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A comprehensive review of CO2 laser treatment for oral leukoplakia

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Abstract:

Oral leukoplakia, also known as oral mucosal leukoplakia or oral leukoplakia, is a common oral disease characterized by patchy lesions of white or grayish white keratinization on the oral mucosa, it is recognized by the World Health Organization (WTO) as a precancerous oral mucosal disease, which has significant implications for its treatment. Carbon dioxide (CO2) laser refers to a laser that uses carbon dioxide gas as the working medium and has been widely used in oral mucosal diseases in recent decades, including oral leukoplakia. As an advanced medical technology, CO2 laser plays an important role in the field of medicine. This comprehensive review delves deeply into the intricate principles, multifaceted advantages and disadvantages, intricate operation methods, as well as the promising prospects of CO2 laser treatment for oral leukoplakia by meticulously examining and synthesizing relevant scientific literatures, to provide clinicians and researchers with a comprehensive and scientifically sound guideline for the treatment of oral leukoplakia.

Keywords: CO2 laser, Oral leukoplakia, Treatment, Surgery.

1. Introduction

With the development of science and technology and the progress of society, laser technology is also gradually upgrading. Albert Einstein is the first person who proposed that photons could excite excited atoms to send out identical photon [1]. After that, Maiman first demonstrated laser in 1960 [2]. Although the history of lasers began in 1951, the first medical application was reported by Goldman in 1962 [3]. Leon Goldman is a pioneer in laser. Laser was marketed for Dentistry in 1990 by Mayers. Numerous types of laser devices have been documented for use in laser surgery, encompassing Nd:YAG, Er:YAG, diode, and carbon dioxide (CO2) lasers [4]. Laser is short for light amplification by stimulated emission of radiation, invented by Kumar Patel in 1964 at Bell Laboratories, and it was first used medically as a surgical laser method in the early 1970s [5]. The CO2 laser pulse and continuous wave modes of rotation vibration transition of carbon dioxide operating in the mid infrared band at 10.6 and 9.4μm wavelengths, it is one of the most formidable and effective lasers available [6]. CO2 laser absorption is strong in water and weak in hydroxyapatite [7]. CO2 laser is efficient in cutting oral soft tissues and only produces superficial thermal damage, so CO2 laser is widely

used in oral diseases of oral mucosa [1]. The utilization of CO2 laser has been demonstrated as an effective treatment modality for benign oral lesions, encompassing fibromas, papillomas, hemangiomas, and gingival hyperplasias stemming from diverse etiologies, including idiopathic cases and those attributed to medication side effects. Furthermore, it has been employed in the management of aphthous ulcers, mucosal frenula or tongue ties (ankyloglossia), and premalignant lesions such as oral leukoplakia [8].

Oral leukoplakia represents a predominantly white, distinctive lesion of the oral mucosa, which defies categorization as any other precisely identifiable lesion [9]. The most prevalent potential cancerous oral lesion exhibits a progression rate towards squamous cell carcinoma, varying from 0.1% to 36.4%, emphasizing its significance in medical consideration [10]. This mutation is contingent upon various factors, including gender, genetic loci, disease manifestation, and the occurrence of epithelial dysplasia [11]. The morbidity of oral leukoplakia is very high [12], seriously affecting the health of these people. Oral leukoplakia has been classified into homogeneous and heterogeneous based on their appearance. The first type is the most common, uniform, white, thin, occasionally with shallow grooves, and almost no symptoms, the latter is mainly white, although uneven, but in cases of erosion, there are related symptoms such as pain, burning, and stabbing pain, which are further divided into warts, nodules, red and white matter plastic surgery, and proliferative exowarts [13]. Up to now, the pathogenesis of oral leukoplakia is still unclear [14]. The treatment of oral leukoplakia includes conventional surgical resection, local and systemic medication, laser surgery, and even conservative treatment [15]. Since 1970s, many studies have discovered that CO2 laser has good therapeutic effect and healing results for oral leukoplakia. Aruna Tambuwala detected that compared with traditional scalpel, CO2 laser significantly reduces the amount of bleeding and postoperative pain in the treatment of oral leukoplakia [16]. Another research found that CO2 laser has fewer infections compared to cryosurgery [17]. This review aims to detailed introduction of the principle, advantages and disadvantages, clinical application, comparative study, and precautions of CO2 laser treatment for oral leukoplakia.

