Titolo: **A dermal substitute for palmar skin regeneration**
Running head: Palmar skin regeneration
Tipo di articolo: case report
Conflitti d'interesse: nessuno
Presentato a precedenti congressi: no

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Abstract
Background: Paediatric palmar burns still represent a surgical challenge for reconstructive surgeons due to the anatomical features of palmar skin and, concomitantly, to hypertrophic scars in children, which may cause severe retraction and functional impairment to the hand. Up to now, many surgical reconstructions techniques involving flaps or skin grafts, combined or not with Z-plasties, have been proposed.
Materials and methods: We present the case of a 5-year-old child affected by the severe sequelae of bilateral palmar burns. In order to avoid further donor-site damage, we used a hyaluronic acid matrix dermal substitute (HyalomatrixPA®) combined with traditional surgical techniques.
Results: At three-year follow-up, both hands presented minimal scar retraction, and good functional and aesthetic outcomes.
Conclusions: Dermal substitutes based on hyaluronic acid enable donor-tissue sparing and help control collagen production and scar formation, and could therefore be considered a valid alternative to skin grafts in delicate regions, i.e., the palm, especially in young patients.

Key-words: burn, dermal substitute, Hyalomatrix, hyaluronic acid, paediatric age, palm.

List of acronyms: none.

Introduction

Burns are a common cause of paediatric injuries throughout the world. As stated by Anjali L et al., the majority of such injuries are sustained by children < 6 years of age (57.7%), and more than one half of all injuries (59.5%) result from thermal burns (1). Though the hand constitutes only 3% of

the total body surface area, a burned hand is a major injury, as recognized by the American Burn Association. Indeed, loss of a hand constitutes a 57% loss of function for the whole person (2). Moreover, in case of subsequent acute compartment syndrome, deeper soft tissue may be involved, with dramatic sequelae (3,4). Therefore, reconstruction of a burned hand is key to the overall rehabilitation of the patient, and it is vital to achieve successful management.
Burned hands in children represent a great challenge for plastic and hand surgeons for two reasons. Firstly, children tend to more frequently develop hypertrophic scars that may affect the surgical outcome. Scar contractures pose serious reconstructive challenges to patients and physicians, especially in the paediatric age. Among such patients, for instance, different growth rates for the burn scar and adjacent normal tissues can, in addition to skin loss, contribute to contractures. Concurrently, children have smaller donor tissue areas for skin grafts or local flaps. Secondly, the skin and soft-tissue architecture of the palm have unique characteristics, such as high thickness, hairlessness, high concentration of sensory nerve organs, and strong connections to the underlying fascia by numerous vertical fibres. These features enhance skin stability for proper grasping function, but make the reconstruction of the palmar region very difficult.
The most widely reported reconstructive techniques for the palmar region are local, regional or free flaps. In contrast, experience in the use of dermal substitutes for palm reconstruction is still largely lacking. Dermal substitutes are bioengineered products with a structured three-dimensional connective fibre organization. They employ collagen and glycosaminoglycan (e.g., Integra®) or hyaluronic acid scaffold (i.e., HyalomatrixPA®), to regenerate dermal tissue. We report a case of a child with bilateral burned hands treated by surgical reconstruction combined with a dermal substitute.

Case report

We report the clinical findings of a 5-year-old child who presented to our clinic with the sequelae of a domestic burn to the palmar region of both hands; the injury had caused retraction of the digits and devastating functional damage, including severe limitations to the flexion-extension of the long fingers, and the impossibility of abduction, adduction and opposition of the thumb. The patient had no other relevant pathologies. The patient had previously been treated in another plastic surgery department in 2010, where colleagues performed multiple Z-plasties of the thumb, index and ring fingers on the left hand, in addition to removal of the retracting scars and partial closure with local flaps. They also performed temporary arthroereisis of the above fingers to contrast scar retraction. The Kirschner wires were removed after 4 weeks, and wounds were completely healed. Three months later, they performed multiple Z-plasties of the thumb, ring and little finger on the right hand, and closed the palmar wounds with a full-thickness skin graft taken from the groin region. In this case too, arthroereisis was performed to counter scar retraction. The Kirschner wires were removed 4 weeks later, and the wounds were completely closed. After surgery to each hand, the patient was given physical rehabilitation therapy and provided with hand braces for nightwear to maintain the extension of the fingers achieved by the operations. At 6-month follow-up, despite continuous physiotherapy, however, the patient presented severe scar contractions causing progressive retraction of the fingers and, consequently, came to our department (Fig. 1A-B).
On January 2011, we performed multiple Z-plasties on the left hand, removed the retracting scars and executed arthroereisis with Kirschner's wires. At the same time, we applied a dermal substitute (HyalomatrixPA®, Anika Therapeutics SRL, Padua, Italy) to the uncovered areas. We removed the outer silicone layer of HyalomatrixPA® three weeks after, and the steel wires four weeks later. On April 2011, we performed multiple Z-plasties of the scars on the right hand, in addition to removal of retracting scars on the palmar region, arthroereisis with steel wires, and application of dermal substitute (HyalomatrixPA®) to cover the open wounds. We removed the outer silicone layer of HyalomatrixPA® after three weeks, and the Kirschner wires four weeks later. We recommended

physiotherapy after both procedures, and at three-year follow-up observed good clinical outcomes in both hands, with minimal retracting scars and acceptable aesthetic outcome (Fig. 2A-B).

