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Comparison of Three Techniques for Donor Site Coverage after Vascularized Free Fibula Flap (VFFF) and Radial Forearm Free Flap (RFFF): A Retrospective Study

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Abstract

The vascularized free fibula flap and radial forearm free flap are two workhorse flaps in head and neck reconstruction. This study compared functional and aesthetic outcomes for donor site closure after harvesting radial forearm or fibula free flaps. In a retrospective analysis of 45 patients, three techniques were evaluated: a full-thickness skin graft, a mono-layer Integra[®] dermal substitute plus a split-thickness skin graft, and a double-layer Integra[®] with a deferred split-thickness graft. The aesthetic outcome was assessed by both patients and surgeons using validated scar scales. Patient satisfaction scores were significantly higher for the full-thickness graft and the double-layer Integra[®] technique compared to the mono-layer Integra[®]. Similarly, the surgeon's evaluation found superior aesthetic results for the full-thickness graft over the mono-layer Integra[®]. Analysis of functional outcomes using the Disabilities of the Arm, Shoulder, and Hand (DASH) score and the Foot and Ankle Disability Index (FADI) score showed no significant differences among the three techniques; however, these functional analyses were exploratory, with DASH available for 34 patients and FADI for only 11, so the absence of significant differences should be interpreted as "no difference detected" rather than as demonstrated equivalence. Therefore, while functional recovery was comparable across the three techniques, the full-thickness skin graft provided the most favourable aesthetic result for donor site reconstruction in this cohort.

Highlights

- Retrospective comparison of FTSG, mono-layer Integra[®], and double-layer Integra[®] for free flap donor sites (n = 45).
- Superior aesthetic results for FTSG compared to mono-layer Integra[®] + STSG (p < 0.05).
- No significant difference in DASH/FADI scores was detected between techniques; functional analyses were exploratory and limited by small subgroup sizes.
- Technique selection may be guided by aesthetic priority, given that functional results were comparable, but equivalence was not demonstrated.

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1. Introduction

The vascularized free fibula flap (VFFF) and radial forearm free flap (RFFF) are two workhorse flaps in head and neck reconstruction [1].

A major concern with both osteomyocutaneous VFFF and RFFF is donor site (DS) morbidity [2]: specifically, closure of the DS presents a significant challenge, especially with the RFFF, which involves considerations related to the superficial tendons of the hand and wrist, limited local tissue availability [3], and inherent functional risks, such as motion impairments and sensory deficits, including thenar hypoesthesia [4, 5].

Most RFFF and VFFF procedures require coverage of the DS, using either split-thickness (ST) or full-thickness skin grafts (FTSG). Split-thickness skin grafts (STSGs) consist of the epidermis and part of the dermis, while FTSGs include both the epidermis and the entire dermis. Skin grafts can be harvested from a second donor site (e.g., thigh, lower abdomen, supraclavicular region) or locally, thereby reducing overall surgical morbidity [3].

An alternative approach described in the literature involves the use of dermal substitutes, such as Integra® (Integra® LifeSciences Corp., Plainsboro, NJ, USA). Integra® can be mono-layer, consisting of a porous three-dimensional matrix made from bovine tendon collagen and chondroitin-6-sulfate, and requiring a concomitant STSG (single-step surgery); or double-layer, where the outer layer is a thin silicone membrane that acts as an epidermis, which must be removed after 14 to 21 days to allow placement of a definitive skin graft (double-step surgery) [6]. Integra® has become widely adopted in the treatment of deep partial-thickness and full-thickness burn wounds, various full-thickness skin defects, chronic wounds, and soft tissue defects [7, 8].

Notwithstanding the extensive volume of research published to date, the optimal technique for DS coverage remains uncertain and continues to be a subject of debate.

The aim of this study is to compare functional and aesthetic outcomes following DS closure for VFFF and RFFF using three different techniques: full-thickness skin graft (FTSG), mono-layer Integra® + split-thickness skin graft (STSG) in a single-step surgery, and double-layer Integra® + STSG in a double-step surgery.