2. The origin of CO2 laser

CO2 laser belongs to a type of laser, and the origin of laser invention comes from basic physics research. Albert Einstein assumes that specific frequency incident photons and excited photons interact, transforming them into low-energy forms while releasing two photons with the same frequency, amplitude, and similar propagation direction, to demonstrate this process more intuitively, readers can refer to the schematic diagram in Figure 1. This figure depicts the three key steps of light assimilation, spontaneous radiation, and stimulated stimulated emission in a concise and clear manner [6].

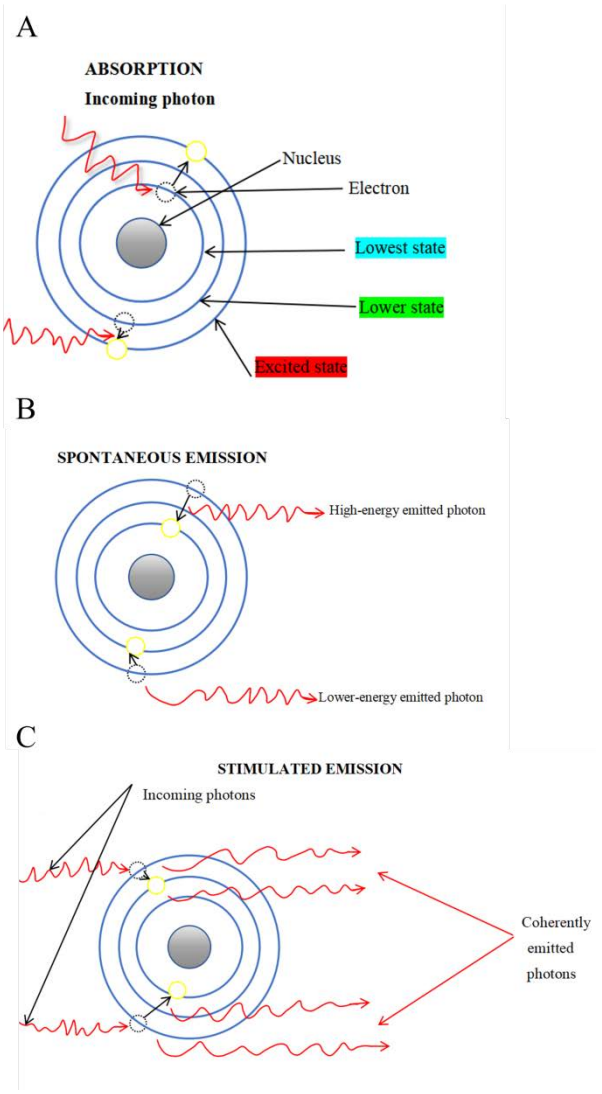

Fig. 1 A depiction of the mechanisms of absorption (A), spontaneous radiation (B), and stimulated radiation (C) involving two photons differing in their frequencies is displayed.

3. The principle of CO2 laser treatment for oral leukoplakia

CO2 laser, also known as carbon dioxide laser, is a gas laser with a wavelength of 10600nm [18]. When CO2 laser is irradiated onto biological tissue, directly acts on

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the diseased tissue, the tissue absorbs the laser energy and converts it into thermal energy [19]. Due to the fact that the rate of increase in thermal energy is much faster than the rate of tissue heat dissipation, tissue temperature rapidly rises, reaching up to 100 degrees or even higher, leading to protein coagulation, necrosis, carbonization, and gasification [20], during this process, the diseased tissue is damaged and removed, thereby achieving the effect of treating oral leukoplakia.

