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# Optimizing Palatal Scar Healing Post Cleft Palate Repair- A Comprehensive Literature Review

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**KEYWORDS**

Cleft palate repair, palatal scarring, wound healing, laser therapy, regenerative medicine, surgical techniques, scar management

**ABSTRACT:** Cleft palate is a congenital condition requiring surgical intervention to restore oral function, speech, and aesthetics. Despite advances in surgical techniques, post-surgical scarring remains a major challenge, often leading to speech impairment, restricted maxillofacial growth, and velopharyngeal dysfunction. Excessive fibrosis and contracture can compromise palatal mobility, affecting long-term outcomes. To mitigate these effects, various scar modulation strategies have been explored. Surgical refinements like Z-plasty, Furlow palatoplasty, and tension-free closures improve tissue flexibility, while pharmacological agents such as topical silicone, corticosteroids, and botulinum toxin help control fibroblast activity and prevent hypertrophic scarring. Additionally, laser therapy, platelet-rich plasma (PRP), stem cell applications, and mechanical therapies offer promising approaches to enhance healing and scar remodeling. Recent advances in molecular biology and regenerative medicine have deepened the understanding of scar pathophysiology, paving the way for biologically driven interventions. Early rehabilitation protocols and individualized treatment planning are critical in optimizing both aesthetic and functional recovery. This review aims to comprehensively evaluate current and emerging strategies for minimizing palatal scarring, highlighting future directions for improving post-surgical outcomes in cleft palate repair.

## 1. Introduction

Cleft palate is among the most prevalent congenital craniofacial anomalies with the global prevalence of cleft palate estimated ranging from approximately 1 in 500 to 1 in 1,000 live births, depending on geographic region and ethnic background.[1]. While modern surgical techniques and multidisciplinary care have significantly improved outcomes for affected individuals, challenges related to repair and subsequent healing persist, necessitating ongoing clinical attention. The standard approach to managing cleft palate involves early surgical intervention, typically within the first year of life, to separate the oral and nasal cavities, thereby enabling proper feeding and the development of normal speech [1,2]. Over the years, several surgical modalities have evolved- from traditional one-stage repairs to more sophisticated techniques such as the Furlow double-opposing Z-plasty, which aim to achieve tension-free closure of the palatal tissues. Despite these improvements, surgical repair of cleft palate is not without its drawbacks[3]. A major postoperative complication is the development of palatal scarring[4] This literature review examines current strategies aimed at improving palatal scar healing following cleft palate repair. It evaluates various approaches- including surgical refinements, pharmacological interventions, laser therapies, regenerative medicine, and rehabilitative protocols- to assess their effectiveness and limitations. Enhancing scar healing is crucial for optimal maxillary development, improved orthodontic outcomes, and a better quality of life for individuals with cleft palate.

## 2. Objectives

### Palatal wound healing

Wound healing is a biological process aimed at restoring the integrity and function of damaged tissue. It proceeds through overlapping phases: inflammation, tissue formation, and tissue remodeling. During inflammation, bleeding is controlled (hemostasis), and bacteria and debris are cleared. This is followed by the formation of

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new tissue and wound contraction[5]. Finally, tissue remodeling strengthens the newly formed tissue, often resulting in scar formation. Intraoral wounds, such as those in the mouth, generally heal faster and with less scarring than skin wounds. This is partly due to lower levels of pro-inflammatory and pro-fibrotic cytokines, as well as the presence of saliva, which contains growth factors like epidermal growth factor (EGF)[6]. Fibroblast differences between skin and oral tissues also contribute to this enhanced healing.[7]

Within the oral cavity, buccal and palatal mucosa show different healing behaviors. Buccal mucosa is more flexible and elastic, while palatal mucosa is a mucoperiosteum- firm, cornified, and tightly bound to the bone[8]. These structural differences influence the wound healing outcomes[9]. Nonetheless, both follow a general process similar to that of skin. It is important to note that wound healing phases overlap in time and progress unevenly across the wound, with faster healing at the edges than in the center[10].

