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Electromyographic Evaluation of Superior Orbicularis Oris Muscle Activity in Patients With Complete Cleft Lip and Cleft Palate Before and After Vestibuloplasty Using Carbon Dioxide Laser Therapy

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Abstract

Introduction: Cleft lip and cleft palate are the most typical congenital craniofacial anomalies. Post-surgical scars in cleft lip patients can cause shallow upper labial sulcus and reduced upper lip length. The aim of the present study was to evaluate the impact of CO_2 laser vestibuloplasty on the electromyographical (EMG) activity of patients' superior orbicularis oris muscle, depth of labial sulcus, and upper lip length, and their satisfaction with the procedure and its results. The CO_2 laser is an effective vestibuloplasty procedure, is safe and highly acceptable for patients, and has little effect on muscle contraction.

Methods: A total of 15 cleft lip and cleft palate patients participated in this study. Vestibuloplasty was performed using carbon dioxide laser therapy in one session in such a way that EMG activity in the upper lip muscle, depth of labial sulcus, and upper lip length were measured two times: before (T0) and twenty days after surgery (T1). Patients' satisfaction surveys were also recorded using a patient questionnaire at T1.

Results: The mean values for vestibular depth at T0 and T1 were 2.00 ± 1.71 and 4.52 ± 1.43, respectively. The mean values for upper lip length at T0 and T1 were 6.90 ± 2.32 and 8.00 ± 2.40, respectively, suggesting a significant change in vestibular depth and upper lip length. The vestibular depth and upper lip length significantly increased at T1. The EMG recording of the upper lip muscle experienced a moderate decrease after laser treatment, both at rest and at maximum lip protrusion. Moreover, patients' satisfaction with the surgical procedure was 82% positive.

Conclusion: Using the CO_2 laser increased the vestibular depth and upper lip length successfully and made small changes in the EMG activity of the superior orbicularis oris.

Keywords: Cleft lip; Cleft palate; Electromyography; CO_2 laser; Vestibuloplasty.

Introduction

Cleft lip and cleft palate, collectively termed oral clefts (OCs), are the most typical congenital craniofacial anomalies known to include *syndromic* and *non-syndromic* (i.e. isolated) subtypes.[1] The prevalence of this congenital deformity is 0.7 in the United States and 1.03 to 3.37 in Iran.[2-4] The treatment for patients with cleft lip and cleft palate begins after birth and may continue until they stop growing.[5,6] The treatment for all such patients includes lip and palate closure surgery and alveolar bone repair.[7,8] Current techniques for the surgical repair of a cleft lip and palate aim at restoring the shape and muscle functions around the mouth, especially the superior orbicularis oris. The reason is that muscle shape and function are the basis for preventing or minimizing secondary skeletal and soft tissue changes in the midface.[9,10] Primary lip and palate repair procedures lead to cleft scar formation that creates functional chewing and speech problems, even hindering hygiene practices. If conducted inappropriately and aggressively, such surgical procedures will worsen the formed scars like improper adhesion of the upper lip to the maxillary labial gingiva.[11] Consequently, surgeons utilize different vestibuloplasty techniques to remove this adhesion and increase the depth of the sulcus.[12] The vestibuloplasty complication is scar formation and relapse, eventually causing tension in the affected tissues, re-fusion of the upper lip to the gingiva, and reduction of vestibular depth.[13] Numerous attempts have always been made to decrease the rate of complications through various surgical techniques.

One is the use of skin grafts, that is, a surgical procedure wherein a piece of skin is transplanted from one area to

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another. It is less satisfactory due to the formation of distinct textures in the area.[14] One of the most innovative surgical techniques to prevent refusion is the use of lasers. The CO_2 laser has recently been introduced as an effective and dependable alternative to surgical scalpels in oral soft tissue surgeries. The laser technique features include tissue cutting and simultaneous coagulation, effective homeostasis, post-surgery minimal swelling, reduced patient pain, discomfort, and risk of infection, faster healing, and most importantly, lower risk of scar formation, in other words, lack of cleft lip adhesion recurrence.[15,16]

Electromyography (EMG) is an instrument frequently employed to evaluate orofacial muscle activity with an electrical approach.[17] EMG is also one of the few diagnostic tools that directly and objectively evaluate muscle function as it is non-invasive and readily approved by patients.[18,19]

The present study was an electromyographic evaluation of the superior orbicularis oris muscle activity in patients with complete cleft lip and cleft palate before and after vestibuloplasty by the CO_2 laser.