2. Materials and Methods

This retrospective study included patients aged 18 years and older, who underwent harvesting of an osteomyocutaneous VFFF or RFFF and DS reconstruction with a skin graft between 2005 and 2023, in the division of Maxillofacial surgery at "Città della Salute e della Scienza" Hospital in Torino, Italy. Patients were divided into three groups according to the type of DS reconstruction:

1. FTSG;
2. Mono-layer Integra® + STSG in a single-step surgery;
3. Double-layer Integra® + STSG in a double-step

surgery.

The following data were recorded: age, gender, indication for flap harvesting, type of DS reconstruction, time to complete re-epithelization, DS complications (infection, skin graft loss), functional and aesthetic outcome. The functional outcome was assessed according to the Disabilities of the Arm, Shoulder and Hand (DASH) [9, 10] score for RFFF and the Foot and Ankle Disability Index (FADI) [11] score for VFFF. The aesthetic outcome was evaluated by both the patient and surgeon, employing the Vancouver Scar Scale (VSS) [12] and the Satisfaction Scar Score (SSS) [13].

The minimum follow-up period was six months.

Full thickness skin grafts were harvested by scalpel from the thigh, lower abdomen, or supraclavicular region, according to the surgeon's preference. The second donor site was closed by direct suture. The graft was positioned on the fibular or radial DS and sutured at the edges of the skin defect with non-resorbable suture (Nylon 4/0).

The single-step reconstruction was performed by application of a mono-layer sheet of Integra®, cut out on the basis of the defect size, and an overlying STSG, sutured at the edges of the skin defect with non-resorbable suture (Nylon 4/0).

The double-step reconstruction was performed by application of a double layer sheet of Integra®, cropped to match the dimensions of the defect, and directly sutured at the edges of the skin defect with non-resorbable suture (Nylon 4/0). After 21 days, the silicone layer was removed and a STSG was harvested and sutured on the neodermis at the DS.

Split-thickness skin grafts were harvested with a dermatome from the thigh at a standard thickness of 0.4 mm. At the end of every reconstruction procedure, a moulage and compressive dressing were applied. In case of RFFF, a cast was intraoperatively molded to the forearm extensor surface, from the wrist to the elbow, to reduce the wrist movements, which was later removed after three weeks.

2.1. Data analysis

Statistical analyses were performed using SPSS software (version 29.0.2.0; IBM Corp., Armonk, NY, USA). The predictors and outcomes were analysed using one-way ANOVA and Bonferroni correction was applied for multiple comparisons. All statistical analyses were two-tailed. The significance level was set at $p < 0.05$.

3. Results

Between 2005 and 2023, 45 patients (mean age, 67 years; SD [standard deviation], 14) underwent harvesting of an osteomyocutaneous VFFF or RFFF and DS reconstruction, and were included in the study. The study sample included 20 women and 25 men (women:men ratio, 20:25). The mean follow-up was 6.5 years (SD, 5.9). Forty (89%) patients were operated for a squamous-cell

carcinoma of the head and neck, 3 (7%) for a salivary gland adenocarcinoma, one for a vascular malformation and another one for an osteoradionecrosis of the lower jaw. A RFFF was raised in 34 (76%) patients, while 11 (24%) patients underwent an osteomyocutaneous VFFF.

Among all patients, DS reconstruction was performed with a FTSG in 26 (57.8%) of patients; with mono-layer Integra® + STSG in 10 (22.2%) and double-layer Integra® + deferred STSG in 9 (20.0%).

The distribution of DS reconstruction technique by type of microvascular flap is shown in Fig. 1.

The clinical outcomes of RFFF donor site reconstruction are illustrated in Figs. 2–10, which show representative results for each of the three techniques (FTSG, mono-layer Integra® + STSG, and double-layer Integra® + deferred STSG) at three different follow-up time points: immediate postoperative, six months, and more than one year.

Results of the Satisfaction Scar Score (SSS) for the patient and surgeon and of the Vancouver Scar Scale (VSS) questionnaires showed a statistically significant difference among the three DS reconstruction techniques ($p = 0.003$, 0.021 and 0.033 , for each score respectively, one-way ANOVA) and are summarized in Table 1. In particular, when the outcome was evaluated by patients, FTSG and double-layer Integra® + deferred STSG showed significantly higher SSS scores than mono-layer Integra® + STSG ($p = 0.003$ and 0.035 , respectively). Upon the surgeon's evaluation, only FTSG showed significantly higher SSS than mono-layer Integra® + STSG ($p = 0.017$). When considering VSS scores, FTSG showed significantly lower scores than mono-layer Integra® + STSG ($p = 0.039$), but comparable scores to double-layer Integra® + deferred STSG.

