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ახალგაზრდა მკვლევარები

Vol. 3 Issue 3, 2025

https://doi.org/10.52340/jr.2025.03.03.12

Free Muscle and Nerve Transfers for Facial Reanimation: Evaluating Techniques, Donor Nerve Selection and Outcomes for Smile Restoration

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Abstract:

This comprehensive review examines Free functional muscle transfer (FFMT) techniques for facial reanimation, focusing on smile restoration in patients with long-term facial paralysis. Multiple neurotization techniques such as the Motor Nerve of Masseter (MNM), Cross-Facial Nerve Graft (CFNG), and Dual Innervation (DI) are explored in depth to clarify and understand the specific set of indications and advantages of each technique. A literature review was conducted using PubMed for articles published within the last 10 years. It was found that even though FFMT using the Gracilis muscle is the gold standard, DI strategies combining MNM and CFNG provide a balance of high smile excursion, resting tone and spontaneity, thus containing the advantages of both techniques. Pediatric patients demonstrate further advantages such as enhanced cortical adaptation often achieving spontaneous smiles even with MNM alone. In conclusion, careful patient selection, appropriate surgical timing, and donor nerve choice are crucial for successful FFMT outcomes. Limitations such as the heterogeneity in outcomes and non-standardized assessment methodologies restrict understanding of the area. Further research will benefit from long-term prospective studies with unified assessment modules, to directly compare and quantify functional benefits.

Keywords: facial reanimation, facial paralysis, smile reconstruction

Abbreviations:

Free Functional Muscle Transfer - FFMT

Motor Nerve of Masseter - MNM

Cross-Facial Nerve Graft - CFNG

Dual Innervation - DI

Double-Powered Gracilis - DPG

Introduction:

Facial expression is fundamental to human communication, with the smile serving as a primary means of conveying emotion, social intent, and identity [1,6]. In individuals affected by long-standing facial paralysis, the inability to smile results in more than just facial asymmetry; it disrupts emotional expression, impairs interpersonal interaction, and often diminishes psychological well-being and quality of life [1,2,6,9].

Surgical reanimation of the face has evolved significantly in response to these challenges, with the restoration of dynamic smile function becoming a central goal in modern reconstructive strategies [1,3,9]. Among these, free functional muscle transfer (FFMT) has emerged as a widely adopted solution for re-establishing movement in the paralyzed face, particularly in cases where native musculature is irreversibly denervated or absent [2,3,6,10]. The gracilis muscle, in particular, is frequently used due to its favorable anatomical characteristics and adaptability for microvascular transfer [2,3,9].

A key factor influencing the success of FFMT is the selection of the donor nerve for reinnervating the transferred muscle. Several options have been established in clinical practice, each offering unique characteristics in terms of surgical technique and neural input. The motor nerve to the masseter (MNM) is valued for its proximity and robust axonal input, which supports reliable muscle activation and early postoperative movement [2,4,10,12]. Alternatively, the cross-facial nerve graft (CFNG) connects the transferred muscle to the contralateral facial nerve, providing the potential for movement that more closely mimics spontaneous emotional expression [1,2,10]. In recent years, dual innervation (DI), a technique combining MNM and CFNG, has been introduced in an effort to integrate the functional strengths of both nerve sources [1,2,4,14].

While a variety of nerve strategies and surgical refinements have been introduced, comparisons between techniques remain complex due to differing methodologies and inconsistent outcome measures across published studies. Current literature evaluates a range of postoperative metrics, including commissure excursion, symmetry, and spontaneity of smile, but a lack of standardized criteria often limits direct comparison and interpretation [3,4,5,14].

This article provides a comprehensive overview of free muscle and nerve transfers for facial reanimation, with a focus on evaluating the main neurotization strategies; MNM, CFNG, and DI, as they relate to smile restoration. By examining surgical approaches and outcome domains, this review aims to inform ongoing efforts to refine facial reanimation techniques while recognizing the multifactorial nature of successful dynamic reconstruction.

