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Technical procedure

Novel flapless esthetic procedure for the elimination of extended gingival metal tattoos adjacent to prosthetic teeth: Er:YAG laser micro-keyhole surgery

Koji Mizutani [a], Risako Mikami [a], Akira Tsukui [b], Shigeyuki Nagai [c], Verica Pavlic [d,e], Wataru Komada [f], Takanori Iwata [a], Akira Aoki [a,*]

[a] Department of Periodontology, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University (TMDU), Tokyo, Japan

[b] Hillside Dental Clinic, Kanagawa, Japan

[c] Nagai Dental Clinic, Tokyo, Japan

[d] Department of Periodontology and Oral Medicine, Medical Faculty University of Banjaluka, Bosnia and Herzegovina

[e] Department of Periodontology and Oral Medicine, Institute of Dentistry, Banja Luka, Bosnia and Herzegovina

[f] Fixed Prosthodontics, Division of Oral Health Sciences, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University (TMDU), Tokyo, Japan

Abstract

Purpose: This article describes a novel, minimally invasive procedure called Er:YAG laser micro-keyhole surgery (EL-MIKS) that removes metal or amalgam tattoos in the gingiva adjacent to prosthetic teeth without gingival deformity and recession. We aimed to evaluate the clinical efficacy of EL-MIKS for removing metal tattoos and present its long-term treatment outcomes.

Methods: The EL-MIKS procedure consists of several steps that are all performed under a microscope. First, a micro-keyhole (1-2 mm diameter) was prepared using an Er:YAG laser in the center of the metal pigmentation. The connective tissue was evaporated in the deep layer, where metal debris was deposited. Second, within the accessible range, the irradiation angle was changed in various directions to ablate the metal pieces and discolored connective tissue without enlarging the keyhole. Finally, after blood filled the space created by the tissue evaporation, the surface of the blood clot at the entrance of the micro-keyhole was thermally coagulated with defocus laser irradiation. Pigmentation that could not be successfully removed from a single micro-keyhole was treated by forming new micro-keyholes at a distance of 3 mm or more from each previously created hole. Depigmentation over an extended area was completed over a few sessions every 4 weeks without gingival recession after surgery.

Conclusion: EL-MIKS, a novel depigmentation technique, was able to successfully remove an extended area of metal tattoos in the gingiva using a simpler, easier, and less invasive procedure than conventional periodontal plastic surgery. Esthetic restoration was successfully achieved without postoperative alteration of the gingival contour.

Keywords: Esthetic, Laser, Metal tattoos, Minimally invasive, Pigmentation

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1. Introduction

The ultimate goal of esthetic restorative dentistry is to restore the esthetics of the teeth and establish a healthy harmony with sound periodontal tissue [1]. Removal of gingival discoloration, caused by excessive melanin deposition or metal tattoos, is a common esthetic demand. Melanin deposits are endogenous and located mainly in the basal and suprabasal cell layers of the oral epithelium [2]. On the other hand, a metal or amalgam tattoo is found adjacent to teeth with prosthetics [3,4]. Therefore, metal tattoos are iatrogenic and are related to the preparation of metal abutments for crown restoration. Since melanin deposits are mainly located on the surface of the gingiva, numerous procedures have been developed for depigmentation, such as epithelial abrasion, free gingival graft, gingivectomy, cryosurgery [5], and laser surgery [6]. However, few studies have been conducted on the removal of metal tattoos. Furthermore, while studies on periodontal plastic surgery have reported methods, such as the use of free gingival grafts [7] and connective tissue grafts [8-10] to remove metal tattoos, optimal treatments have not been well studied or established.

To date, laser ablation has been recognized as one of the most effective and reliable minimally invasive treatment options for the removal of metal tattoos [11,12]. In 2004, our research group report-

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***Corresponding author:** Akira Aoki, Photoperiodontics, Department of Periodontology, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University (TMDU), 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8549, Japan.
E-mail address: aoperi@tmd.ac.jp (A. Aoki).

