Examining the Histopathological Effect of Er,Cr:YSGG Laser in the Treatment of Oral Benign Soft Tissue Lesion

Zainab Fadhil Odah[1], Hanan Jafer Taher[2], Ammar Saleh Alalawi[3]

[1]Medical And Biological Applications Branch, Institute of Laser for Postgraduate Studies, University Of Baghdad, Baghdad, Iraq, Zainab.Awda2102m@Ilps.Uobaghdad.Edu.Iq
[2]Photonics Units, Institute of Laser for Postgraduate Studies, University of Baghdad, Baghdad, Iraq, Hanan@Ilps.Uobaghdad.Edu.Iq
[3]Laser Surgery Unit/Department of Maxillofacial Surgery/Al-Emamein Al-Kadhemein Medical City, Baghdad, Iraq, Amzain225@Yahoo.Com

Studying the effect of Er,Cr:YSGG laser histologically can help in improving the treatment of benign soft tissue overgrowths of oral cavity. As this current research project progresses, our findings may support the potential use of Er,Cr:YSGG laser devices for overall dental treatment. This could lead to a reality in which precision and innovation collaborate to enhance patient outcomes.

Keywords: Oral benign soft tissue lesions; Er,Cr: YSGG; laser, thermal damage, excisional biopsy, desiccation, carbonization.

1. Introduction

Various tumors and tumor-like growths, which can be either non-cancerous or cancerous, are commonly found in the mouth. Accurate diagnosis of oral mucosa lesions requires careful consideration of their color, location, size, shape, and a comprehensive clinical history. Nevertheless, the definitive diagnosis is confirmed through histological investigation of the injured tissue.(1)

Oral lesions can impact oral health by causing pain or discomfort that hinders speech, swallowing, and chewing.(2) Several surgical techniques, including the use of conventional scalpels, electrosurgical scalpels, and lasers, can be used to remove these lesions.(3)

In soft tissue surgery, the surgical blade has long been a standard instrument. Despite the fact that it is accurate, quick, inexpensive, simple to use, and causes little harm to the surrounding tissues, it cannot provide the blood-free environment required for highly vascularized tissue procedures. On the other hand, a novel technique for soft tissue surgery in the mouth is the use of lasers. The primary distinction between surgical blades and lasers is that the latter is considered a minimally invasive technique with several advantages, including excellent wound recovery, minimized after surgery pain and swelling, decreased scarring and tissue shrinkage, enhanced visibility in the surgical area, accurate cutting, hemostasis, minor cicatrization, better infection control, fewer tools at the site of operation, and increased satisfaction among patients.(4–6) But there are also disadvantages to this approach, such as the high cost of the equipment, the requirement for specific training in the therapeutic application of different lasers, and the risk of heat damage.(7)

While absorption is the ideal result, the nature of the laser-tissue interaction is based on the properties of the tissue as well as the laser, particularly its wavelength. The target tissue's absorption coefficient and the laser's particular wavelength determine the total penetration depth of laser light. As a result, different wavelengths affect different tissues therapeutically and have varying thermal penetration depths.(8,9)

In the photothermal interaction mechanism, lasers interact with particular tissue chromophores, is the basis for the laser's soft tissue cutting effect. This effect causes the targeted tissues to heat up and vaporize, which in turn causes tissue dissection. This mechanism of action causes a heat effect on the specimen's edges. Numerous studies have been conducted utilizing different lasers and parameters to evaluate the degree of the thermal impact and its influence on histological assessment and interpretation in order to establish a standardized protocol that maximizes the benefits while minimizing the drawbacks of using a laser as a surgical incision tool. This is because reliable and clear edges of obtained samples, particularly of worrisome dysplastic or neoplastic tumors, are important.(10)

With a wavelength of 2780 nm, the Er,Cr:YSGG laser, a member of the Erbium family, is categorized as a hard tissue laser. Yttrium, Scandium, Gallium, and Garnet (YSGG) doped with Erbium and Chromium makes up this laser system. Its strong water absorption is one of its most notable characteristics; this property makes it easier to apply on soft tissues without causing unfavorable heat damage. Due to this attribute, it has been effectively employed in medical operations concerning non-cancerous soft tissue abnormalities in the oral cavity.(11,12)

This study intends to analyze the histological alterations caused by Er,Cr:YSGG laser treatment in order to provide valuable insights that can assist practitioners in optimizing laser parameters for enhanced therapeutic results. The study focuses on examining detailed tissue reactions to gain an improved knowledge of the therapeutic outcomes.

