



Research Article

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Impact of Fractional CO₂ Laser on the Aesthetic Improvement of Scars Post-Cleft Lip and Palate Repair

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Summary

Cleft lip and palate is a prevalent craniofacial anomaly, affecting 1 in 700 births. Managing post-surgical scars is crucial, as it impacts both aesthetics and functionality, and can negatively affect patients' self-esteem and quality of life. Fractional CO₂ laser is noted for its efficacy in treating scars, promoting rapid healing, and improving both the appearance and functionality of scars. Early use, starting three months postoperatively, optimizes aesthetic outcomes and reduces related deformities. Additionally, laser therapy combined with Intense Pulsed Light (IPL) offers superior benefits compared to conventional treatments, significantly enhancing the appearance of scars and the quality of life for patients with cleft lip and palate.

Keywords: Cleft lip and palate, Post-surgical scars, Fractional CO₂ laser therapy, Collagen regeneration, Scar treatment, Aesthetic morbidity, Reconstructive surgery, Patient quality of life, Congenital craniofacial anomalies, Laser treatment efficacy

Introduction

Cleft lip and palate is the most common congenital craniofacial malformation worldwide [1]. Although surgical correction of this condition aims to normalize aesthetic appearance and correct structural issues, residual scars from primary surgeries present a significant clinical challenge due to their aesthetic impact and the consequent effect on the patient's quality of life [2]. Fractional CO₂ laser treatment has been established as a highly effective and accepted option for improving the appearance of scars. This procedure applies controlled heat to dermal collagen, removing the fragmented collagen matrix and stimulating the generation of new collagen, which significantly improves the overall appearance of the scar [3]. Additionally, fractional CO₂ laser offers controlled precision that allows for specific, targeted treatment of affected areas,

minimizing the risk of adverse effects associated with other types of CO₂ lasers [4].

In this context, this literature review is proposed to address the fundamental concepts in terms of the effectiveness, healing process, and safety of CO₂ laser in the treatment of post-surgical scars in patients with cleft lip and palate. The existing evidence on how fractional CO₂ laser can contribute to improving residual scars will be explored, highlighting its ability to stimulate dermal collagen regeneration and its precision in targeted treatment, thereby minimizing associated risks [5].

Materials and Methods

For this literature review, a search algorithm was specifically designed to identify relevant studies in the PubMed, MEDLINE,



and ScienceDirect databases. The algorithm included search terms combined with Boolean operators, focused on patients with cleft lip, cleft palate, and similar craniofacial conditions treated with carbon dioxide (CO₂) lasers. Filters were applied to select articles published in English in peer-reviewed scientific journals. After reviewing titles and abstracts, relevant studies were identified and analyzed in depth to extract information on treatment efficacy, clinical effectiveness, therapy duration, and other pertinent outcomes. This method provides a solid foundation for discussing and evaluating the clinical use of CO₂ lasers in the context of congenital craniofacial conditions.

Results

Overview of Cleft Lip and Palate

Cleft Lip and/or Palate is the most common congenital craniofacial defect in the global population, characterized by a fissure between the nasolabial groove and the upper lip, sometimes affecting both the primary and secondary palate. This malformation affects 1 in every 700 newborns annually [6], and its multifactorial etiology involves genetic and environmental factors such as advanced maternal age and the use of certain medications during pregnancy [7]. The embryological classification by Stark and Kernahan is widely used to categorize palatal clefts in terms of location and extent [8]. Patients with cleft lip and/or palate face various clinical complications depending on the severity of the condition, including difficulties with feeding and phonation, as well as an increased risk of acute otitis media and conductive hearing loss [9,10]. Moreover, they are at significant risk for psychosocial complications, such as language development problems and social interaction issues due to hypernasal speech and other speech anomalies [10]. It is essential to implement early interventions that include speech therapy and psychological support to improve the quality of life for these patients. Multidisciplinary care, including social work, psychology, and support groups, plays a crucial role in the comprehensive management of these cases [10].

Conventional Treatments for Cleft Lip and Palate Correction

Conventional surgical treatment methods for unilateral cleft lip include the Millard technique, which involves rotating the medial portion of the lip and advancing the lateral portion, and the Tension-Randall technique, which uses triangular flaps and Z-shaped incisions for precise closure. For cleft palate, the Von Langenbeck technique is employed, which mobilizes mucoperiosteal flaps of the hard palate [11]. While these procedures are effective in the initial structural correction, they face significant challenges such as poor healing with the formation of hypertrophic or keloid scars [12]. Defective healing not only has aesthetic implications for the patient but can also lead to significant psychosocial and functional consequences. From a psychological perspective, visible facial scars can contribute to low self-esteem, social anxiety, and depression, negatively impacting the patient's quality of life [13]. Socially, these scars may lead to stigmatization and discrimination, making social and professional integration difficult [14]. Functionally, scars in the mouth and palate area can interfere with the patient's speech, eat-

ing, and proper breathing, making early treatment of these scars crucial [15].