Wound contraction and scarring are key factors contributing to growth disturbances after cleft palate repair. Wound contraction, responsible for 80-90% of closure, involves approximation of wound edges to reduce infection and dehydration risks[11]. Two main theories attribute contraction to either fibroblast-generated tension or myofibroblast-mediated contraction via alpha-smooth muscle actin (ASMA)[12]. The consensus theory integrates both, suggesting fibroblasts initiate tension that promotes myofibroblast differentiation, particularly under TGF-β1 influence.[13] Myofibroblasts then drive coordinated contraction of the matrix. Concurrently, matrix metalloproteinases (MMPs) mediate collagen remodeling, replacing type III with type I collagen aligned to tension vectors. This remodeling initiates scar formation. Scar tissue is characterized by reduced vascularity and cell density due to apoptosis of fibroblasts and endothelial cells. Lack of elastin resynthesis and aligned collagen fibers result in stiff, inelastic scar tissue. In the palate, scar adhesion to bone further impairs maxillary growth[14].

**Palatal Scarring in Cleft Palate Patients: Composition and Complications**

Scarring of the palatal tissue following cleft palate repair is an unavoidable outcome of surgical intervention, as the body's natural healing process results in fibrotic tissue formation. The primary goal of cleft palate closure is to restore both structure and function, allowing for improved speech, feeding, and facial growth. However, the healing process initiates a complex inflammatory response that involves fibroblast activation, extracellular matrix remodeling, and collagen deposition, leading to the development of scar tissue.[15] The severity of fibrosis depends on multiple factors, including the surgical approach used, the patient's biological healing capacity, and the age at which the surgery is performed.[16] A study by Pilmane et al highlights the scar's anti-inflammatory profile showing distinct cellular changes, including increased IL-1α, IL-10, PAX-9, MSX-1, and RYK expression.[17]

The structural composition of palatal scar tissue differs markedly from that of healthy palatal mucosa. The normal mucosa comprises an extracellular matrix that balances Type I and Type III collagen, along with elastin fibers that provide resilience and adaptability. [18,19] In contrast, scar tissue exhibits an excessive accumulation of Type I collagen while having significantly reduced amounts of Type III collagen and elastin. This compositional imbalance leads to the formation of a dense, rigid tissue structure that lacks the flexibility of normal mucosa, thereby restricting movement and elasticity[18–20] Additionally, myofibroblasts, which are specialized contractile cells responsible for wound closure, become hyperactive in palatal wounds, generating excessive contractile forces that further contribute to fibrosis and restriction of maxillary growth [21].

While these cells are essential for normal wound healing, their persistent activity in the palatal region can lead to functional deficits. The long-term consequences of excessive palatal scarring extend beyond localized tissue stiffness. One of the most significant complications is velopharyngeal dysfunction (VPD), which arises when the scarred soft palate loses its ability to close effectively against the pharyngeal wall. This results in nasal air escape during speech, leading to hypernasality, articulation difficulties, and impaired resonance.[22,23] Patients with severe VPD may require secondary corrective surgeries, such as pharyngeal flaps or sphincteroplasty, in addition to extensive speech therapy.[24]

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**Challenges and Implications of Palatal Scarring in Orthodontic Treatment for Cleft Patients**

**1. Impact of Palatal Scarring on Orthodontic Treatment**

Orthodontic management of cleft patients is often complicated by the presence of palatal fibrosis, which creates resistance to the forces applied for dental and skeletal correction. One of the most commonly used techniques, rapid maxillary expansion (RME), depends on the successful separation of the midpalatal suture to increase the transverse dimension of the maxilla.[25] However, severe scarring makes the palatal tissue rigid, hindering suture opening and reducing the effectiveness of conventional RME. In such cases, surgically assisted rapid palatal expansion (SARPE) or distraction osteogenesis may be required to achieve the necessary skeletal widening.[26]

Additionally, scarring in cleft patients often leads to compromised periodontal health. The altered vascularization within fibrotic tissue reduces its ability to support tooth movement, leading to slower orthodontic progress and an increased risk of root resorption and bone loss.[27], [28] Furthermore, cleft patients frequently present with missing, malformed, or ectopically erupted teeth, further complicating orthodontic mechanics and necessitating a multidisciplinary approach involving orthodontists, prosthodontists, and maxillofacial surgeons.[29] (Fig 1)