Focus on dermal substitute application to wounds

After scar removal and multiple Z-plasties (Fig. 3), sheets of HyalomatrixPA® 2 mm larger than the area requiring coverage are applied. The HYAFF® layer has to be in direct contact with the wound bed, while the elastomeric film layer is on the outer side (Fig. 4). The scaffold is sutured in place with 4-0 absorbable suture material, after piercing its transparent elastomeric film with the blade tip to favour its adhesion to the tissues by preventing haematoma formation. The skin is also sutured with 4-0 absorbable suture material. Wounds are dressed with sterile cotton gauze, and an elastic bandage is applied for non-compressive coverage.

Discussion

Many authors have proposed various different surgical or non-surgical techniques for reconstruction of the palm. Indeed, the use of traditional skin grafts to resurface palmar defects of the hand results in noticeable colour and texture mismatch, especially in dark-skinned patients (5). Hair growth in such grafts leads to further mismatch. Other possible complications are hyperkeratosis, marginal hypertrophic scarring, fissuring and breakdown. In 1970, Lie et al. described the suitability of the exact ulnar border of the palm for full-thickness grafting of appropriately limited-in-size palmar and volar digital defects, thereby offering an accurate "like with like" reconstruction (6). Several flaps, such as medial arm flap (7), sensory dorsalis pedis flap (8), radial forearm flap (9) and free extended lateral arm flap (10) have been used for hand reconstruction. Large fasciocutaneous flaps such as the groin (11), peroneal (12) or parascapular (13) flaps may also be used, but with the disadvantages that they are bulky and lack sensation. Muscular flaps combined with skin grafts have also been proposed for palmar reconstruction (14). However, even though all these flaps can provide reliable coverage of tendon and bone structures, such units are often complicated by significant donor site morbidity (i.e., the radial forearm flap requires the sacrifice of the radial artery), long operating times, and difficult dissection technique.

Nowadays, it is recognised that limb reconstruction should ideally replace like tissue with like, minimize donor-site morbidity, preserve main vascular trunks, and reduce operating and hospitalization times (15). In the last decade, several perforator flaps have been introduced in the soft-tissue reconstruction of hand; the advantages of these reconstructive units are less donor-site morbidity (e.g., no sacrifice of main vessels), better sensory recovery, and improved cosmetic appearance; on the other hand, these flaps are only usually indicated for small-to-moderate size skin defects, and require long operating time and a high level of technical skill (16). Regarding tissue expansion, few cases have been reported, and only for the reconstruction of the dorsum of the hand (17).

The evolution of reconstructive surgery to regenerative surgery has led to the introduction of many bio-engineered products. Nowadays, several dermal substitutes are available for different indications; despite their differences, they all tend to spare, or at least reduce, donor tissues. In hand injuries, many dermal substitutes have been used with success, but almost all these cases involved the dorsum of the hand (18,19,20,21,22). However, Landi et al. obtained good results in 26 cases of congenital syndactyly, a particular region composed of both palmar and dorsal hand skin. After syndactyly release, they used HyalomatrixPA® to cover the bare areas in all cases. No skin grafts were taken. Infection occurred in only one case, and there were no hypertrophic scars or keloids. In all cases they obtained good functional and aesthetic outcomes (23).

In our case, we used a dermal substitute composed of a double layer of esterified hyaluronic acid scaffold beneath a silicone membrane (HyalomatrixPA®) to treat palmar contractures. The wound contact layer consists of an absorbent, biodegradable, non-woven pad with ?bres entirely composed of the benzyl ester of hyaluronan. These ?bres integrate themselves into the wound bed, and provide

a three-dimensional scaffold useful for the ordered colonization of ?broblasts and endothelial cells, as well as the deposition of extra-cellular matrix components. The outer layer is made of a ?exible and transparent elastomeric ?lm that acts as a semi-permeable barrier against external agents, and as a ?uid-retention mechanism.
Hyaluronic acid has several well-known beneficial properties, like angiogenesis induction (24), induction of fibroblast migration through binding to CD44 (25), and reduction of scar collagen product by skin fibroblasts (26). At the same time, recent studies have demonstrated that levels of hyaluronan are significantly lower in keloid and hypertrophic scarring than in normal skin and scar fibroblasts (27,28).
We used this dermal substitute not to replace traditional surgery, but to secure its effects, limiting hypertrophic scarring and, at the same time, sparing donor tissues from further skin grafts. Probably thanks to the aforementioned features of hyaluronic acid, the dermal substitute helped prevent new scar contractures in both hands, strengthening and preserving the surgical outcome. In this case the effect was further highlighted by comparison with the two previous conventional operations, where functional and aesthetic outcomes had been heavily impaired by the patient's pathological scarring.