Methodology:

This literature review collected, reviewed and summarized current evidence on facial reanimation surgery and nerve transfer for facial paralysis.

Database and Search Strategy

We searched the pubmed database using the keywords, "Facial Reanimation Surgery", "Facial Nerve", and "Reconstructive Nerve Transfer for Facial Paralysis" using boolean operators. We applied filters to include only articles published in the last 10 years and excluded books and documents from our search.

Screening and Selection

We screened the titles and abstracts of all the articles on the basis of their relevance to the topic and then included studies which had promising evidence on the subject of interest, and were in English. Conflicts were resolved by consensus or a third researcher.

Indications, Patient selection and Procedure timing for FFMT in Facial reanimation:

Facial expressions are produced by the coordinated activity of 17 pairs of facial muscles. Among them, smiling is especially important for both verbal and nonverbal communication, playing a crucial role in forming and maintaining social connections at any age. Facial paralysis presents significant challenges, not only functional and aesthetic but also psychosocial.[1]

The primary goal of facial reanimation surgery is to restore resting muscle tone, oral commissure movement, and overall facial symmetry. FFMT has become the gold-standard surgical technique for the dynamic reanimation of long-standing facial paralysis, especially when native facial muscles are absent or irreversibly damaged [1,7,14]. This approach is primarily indicated for patients with chronic facial palsy lasting more than 12 to 18 months, congenital or developmental facial paralysis, or cases involving irreversible muscle fibrosis where neural repair alone is insufficient [6,11,14].

The gracilis muscle is the most commonly used donor muscle for FFMT due to its favorable anatomical characteristics, including consistent and predictable neurovascular pedicle anatomy, sufficient muscle length, and minimal donor site morbidity [1,5,6,7,11,14]. Its muscle microarchitecture allows for rapid and robust excursion once reinnervated, contributing to functional and aesthetic restoration of smile dynamics [14].

The timing of facial reanimation surgery is a critical factor influencing surgical decision-making and outcomes. It is generally classified into three categories based on time into Immediate (within 72 hours), Subacute (72 hours to 12 months), and Late interventions (beyond 12 to 18 months) [11].

Immediate interventions, focus primarily on re-establishing nerve continuity through primary repair or nerve transfers to allow for timely reinnervation and muscle preservation. During this period, nerve stimulators can aid intraoperative identification as neurotransmitter stores diminish rapidly [11].

In the Subacute phase , preserving muscle bulk and preventing irreversible atrophy is paramount. If the facial nerve is transected, primary repair is attempted; otherwise, management is guided by serial electromyography and clinical examinations. Expectant observation is appropriate when spontaneous nerve recovery is evident. However, if no improvement is detected after a period of 8 months, neurotization or muscle transfer procedures are indicated to restore function before permanent muscle degeneration occurs [11].

Late interventions,Performed in congenital cases or after 12-18 months of paralysis, focus on dynamic muscle replacement because of fibrosis and atrophy in the native muscles [6,11,14]. Interventions include FFMT and Regional muscle transfer, and selection depends on patient factors such as microsurgical candidacy and extent of paralysis [11]. Static surgical options may be reserved for older patients who have completed growth or are not candidates for dynamic reconstruction [11].

Patient selection for FFMT depends on several key factors including the etiology and duration of facial paralysis, anatomic considerations, patient age, and microsurgical candidacy [1,6,11,14].

FFMT is primarily indicated for patients with long-standing facial paralysis, typically beyond 12 to 18 months, where native facial musculature is absent, severely atrophic, or fibrotic, rendering isolated nerve repair ineffective [6,11,14]. It is also employed in congenital or developmental facial palsy cases with nonfunctional or hypoplastic muscles [11,12].

Unilateral versus bilateral involvement influences surgical planning. In unilateral palsy, if the contralateral facial nerve is intact, CFNG combined with FFMT results in a more spontaneous and emotional smile [11,7]. For bilateral cases, options include staged or single-stage procedures with muscle transfers powered by the MNM or regional muscle transfers like lengthening temporalis myoplasty [11].