2. Material and Method

This study, ran from January 1st, 2023, to January 1st, 2024. 22 participants (17 females and 5 males) with exophytic soft tissue lesions of oral cavity were included in the study. They were 17 to 63 years old, their complaints were discomfort and bleeding, thus, laser treatment was suggested. Histopathological analysis using an excisional biopsy technique was used to diagnose the benign lesion. Some of the patients were treated at the laser medical research clinics of the Institute of Laser for Postgraduate Studies at University of Baghdad, while others were treated at Nawar Mousa specialized dental center.

A 2780 nm-wavelength Er,Cr:YSGG laser (Waterlase iplus, Biolase, California, USA) was used to treat each patient), power range from 2.75 W to 3 W, a pulse rate of 75 Hz (energy per pulse 0.036 J/pulse- 0.04 J/pulse), air at 20%, and water at 40%. The MGG6 tip, 600 µm diameter and 6 µm length in H mode (pulse width of 60 µs) was employed, with the laser tip maintained in 1mm away from or direct contact with the oral lesion. After administering local anesthetic (2% lidocaine and a 1:80,000 adrenaline), the lesion or tumor was extracted from its base. Finally, coagulation (laser bandage) was achieved by setting laser at 0.5 W, 30 Hz, 1% water and 20% air, and the tip in non-contact 'S' mode. The wounds after the surgical treatment were healed by secondary intention.

After being quickly fixed in 10 % formalin solution, all excisional biopsies were sent for histopathological analysis to determine the type of lesions, the criteria for the histopathological assessment were: measuring the extent of thermal damage in millimeters, carbonization and desiccation caused by the laser treatment were categorized as follows: a score of 0 corresponds to absence of carbonization and desiccation, while a score of 1 corresponds to presence of them. Analgesics were given to patients as needed after surgery to ensure their comfort and pain control during the healing period.

Histopathological analysis

Biopsy specimens were fixed in a 10% formalin solution, sectioned in slices of 5 µm using a semiautomatic microtome and stained with hematoxylin-eosin for histopathological evaluation. A total of 22 sections were evaluated for thermal damage extent (which was measured as the distance between excised specimen borders and the end of thermal artefacts). In addition to that, the presence and absence of carbonization, and desiccation (which was expressed as a dense eosinophilic layer) were also evaluated. These evaluations made by using Light microscope (GOWE Lab Instrument Laboratory Binocular Head Biological microscope, Japan), camera (5MP USB CMOS Camera Microscope Digital Electronic Eyepiece w/ 0.5X C Mount Lens, mainland China), and software computer program (S EYE 2.0, china). All measurements were done by the same experienced pathologist.

3. RESULTS

The study involved 22 participants with a mean age of 43.0 ± 17.1 years, 77.3% (17) of whom were female and 22.7% (5) were male. The histopathological diagnoses of the lesions were as follows:

- Pyogenic granuloma: 10 (45.5%)

- Fibroepithelial Polyp: 9 (40.9%)

- Plexiform neurofibroma: 2 (9.1%)

- Peripheral giant cell granuloma: 1 (4.5%)

The size of the lesions ranged from 5 to 15 mm, with a mean size of 7.82 ± 3.78 mm. Thermal damage was present in all lesions, with a mean of 0.27 ± 0.07 mm. Carbonization was observed in 7 (31.8%) of the lesions, while desiccation was present in 20 (90.9%) of the lesions.

Table 3.1: Description of the study characteristics (N=22).