Materials and Methods

The samples of the present study included 15 patients aged 12 to 15 years suffering from complete cleft lip and cleft palate (unilateral or bilateral) with vestibular depth loss in the anterior maxillary area after primary cleft surgery. The exclusion criteria were secondary vestibuloplasty surgery, syndromic cleft, and other systemic problems such as heart disease (pacemaker), malignancy, and neuromuscular disease. The research samples were referred to the Department of Orthodontics of Yazd University of Medical Science for essential treatment.

As the trial (T0) began, patients' sulcus depth and lip length were measured and they were referred to Shahid Sadoughi hospital (Physical Medicine and Rehabilitation unit) to have the EMG activity of their Orbicularis oris muscle evaluated.

The EMG activity of the superior orbicularis oris muscle was measured at T0 and twenty days after laser treatment (T1) performed by merely one physiatrist specializing in physical medicine and rehabilitation.

EMG was recorded using bipolar Silver/Silver Chloride (Ag/AgCl) surface electrodes (Ambu® 71015-K/C/12, Malaysia) in such a way that two electrodes were connected to the upper lip at an equal distance from the philtrum with an inter-distance of 15 mm on a line running from the lip commissure to the sub-nasal point. Similarly, a reference electrode was also attached to the forehead. To reduce skin impedance, the patients' skin was cleaned with 70% ethyl alcohol.

Moreover, to minimize any movement of the electrodes during the muscle activity recording, the patients were placed on a bed in a supine position, i.e. lying face upwards so that the head and body were in a line. The EMG activity of the superior orbicularis oris muscle was recorded at the maximum lip protrusion. Each process was repeated five times, and the peak EMG activity was recorded. The electrodes interfaced with a computer, which recorded the data for further analysis. Furthermore, the sulcus depth and upper lip length were measured via Digital Caliper (Guilin Guanglu Measuring Instrument Co., P.R.C). Only one author performed all of the analyses to reduce interfering factors. The vestibular depth was measured, from the deepest labial vestibule to the adjacent teeth gingival margin, and the lowest upper lip length was quantified from the subnasal point[15] to the superior border of the vermilion.

Prior to the surgery, the patients used mouthwash chlorhexidine-0.2% (Najo, Iran) to reduce the microbial load. First, local anesthesia was administered with 4% articaine with 1:100,000 epinephrine (A100) (Exir Pharmaceutical Co, Tehran, Iran). The clinician and the patients wore laser safety glasses.

CO_2 laser vestibuloplasty was initiated in the area with the least vestibule depth. During the surgery to cut tissues, the laser tip distance was 1-3 mm, whereas some other times, the distance was raised to 10 mm to create homeostasis and coagulation. The hand speed was a mere few millimeters per second and the movement of a laser tip was sweeping. This process persisted until the authors reached the accepted vestibular depth and all the deformed upper lip adhesions to the gingiva were released.

The surgery was conducted using a CO_2 laser (Daeshin Enterprise, Seoul, Korea; DS-40UB, 1-30 W, continuous wave, with an output power of 5 W (E.D. = 442.477 W/cm^2). The application tip employed was a needle with a beam having an inner diameter of 0.6 mm and a spot diameter of 0.1 mm. Twenty days after surgery (T0), the patients were contacted for re-evaluation of the EMG activity, lip length, sulcus depth, and a complete satisfaction questionnaire.

After data collection, statistical analysis was accomplished using PASW® Version 17 (SPSS, Chicago, IL). Indicators and tables were prepared, and a paired-sample *t* test was used to compare all the results. The level of significance was set at $P < 0.05$.

Results

All the patients participating in the study were included in a follow-up program. The patients experienced the CO_2 laser vestibuloplasty operation comfortably, with no reported intraoperative and postoperative complications. A follow-up examination performed 20 days after surgery displayed adequate epithelialization, a completely healed surgical site with smooth pliable tissue, and no scar formation. Consequently, no reoperation was required in any of the cases.

As shown in Table 1, the mean values for the vestibular depth in T0 and T1 were 2.00 ± 1.71 and 4.52 ± 1.43

Table 1. The Mean Vestibular Depth (mm) and Upper Lip Length (mm)

	Patients Number	T_0 Mean ± SD	T_1 Mean ± SD	Difference Mean ± SD	*P* Value
Upper lip length	15	6.90 ± 2.32	8.00 ± 2.40	1.10 ± 0.40	0.001
Vestibular Depth	15	2.00 ± 1.71	4.52 ± 1.43	2.50 ± 0.90	0.001

T_0: The measurement of vestibular height and upper lip length before CO_2 laser surgery
T_1: The measurement of vestibular height and upper lip length 20 days after CO_2 laser surgery

respectively, and the mean values for the upper lip length in T0 and T1 were 6.90 ± 2.32 and 8.00 ± 2.40, respectively. The differences were estimated by a paired-sample t-test and shown to be significant with a $P < 0.001$. This means that CO_2 laser vestibuloplasty significantly increased the upper lip length and vestibular depth.