Microsurgical candidacy is also essential, as FFMT requires adequate recipient vessels and patient tolerance for anesthesia and prolonged surgery [6,11]. In patients unsuitable for microsurgery or preferring less invasive options, regional muscle transfers such as temporalis or masseter muscle flaps may be employed, although these often result in voluntary rather than spontaneous smile restoration [11].

In summary, ideal candidates for gracilis FFMT are those with chronic facial paralysis, preserved general health, appropriate age, and sufficient microsurgical anatomy to support free tissue transfer, with unilateral cases benefiting most from cross-facial nerve grafting when feasible [1,6,7,11,14].

Surgical Technique of FFMT Using the Gracilis Muscle

Facial reanimation using FFMT can be performed via either single-stage or two-stage surgical approaches, with the choice influenced by patient-specific factors including laterality of paralysis, donor nerve availability, and surgeon preference [6,11].

The classic two-stage approach involves initial CFNG from the contralateral healthy facial nerve, followed by a waiting period of several months to allow for nerve regeneration before performing the microvascular free gracilis muscle transfer [6,7,11]. This staged method is considered the gold standard for unilateral facial paralysis and facilitates restoration of spontaneous, emotionally-driven smiles by allowing the transferred muscle to be innervated by the CFNG [7,11].

Single-stage procedures have been developed to reduce total treatment time and enable earlier functional recovery. These often employ dual innervation of the gracilis flap using both the MNM for immediate strong motor input and the CFNG for spontaneous smile development over time [5,6,11]. This approach offers the advantage of immediate muscle contraction via the MNM and later acquisition of emotional smile via the CFNG, potentially improving patient satisfaction and shortening rehabilitation [11].

In bilateral facial paralysis, staged procedures using the MNM for free gracilis transfer with appropriate intervals between surgeries are typical, whereas single-stage options such as lengthening temporalis myoplasty may be preferred for quicker reanimation [11].

The decision between single and staged procedures is individualized, weighing patient specific factors and institutional preference. Some institutions favor the single-stage DI technique for its combination of early power and eventual spontaneous smile, while others continue to utilize the two-stage approach for its reliable and well-studied outcomes [11].

The gracilis muscle is harvested from the medial thigh through a longitudinal incision typically placed 4 to 11 cm below the inguinal crease, posterior to the pubic tubercle. Dissection involves identification and careful preservation of the anterior branch of the obturator nerve and the vascular pedicle, which usually arises from branches of the profunda femoris artery along with accompanying veins [6,11,14].

An 8 to 5 cm segment of the gracilis muscle flap is harvested in the standard fashion, maintaining the neurovascular bundle to ensure viability [14]. The muscle is usually trimmed to between one-third and one-half of its width to avoid facial bulk and facilitate natural contouring upon inset [6,11]. Thinning of the muscle flap is often performed in situ while the muscle remains perfused to reduce ischemic time and minimize the risk of hematoma [6]. The harvested flap is then transferred into a prepared pocket in the facial region and secured, commonly by anchoring the medial attachment using previously placed sutures [14]. Microvascular anastomoses are performed in an end-to-end fashion between the flap vessels and recipient facial vessels, ensuring adequate blood supply [6,14].

Nerve coaptation is achieved by connecting the anterior branch of the obturator nerve of the gracilis muscle to a donor motor nerve. This donor nerve may be the MNM (for strong voluntary contraction), the CFNG (for spontaneous smile reinnervation), or both for DI [5,6,7,11,14]. The nerve coaptation is also performed end-to-end to optimize axonal regeneration and functional recovery [14].

The gracilis muscle is inset under neutral tension corresponding to its resting length at harvest to prevent overcorrection or lateral displacement of the oral commissure [6]. Postoperatively, patients undergo physiotherapy to promote muscle re-education and to optimize smile function [11].

Complications of FFMT with gracilis muscle include hematoma, vascular compromise, failed reinnervation, and flap loss, though these are relatively uncommon with modern microsurgical techniques and careful perioperative care, with flap failure rates reported around 3% [5,11]. Long-term outcomes demonstrate significant improvements in oral commissure movement, facial symmetry, and patient quality of life [1,5,7].