Characteristic	**N = 22[1]**
Age (years)	43.0 ± 17.1
Sex	
Female	17 (77.3%)
Male	5 (22.7%)
Histopathological diagnosis of the lesion	
Pyogenic granuloma	10 (45.5%)
Fibroepithelial Polyp	9 (40.9%)
Plexiform neurofibroma	2 (9.1%)
Peripheral giant cell granuloma	1 (4.5%)
Size of the lesion (mm)	7.82 ± 3.78
Thermal damage (mm)	0.27 ± 0.09
Carbonization	7 (31.8%)
Desiccation	20 (90.9%)
[1]Mean ± SD; n (%)	

1Mean ± SD; n (%)

The study parameters were stratified by histopathological diagnosis, revealing the following characteristics:

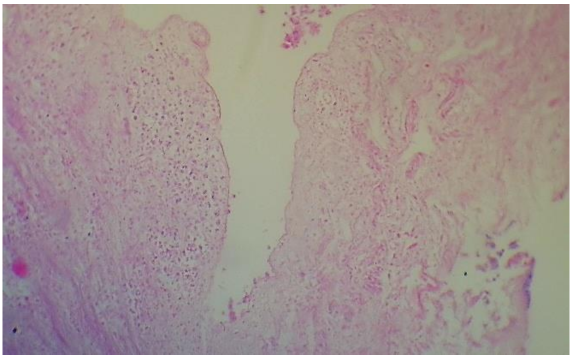

Fig. 1: Pyogenic granuloma, cross- sectional histological view (10x) showing the presence of desiccation as a highly eosinophilic layer and absence of carbonization

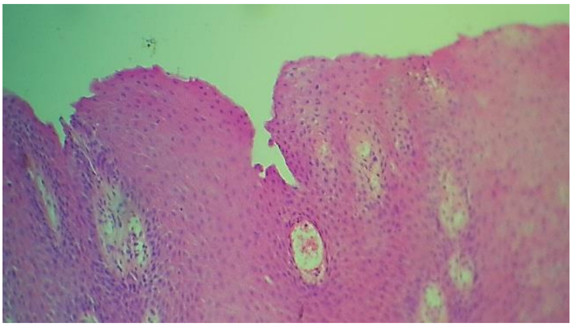

Fig. 2: Pyogenic granuloma, cross- sectional histological view (10x) showing the excision margin with no carbonization or desiccation

The lesions size of fibroepithelial Polyp or fibroma was 6.11 ± 3.33, but the extent of thermal damage in relation to the lesion size was more than that observed with pyogenic granuloma, desiccation observed in all cases and carbonization appeared in 4 cases from a total of 9 cases. (Figure 3)

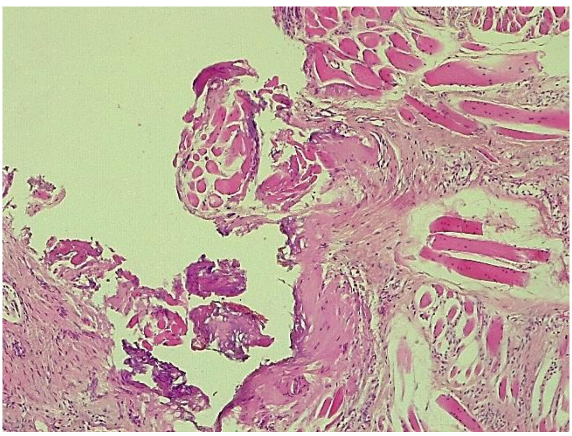

Fig 3: Fibroma, cross- sectional histological view (10x) showing the presence of desiccation along the excision margin as a highly eosinophilic layer

In plexiform neurofibroma cases the extent of the thermal damage was 0.25 ± 0.07mm without carbonization, but desiccation appeared in both cases. (Figure 4)