**Figure 1:** Palatal scarring post cleft palate surgery

**2. Effects of Palatal Fibrosis on Maxillary Growth**

Palatal fibrosis significantly restricts maxillary growth, particularly in the transverse and sagittal planes. The inflexibility of scar tissue prevents normal palatal expansion, leading to a constricted dental arch. As a result, many cleft patients develop maxillary hypoplasia, which is associated with Class III skeletal malocclusion, posterior crossbites and midfacial deficiency[30]. These craniofacial discrepancies are especially concerning in growing children, as they influence both functional and aesthetic development. The underdevelopment of the maxilla can cause long-term dental malocclusions, often requiring early orthodontic and surgical interventions to minimize its effects.[31]

**3. Psychosocial and Functional Implications of Palatal Scarring**

Beyond the physical and orthodontic challenges, palatal scarring also has profound psychosocial effects. Malocclusion and midfacial hypoplasia can significantly impact facial esthetics, leading to self-esteem issues and social anxiety, particularly during adolescence.[31,32]. Additionally, speech difficulties caused by velopharyngeal dysfunction (VPD) can further contribute to communication challenges, negatively affecting academic performance and social interactions. Addressing these concerns through early intervention is essential to ensure both functional and psychological well-being[33].

**<u>Various treatment modalities for enhancement of palatal scar healing following cleft palate repair</u>**

**1. Surgical Techniques & Modifications**

In cleft palate repair, various surgical techniques have been developed to optimize functional outcomes and minimize scarring. Various palatal flaps are used to manage palatal scarring after cleft palate surgery, depending on the severity of fibrosis and functional impairment. Furlow's double-opposing Z-plasty is effective for mild scarring, improving velopharyngeal function by lengthening the soft palate by enhancing soft palate mobility by lengthening the palate and reorienting the palatal muscles, thereby reducing velopharyngeal insufficiency. Additionally, the V-Y pushback palatoplasty is employed to lengthen the palate and improve speech outcomes[34,35]. Buccal myomucosal and tongue flaps provide well-vascularized tissue for

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moderate to severe fibrosis or fistula closure, with tongue flaps requiring staged procedures[36] (Figure 2, 3). Radial forearm free flaps (RFFF) are used for extensive tissue deficiencies, offering pliable, vascularized tissue but requiring microvascular surgery.[37]. Pharyngeal flaps are employed in cases of severe velopharyngeal dysfunction (VPD) to improve speech but may pose airway risks[38]. The Bardach two-flap palatoplasty, introduced in 1967, enables complete closure of palatal clefts with two-layer closure of the hard palate and three-layer closure of the soft palate. This technique minimizes exposed bone, enhances soft palate mobility, and achieves normal speech in approximately 75–80% of patients, with an oronasal fistula rate averaging around 5.2%[39]. The choice of flap depends on defect size, functional needs, and long-term rehabilitation goals. The use of fine sutures and tissue adhesives in these procedures minimizes tissue trauma and inflammation, promoting better healing with reduced scar formation[40]. Additional surgical techniques to enhance palatal scar healing include the Modified Sommerlad-Furlow technique for wide clefts, vomer flap surgery for nasal lining reconstruction, and distraction osteogenesis to reduce soft tissue tension[41] Two-stage palate repair minimizes healing tension, aiding maxillarygrowth and reducing scarring[42]. Collectively, these surgical strategies aim to improve both the functional and aesthetic results of cleft palate repair.