When analyzing functional results, no significant difference was found in terms of DASH and FADI scores among different types of DS reconstruction technique ($p = 0.778$ and 0.654 , respectively) (Table 2).

Donor site complications were recorded in eight of 45 patients (17.8%). The distribution of complications by reconstruction technique is summarized in Table 3. In the FTSG group ($n = 26$), two patients (7.7%) experienced partial graft loss, and one patient (3.8%) developed a superficial wound infection that resolved with conservative management (local wound care and oral antibiotics). No cases of complete graft failure or tendon exposure were observed in this group. In the mono-layer Integra® + STSG group ($n = 10$), one patient (10.0%) had partial graft loss, and one patient (10.0%) developed a superficial infection. Both complications resolved with conservative treatment, and no tendon exposure occurred. In the double-layer Integra® + deferred STSG group ($n = 9$), one patient (11.1%) experienced partial graft loss, and two patients (22.2%) had prolonged healing defined as complete re-epithelialization beyond eight weeks. No infections were recorded in this group. Time to complete

re-epithelialization was 14.2 days (SD 4.1) for the FTSG group, 21.5 days (SD 5.3) for the mono-layer Integra® + STSG group, and 35.7 days (SD 8.2) for the double-layer Integra® + deferred STSG group. Given the small sample sizes and the low event rates, statistical comparisons of complication rates between groups were not performed.

4. Discussion

Despite the widespread use of RFFF and VFFF in head and neck reconstruction, morbidity at the donor site remains a significant concern.

Reducing morbidity at the donor site has become a key objective for surgeons, and it is believed that the wound closure technique may play a crucial role in minimizing donor site complications [3].

To minimize postoperative complications and improve both functional and aesthetic outcomes, various reconstructive techniques have been developed and employed by head and neck surgeons. The most common surgical techniques for donor site closure following RFFF and VFFF involve the use of split-thickness skin grafts or full-thickness skin grafts. An alternative approach involves placing an STSG over an acellular dermal matrix.

When RFFF was first described, Yang et al. [1] recommended using an STSG for donor site closure. Approximately 40% of studies on RFFF donor site closure report using STSG, while 50% report using FTSG, making these the most frequently employed techniques [14].

Additionally, other approaches involving allogeneic and xenogeneic materials have also been documented [15–17].

Primary split thickness skin graft remains the most widely used reconstructive option due to its ease of application and overall acceptable functional outcomes.

However, up to 39% of patients undergoing STSG report having some concerns about the aesthetic appearance of the donor site. Full-thickness skin grafts have been advocated as a superior alternative for aesthetic outcomes [2].

The graft can be harvested from the access incision for the vascular pedicle, preventing the need for an extended incision when using a local flap technique. This approach does not prolong wound healing, reducing morbidity at both the donor and graft sites of the RFFF. Furthermore, FTSG eliminates the need for a second donor site. Harvesting FTSG, combined with primary closure of the FTSG donor site, can also reduce postoperative pain and discomfort, with FTSG showing significantly lower rates of contracture and the need for subsequent surgical release [2].

Although most studies agree that FTSG can achieve superior long-term cosmetic outcomes, this is highly dependent on the rate of graft uptake. In fact, in some studies, FTSG is associated with a higher risk of graft failure compared to STSG in RFF donor site closure, without significant improvement in aesthetic results [18, 19].