4. The entire treatment process of CO2 laser treatment for oral leukoplakia

4.1 Preparation before treatment

To begin with, the dentist will conduct a detailed assessment of the patient's oral leukoplakia, including the size, location, type (such as homogeneous, heterogeneous, etc.) of the leukoplakia, as well as the overall health status of the patient [16]. Then, the surgeon should explain to the patient principle, process, possible risks and syndrome of CO2 laser treatment, as well as the expected therapeutic effect to ensure that the patient fully understands and agrees to the treatment plan [21]. The final step is that patients need to undergo oral cleaning to ensure the cleanliness and sterility of the treatment area. At the same time, assistant or nurse should also prepare the equipment and consumables required for laser treatment [22].

4.2 Therapeutic process

Depending on the patient's specific condition, surgeon may choose local anesthesia or surface anesthesia to alleviate pain during the treatment process. Currently, most research use lidocaine and articaine for tissue infiltration anesthesia [4, 17]. Of course, there is also general anesthesia available [23]. After completing anesthesia, the dentist should use gauze to separate the cheek mucosa, lips, or tongue based on the location of the lesion. Before each surgery, the laser is tested on wet gauze and mandatory special masks and glasses are worn to protect oneself. Using an efficient vacuum device to extract laser plumes [4]. Next, surgeon would use a CO2 laser to target the white spot area for irradiation. During the use of laser irradiation, surgeon should precisely control the depth and range of laser irradiation to ensure that only diseased tissue is removed without damaging surrounding normal tissue, with an optimal depth of 0.1 millimeters [20]. At the same time, surgeon should adjust the laser parameters and treatment strategies in a timely manner based on the actual situation during the treatment process, such as the patient's reaction, changes in oral leukoplakia, etc.

4.3 Post treatment care

After treatment, patients need to maintain oral hygiene to avoid infection. Surgeon may prescribe some oral cleaning agents and mouthwash for patients to use [24]. Meanwhile, Surgeon should require patients to make dietary adjustments. Patients should avoid consuming spicy and irritating foods to prevent pain or discomfort in the treatment area caused by stimulation. Although there is currently no evidence to suggest the effective value of postoperative follow-up [4], patients still need to undergo regular follow-up. Currently, certain research indicates that patients ought to undergo follow-up assessments every three months during the initial year, subsequently every six months in the second year, and thereafter annually for the remainder of their lives [25]. If any abnormal changes are found in the surgical site during the reexamination process, a new biopsy must be performed [26].

5. The advantages of CO2 laser treatment for oral leukoplakia

CO2 laser has many advantages in the treatment of oral leukoplakia, the first of which is the high efficiency of CO2 laser, CO2 laser can quickly act on diseased tissue, achieving the effect of quickly removing white spots. On top of that, CO2 laser has high accuracy. In a study, the precision of the laser beam during the treatment process was more refined compared to traditional surgical knife treatments, thereby minimizing damage to surrounding normal tissues to the greatest extent possible [16]. Moreover, good hemostatic effect is also an advantage of CO2 laser. During the treatment process, CO2 laser can have a certain hemostatic effect due to tissue carbonization, reducing bleeding during surgery, thus achieving optimal visibility [20]. But if the surgery is performed with a traditional surgical knife, there will be a lot of intraoperative bleeding [16]. And Pía López-Jornet and Fabio Camacho-Alonso also found that CO2 laser treatment can alleviate postoperative pain and swelling [26]. In addition, CO2 laser can reduce the occurrence of bacteremia during the treatment of oral leukoplakia [27]. For patients, the most important thing is surgical comfort. CO2 laser provides high comfort for patients as there is no need to close the primary wound with sutures [20]. Last but not least, CO2 laser is beneficial for postoperative soft tissue recovery [16]. It has been found that the number of myofibroblasts in laser wounds is significantly lower [28], resulting in minimal wound contraction and scar formation [16]. After the end of laser treatment, patients usually recover quickly and generally do not leave scars. Overall, CO2 laser treatment for oral leukoplakia is a safe, effective, and

minimally invasive treatment method with multiple advantages.