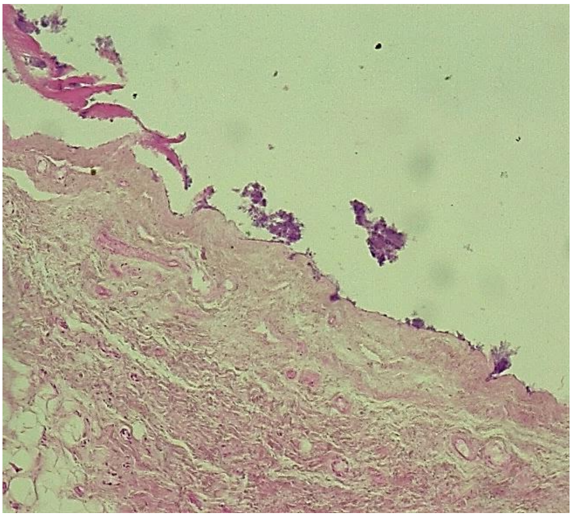

Fig 4: Plexiform neurofibroma, cross- sectional histological view (10x) showing the presence of desiccation along the excision margin as a highly eosinophilic layer

In one case of peripheral giant cell granuloma the thermal damage extent was 0.3 mm (Figure 5) with both carbonization and desiccation at the excision margin.

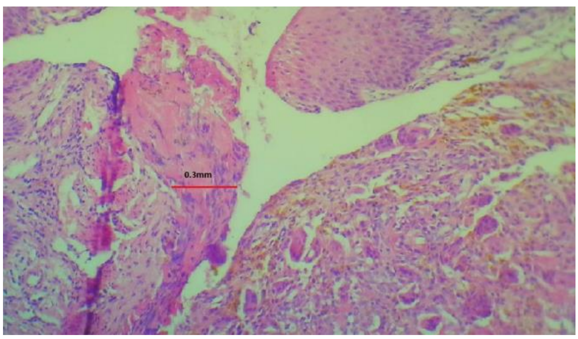

Fig. 5: Peripheral giant cell granuloma, cross sectional view (10x) showing the extent of thermal damage.

Table 3.2: Description of the study parameters stratified by the histopathological diagnosis.

Characteristic	**Pyogenic granuloma, N = 10[1]**	**Fibroepithelial Polyp, N = 9[1]**	**Plexiform neurofibroma, N = 2[1]**	**Peripheral giant cell granuloma, N = 1[1]**	**p-value[2]**
Age (years)	44.8 ± 18.2	40.9 ± 13.4	60.0 ± 0.0	11.0 ± NA	0.12
Sex					**0.010**

Female	9 (90.0%)	8 (88.9%)	0 (0.0%)	0 (0.0%)	
Male	1 (10.0%)	1 (11.1%)	2 (100.0%)	1 (100.0%)	
Size of the lesion (mm)	9.00 ± 3.94	6.11 ± 3.33	11.00 ± 1.41	5.00 ± NA	0.2
Thermal damage (mm)	0.26 ± 0.11	0.28 ± 0.10	0.25 ± 0.07	0.30 ± NA	>0.9
Carbonization	2 (20.0%)	4 (44.4%)	0 (0.0%)	1 (100.0%)	0.3
Desiccation	8 (80.0%)	9 (100.0%)	2 (100.0%)	1 (100.0%)	0.6
[1]Mean ± SD; n (%) [2]One-way ANOVA; Fisher's exact test					

4. Discussion

Er,Cr:YSGG lasers are increasingly being favoured in diverse dental specializations due to their inherent adaptability. This mid-infrared wavelength has high absorption in water and hydroxyapatite which makes its application appropriate when ablating soft tissue and hard tissue, and they have the ability to adjust the parameters to accommodate the distinct requirements of each treatment.(13,14) The Er,Cr:YSGG laser is a highly valuable and highly precise ablation tool. It exhibits a high affinity for water and causes minimal harm to adjacent tissues, particularly the underlying muscle layers. This minimal tissue injury facilitates a favorable postoperative recovery period characterized by minimal scarring.(15) Furthermore, the utilization of this laser technology effectively seals lymphatic and nerve connections, also minimizing thermal artifacts during pathological examination and providing enhanced surgical margins. Additional benefits include reduced bleeding and scarring, as well as a shorter recovery period accompanied by decreased pain and edema.(16)

Laser surgery is commonly recommended in the literature for treating oral soft tissues.