In conclusion, the gracilis free muscle transfer remains the cornerstone of dynamic facial reanimation surgery, offering a reliable and effective solution for restoring smile function and facial symmetry in patients with long-standing facial paralysis [1,5,6,7,11,14].

Donor Nerve Selection for Gracilis Transfer:

Dynamic facial reanimation aims to restore facial movement, like the smile, in patients with long-standing facial paralysis. FFMT using the Gracilis muscle is the gold standard surgical technique, and the choice of donor nerve for reinnervation of the transplanted muscle plays a crucial role in the functional outcome. The commonly used donor nerves include the MNM, hypoglossal nerve (XII), and CFNG. Each donor nerve presents distinct advantages and limitations in terms of spontaneity, strength, and recovery time. Recently, dual innervation strategies combiningMNMand CFNG have emerged to optimize outcomes [2, 3, 4, 13].

Outcomes:

The effectiveness of FFMT for smile reanimation is evaluated using objective metrics, aesthetic analysis, and patient-reported outcomes. 3D optoelectronic motion analysis tracks facial movements by capturing the displacement of anatomical landmarks during both rest, voluntary or spontaneous smiling. Hence, it is the gold standard for precisely measuring smile dynamics and is essential in research and clinical settings. Alternates include FACEgram and FACIAL CLIMA, 2D imaging systems that assess smile excursion and alignment. Multiple scales have also been introduced to accurately analyse results, such as the House-Brackmann, Socolovsky et al., the Terzis and Noah scale, and the Sunnybrook Facial Grading System, and static photographic methods, like the tragion-to-commissure distance are also commonly employed for the same [4,10,11,12,14].

In the case of functional recovery, Electromyography (EMG) is used to track spontaneous and voluntary muscle activation, and MRIs to demonstrate overlapping cortical activation during smiling and jaw clenching [12,13].

Assessing results of FFMTs hence involve a dual-prong approach involving both aesthetic and functional markers. Smile activation during voluntary and teeth-clenching smiles, and smile symmetry, were assessed by a single-center study of 13 patients undergoing DI using both MNM and CFNG. They reported that smile activation improved from 52% preoperatively to 75% postoperatively during voluntary smiles, and further to 91% when smiling with teeth clenching. Smile asymmetry also decreased from 30% to 20% [14].

The patient, however, measures the results through the naturality and emotional expressiveness of the smile. In this area, DI reports higher rates of self-confidence, improved social interactions, and more emotionally resonant smiles compared to those with single-nerve reinnervation. Objective analyses align with these reports, showing enhanced labial commissure movement, midline alignment, and overall facial harmony, especially when rehabilitation is incorporated early. Spontaneousness is where the CFNG gains an upper hand, demonstrating the highest frequency of spontaneous smiles, while DI only manages to do so in up to 70% of patients. Nevertheless DI is a powerful option for balancing strength and emotional nuance [4,11,14].

However, significant limitations still remain. Approximately 15% of DI patients fail to achieve satisfactory outcomes, often due

to poor regenerative capacity, vascular issues within the flap, or competition between donor nerves that may limit spontaneous activation [4,14]. Additionally, concerns have been raised about masseter muscle atrophy following nerve harvest, even though it has not been associated with visible facial asymmetry [12].

Ultimately, when guided by thoughtful patient selection and reinforced through physiotherapy, DI techniques offer the most balanced approach, uniting the MNM's reliable strength with the CFNG's potential for emotional spontaneity, resulting in improved symmetry, natural facial movement, and greater patient satisfaction across diverse clinical scenarios [4,11,14].

Meta-analysis of FACEgram data revealed that MNM reinnervation resulted in significantly greater smile excursion than CFNG, with a mean difference of 0.55 mm and no inter-study heterogeneity[4]. Although MNM also showed slightly better symmetry angles at rest and during smiling, these differences were not statistically significant [4,11].