**Pharmacological Approaches**

To enhance scar healing and minimize hypertrophic scar formation following cleft palate surgery, several pharmacological interventions specifically target myofibroblast activity and the development of fibrous tissue. Topical Silicone gels and sheets are widely recognized as effective treatments for scar management. Silicone products work by creating a hydrated environment over the scar, which promotes healing and can help flatten and soften the scar tissue. They function by reducing collagen production, thereby preventing excessive fibrosis. The use of silicone is often recommended for both prevention and treatment of hypertrophic scars and keloids, making it a cornerstone in post-surgical scar care[43]. Corticosteroids (e.g., Triamcinolone Acetonide- TAC) are also commonly used in the management of hypertrophic scars. Administered via intralesional injections, TAC helps alleviate inflammation and directly inhibits fibroblast proliferation, crucial factors in the development of fibrous tissue. Additionally, corticosteroids reduce collagen synthesis and promote the activity of collagenase, which breaks down collagen[44]. A notable study has shown that combining TAC with laser-assisted delivery can significantly improve scar texture over a six-month period, highlighting the potential for enhanced treatment outcomes through this combined approach.[45] 5-Fluorouracil (5-FU): This chemotherapeutic agent has been utilized for intralesional injections in treating various types of pathological scarring, including hypertrophic scars and keloids. 5-FU functions by inhibiting fibroblast proliferation and collagen synthesis, effectively reducing the amount of fibrous tissue within scars. Although the evidence supporting its use specifically for cleft palate scars is limited, its successful application in other types of scars suggests potential benefits in this area as well.[46]

Botulinum Toxin (Botox): Botox has gained attention for its potential role in scar management. By reducing muscular tension around the scar, Botox can lead to improved flexibility and appearance of the scar tissue. This treatment works by inhibiting the release of acetylcholine, which diminishes muscle contractions that might exacerbate scar formation. Moreover, studies suggest that Botox may also reduce fibroblast activity, resulting in less collagen deposition, thereby contributing to smoother scars.[47] Various laser modalities, such as fractional laser resurfacing, are employed to treat scars by promoting collagen remodeling and improving overall skin texture. Laser treatments enhance the absorption of topical agents, such as TAC, making them more effective in reducing scar thickness and improving aesthetics. The precision of laser therapy allows for targeted treatment, minimizing damage to surrounding tissues while effectively addressing scar issues.[48] Administration of interferon proteins have shown promise in the management of hypertrophic scars and keloids.

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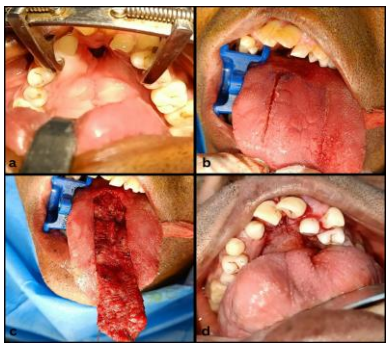

**Figure 2:** Tongue flap for palatal cleft closure

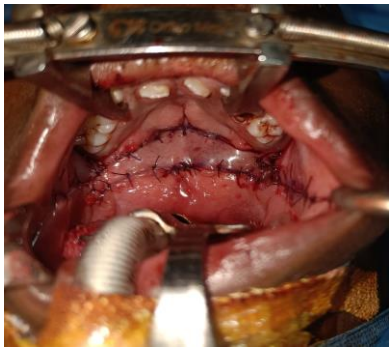

**Figure 3:** Bilateral buccinator myomucosal flap for palatal cleft closure

Interferons modulate fibroblast activity and can inhibit the proliferation of myofibroblasts, which are responsible for excessive collagen production in scars. Their use in scar management is still being explored, but they offer a potential avenue for reducing scar formation. Collectively, these pharmacological and non-pharmacological approaches aim to modulate the wound healing process, reduce excessive fibrosis, and enhance both the aesthetic and functional outcomes of scar formation following cleft palate surgery. Each method can be tailored to individual patient needs, and often they are used in combination to achieve the best possible results in scar management.[49]