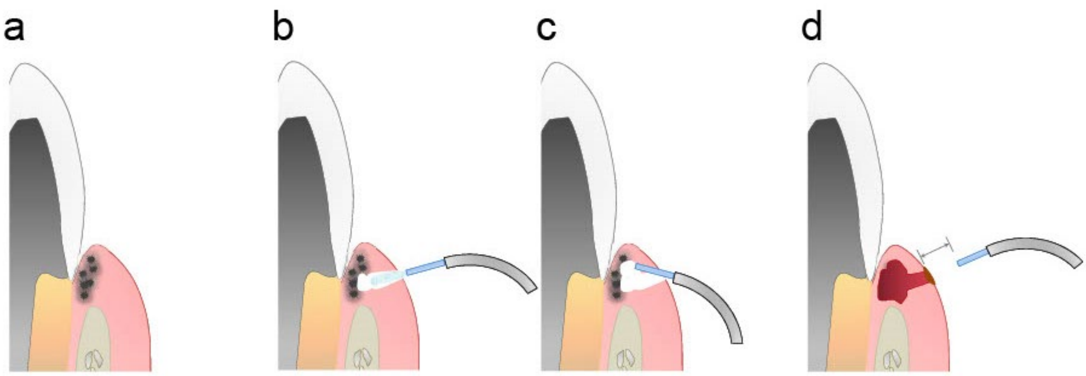

Fig. 1. Step-by-step procedure of Er:YAG laser micro-keyhole laser surgery (EL-MIKS) for removing metal tattoos in the gingiva adjacent to prosthetic teeth (a). Making a small keyhole with a diameter of 1-2 mm to access the pigmented gingiva to ablate metal fragments and the surrounding discolored connective tissue using an Er:YAG laser (b). Shifting the laser direction to ablate the metal and surrounding tissue. Eliminate micro-metal fragments as much as possible through the keyhole so as not to expand the size of the keyhole. Carefully preserve the overlaying gingiva of the discolored tissue intact (c). After the tissue evaporation, the ablated space fills with blood. Defocus irradiation (10 Hz, 60 mJ) without a water spray to the micro-keyhole entrance with more than 5 mm distance between the laser tip and gingiva (double-headed arrow) was performed. The coagulation of the blood surface is encouraged by a laser-derived heat reaction. The blood clot is stabilized within the evaporated space (d). If the pigmentation is widespread, the area to be treated must be divided into several parts that are treated one by one. Micro keyholes are prepared to access the center of each part.

ed efficient metal tattoo removal using an erbium-doped yttrium aluminum garnet (Er:YAG) laser combined with a microscope for the first time [13]. Er:YAG lasers have been used in various periodontal therapies [14-16], such as soft tissue incision [17], granulation tissue ablation [18], calculus removal [19], and bone cutting [20-22]. The Er:YAG laser has a wavelength of 2940 nm which is superficially absorbed in tissues that contain water molecules [14,23]. This results in minimal thermal damage to the lased tissue [17], no pain [24,25], and favorable soft tissue healing [14]. Er:YAG laser irradiation with a thin contact tip and coaxial water spray yields a fine procedure under a microscope. It is a minimally invasive treatment [14-16] that enables selective removal of pigmented connective tissue and metal fragments [13]. Recently, we proposed that the application of the minimally invasive Er:YAG laser technique for metal tattoo removal resulted in improved esthetics [26]. Consequently, in this study, we developed a novel, minimally invasive technique for metal tattoo removal called Er:YAG laser micro-keyhole laser surgery (EL-MIKS). This procedure can help preserve the gingiva that overlies the pigmentation to a large extent. Additionally, using case series data, we aimed to evaluate this improved technique's clinical efficacy and the long-term treatment outcomes.

2. Materials and methods

2.1. Indication

This procedure was developed for esthetic recovery from blue-gray pigmentation in the gingival tissue called metal or amalgam tattoos. It can be challenging to distinguish between a metal tattoo and melanoma based only on anamnesis and clinical appearance. In such cases, a preliminary oral biopsy of the pigmented gingiva may be necessary [27,28]. However, in the present study, a metal tattoo was diagnosed based on anamnesis and clinical appearance. Therefore, biopsies were not performed.

2.2. Devices

The EL-MIKS procedure utilizes an Er:YAG laser device (Erwin Adveal, Morita Inc., Japan). The Er:YAG laser is characterized by a wavelength of 2940 nm, which can efficiently evaporate soft tissue without visible thermal damage by implementing water spray cooling during irradiation. Bleeding and debris in the surgical field can be flushed with a sterile saline spray coaxial with the laser. In this study, a cylinder-shaped curved contact tip with a diameter of 400 μm (C400F, Morita Inc., Japan) was used. In addition, a microscope (M320, Leica , Solms, Germany) at a magnification of 20x was used to make the micro-keyholes as small as possible to successfully ablate metal fragments and discoloration.

