP mode- long pulse mode, CW- continuous wave, PW- pulsed wave).

Name of the author and the year of the publication	Study design	Number of patients	Laser device (wavelength)	Laser settings	Use of anesthesia in Er:YAG treated sites	Follow up	Repigmentation/ recurrence	Findings
Tal H. et al. (2003, 5)	Case presentations	10	Er:YAG laser (2940 nm)	500 mJ/10 pulses/second defocused mode	Yes (the topical)	6 months	No	● No severe pain (during the first week postoperatively) ● Healing uneventful, no need for supportive therapy
Rosa DS. et al. (2007, 6)	Case presentations	5	Er:YAG laser (2940 nm)	64.0 mJ/pulse (panel setting 100 mJ/pulse; 8.5 J/cm^2 per pulse) and 10 Hz under water spray in oblique contact mode	Yes (the topical and local/2% lidocaine)	Immediate, 24 h, 1 week, 1 and 3 months	Yes	● Patients expressed moderate to slight pain postoperatively ● Healing uneventful (within 1 week)
Azzeh MM. (2007, 13)	Case presentations	6	Er:YAG laser (2940 nm)	250 mJ, 15 Hz, with water and air and using the defocused non-contact mode (1 cm away from the tissue)	No	6–18 months	No	● No discomfort, pain, or bleeding complications during and after operation ● Healing uneventful (within 4 days)
Simşek Kaya G. et al. (2012, 12)	RCT comparative study (Er:YAG vs diode laser)	20	Er:YAG (2940 nm) Ga-Al-As diode (808 nm)	Er:YAG laser: 1W, non-contact mode (5 mm away from the tissue) Diode laser: 1W, CW	No	Diode laser: up to 96 months Er:YAG laser: up to 36 months	No	● The total length of treatment was significantly shorter with the diode than with the Er:YAG laser ● Diode and Er:YAG lasers were both satisfactory regarding healing
Hegde R. et al. (2013, 15)	Comparative study (Er:YAG vs CO_2 laser vs scalpel)	35	Er:YAG (2940 nm) CO_2 (10600 nm)	CO_2: 2–4 W, CW, defocused mode Er:YAG: 10 Hz, 180 mJ, LP mode, total power of 1.8 W, defocused mode	Yes (the topical/ lignocaine hydrochloride spray)	1 day, 1 week, 1, 3 and 6 months	Yes (mostly in Er:YAG laser group)	● CO_2 laser- carbonization, prolonged wound healing and scarring ● Er:YAG laser- the least amount of pain during and after the operation ● Patients' preference: Er:YAG laser
Gianelli M. et al. (2013, 14)	RCT	21	Er:YAG laser (2940 nm) Diode laser (810 nm)	Er:YAG laser: 100 mJ, 10 Hz, LP mode (400μs), fiber diameter 0.8mm Diode laser: 0.6 W, 69 mJ, PW, pulse duration 18 ms, fiber diameter 0.6 mm	No	0, 7, 30 and 180 days	Yes (mostly in Er:YAG laser group)	● No severe pain during operation or postoperatively ● Delayed healing in Er:YAG laser treated sites
Kishore A. et al. (2014, 17)	Comparative study (Er:YAG vs CO_2 laser)	20	Er:YAG (2940nm) CO_2 (10600nm)	Er:YAG laser: 180mJ, 10 Hz, LP mode, total power of 1.8 W, no water, no air defocused non-contact mode CO_2 laser: 2–4 W, CW, defocused non- contact mode	No	1, 7, 30, 90 and 180 days	Yes	● Both treatment modalities are highly effective, excellent esthetics results ● Regarding pain and wound healing Er:YAG was considered better than CO_2 laser

reports and presentations, as well as some randomized clinical trials (RCTs). The studies offer completely different laser procedure protocols (complex settings of laser parameters), and criteria for the assessment of depigmentation and repigmentation, thus hampering comparison of the results and making a final conclusion even more difficult. Therefore, further studies are necessary to give an optimal recommendation on the use of Er:YAG laser in gingival melanin hyperpigmentation.

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