Various factors affect the extent to which light may pass through tissues, such as the wavelength of the laser light, the presence of chromophores in the tissue, and the tissue's consistency. The photothermal effect refers to the process of converting light energy into thermal energy, This results in tissue coagulation/hemostasis, vaporization, and ablation.(17)

When tissues are exposed to radiation, they frequently suffer thermal damage due to the photothermal effects.(18) When lasers are employed in living organisms, it is crucial to consider the temperature impact they have on the surrounding tissues.

In order to reduce the unavoidable thermal implications, it is necessary to modify the use of lasers in oral biopsies by controlling variables related to the intensity of histological thermal effects. The variables include the size of the excised lesion, the surgeon's expertise, the source of energy emission, the lesion's characteristics, and the duration of exposure.(10)

Preserving the integrity of the specimen is of utmost importance in oral surgery, particularly in cases of concerning lesions, to ensure that the edges of the specimen remain readable and undamaged. Therefore, any instruments that cause heat or traumatic effects on the surrounding tissues can potentially hinder a safe and accurate histological examination. Therefore, when doing a biopsy, it is essential to ensure the integrity of the cut edges and allow for the assessment of both marginal infiltration and malignant transformation.(18)

There has been limited analysis of the impact of the Er,Cr: YSGG (2780 nm) laser on tissue histology during oral pathological procedures.

The Er,Cr: YSGG laser demonstrated promising findings in this investigation, as the peripheral damage in all cases was consistently less than 1 mm. This little damage did not impede the histological diagnosis of the lesions.

All cases discussed in this paper are associated with thermal damage. Upon comparison, it was observed that certain cases resulted in more damage than others. Carbonization was observed in 7 cases, and these results can be attributed to various factors such as the operator's technique, duration of exposure, and the size and composition of the lesion (lesions with more fibrous tissue require more cutting to completely remove them). As the level of thermal damage increases, the tissue will experience greater harm and undergo carbonization,(19) and the healing of such lesions require a longer duration.(20)

The process of mucosal healing involves a sequence of processes in which the cellular and molecular dynamics of the damaged tissue participate, aiming to restore integrity through the migration of epithelial cells. This migration can be influenced by several variables. During the process of epithelial regeneration, when the tissue is burned by the cutting instrument, it results in the necrosis of the burned area. The presence of necrotic tissue hinders the ability of cells to carry out the process of repair. The process of inflammation intensifies when leukocytes eliminate tissue debris by means of phagocytosis and lysis. Furthermore, necrotic tissue provides an environment conducive to the rapid growth and multiplication of bacteria, hence elevating the likelihood of infection. Several documented biological effects of the laser have the potential to enhance or reduce the thermal damage caused by the irradiation of the gingival tissue during the cutting process. The cells experience an increase in ATP generation as a result of absorbing the laser light, leading to the stimulation of cell migration and proliferation. Conversely, the laser's photo-biomodulation impact stimulates the growth of new blood vessels and improves the drainage of lymphatic fluid in the affected area, resulting in a reduction of inflammation and swelling. The observed results may be associated with the relieving of pain, reduction of inflammation, and decrease in postoperative swelling.(20)

A scholarly publication in 2010 entitled "Histologic evaluation of thermal damage produced on soft tissues by CO 2, Er,Cr:YSGG and diode lasers"(21) Investigated the thermal effects of different laser types on soft tissues. The Er,Cr:YSGG samples that underwent irradiation with a water/air spray showed a carbonization area that was smaller than 25% of the periphery of the irradiation margin. Noticeable differences were observed between those who were subjected to water/air spray irradiation and those who were not, suggesting the presence of a moderate carbonization zone.

Specifically, this work demonstrated the safe applicability of the Er,Cr: YSGG laser in oral biopsy procedures.