Conclusions

This case demonstrates that a dermal substitute based on hyaluronic acid may be considered as an alternative to skin grafts in delicate regions, i.e., the palm, because of its control over collagen production and scar formation. This advantage is particularly significant in children, where smaller donor tissue areas and hypertrophic scarring often coexist.

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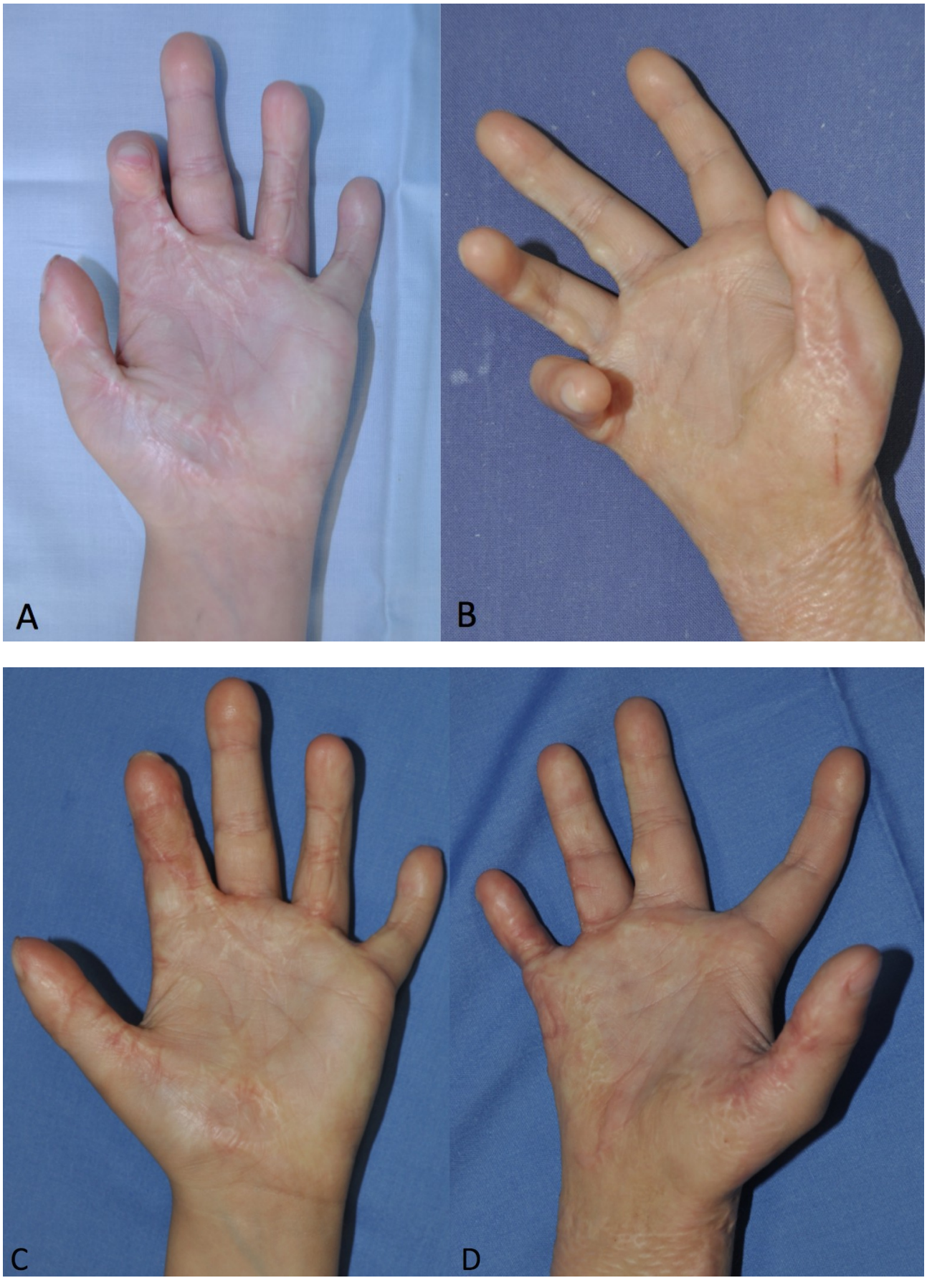
Figure legends

Fig. 1A-B: Bilateral burned hand after first traditional operation of scar removal and multiple Z-plasties

Fig. 2: Three-year postoperative view of both hands after conventional scar removal surgery, multiple Z-plasties, and use of dermal substitutes

Fig. 3: Intraoperative view of left hand after scar removal, multiple Z-plasties and arthroereisis with K-wires

Fig. 4: Intraoperative view of left hand after dermal substitute application to open wounds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