EMG has revealed spontaneous activity in 40–60% of patients with MNM innervation, particularly when coactivation training is part of rehabilitation [4,14]. Such findings suggest that even motor-dominant donor nerves can support emotionally driven smiles under the right conditions.

Indeed, a study of 66 patients showed spontaneous smiling not only in CFNG recipients but also in those who underwent MNM reinnervation and masseteric–facial nerve neurorrhaphy, challenging long-held assumptions about the exclusivity of CFNG in restoring spontaneity [12].

Advances in Dual Innervation and Double-powered Gracilis Transfers:

Facial reanimation has evolved with the development of dual innervation techniques that aim to combine the strengths of multiple donor nerves to optimize both movement strength and spontaneity. Traditional single nerve transfers, such as using the MNM or CFNG, often required a compromise between robust contraction and natural, emotionally driven facial expressions [2,3,4,14]. Innovations now involve simultaneously coapting both nerves to a free muscle flap, such as the gracilis, to maximize outcomes [2,4,14].

One strategy involves using the MNM for strong, volitional movement, while CFNG offers the potential for spontaneous emotional smile due to its origin from the healthy side's facial nerve [2,4]. This dual neurotization improves excursion and helps overcome limitations of each nerve when used alone [4,14]. Additionally, combining these nerves appears to reduce asymmetry and increase activation ratio, including during spontaneous smiling, based on motion analysis studies [14].

In parallel, technical refinements such as the use of end-to-side coaptation, meticulous identification of facial branches, and careful tension-free nerve approximation are essential in optimizing surgical success and reducing complications like synkinesis [3,12].

In an effort to achieve both strength and spontaneity in smile reanimation, dual innervation (DI) techniques have emerged as a prominent strategy. These involve coapting the transferred free muscle to two distinct nerve sources, typically the MNM (for power) and the cross-facial nerve graft (CFNG) (for spontaneity). This strategy allows one donor to dominate early reinnervation, while the other contributes spontaneous, emotionally-driven movement over time [12,13,14].

Among the earliest clinical DI protocols, Biglioli et al. used end-to-end CFNG with end-to-side MNM coaptation in 14 patients, observing improved symmetry and smile spontaneity [14]. Later studies, such as those by Borschel and colleagues, adopted a MNM end-to-end with CFNG end-to-side coaptation, noting earlier reinnervation and smile onset [2,3,13,14]. This variation capitalizes on the MNM's high axonal load to ensure rapid muscle activity, while allowing spontaneous input from the CFNG to develop gradually. Another technique involves splitting the obturator nerve to allow dual end-to-end coaptation with both CFNG and masseteric branches. This method theoretically offers balanced input and may avoid the potential signal competition seen in side-to-end coaptations [13].

While dual innervation shows promise, concerns remain regarding synkinetic movements and donor nerve dominance. Some patients exhibit masseter-driven smiling without significant spontaneous contribution, leading to an appearance of artificial or learned smiles [12]. Electromyographic studies suggest variable recruitment patterns, and further work is needed to understand long-term cortical adaptation in dual-innervated constructs.

Specifically, DI strategies aim to synergistically combine the strengths of both nerves, pairing the rapid, strong contractions of MNM with the spontaneous, natural facial expression driven by CFNG [2,4,13]. Though DI improves smile excursion, resting tone, and overall symmetry beyond CFNG alone, spontaneous smile rates in DI may be slightly lower than pure CFNG innervation, potentially due to neural competition or incomplete cortical adaptation [4]. Furthermore, DI techniques vary, with one-stage procedures involving end-to-end coaptation ofMNMand end-to-side coaptation of CFNG showing reinnervation as early as 2.9 to 4.7 months and spontaneous smile rates up to 70% in select cohorts [4, 11]. Two-stage DI approaches allow CFNG axons to establish initial dominance, potentially improving spontaneous motor unit recruitment and facial symmetry by minimizing axonal competition. While the MNM and CFNG single innervation yield similar and greater commissure excursion (~8.46 mm and ~7.15 mm respectively), DI typically results in somewhat lower excursion (~5.18 mm) [4].