The laser beam's photothermal effects result from the heat generated by laser-tissue interactions. This heat leads to several outcomes in the tissue, such as protein denaturation, coagulation, hyalinization, and carbonization. This reaction is classified as high reactive intensity laser therapy since it has the capacity to permanently modify or eliminate tissue. The various attributes of the laser beam, such as its wavelength, power settings, and mode of operation, have a direct impact on the nature of the photothermal reactions. When tissue is exposed to a pulsed laser, the power is at its maximum right beside the beam, and as the laser diffuses within the tissue, the power density decreases. Hence, photothermal effects are associated with the destruction of tissue in adjacent areas using a low energy zone (known as low reactive-level laser therapy), This is based on the wavelength and absorption capacity of the particular tissue that is being addressed. Low energy zones are known to cause photobiomodulation of the tissue, which lowers inflammation and increases cell proliferation and differentiation.(17)

The assessment of these outcomes can be done using traditional microscopy techniques and the standard staining method of hematoxylin-eosin. Our investigation found that nearly all specimens had a highly eosinophilic layer, indicating desiccation caused by the photothermal effect of a laser. This desiccation occurred because the free water in the tissue evaporated earlier during the heating phase, before the tissue reached the temperature required for ablation. (22)

It is noteworthy that thermal damage does occur even if the majority of research show that the thermal effect of different laser wavelengths does not impair histological diagnosis and evaluation. Therefore, it is crucial to reduce the thermal effect by optimizing laser parameters.(23)

This study assessed the histological results of 22 excisional biopsies of various oral benign soft tissue lesions that were removed using the Er,Cr:YSGG laser. As far as we know, there have been no studies that specifically examine the histological alterations that occur when lesions are removed from the human oral cavity using the Er,Cr:YSGG laser. Our study results cannot be directly compared to the results obtained from animal studies due to significant differences in experimental conditions. Animal studies often involve ex vivo circumstances, in which specimens are withheld blood and lasers are applied to healthy tissue with precise control over the timing and location of incisions. Additional investigation is required to enhance comprehension of the correlation between laser treatment parameters and histological outcomes, with the aim of optimizing the use of lasers for the therapy of oral soft tissue lesions.

5. Conclusion

In conclusion, the study demonstrated that the laser's effect on tissue histology was controllable, although thermal damage was present. The Er,Cr:YSGG laser treatment is effective and precise in treating oral soft tissue lesions. The study highlighted the potential of this treatment to enhance therapeutic results and provide greater comfort for patients. However, further research with larger sample sizes is warranted to validate these findings