2.3. Procedures

The step-by-step procedure is shown in **Figure 1**. Treatments were performed using an Er:YAG laser (panel setting parameters: 20 Hz, 60-80 mJ with water spray) (**Fig. 2a**). First, a keyhole with a diameter of 1-2 mm was prepared in the center of the pigmentation area under local anesthesia with 0.2-0.45 mL of lidocaine. (**Fig. 2b**). Then, the deposited metal fragments and surrounding discolored tissue in the deep layer of the connective tissue were removed (**Fig. 2c**). In cases where the pigmentation is close to the root surface, the laser should be used cautiously to avoid perforating the thin gingiva and, consequently, ablating the root surface. Second, the irradiation angle was changed to evaporate the adjacent discolored tissue and prevent expansion of the keyhole entry point. The accessible metal pieces and surrounding pigmented connective tissue were then carefully evaporated. The gingiva in the margin area of the keyhole was retracted with a contact tip or periodontal probe so that the inside could be seen under a microscope. The water spray synchronized with laser irradiation caused the metal pieces to flow out of the keyhole (**Fig. 2c**). Third, the irradiation angle was repeatedly changed in various directions through one micro-keyhole to evaporate the pigmented tissue as much as possible. Er:YAG laser irradiation using a water spray has a low hemostatic effect, resulting in moderate bleeding from the lased tissue (**Fig. 2d**). After the space created by the tissue evaporation was filled with blood, defocus irradiation (10 Hz, 60 mJ at panel setting) without the water spray was performed. At the micro-keyhole entrance, the surface of the blood was coagulated by heat to form a blood clot in the evaporated space.

If the range of pigmentation is vast, additional micro-keyholes can be prepared at a distance of 3 mm or more from the already

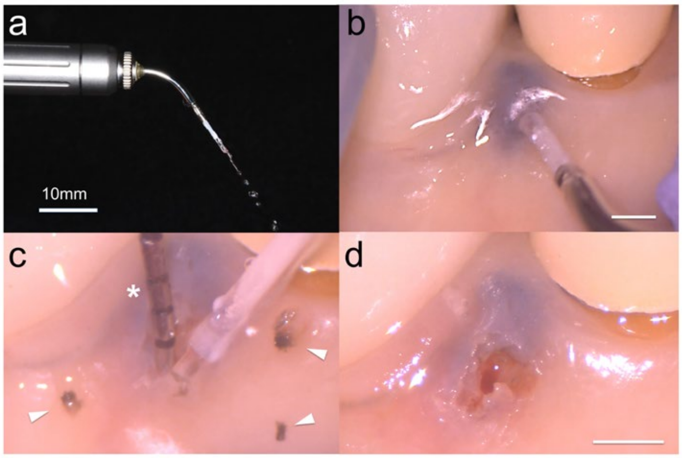

Fig. 2. Laser apparatus and photographs of the surgical field under a microscope during Er:YAG laser micro-keyhole laser surgery (EL-MIKS). Er:YAG laser irradiation with coaxial water spray for cooling of the lased area through a cylinder-shaped curved contact tip (diameter 400 μm). Bar: 10 mm (a). A keyhole with a 1-2 mm diameter was prepared in the center of the pigmented gingiva using an Er:YAG laser (20 Hz, 80 mJ) with a thin contact tip and coaxial water spray. Magnification: 12.5x; bar: 1 mm (b). Carefully evaporate the accessible metal pieces and the discolored connective tissue surrounding them through the micro-keyhole. Note that some of the eliminated metal pieces can be observed (arrowheads). To see the inside, the marginal gingiva of the keyhole is retracted with a periodontal probe (asterisk). Magnification 20x (c). Immediately after the first session, discoloration was partly eliminated by laser irradiation through the micro-keyhole. Magnification 20x; bar: 1 mm (d).

formed micro-keyhole. In the same way, the metal fragments and discolored connective tissue within the range accessible from the newly prepared micro-keyhole should be removed. If the distance between the micro-keyholes is not sufficiently secured, the gingiva will collapse after the operation. Therefore, treatment should be completed over a series of sessions. After 4 weeks, the same procedure can be performed on the remaining pigmented sites after confirming that the gingiva at the treatment site has completely healed.

2.4. Evaluation

The collection of clinical data from the patients' medical records for this study was conducted in accordance with the Helsinki Declaration of 1975 as revised in 2013 and approved by the Dental Research Ethics Committee of Tokyo Medical and Dental University (Approval number: D2020-20). Informed consent was obtained from each patient prior to treatment.