Table 2 shows that changes in Amplitude and Area indices were minor and that there was no statistically significant difference. Furthermore, the questionnaire that assessed patients' satisfaction with the surgical procedure and its results revealed that the mean score for patient satisfaction obtained from five items ranging from 0 to 9 was 7.40 ± 1.96. It suggested that 82% of the patients were satisfied with CO_2 laser vestibuloplasty.

Table 2. Electromyography Activity of the Superior Orbicularis Oris Muscle

	N	Mean	Standard Deviation
Before amplitude	15	217.06	158.05
After amplitude	15	141.00	43.08
Before Area	15	1029.06	564.22
After Area	15	765.46	389.24

Discussion

Regardless of the surgical team's many efforts to prevent tissue scar formation or to prevent it from growing and expanding, some tissue scars are created after the primary repair surgery. One of the results of the formed scars is the misplaced (Ectopic) adhesion of the upper lip to the maxillary labial gingiva tissue, resulting in a significantly reduced vestibule depth in this area. Various techniques have been employed to recover and increase the vestibule depth, including polyglactin mesh and skin grafts.[12] Aside from their advantages, the disadvantages include the need for a donor site to obtain skin grafts, a texture distinct from the surrounding tissues, and a high risk of re-adhesion. These are the reasons why alternative ways such as the use of laser technology in these patients have been developed. One type of laser utilized in oral soft tissue surgeries, i.e. vestibuloplasty, is the CO_2 laser.[16] It makes it possible for hemostasis to occur and allows for tissue cutting/ablation at the same time. In other words, the CO_2 laser technique is characterized by synchronous coagulation and tissue vaporization. It should be noted that no other type of laser method has this double capability.[20] The present study employed the CO_2 laser technique given some of its unique features discussed as follows.

Immaculate hemostasis and coagulation develop due to a close match between coagulation depth and gingival blood vessel diameter. Since the soft tissues of the mouth are vascular-enriched, hemostasis enhances the visibility of the surgical field, allowing for the tissue to be removed highly accurately. In addition, thanks to this feature, wounds often do not require suturing or surgical dressing.[21]

During the tissue-cutting procedure using the laser technique, lymphatic vessels adjacent to the incision margin underwent closure, leading to minimal post-operative swelling, edema, and pain after surgery.[22] Likewise, slight wound contraction and reduced risk of scar formation are among the biggest advantages of CO_2 laser surgery.[21,23-25]

In scalpel incision healing, the prevailing cells are myofibroblasts, which are prone to tissue contraction, scar formation, and reattachment. Nonetheless, the healing process in CO_2 laser irradiation wounds is characterized by a higher proliferation of fibroblasts that result in the active production of collagen.[25-28] The previous factors could account for acceptable cosmesis after CO_2 laser surgery, characterized by smooth, elastic, new tissue with no fibrosis or scar formation.[24]

To measure the EMG activity of Orbicularis oris muscle, like in the study by Woźniak et al, we employed surface electrodes owing to their noninvasive features, which is why patients better receive them.[18]

The patients were asked to protrude their lips as much as possible so that the electrical activity could be recorded. This movement was thought to be the maximum activity of the orbicularis oris muscle with the highest electrical potential.

The electromyographic data showed that EMG indices, including Amplitude and Area, reduced clinically and medically, which was not statistically significant. The absence of a significant change can be accounted for by the fact that the laser method did not affect the quantity and quality of muscle tissues. This means that laser treatment is likely to lead to reduced adhesion and cannot improve the flexibility of the affected tissue. Meanwhile, it should also be noted that it was the small sample size that led to this result.

In addition, surface electrodes can collect signals that are reflective of not only the underlying muscle activity but also the degree of connective tissues, skin thickness, and the potential activity of nearby nerves. These conditions may be similar in patients both before and after CO_2 laser vestibuloplasty.

One of the controversies in different articles is whether muscle force at maximum activity will have a restriction effect on maxillary development. Although a number of studies have confirmed this effect, others have stated that due to very short duration activity, increasing muscle contraction will not affect maxillary development. Nevertheless, it can affect the ease with which muscles function like speech, eating, and oral hygiene protocols.