References

1. Zahid E, Bhatti O, Zahid MA, Stubbs M. Overview of common oral lesions. Vol. 17, Malaysian Family Physician. Academy of Family Physicians of Malaysia; 2022. p. 9–21.
2. Gaphor SM, Sc M, Abdullah MJ. Prevalence, sex distribution of oral lesions in patients attending an oral diagnosis clinic in Sulaimani University. J Bagh Coll Dent. 2011;23(3):2011.
3. Gholizadeh N, Taheri JB, Namazi Z, Mashhadiabbas F, Bakhtiari S, Rahimzamani A, et al. Excision of Different Oral Benign Exophytic Lesions With a Diode Laser: A Clinical Case Series. J Lasers Med Sci. 2020;11(4):502–8.
4. Broccoletti R, Cafaro A, Gambino A, Romagnoli E, Arduino PG. Er:YAG Laser Versus Cold Knife Excision in the Treatment of Nondysplastic Oral Lesions: A Randomized Comparative Study for the Postoperative Period. Photomed Laser Surg. 2015;33(12):604–9.
5. Al-Alawi AS. The effectiveness of Diode Laser 810 nm in the removal of oral pyogenic granuloma in repetitive pulsed mode. Iraqi JMS. 2017; Vol. 15(3): 262-267.
6. Al-Ani AJ, Taher HJ, Alalawi AS. Histological evaluation of the surgical margins of oral soft tissue incisions using a dual-wavelength diode laser and an Er, Cr:YSGG laser; an ex vivo study. J Appl Oral Sci. 2024;32:e20230419.
7. Tunç SK, Yayli NZA, Talmaç AC, Feslihan E, Kaplan V. Evaluation of dental anxiety in patients undergoing second-stage surgery with er, cr: YSGG laser treatment: Randomized clinical trial. East J Med. 2020;25(1):45–54.
8. Romanos G. Current concepts in the use of lasers in periodontal and implant dentistry. J Indian Soc Periodontol. 2015;19(5):490–4.
9. Elavarasu S, Naveen D, Thangavelu A. Lasers in periodontics. J Pharm Bioallied Sci [Internet]. 2012 Mar [cited 2024 Jan 13];4(Suppl 2):S260. Available from: /pmc/articles/PMC3467892/
10. Tenore G, Mohsen A, Nuvoli A, Palaia G, Rocchetti F, Di Gioia CRT, et al. The Impact of Laser Thermal Effect on Histological Evaluation of Oral Soft Tissue Biopsy: Systematic Review. Vol. 11, Dentistry Journal. MDPI; 2023.
11. Al-Karadaghi TS, Franzen R, Jawad HA, Gutknecht N. Investigations of radicular dentin permeability and ultrastructural changes after irradiation with Er,Cr:YSGG laser and dual wavelength (2780 and 940 nm) laser. Lasers Med Sci. 2015 Nov 1;30(8):2115–21.
12. Studies P. Smear Layer Removal from the Apical Third Using the Er , Cr : YSGG Photon-induced Photoacoustic Streaming. 2021;16(4):238–43.
13. Rehman F, Chaturvedy V. Soft Tissue Applications of Er,Cr:YSGG Laser in Pediatric Dentistry. Int J Clin Pediatr Dent. 2017 Jun;10(2):188–92.
14. Tianmitrapap P, Srisuwantha R, Laosrisin N. Flapless Er,Cr:YSGG laser versus traditional flap in crown lengthening procedure. J Dent Sci [Internet]. 2022;17(1):89–95. Available from: https://doi.org/10.1016/j.jds.2021.05.004
15. Tandon S, Lamba AK, Faraz F, Chawla K. Treatment of Pyogenic Granuloma using Er,Cr:YSGG Laser. Int J Laser Dent. 2013 Apr;3(1):29–32.
16. Castelo-Baz P, Seoane-Romero JM, García-Caballero L, Suárez-Peñaranda JM, Romero-Méndez MA, Varela-Centelles P. Unifocal orofacial granulomatosis in retromolar mucosa: Surgical treatment with Er,Cr: YSGG laser. J Clin Exp Dent. 2014;6(2):6–9.
17. Estrin NE, Lesniewski A, McClain S, Hou W, Romanos GE. Thermal Penetration Depth of Pulsed Lasers in Gingival Tissues: An in Vitro Study. Photobiomodulation, Photomedicine, Laser Surg. 2022;40(6):410–6.
18. Romeo U, Libotte F, Palaia G, Del Vecchio A, Tenore G, Visca P, et al. Histological in vitro evaluation of the effects of Er:YAG laser on oral soft tissues. Lasers Med Sci. 2012 Jul;27(4):749–53.
19. Ansari MA, Erfanzadeh M, Mohajerani E. Mechanisms of laser-tissue interaction: II. tissue thermal properties. J Lasers Med Sci. 2013;4(3):99–106.
20. Orozco J, Rico D, Barrios L, Hoyos V, Blanco P. Histological artifacts associated with laser

and electroscalpel gingivectomy: Case series. Biomedica. 2023;43(3):315–22.
21. Cercadillo-Ibarguren I, España-Tost A, Arnabat-Domínguez J, Valmaseda-Castellón E, Berini-Aytés L, Gay-Escoda C. Histologic evaluation of thermal damage produced on soft tissues by CO 2, Er,Cr:YSGG and diode lasers. Med Oral Patol Oral Cir Bucal. 2010;15(6):912–8.
22. Lukač M, Košir J, Žel T, Kažič M, Šavli D, Jezeršek M. Influence of tissue desiccation on critical temperature for thermal damage during Er:YAG laser skin treatments. Lasers Surg Med. 2024;56(1):107–18.
23. Tenore G, Mohsen A, Nuvoli A, Palaia G, Rocchetti F, Di Gioia CRT, et al. The Impact of Laser Thermal Effect on Histological Evaluation of Oral Soft Tissue Biopsy: Systematic Review. Dent J. 2023;11(2):1–24.