Conventional Treatments for Improving Scar Healing in Cleft Lip and Palate

The comprehensive treatment of patients with cleft lip and palate spans from early diagnosis to adolescence, focusing on improving quality of life through reconstructive surgeries and multidisciplinary therapies such as orthodontics and speech therapy [16]. These treatments aim not only for aesthetic correction but also for the proper function of the affected tissues.

Non-surgical treatments play a crucial role in managing post-surgical scars in patients with cleft lip and palate. Microporous paper tapes and silicone sheets are used to reduce tension on the scar and promote proper maturation [17]. These methods are accessible and effective in the postoperative stage to minimize complications such as hypertrophic or keloid scars. Additionally, intralesional corticosteroids are used for refractory scars due to their localized anti-inflammatory effect and their ability to modulate collagen synthesis at the site of healing [17]. Botulinum toxin type A is also employed to inhibit muscle contraction and reduce the formation of hypertrophic scars during healing, offering an effective alternative to conventional treatments [17]. In cases where scars persist or present severe complications, surgical procedures such as excision of pathological scars are considered to improve both the function and aesthetic outcome of the final scar, always under careful evaluation of the scar's maturation state and morphology [17].

Overview of Fractional CO₂ Laser

The carbon dioxide (CO₂) laser is a type of gas laser that uses a specific mixture of CO₂, nitrogen, and helium, with a wavelength of 10,600nm [18]. This laser has a selective effect on biological tissue, primarily due to its high absorption by the water present in the skin, minimizing its impact on tissues with lower water content, such as bone [19]. In dermatology and plastic surgery, fractional CO₂ laser is used to create thermal micro-injuries in the dermis, stimulating healing and collagen production through controlled dermal remodeling.

The fractional CO₂ laser generates thermal action that denatures proteins, coagulates, and eventually ablates dermal structures, favoring the formation of microholes in a grid-like pattern. These micro-damages induce a rapid healing response and stimulate dermal tissue contraction, thereby improving the appearance of hypertrophic scars [20]. Laser manipulation includes adjustments such as spot size and pulsed mode, allowing control over the depth and intensity of ablation, making it a versatile tool in dermatological and aesthetic procedures [19].

Effectiveness of Fractional CO₂ Laser

The effectiveness of ablative fractional CO₂ laser in scar healing for patients with cleft lip has been evaluated. A recent study found that the Vancouver Scar Scale (VSS) scores, which assess scar appearance, showed a consistent improvement after six sessions of CO₂ laser treatment, suggesting a favorable evolution in scar ap-

pearance [21]. This result indicates a significant reduction in the severity of postoperative scars, reflecting timely clinical progress following fractional CO₂ laser application.

Additionally, another study investigated the impact of fractional CO₂ laser on scar appearance and the electromyographic activity of the upper lip muscle in patients with cleft lip and palate. The results demonstrated that laser treatment not only improved the texture, color, and prominence of the scars but also significantly reduced the electromyographic activity of the upper lip muscle both at rest and during maximum compression [4]. This effect could potentially facilitate normal maxillary growth in young patients affected by these congenital conditions.

Comparison with Other Treatments

In a comparative study, it was demonstrated that fractional CO₂ laser was more effective than topical corticosteroid cream in improving postoperative cleft lip scars. Patients treated with CO₂ laser showed significantly lower Vancouver Scar Scale (VSS) scores compared to those treated with topical cream. This suggests that CO₂ laser treatment was more effective in improving scar appearance than topical corticosteroid cream [5].

Additionally, it was found that scars treated with CO₂ laser showed a narrower width both short-term (three weeks) and medium-term (three months) compared to scars treated with topical cream. This suggests that CO₂ laser treatment not only improves the overall appearance of scars but also helps keep them narrower over time compared to topical cream [5].

In another study, the combined treatment of Intense Pulsed Light (IPL) and fractional CO₂ laser showed a significant reduction in VSS scores compared to conventional treatments involving scar massage cream and silicone gel three months after cleft lip repair surgery. This indicates a considerable improvement in scar appearance compared to conventional treatments of massage cream and silicone gel [22].

Moreover, the combined treatment of IPL and fractional CO₂ laser was found to be significantly more effective than conventional treatment in improving scar appearance at six months post-intervention, highlighting the reliability and superiority of this therapeutic approach over conventional treatment. It was observed that the combined IPL and fractional CO₂ laser treatment was extremely effective in the long term, with scars appearing smooth and flat and a VSS score virtually insignificant at six months. In contrast, conventional treatment had a notably higher VSS score, indicating that scars did not improve as much in appearance [22].