Advanced methods involving selective splitting of the obturator nerve fascicles allow targeted coaptation to both the MNM and CFNG, facilitating DI within a single muscle flap. By allocating separate fascicles to each donor nerve, surgeons can minimize axonal competition at the neuromuscular junction, promote more organized reinnervation, and preserve the functional advantages of both inputs. This technique not only enhances the chances of simultaneous voluntary and spontaneous activation but may also reduce synkinesis and improve coordination between the two inputs. Preliminary studies suggest that such fascicle-based coaptation can lead to earlier muscle contraction, improved commissure excursion, and higher rates of spontaneous smile in comparison to non-selective DI approaches [4,13]. Therefore, patient-specific factors such as age, paralysis duration, and functional priorities should guide the choice between single and DI approaches to optimize both cosmetic and functional results [3,4,13]. It is also noted that synchrony of smiles tends to be highest with CFNG, followed by DI, and lowest with MNM alone [4,11].

A novel extension of this concept is the double-powered gracilis (DPG) technique, in which two independent gracilis muscles are inset in parallel and innervated separately—usually one by the CFNG and the other by the MNM. Though technically complex, this offers a theoretical solution to avoid donor signal interference while maintaining robust power and spontaneity [2,3,13,14]. Clinical outcomes with both DI and DPG techniques remain heterogeneous. Some authors report higher smile excursion and spontaneity scores, while others observe no significant advantage over single-nerve transfers. Long-term prospective studies are needed to standardize technique, understand cortical plasticity, and quantify functional benefits [4,13].

Technical Refinements to Improve Spontaneity and Reduce Synkinesis:

Several surgical refinements have been introduced to improve outcomes in facial reanimation. End-to-side coaptation is favored in dual innervation to preserve donor nerve function and reduce the number of neurorrhaphy sites, enhancing axonal input. To avoid excessive eye closure (a form of synkinesis), the inferiormost buccal branch is chosen for masseteric coaptation, avoiding zygomatic branches linked to orbicularis oculi activation [3]. Additionally, In masseter-to-facial nerve neurorrhaphy, using a direct coaptation between the MNM and buccal branch avoids cable grafting, minimizing axonal loss and improving reinnervation speed [12].

Surgeons also emphasize careful microsurgical technique and anatomical familiarity to ensure optimal nerve identification and minimal donor-site morbidity. Moreover, by limiting the number of neurorrhaphies and preserving native donor nerve function, newer techniques reduce the risk of complications such as tongue hemiatrophy (common with hypoglossal transfer) and unintended muscle activation [3,12].

Single vs Dual Innervation Strategies:

Single innervation with the MNM provides rapid and robust reinnervation, with functional muscle contraction typically evident within 3 to 6 months, and superior commissure excursion compared to other donor nerves [2,4,13]. However, due to the MNM's role in mastication, spontaneous and

emotionally driven smile activation is often limited, relying on cortical plasticity and learned coactivation patterns [4].

Electromyography studies indicate that some patients exhibit masseteric coactivation during smiling, which correlates with improved postoperative symmetry, but overall spontaneous smile rates remain modest with MNM alone [4]. CFNG, while slower to regenerate, remains the superior method for restoring spontaneous, synchronous smiles. CFNG preserves native contralateral facial nerve input, which underpins its better outcomes in facial symmetry, resting tone, and emotionally driven smile activation [2,4,13].

Synchrony of smiles also tends to be highest with CFNG, followed by DI, and lowest with MNM alone [4,11]. Nonetheless, the lengthy regeneration pathway and axonal attrition reduce muscle excursion strength, and spontaneous smile recovery can be particularly challenging in older patients [4].