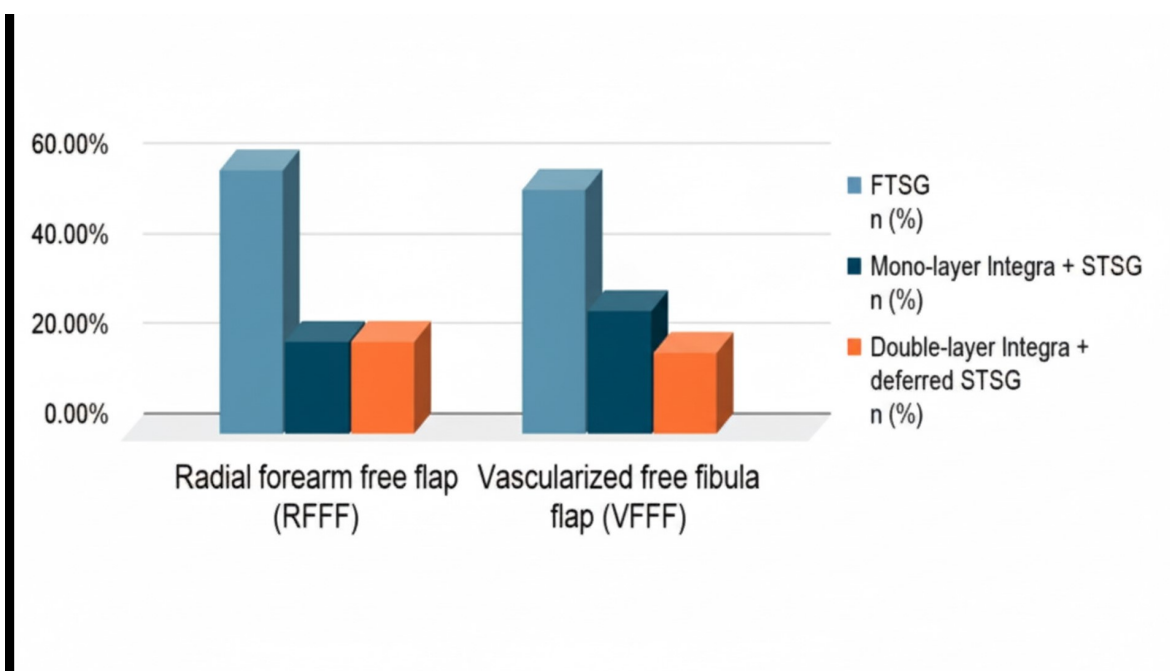


Figure 1. Distribution of donor site reconstruction technique by type of microvascular flap. The bar chart shows the number of patients undergoing RFFF (n = 34) and VFFF (n = 11) for each closure technique: FTSG (n = 26), mono-layer Integra[®] + STSG (n=10), and double-layer Integra[®] + deferred STSG (n=9). FTSG: full-thickness skin graft; STSG: split-thickness skin graft; RFFF: radial forearm free flap; VFFF: vascularized free fibula flap.

Table 1. Satisfaction Scar Score (SSS) and Vancouver Scar Scale (VSS) results by type of donor site reconstruction technique.

	FTSG	Mono-layer Integra [®] + STSG	Double-layer Integra [®] + deferred STSG	P value	Eta squared
Satisfaction Scar Scale (patient), mean (SD)	3.5 (0.9)	2.4 (0.7)	3.4 (1.0)	0.003*	0.238
Satisfaction Scar Scale (surgeon), mean (SD)	3.5 (1.0)	2.5 (0.8)	3.2 (1.0)	0.021*	0.168
Vancouver Scar Scale, mean (SD)	2.6 (2.1)	4.9 (3.0)	2.5 (2.3)	0.033*	0.160

Abbreviations: FTSG, full-thickness skin graft; STSG, split-thickness skin graft.

* One-way ANOVA.

Table 2. Disabilities of the Arm, Shoulder and Hand (DASH) score and Foot and Ankle Disability Index (FADI) results by type of donor site reconstruction technique.

	FTSG	Mono-layer Integra [®] + STSG	Double-layer Integra [®] + deferred STSG	P value
DASH ^a , mean (SD)	42.2 (23.6)	48.6 (23.2)	40.9 (19.1)	0.778*
FADI ^b , mean (SD)	60.8 (17.0)	66.5 (23.3)	77.5 (30.4)	0.654*

Abbreviations: FTSG, full-thickness skin graft; STSG, split-thickness skin graft.

* One-way ANOVA.

^a Evaluated on 34 patients undergoing radial forearm free flap.

^b Evaluated on 11 patients undergoing vascularized free fibula flap.

Table 3. Complication of FTSG group, Mono-layer Integra® + STSG and Double-layer Integra® + deferred STSG.