The treatment time was measured from the preparation of the micro-keyholes to the completion of hemostasis. Postoperative pain was evaluated by the number of analgesics taken on the day of treatment and pain on the first day after surgery using the visual analog scale (VAS) as a patient-reported outcome. An intraoral photograph was taken, and the ratio of the total area of the micro-keyhole to the area of the pigmented gingiva was calculated using ImageJ software.

2.5. Case 1

A representative case of EL-MIKS on a widespread metal tattoo is shown in **Figure 3**. Case 1 was a 61-year-old woman who visited the Periodontics Clinic, Dental Hospital of Tokyo Medical and Dental University, with a chief complaint of impaired esthetics at the anterior part of the maxillary gingiva. An extensively widespread metal tattoo was found on the lateral right maxillary incisor gingiva (# 12). The Er:YAG laser ablation was set at 20 Hz, 80 mJ (panel setting) with a saline spray. Because the pigmentation was widespread, the area to be treated was divided into several parts. Micro-keyholes were prepared to access the center of each part. In this case, the distal part with the most severe discoloration was treated first. During the first session, only the distal pigmentation of the apical part was treated through one perforated micro-keyhole. During the second session, the mesial and buccal middle and distal pigmentation of the coronal part were treated using five newly perforated spaced micro-keyholes. The remaining pigment and metal from the deep gingival region that could not be completely removed were mostly eliminated through four newly formed micro-keyholes during the third session. The remaining gingival discoloration following the third session spontaneously disappeared with gingival turnover during the healing period. Postoperatively, the gingiva had a healthy appearance without infection, swelling, recession, or deformities. The patient reported almost no postoperative pain at any stage of the treatment and was very satisfied with the esthetic improvement of the gingival appearance and color. Three months following the EL-MIKS procedure, an all-ceramic crown was placed on the upper lateral right incisor. Periodontal maintenance therapy was scheduled every 3 months. Two years after the procedures, the improved gingival color was maintained, and the patient was esthetically satisfied with the treatment.

2.6. Case 2

Another representative case of metal tattoo removal around multiple teeth is shown in **Figure 4**. Case 2 was a 51-year-old woman who visited the Periodontics Clinic, Dental Hospital of Tokyo Medical and Dental University, with a chief complaint of pigmented gingiva of the upper arch. Metal tattoos were observed in the interdental gingiva of the left lateral incisors (#22), a canine (#23), and the gingiva around the pontic of the first premolar (#24). Gingival pigmentation occurred immediately after the placement of metal abutments and porcelain-fused metal crowns and did not improve after replacement with resin cores and all-ceramic crowns a few months later. The patient was diagnosed with mild periodontitis (anterior teeth periodontal pocket depth: 2-3 mm, bleeding on probing). Initial periodontal therapy consisted of supra- and subgingival scaling and root planing (SRP) and instructions on brushing and oral hygiene. Two weeks following SRP, EL-MIKS was performed with a microscope under local anesthesia (0.2 mL of lidocaine). The Er:YAG laser was set at 20 Hz and 80 mJ with a saline spray. The procedure was divided into two sessions. In the first session, approximately half of the pigmented areas in each spot were treated using three perforated micro-keyholes. The patient reported slight postoperative pain and was prescribed one tablet of analgesic. In the second session, the residual pigmentation was treated using four new micro-keyholes. Postoperatively, after regression of the inflammatory gingival swelling, a slight gingival recession was observed on tooth #22. Periodontal maintenance therapy was scheduled every 3 months. Two years after the second session, the gingival pigmentation had completely disappeared and been maintained. The patient was esthetically satisfied with the treatment.

3. Difference from conventional methods

The novel modality EL-MIKS is different from the previously reported procedure combined with periodontal plastic surgery [7-10]. It is much less invasive, results in less intraoperative and postopera-

Fig. 3. A representative case of Er:YAG laser micro-keyhole laser surgery (EL-MIKS) on a widespread metal tattoo (a). The patient was a 61-year-old female with a prominent metal tattoo in the gingiva of #12 (b). Because the pigmentation was widespread, the area to be treated was divided into several parts (dotted line). Micro-keyholes were prepared to access the center of each part. In this case, the distal part with the most severe discoloration was treated first (c). All procedures were performed with a microscope and Er:YAG laser under local anesthesia. Immediately after the first session, only the apical part of the distal pigmentation was treated through one micro-keyhole (arrowhead) (d). One month after the first surgery, the area treated in the first session was completely epithelized (e), and treatment of the distal pigmentation of the coronal part and mesial, buccal middle areas were partly performed through five micro-keyholes (arrowheads) in the second session (f). One month after the second session (g), the deposited pigments in the deep mesial region were removed through four micro-keyholes (arrowheads) in the second session (h). At one month after the third session, the pigmentation slightly remained (i). Three months after the third session, the gingival pigmentation had completely disappeared. Since the metal fragments causing the pigmentation had been removed, the slightly remained discoloration spontaneously disappeared with the gingival turnover. The recession of the marginal gingiva was generally prevented. Note the crown was replaced (j). Two years after the procedures, the improved gingival color has been maintained, and the patient was esthetically satisfied with the treatment (k).