Reduction of Vestibular Deformities with CO₂ Laser Treatment

One of the most common secondary complications following primary surgical repair of cleft lip and palate is superficial deformity of the upper vestibular sulcus. This deformity reduces the depth of the upper vestibular sulcus, significantly affecting the aesthetics and functionality of the patient's lips. A study evaluated the effect of CO₂ laser on increasing vestibular depth in patients with this postoperative deformity. It was found that after CO₂ laser interven-

tion, vestibular depth significantly increased after four months of follow-up post-intervention. Patients with unilateral clefts reported a greater gain in vestibular depth compared to those with bilateral clefts. This study demonstrated that CO₂ laser treatment was effective in deepening the upper vestibular sulcus, thereby improving the functionality of the patient's lip [23].

Optimal Timing for Laser Application

A randomized cohort study in patients with cleft lip scars evaluated the optimal timing for initiating CO₂ laser treatment. It was found that all patient groups showed significant improvement in their Vancouver Scar Scale (VSS) scores after receiving CO₂ laser treatment. However, the group that began treatment with fractional CO₂ laser one month postoperatively exhibited significant effectiveness in reducing negative scar characteristics, such as pigmentation, flexibility, and height, compared to those who started treatment three or six months later.

Patients who started CO₂ laser treatment three months after surgery showed an average improvement in scar appearance compared to those who began treatment at six months. The group that started treatment six months later also showed significant improvement, but it was evident that delaying CO₂ laser treatment resulted in an increase in adverse scar characteristics compared to the groups that started treatment earlier.

Overall, the study demonstrated that there was a significant improvement in both appearance and functionality of scars in the group of patients who began treatment one month after reconstructive surgery, highlighting the greater effectiveness of early initiation of laser treatment compared to delayed initiation [24].

Discussion

Cleft lip and palate is one of the most prevalent craniofacial anomalies worldwide, with an incidence of approximately 1 in 700 births [6]. Given the significant variability in surgical intervention needs among patients, it is crucial to highlight that most individuals will require meticulous management of the scarring process. This process can be complex and challenging, as resultant scars affect both aesthetics and functionality, underscoring the importance of a comprehensive approach to their management [25]. The development of pathological scars in patients with cleft lip and palate is widely recognized as a contributor to issues such as low self-esteem, social anxiety, and depression. Furthermore, these scars can influence the patient's perception of surgical success and outcomes [26]. Therefore, a holistic approach addressing both surgical and psychological needs is essential to improve the quality of life for these patients.

Fractional CO₂ laser emerges as a highly beneficial technique for treating scar tissue. Its ability to denature scar tissue proteins accelerates the healing process and promotes dermal tissue contraction. This thermal action not only facilitates dermal remodeling but also significantly enhances the appearance and functionality of scars, providing an effective approach to optimize postoperative outcomes and reduce aesthetic and functional sequelae [19]. Ear-

ly use of fractional CO₂ laser, starting approximately three months post-surgery, has demonstrated improved aesthetic results in patients with cleft lip and palate [24]. This approach not only enhances scar appearance by reducing visibility and prominence but also decreases related deformities, such as reduced vestibular depth. Early intervention with the laser contributes to effective dermal remodeling, resulting in a more aesthetic and symmetrical facial appearance [23]. Moreover, improvements in skin symmetry and texture can positively affect the patient's self-esteem and social interactions, alleviating issues related to aesthetic perception and quality of life.

Given the notable impact of fractional CO₂ laser in treating postoperative scars in cleft lip and palate patients, it is clear that this technology offers significant advantages over conventional methods. Recent studies show that fractional CO₂ laser not only improves the aesthetic appearance of scars, as evidenced by a significant reduction in Vancouver Scar Scale (VSS) scores after six treatment sessions [21], but also optimizes scar texture and color and decreases electromyographic activity of the upper lip muscle, potentially supporting better maxillary development in young patients [4].

Furthermore, when compared to traditional treatments such as topical corticosteroid creams, CO₂ laser demonstrates superior results, with narrower scars and significant aesthetic improvement both short-term and medium-term [5]. The combination of CO₂ laser with Intense Pulsed Light (IPL) has also proven to be more effective than conventional therapies, offering notable improvement in scar appearance six months post-intervention [22]. The consistency and reliability of results obtained with the combined treatment highlight the effectiveness of these advanced techniques in managing postoperative scars, establishing them as a superior option for enhancing patient quality of life.

Conclusions

Fractional CO₂ laser has emerged as an effective tool for treating postoperative scars in patients with cleft lip and palate. Its ability to denature scar tissue proteins accelerates healing and promotes dermal remodeling, resulting in significant improvements in both the appearance and functionality of scars. Studies have demonstrated that early use of the laser, approximately three months post-surgery, optimizes aesthetic outcomes by reducing scar visibility and prominence, and enhancing vestibular depth. Additionally, CO₂ laser not only improves scar texture and color but also may decrease electromyographic activity of the upper lip muscle, facilitating better maxillary development in young patients. These benefits underscore the crucial role of fractional CO₂ laser in the comprehensive enhancement of postoperative results for patients with cleft lip and palate.

Acknowledgement

None.

Conflict of Interest

None.

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