Szyszka-Sommerfeld et al[29] utilized EMG to evaluate the function of the superior orbicularis oris muscle in patients with cleft lip and palate. The samples included 45 children with repaired cleft and 40 children without cleft with a mean age of 6 to 13 years.

An analysis of the EMG results showed that there was no statistically significant difference in the rest and the upper lip activity during the production of the /p/, /b/, and /m/ phonemes combined with the vowel /a/ between the two groups. The highest difference between the mentioned groups was in lip compression.[29] One of the factors that distinguish this study and the present research was the large number of samples.

Ravera et al analyzed the EMG activity of the upper lip muscle at rest and during saliva swallowing, apple swallowing, speech, and chewing. The study group included children with operated unilateral cleft lip and palate and the control group included children with any kind of clefts. They found that the EMG activity of the superior orbicularis oris was significantly higher in cleft patients at rest and during saliva swallowing; however, there was no difference between the two groups in other functions.[30]

In addition, in the present study, the upper lip length and vestibular depth were measured after surgery (20-day follow-up), and the obtained results showed that the vestibular depth and upper lip length increased. The mean rise in the upper lip length and vestibular depth was 1.10 mm and 2.50 respectively.

In 2017, Yassaei et al employed CO_2 laser vestibuloplasty in cleft patients, suggesting an increase in vestibular depth.[13]

Levine and Vitruk used the CO_2 laser technique with a wavelength of 10 600 nm to increase mandibular vestibule depth in patients with a chromosomal disorder, and their examination revealed that vestibule depth increased by 8 mm. Four weeks post-operative the patient was examined and it was observed that the surgical area healed completely with smooth, pliable tissue and no scars. The authors recommended using the CO_2 laser method for oral soft tissue surgery in patients with various developmental disorders, owing to its more acceptable feature for these people due to its high-speed process, flawless hemostasis and lack of postoperative bleeding, minimal inflammation, and reduced pain. This study is consistent with the present study in terms of a selected wavelength, acceptable increase in vestibular depth, and usefulness in patients with developmental disorder.[16]

A further increase in vestibular depth in Levine and Vitruk's study could be attributed to differences in the amount of bone in the surgery site. Apparently, one of the factors that limit the depth and extent of vestibulopathy is the amount of bone available in the surgery area. As we know, the alveolar bone in the cleft area is either absent or very little.

Kovacevska et al utilized Er:YAG laser vestibuloplasty surgery. They observed that the depth of the maxillary vestibule increased. On the 3-week follow-up examination, vestibular depth was 1.71 cm, whereas, on the 6-month examination, it was 1.16 cm. In this study, the relapse rate was 32%, while in Yassaei and colleagues' study, the rate was only 13.67%.[13,15]

In the present study, 82% of the patients were satisfied with the surgical process and its results. It is typically difficult to evaluate pain, but the patients reported they experienced minimum levels of pain during this surgery, although few patients required an analgesic.

Haytac and Ozcelik compared patients' opinions after frenectomy performed with the CO_2 laser and scalpel technique. Patients' perception of CO_2 laser surgery was more positive in terms of postoperative pain and functioning compared to their perception of traditional scalpel surgery. They came to the conclusion that "the CO_2 laser offers safer, more effective, acceptable and impressive results" than the scalpel procedure.[31]

In 2019, Hanna et al used the CO_2 laser for oral soft tissue surgery in patients with health problems. Participants in this study were women in their mid-1970s, who were medically compromised and were on anticoagulant medication. They deduced that the utilization of a CO_2 laser in a low-power setting is a useful surgical tool to minimize postoperative complications and enhance functional rehabilitation in a medically compromised patient.

The results of the present study should be interpreted with caution owing to the small sample size. It is highly recommended that studies with larger sample sizes and longer follow-up sessions be conducted.[32]

Conclusion

In brief, given the findings and limitations of this study, the CO_2 laser in a low-power setting is an effective method of increasing vestibular depth and upper lip length in cleft patients. Correspondingly, this treatment procedure can make small changes in the EMG activity of the superior orbicularis oris muscle which is clinically valuable regardless of its magnitude, especially during orthodontic treatment. As patients' perception of the whole surgery showed, this process is well-tolerated and has a positive effect on their functional rehabilitation and aesthetics.

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this article.

Ethical Considerations

The ethics committee and the research vice-chancellor of the Shahid Sadoughi University of Medical Science confirmed this study under the IR.SSU.REC.139.9.267 ethical code. All the patients' parents delivered their informed consent forms. Besides, the study was registered in Iranian Registry of Clinical Trials (identifier: IRCT20210321050751N1; https://irct.ir/trial/55363).

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