Fig. 4. A representative case of Er:YAG laser micro-keyhole laser surgery (EL-MIKS) on metal tattoos in multiple teeth (a). The patient was a 51-year-old female with mild periodontitis and metal tattoos in the interdental gingiva of #22 to #25 (b). Two weeks after subgingival scaling and root planing, we performed the first procedure using a microscope and Er:YAG laser under local anesthesia. A part of the pigmentation of each tattoo was treated through four micro-keyholes in the first session (c). One month after the first session (d), the pigmentation residual parts were removed through three micro-keyholes (e). One month after the second session, the gingival pigmentation had completely disappeared. Although slight gingival recession was detected in #22, this gradually restored (f). Two years after the second session, the gingival color has been maintained (g), the gingival pigmentation has completely disappeared, and the esthetics improved. The patient was esthetically satisfied with the treatment (h).

Table 1. The time required for the procedures and the number of micro-keyholes in cases 1 and 2. The duration of each session and the total treatment time were shown. The number of micro-keyholes in each session was presented.

		1st session	2nd session	3rd session	Total	Mean
Case 1	Time required (min)	22	32	36	91	30.3
	Number of micro-keyholes	1	5	4	10	3.3
Case 2	Time required (min)	23	43	-	68	34
	Number of micro-keyholes	4	3	-	7	3.5

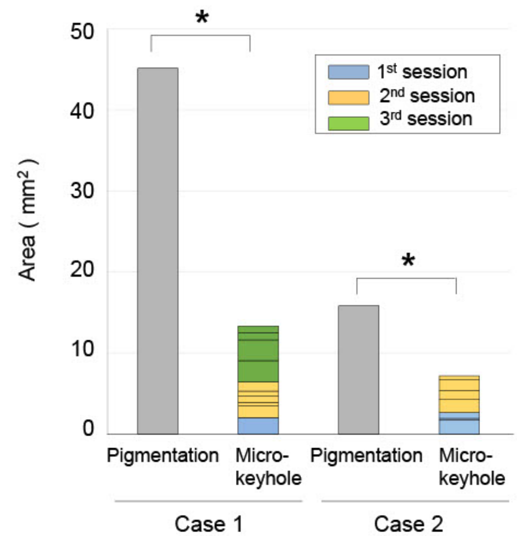

Fig. 5. The area of preoperative gingival pigmentation and surgically-formed micro-keyholes. Elimination of the gingival metal tattoos was achieved with three and two sessions in cases 1 and 2, respectively. In both cases, the total micro-keyhole area was significantly smaller than the area of the pigmentation site.

tive pain, and has a short treatment time followed by fast and favorable wound healing, as well as excellent esthetic improvement. Using a microscope, metal debris removal and tissue evaporation can be selectively and accurately performed with a fine laser tip. In addition, the micro-keyhole preparation technique can minimize therapeutic injury to the gingiva. Micro-keyhole preparation is a unique technique that has not been previously used to remove expansive discolored tissue with metal fragments from the deep connective tissue layer through small access holes. In our previous laser treatment [26], discolored tissue was ablated by preparing grooves along the band-shaped, occasionally long, pigmentated area. Most of the epithelium was ablated in the treated area. Thus, if the pigmentation was widespread, the previous ablation technique was not effectively applicable, and there was also a high risk of postoperative gingival defect or deformity due to the relatively large wound. On the contrary, EL-MIKS can conservatively and efficiently eliminate widespread discoloration by omnidirectionally ablating subepithelial pigmented tissue from multiple micro-keyholes. Since EL-MIKS preserves the epithelium to a large extent in the surgical wound, it can securely maintain blood clots within the subepithelial space and enhance the recovery of blood flow from the surrounding tissue. As a result, the risk of postoperative gingival recession and deformity is greatly reduced, even in cases involving widespread metal tattoos. For this procedure, the use of a microscope is essential for the proper treatment of the inner connective tissue underlying the preserved gingiva through the micro-keyhole. The procedure is technically more sensitive to a surgeon's proficiency in microsurgery. Repeated inspection of the presence of metal micro-pieces could not be performed efficiently without a microscope. EL-MIKS can also help prevent gingival recession, defects, and deformities. Since the area and volume of tissue ablation in a single treatment session are limited, extensive pigmentation is treated over multiple sessions. After confirming that the treated gingiva has completely healed, the residual pigmentation sites can be treated using further micro-keyholes. The keyhole must be as small as possible to retain the blood clot inside the wound and prevent undesirable postoperative gingival deformity due to tissue ablation.