### 3. Laser Therapy & Light-Based Treatments

Laser therapy and light-based treatments have become integral in managing and improving scar appearance through various mechanisms. Ablative lasers, such as fractional $CO_2$ and Er:YAG lasers, work by removing the epidermis, leading to collagen remodeling and improved scar texture[48]. However, these treatments require longer healing times and carry a higher risk profile compared to non-ablative therapies. Non-ablative lasers, like the 585 nm pulsed dye laser (PDL), target vascular components in early scars, reducing redness and preventing hypertrophic changes. Haoshu Chi et. Al studied the effects of PDL on cleft lip scars. Its efficacy on palatal scarring is yet to be studied[50]. These treatments are associated with shorter recovery periods but may offer only minor improvements in the cosmetic appearance of atrophic and acne scars. Low level laser therapy (LLLT) has been explored for its potential to aid in wound healing and reduce fibrosis post-surgery in a systematic review by Seyyedi SA et. al[51] While some studies suggest benefits, further research is needed to establish its efficacy in palatal scar management. Collectively, these laser-based interventions aim to modulate the wound healing process, enhance collagen remodeling, and improve the aesthetic and functional outcomes of scar formation. Laser therapy for cleft palate scars benefits from early initiation (as early as one month post-op) for better outcomes[52]. Combining modalities like PDL and fractional $CO_2$ lasers enhances scar texture and pliability. Intense Pulsed Light (IPL) used with lattice $CO_2$ lasers further improves scar evolution. Low-Level Laser Therapy (LLLT) shows promise in reducing fibrosis and accelerating wound healing. These interventions also contribute to improved functional outcomes and patient satisfaction.[53]

### 4. Mechanical & Pressure Therapy

Mechanical and pressure therapies are pivotal in scar management, aiming to enhance scar appearance and functionality. Microneedling, or collagen induction therapy, employs fine needles to create controlled micro-injuries in the skin, stimulating collagen production and remodeling, which can improve the texture and appearance of scars[5455] Pressure dressings, often utilized in burn care, apply consistent pressure to scar tissue, reducing blood flow and oxygenation, thereby minimizing hypertrophic scar formation and enhancing scar pliability[56]. Massage therapy complements this approach by mechanically disrupting fibrotic tissue, promoting flexibility and softness in the scarred area[57] In the context of cleft palate treatment, orthodontic and prosthetic interventions, such as palatal expanders and obturators, are employed to assist in palatal expansion and minimize post-surgical contractures, thereby improving both functional outcomes and aesthetic appearance[58]

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**5. Regenerative & Biological Therapies**

Emerging therapeutic approaches in scar management focus on enhancing tissue regeneration and reducing fibrosis through various modalities. Platelet-Rich Plasma (PRP) therapy involves concentrating platelets from the patient's own blood to deliver growth factors that promote faster, high-quality healing with reduced fibrosis[59]. This technique has been explored for its potential in improving skin texture and elasticity. Stem cell therapy, particularly using mesenchymal stem cells, is under investigation for its ability to modulate scarring and enhance tissue regeneration.[60] These cells can differentiate into various cell types and secrete bioactive molecules that influence the wound healing process, potentially leading to improved outcomes in scar appearance and function[61]. Hyaluronic acid-based injections are utilized to improve tissue hydration and elasticity, thereby reducing scar rigidity. By attracting water molecules, hyaluronic acid maintains tissue turgor and flexibility, which can soften scar tissue and improve its appearance[62]. FTY720 nanofiber scaffolds enhance oral wound healing and prevent ONF formation by promoting pro-regenerative immune infiltration, modulating interleukin expression, upregulating Sox2, and stimulating keratinocyte migration and proliferation. Future research will explore the underlying mechanisms, supporting FTY720 patches as a potential strategy to prevent ONF in cleft palate repair.[63]. Collectively, these therapies aim to synergistically enhance the wound healing process, minimize fibrosis, and improve the aesthetic and functional outcomes of scar management.

**6. Post-Surgical Rehabilitation & Therapy**

Integrating speech therapy and myofunctional exercises into rehabilitation protocols can significantly enhance oral function and alleviate tension on scarred tissues. These interventions focus on strengthening the orofacial musculature, optimizing speech articulation, and improving swallowing efficiency, thereby reducing undue stress on healing tissues[64]. Concurrently, scar massage and physiotherapy are vital in managing scar tissue by breaking down adhesions, enhancing