MNM vs Hypoglossal vs CFNG in Facial Reanimation:

The MNM is often the preferred choice in elderly patients, in bilateral facial palsy, or when a single-stage procedure is desired [3,4,13]. Its close anatomical proximity to the gracilis muscle allows direct neurotization without the need for interposition grafts, facilitating early reinnervation and reducing operative complexity [12]. Histomorphometric studies have shown MNM possesses a higher axonal load compared to CFNG, contributing to stronger muscle contraction and greater commissure excursion to the smile [2,4,13]. However, its drawback lies in spontaneity, being a nerve of mastication, cortical reorganization is required for patients to use jaw-clenching centers to elicit a smile [4,13]. Although masseteric co-activation has been demonstrated in EMG studies during smiling in some patients (around 40-60%), spontaneous smiles with MNM alone are generally less coordinated or emotionally triggered. Additionally, MNM-driven reanimation may result in involuntary facial movement during chewing or difficulty achieving symmetric resting tone, especially in older individuals [4].

The CFNG is typically indicated in younger patients with good regenerative potential and when repairing a natural smile is a primary goal. CFNG provides the most physiologically natural reinnervation by routing axons from the contralateral facial nerve to the paralyzed side [4,13]. This preserves the native emotional and volitional control of facial expression, enabling the highest rates of spontaneous, synchronous smiles [13]. Anatomically, however, CFNG is more complex: it requires a long nerve graft, usually a reversed sural nerve tunneled across the midface, with two neurorrhaphies, which can result in axonal loss at each coaptation site and a lengthy regeneration pathway (>10 cm) [4]. As a result, reinnervation is slower, typically requiring 8-10 months, and studies show a drop in axonal count from the original donor branch to the recipient gracilis motor nerve, leading to weaker muscle contraction compared to MNM [4,13]. This challenge is magnified in elderly patients, whose reduced axonal regeneration capacity often results in suboptimal outcomes [4]. Moreover, CFNG may lead to complications such as ocular synkinesis and hemiface weakness [2,4,13].

The hypoglossal nerve (XII) is historically considered a gold standard for nerve transfers. It is still used when the facial or MNM are unavailable, particularly in bilateral or congenital cases. It provides good resting tone and robust motor input but is limited in generating smile excursion. However, its use has declined due to significant donor-site morbidity. Partial or complete hypoglossal transfer can result in tongue hemiatrophy, dysphagia, and impaired speech articulation. Additionally, facial movements derived from hypoglossal input are not intuitive,The hypoglossal nerve does not easily undergo cortical adaptation for facial expression, making spontaneous smiles difficult to achieve. Patients must consciously engage tongue movements to trigger a smile, which is neither intuitive nor emotionally driven. It is contraindicated in patients with pre-existing swallowing dysfunction or at risk of aspiration [3,12,13].

Although less commonly used, the spinal accessory nerve (CN XI) has been proposed as an alternative in select cases, such as congenital facial palsy or absence of viable facial or MNM. Some reports suggest favorable outcomes, though evidence remains limited and further studies are needed to validate its efficacy in restoring spontaneous, symmetric facial movement [3]

Pediatric and High-risk Elderly considerations:

Pediatric facial reanimation presents unique challenges distinct from adult patients, primarily due to ongoing craniofacial growth, neural plasticity, and psychosocial factors. FFMT has emerged as a preferred reconstructive option in children with long-standing facial paralysis, offering dynamic restoration of smile and facial symmetry [11]. The gracilis muscle is commonly used for FFMT in pediatric patients due to its favorable anatomy, reliable neurovascular supply, and minimal donor site morbidity.

The increased neural plasticity in children allows for enhanced cortical adaptation, facilitating improved functional outcomes even when using donor nerves that do not initially produce emotional facial movements. For example, nerve transfers utilizing the motor branch to the masseter muscle can result in voluntary smile restoration, with children eventually developing spontaneous emotional expressions through cerebral remodeling [11]. This is a notable advantage in pediatric patients compared to adults, where such cerebral adaptation is more limited.

The timing of reconstruction is of particular importance in pediatric populations. While some centers delay FFMT until school age (typically 5-6 years old) to allow for patient participation in therapy and sufficient vessel size for microsurgical anastomoses, early intervention may be warranted in select cases to prevent muscle atrophy and psychosocial consequences [11]. Postoperative rehabilitation with targeted physiotherapy plays an essential role in optimizing functional recovery, with protocols tailored to the specific nerve transfers and muscle flaps used.