4. Effect or performance

The average duration of each operation was 30.3 and 34.0 min, and the total treatment time was 91 and 68 min in cases 1 and 2, respectively (**Table 1**). The patients reported VAS scores of 0 on the day of treatment and the following day. In case 2, one analgesic tablet was administered following the first treatment, but no additional tablets were administered after the following sessions. The average area of the micro-keyholes was 1.3 ± 0.8 mm^2 in case 1 and 1.2 ± 0.6 mm^2 in case 2. The ratio of the keyhole area to the area of the colored gingiva was calculated (**Fig. 5**). In both cases, the micro-keyhole area was significantly smaller than the pigmentation site (29.5% in case 1 and 45.4% in case 2). By preserving a large amount of intact overlying gingiva, extensive pigmentation could be removed with little gingival recession and without gingival deformity. These findings suggest that even though visibility was limited due to the minimized surgical area, the microscope visibility was accurate and enabled the micro-metal fragments to be accurately removed. No recurrence or complications were observed after 2 years of follow-up. Thus, this novel surgical modality can be considered clinically safe and effective, as in our previous case reports of metal tattoo removal with an Er:YAG laser [13,26].

Based on the above results, it can be concluded that EL-MIKS is a simpler and easier gingival depigmentation modality than conventional plastic surgery, such as gingival grafting. Free gingival or connective tissue grafts require two surgical sites (donor and recipient sites). In contrast, in EL-MIKS, the surgical site was limited to the pigmented site. Furthermore, EL-MIKS does not require suturing since the gingival flap has not been elevated, and EL-MIKS provides rapid hemostasis during laser irradiation. The simplicity of the presented modality directly reduces the time required for treatment and might reduce the burden on the patient and operator, especially benefiting general practitioners who are not familiar with periodontal surgery. The second advantage of EL-MIKS is less postoperative pain. This is consistent with the characteristics of Er:YAG laser treatment. Previous *in vivo* [24,25] and clinical studies [29] have shown that soft tissue treatment associated with periodontal therapy using Er:YAG or Er,Cr:YSGG lasers is less painful than conventional treatment methods. Third, the esthetic risk of alteration of gingival contours, such as recession, defects, and deformity, can be avoided. Since the amount of tissue ablated in each treatment session is limited, the ablated defect size is so small that the adjacent gingiva can maintain the tissue volume like a wall. As a result, significant changes in gingival morphology are unlikely to occur. However, this technique has several disadvantages, including the need for multiple treatment sessions and a healing period between them. While the short treatment time of each session results in less discomfort for the patient, the cumulative treatment time is longer, with more than a couple of hours required to complete all of the sessions. Second, the procedure is an operator-dependent technique due to the minute surgical field. Therefore, training and experience in laser-based microsurgery are required.

With the performance of minimally invasive and quick procedures such as EL-MIKS, both the patient and operator's stress can be significantly reduced, and patient satisfaction improved. More minimally invasive dental care procedures will be needed in the future, particularly as many countries have aging societies that may require some form of dental treatment, including periodontal therapy [30] and treatment for other age-related chronic conditions and diseases [16]. Following the consensus report on dental caries and periodontal diseases in aging populations [31], dental care should be modified so that pain-free, functional dentition can be maintained using minimally invasive and/or palliative treatment strategies. In the future, well-designed clinical studies will be needed to verify the benefits of this modality and establish it as the optimal minimally invasive approach for the removal of metal tattoos.

5. Conclusion

EL-MIKS is a novel technique that safely and effectively removes an extended area of metal tattoo pigmentation in the gingiva less invasively than conventional periodontal plastic surgical approaches. Postoperative pain and alteration of the gingival contour were negligible, and esthetic improvement was successfully achieved.

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Conflicts of interest

The authors declare no conflict of interest. The authors do not have any financial interest in the companies whose materials are included in this article.

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