	FTSG (n = 26)	Mono-layer Integra® + STSG (n = 10)	Double-layer Integra® + deferred STSG (n = 9)
Partial graft loss, n (%)	2 (7.7%)	1 (10.0%)	1 (11.1%)
Infection, n (%)	1 (3.8%)	1 (10.0%)	0 (0%)
Prolonged healing (>8 weeks), n (%)	0 (0%)	0 (0%)	2 (22.2%)
Time to re-epithelialization, days (SD)	14.2 (4.1)	21.5 (5.3)	35.7 (8.2)

**Figure 2.** Immediate postoperative result of a full-thickness skin graft (FTSG) at the donor site of RFFF.**Figure 4.** Immediate postoperative result of a Double-layer Integra® with split-thickness skin graft (STSG) at the donor site of RFFF.**Figure 3.** Immediate postoperative result of a Mono-layer Integra® with split-thickness skin graft (STSG) at the donor site of RFFF.

A further limitation of FTSG reconstruction is that donor site closure is constrained by the size of the initial wound. In contrast, STSG closure offers advantages such as faster early healing, larger surface area coverage, shorter harvest time, and a lower rate of graft failure [19].

Recent systematic reviews by Mosquera et al. [20], Saleki et al. [21], and Zhang et al. [4] have compared RFFF closure using FTSG versus STSG.

In a 2024 systematic review and meta-analysis, Zhang et al. [4] found no significant difference in aesthetic outcomes between FTSG and STSG, as assessed by both observers (SMD = -0.37, $p = 0.17$) and patient (SMD = -0.016, $p = 0.93$). Full-thickness skin grafts were associated with higher risk of graft failure than STSG in RFF donor site closure, without significant improvement in aesthetic results. Consequently, they recommend STSG over FTSG for RFFF donor site closure due to lower graft loss rates and similar aesthetic outcomes, infection rates, and tendon exposure.

In contrast, Mosquera et al. [20] and Saleki et al. [21], concluded that FTSG offered improved aesthetics, with comparable outcomes in terms of donor site pain, scarring, and infection.

Another technique used is STSG overlying an acellular dermal matrix.

Integra® is an off-the-shelf acellular dermal matrix available in a range of sizes, which can accommodate almost any donor defect size. As a result, this technique is applicable to a broader range of clinical scenarios.



Figure 5. Postoperative result of a full-thickness skin graft (FTSG) at the donor site of RFFF at six months follow-up.



Figure 6. Postoperative result of a Mono-layer Integra® with split-thickness skin graft (STSG) at the donor site of RFFF at six months follow-up.



Figure 7. Postoperative result of a Double-layer Integra® with split-thickness skin graft (STSG) at the donor site of RFFF at six months follow-up.



Figure 8. Postoperative result of a full-thickness skin graft (FTSG) at the RFFF donor site at >1 year follow-up.



Figure 9. Postoperative result of a Mono-layer Integra® with split-thickness skin graft (STSG) at the RFFF donor site at >1 year follow-up.



Figure 10. Postoperative result of a Double-layer Integra® with split-thickness skin graft (STSG) at the RFFF donor site at >1 year follow-up.

However, the use of a dermal substitute has the disadvantages of adding operative time and cost to the surgery, without reducing the morbidity associated with STSG harvest [17].

Yi and Kim demonstrated that the combination of acellular dermal matrix and autologous STSG yielded better results in terms of scar appearance compared to autologous STSG alone [15, 22].

Reconstruction with Integra® followed by STSG showed favorable functional outcomes when compared to prior reports examining primary STSG or FTSG [14, 16, 19, 23].

Murray et al. [15], in the largest study examining Integra® and STSG, supported these positive results. By using a two-stage closure, their method minimizes aesthetic and functional morbidity associated with graft failure by providing two layers of closure scaffolding. They suggest that the thick dermal bed created by the Integra® matrix helps prevent underlying wound contraction, achieving results similar to those observed in patients undergoing FTSG. The Integra® and STSG system mimic the functional outcomes of STSG while achieving superior aesthetic results compared to FTSG.

A criticism of two staged methods utilizing a STSG and dermal substitute is the comparatively long healing time of 8 to 16 weeks and additional costs.

Regarding functional outcomes, no significant differences were found in terms of DASH and FADI scores between the different DS reconstruction techniques. These findings align with previous studies by Mosquera et al. [20], Saleki et al. [21] and Zhang et al. [4], which showed overlapping functional results in the comparison between FTSG versus STSG. However, these functional findings should be interpreted with caution. The DASH score was available for 34 RFFF patients, while the FADI score was calculated on only 11 VFFF patients, limiting the statistical power of these analyses. Therefore, the absence of significant differences should be interpreted as 'no difference detected' rather than as demonstrated equivalence. These analyses remain exploratory and should be confirmed in larger, prospective cohorts.