Overall, pediatric FFMT demonstrates promising outcomes in smile restoration and facial reanimation, with donor nerve selection and surgical technique carefully individualized to the patient's age, to either postpone or intervene prematurely [11].

In high-risk elderly patients, facial reanimation procedures pose additional challenges related to comorbidities and reduced physiological reserve. Traditional general anesthesia and prolonged surgical times may increase perioperative risk in this population. To address these concerns, nerve transfer procedures performed under sedation and local anesthesia have been explored as a viable option for facial reanimation in elderly patients deemed unfit for extensive surgery [8].

Nerve transfers targeting the MNM or hypoglossal nerve can be performed with minimal operative time and anesthesia exposure, offering a dynamic solution for smile restoration in this population. Although these transfers primarily provide voluntary motor control rather than spontaneous emotional expressions, they have shown significant improvements in facial symmetry and oral competence postoperatively [8]. The reduced invasiveness of these techniques allows elderly patients to benefit from facial reanimation with lower surgical risk and faster recovery.

Careful patient selection and preoperative evaluation are paramount to optimize outcomes. While the cerebral plasticity seen in younger patients is diminished in the elderly, functional improvements in facial movement and quality of life have been documented. Adjunctive therapies including physical rehabilitation remain important to maximize functional gains following nerve transfer under sedation [8].

Limitations:

The limitations of this study are inherent to a literature-based study. Our literature search was confined to Pubmed within the last 10 years which may not contain all relevant literature from other databases or older publications, and was limited by the unavailability of full-text access to articles. Furthermore, high heterogeneity of reported outcomes and assessment methodologies limited direct comparison and quantitative meta-analysis in some areas. The lack of long-term prospective studies for some of the more advanced techniques, also restricts the definitive conclusions that can be drawn regarding long-term efficacy and patient satisfaction.

Conclusion:

Facial paralysis profoundly disrupts emotional expression and social interaction, making the restoration of a natural smile a key goal in reconstructive surgery. FFMT, particularly with the gracilis muscle, has become the gold standard for dynamic reanimation in patients with long-standing paralysis, offering both functional and aesthetic restoration when native facial musculature is absent or non-functional [1,5,6,7,11,14].

However, the success of FFMT depends on more than the choice of muscle; careful patient selection, appropriate surgical timing, and the choice of donor nerve for reinnervation are crucial for its successful implementation [1,6,11,14]. Each donor nerve carries unique benefits and limitations. The MNM provides strong, early contraction and is especially useful in elderly or high-risk patients, but lacks emotional spontaneity [2,4,13]. The CFNG preserves spontaneous and symmetric smiling through contralateral facial nerve input but offers weaker contraction and slower reinnervation, particularly in older individuals [4, 13]. The hypoglossal and spinal accessory nerves, while less frequently used today, may still be considered in specific cases whereMNMor CFNG are unavailable [3,12,13].

To overcome the limitations of using a single nerve, DI techniques have gained prominence. By combining MNM's strength with CFNG's spontaneity, DI aims to achieve a smile that is both powerful and natural [2, 4, 13, 14].

Pediatric patients benefit from their greater neural plasticity, often developing spontaneous smiles even withMNMinnervation through cortical adaptation [11]. Meanwhile, elderly or high-risk patients may still achieve meaningful improvements in function and symmetry through simplified nerve transfer procedures performed under sedation [8].

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Acknowledgements:

We extend our sincere gratitude to all the authors whose original research contributed to the primary data reviewed herein. The manuscript was written section-wise in collaboration by all team members. To further include a varied perspective and understanding, each section was written together by two authors. The section-wise submissions were then reviewed by the first author, who edited it and combined the sections into a congruent manuscript. All the other authors contributed in an equal fashion.

Declaration of Funding, Human ethics, and Consent to Participate:

No funding or grafts were involved in this research article. Human ethics and Consent to Participate do not apply to this article.