6. The disadvantages of CO2 laser treatment for oral leukoplakia

Although laser therapy can remove diseased tissue, the recurrence rate of oral leukoplakia still exists. After CO2 laser treatment, the recurrence rate of may be between 0% and 40.7% [4, 17, 18, 29, 30]. The specific recurrence rate is related to various factors, such as the mode of laser application, the range and depth of lesion cutting, the nature and location of the lesion, etc. Especially for lesions with heterogeneous white patches and mild atypical hyperplasia, the recurrence rate may be higher [24]. Of course, this may also be related to individual differences. Furthermore, some oral leukoplakia with a large lesion range (≥2 cm), postoperative pain is still quite obvious after CO2 laser treatment [24]. The biggest disadvantage in laser surgery is still unintentional radiation damage to patients and surgeons, resulting in burns to the eyes and skin [16]. The research found that whether preoperative or intraoperative, if biopsy is required, it must be performed through other methods, which complicates the surgery [31]. The last major issue is that the CO2 laser therapy may be more expensive compared to other treatment methods [16], especially in high-end medical institutions such as tertiary hospitals. This may be a consideration factor for some patients with limited economic conditions.

7. Precautions during CO2 laser treatment of oral leukoplakia

Before CO2 laser irradiation, surgeon choose specific laser parameters based on the size and severity of the patient's oral leukoplakia. Some studies suggest that the CO2 laser power should be between 15 and 20 watts [4, 31]. If the power is too high, it may cause damage to the original normal tissue [6]. At the same time, surgeon should also warn patients before and after treatment to avoid smoking and drinking alcohol, as these bad habits may stimulate wounds, worsen symptoms, or cause white patches to recur [21].

8. Comparison of CO2 laser and traditional resection in the treatment of oral leukoplakia

This table mainly refers to Aruna Tambuwala's article [16] and shows the difference between CO2 laser and traditional surgical knife treatment for oral leukoplakia. Among them, the bleeding index is calculated based on the number of gauzes used and the difference in its dry and wet weight, the scar index is the average value of scars, and the pain index is collected using Visual Access Site(VAS) measurement (Table.1) [32].

Table 1. Various data on the treatment of oral leukoplakia with CO2 laser and traditional resection

	CO2 laser therapy	Traditional resection treatment
Principle	Laser irradiation causes tissue coagulation, necrosis, carbonization, and gasification	Surgical knife directly cuts the diseased tissue
Indication	The lesion area is small and located in the anterior part of the oral cavity	Wide range of lesions, ineffective non-surgical treatment, or a tendency towards malignant transformation
Postoperative bleeding index	1.4	4.3
Postoperative scar count	1.5	2.0
Postoperative pain for two days	About 2.2	About 2.4

9. Future prospects of CO_2 laser treatment for oral leukoplakia

With the development of global aging, the oral health of the elderly is becoming increasingly prominent. The incidence of oral leukoplakia in the elderly is higher than in other age groups [33], which drives the market demand for CO2 laser treatment of oral leukoplakia. At present, research has applied CO2 laser combined with photodynamic therapy [34] and microscopic CO2 laser technology in the treatment of oral leukoplakia [24], and achieved positive results. In the future, these excellent treatment

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methods may be widely applied to improve treatment effectiveness and reduce recurrence rates.

10. Summary

This review introduces the treatment of oral leukoplakia with CO2 laser. CO2 laser can precisely control the laser energy, density, and irradiation time, accurately remove the lesion site, and improve the quality of life of patients. In the future, with the continuous development and improvement of laser technology, the effectiveness of CO2 laser treatment for oral leukoplakia will be further improved.

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