| Modality | Subtypes / Techniques | Mechanism / Purpose | Key Benefits / Outcomes |
|---|---|---|---|
| 1. Surgical Techniques | - Furlow Z-Plasty<br>- V-Y Pushback<br>- Bardach Two-Flap -Buccal & Tongue Flaps<br>- RFFF<br>- Pharyngeal Flaps | Reorientation of palatal muscles, lengthening palate, improving tissue vascularity and closure tension | Reduces VPD, improves mobility and speech, decreases scarring, improves healing |
| 2. Pharmacological Approaches | - Topical Silicone<br>- Corticosteroids (TAC)<br>- 5-Fluorouracil (5-FU)<br>- Botulinum Toxin<br>- Interferons | Modulate fibroblast activity, reduce collagen synthesis, control inflammation | Decrease hypertrophic scarring, improve scar texture, enhance drug delivery when combined |
| 3. Laser Therapy | - Fractional $CO_2$ Laser<br>- Er:YAG<br>- Pulsed Dye Laser (PDL)<br>- Low-Level Laser Therapy (LLLT) | Stimulates collagen remodeling, improves vascular response, enhances absorption of topical agents | Enhances scar aesthetics, reduces thickness and redness, shortens recovery |
| 4. Mechanical & Pressure Therapy | - Microneedling<br>- Pressure Dressings<br>- Scar Massage<br>- Palatal Expanders / Obturators | Induce collagen remodeling, break down fibrotic tissue, maintain tissue flexibility | Improves scar pliability and texture, prevents contracture, supports palatal growth |
| 5. Regenerative Therapies | - PRP<br>- Stem Cells<br>- Hyaluronic Acid<br>- FTY720 Scaffolds | Stimulate tissue regeneration, modulate immune response, maintain hydration | Accelerate healing, reduce fibrosis, improve elasticity and cellular organization |
| 6. Rehabilitative Therapies | - Speech Therapy<br>- Myofunctional Exercises<br>- Transverse Friction Massage (TFM) | Strengthen orofacial musculature, improve articulation, reduce tension on healing tissues | Improves oral function, reduces contracture, enhances patient recovery and quality of life |

**Figure 4:** Palatal scarring post cleft palate surgery

flexibility, and minimizing the risk of contracture formation. For instance, transverse friction massage (TFM) has been shown to influence neuromotor mechanisms by altering electromechanical delay and force transmission, suggesting a reduction in active muscle stiffness[65] Collectively, these therapeutic strategies contribute to improved functional outcomes and aesthetic results in patients undergoing rehabilitation for conditions involving scar tissue.

**Conclusion**

Palatal scarring following cleft palate repair presents a significant challenge due to its potential to impair speech, hinder maxillary growth, and negatively affect both function and aesthetics. To address this complex issue, a multimodal approach that combines surgical precision, pharmacologic interventions, laser therapy, and rehabilitative strategies has emerged as the most effective pathway for improving scar outcomes. Early identification of scar type and timely intervention are critical, as they allow for treatment plans to be customized according to the individual's functional requirements and tissue response. Surgical techniques aimed at minimizing trauma, maintaining vascular integrity, and ensuring tension-free closure play a foundational role in preventing excessive scarring. Adjunctive pharmacologic agents—such as corticosteroids, botulinum toxin, and novel anti-fibrotic compounds—can modulate the wound healing process, reducing inflammation and fibroblast proliferation. Laser

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therapies, including fractional $CO_2$ and pulsed dye lasers, contribute by promoting collagen remodeling, enhancing tissue pliability, and improving the overall appearance of the scar. Rehabilitation strategies, such as speech therapy, palatal stretching exercises, and myofunctional training, further aid in restoring oral function and enhancing scar mobility. In addition, advances in regenerative medicine—such as the use of growth factors, platelet-rich plasma (PRP), and mesenchymal stem cells—are paving the way for biological modulation of scar formation at the molecular level. This review consolidates current evidence on these diverse scar reduction strategies, evaluates their individual and combined effectiveness, and highlights future directions for optimizing outcomes in cleft palate patients. An integrative and patient-specific therapeutic model is key to addressing the multifactorial nature of palatal scarring and achieving optimal long-term functional and aesthetic results.

**Ethics Approval**

This study was approved by the Committee], approval/exemption number [XXXX].

**Competing Interests**

The authors declare that they have no competing interests.

**Data Availability**

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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