Murray et al. [15], in his above-mentioned study, concludes that the use of the Integra® and STSG system mimic the functional results of STSG.

In terms of aesthetic outcomes, FTSG and Integra® + Delayed Dual Layer STSG showed significantly higher scar satisfaction scores (SSS) compared to mono-layer Integra® + STSG. Similarly, Vancouver Scar Scale (VSS) scores were significantly lower (indicating better scar quality) for FTSG compared to mono-layer Integra® + STSG ($p = 0.039$). No significant difference in VSS scores was observed between FTSG and double-layer Integra® + deferred STSG. Notably, FTSG demonstrated superior outcomes, which is consistent with the findings of Mosquera et al. [20] and Saleki et al. [21], who reported improved aesthetics with FTSG, alongside comparable results in terms of donor site pain, scarring, and infection.

Our results appear to contradict those of Zhang et al. [4], whose work found no aesthetic advantage for FTSG compared to STSG, citing a higher risk of graft failure with FTSG.

The choice of closure method should take into account the size and shape of the defect, the surgeon's familiarity with the technique, and patient-specific factors that may affect healing and mobility.

Several limitations of this study should be acknowledged. First, the retrospective design and the small sample size—particularly in the Integra® groups (mono-layer $n = 10$, double-layer $n = 9$)—limit the generalizability of our findings; the small sample size also precluded multivariate analysis to adjust for potential confounders. Second, the technique choice over the 18-year study period (2005 – 2023) was not protocol-driven; it reflected evolving surgical practices and individual surgeon preferences, which may have introduced selection bias. Third, the aesthetic comparison pooled RFFF and VFFF donor sites, which differ in anatomical location and scarring characteristics. Fourth, scar evaluations were not performed in a blinded manner; the assessing surgeon was aware of the reconstruction technique, which may have influenced VSS and SSS ratings. This represents a potential source of detection bias. Fifth, the range of follow-up was wide (mean 6.5 years, SD 5.9), and scar maturation may have varied considerably between patients assessed at six months versus those evaluated after several years. A more standardized follow-up protocol would have strengthened the reliability of the aesthetic assessments. Sixth, the functional analyses were exploratory in nature. The DASH score was available for 34 RFFF patients, while the FADI score was calculated on only 11 VFFF patients, limiting the statistical power of these analyses. Therefore, the absence of significant differences should be interpreted as 'no difference detected' rather than as demonstrated equivalence. These findings should be confirmed in larger, prospective cohorts. Finally, complication data—including infection, partial graft loss, and time to re-epithelialization—were recorded but, due to the retrospective design and small sample sizes, could not be subjected to formal statistical comparison. Descriptive data are provided, but these findings should be interpreted with caution. Despite these limitations, the study provides valuable real-world data from an 18-year single-center experience, with consistent surgical techniques and standardized outcome measures.

5. Conclusion

This retrospective study demonstrates that full-thickness skin graft (FTSG), mono-layer Integra® with split-thickness skin graft (STSG), and double-layer Integra® with deferred STSG are all viable options for reconstructing donor sites following radial forearm free flap (RFFF) and vascularized free fibula flap (VFFF) harvest, with comparable functional outcomes in terms of DASH and FADI

scores. However, FTSG showed superior aesthetic outcomes compared to mono-layer Integra® + STSG, as assessed by both patients and surgeons. The double-layer Integra® + deferred STSG technique also yielded satisfactory aesthetic results, albeit with longer healing times and a two-stage procedure. Given the comparable functional recovery across all three techniques, the choice of reconstruction method should be individualized, taking into account aesthetic priorities, healing capacity, patient-specific factors, and the operating surgeon's experience and preference.

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Declaration of AI use

No artificial intelligence tools were used in the preparation of this manuscript, including data analysis, writing, or figure generation. All content is the original work of the authors.

Ethical statement

All procedures performed were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments.

Informed consent

Informed consent was obtained from all individual participants included in the study, in accordance with institutional guidelines for retrospective data collection.

Data Availability Statement: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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