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Free tissue transfer in hand surgery – essential step in hand transplantation

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Rezumat

Transferul liber tisular în chirurgia mâinii – etapă importantă în realizarea transplantului de mână

Introducere: Apariția microchirurgiei a însemnat un mare pas înainte pentru chirurgia reconstructivă a membrului superior. Astfel, transferul liber digital a însemnat o adevărată revoluție în reconstrucția mâinii mutilate, cu amputații multiple și compromisă din punct de vedere funcțional. De asemenea transferul liber de țesuturi a început să fie folosit treptat și în alte procedee reconstructive la nivelul mâinii, antebrațului sau brațului. Au putut fi evitate numeroase amputații și de asemenea s-au putut realiza reconstrucții de calitate și într-un singur timp chirurgical în cazuri la care prin metode clasice nu ar fi fost posibil. Nu trebuie neglijat nici faptul că transferul liber tisular, ca și replantarea mâinii reprezintă o etapă importantă pentru centrele de microchirurgie reconstructivă în pregătirea transplantului de mână.
Material și metodă: În clinica de chirurgie plastică a spitalului "Bagdasar-Arseni" s-au efectuat între anii 2000-2010, 48 de transferuri libere de țesuturi la nivelul membrului superior. Din acestea, 18 au fost transferuri libere digitale, 11 transferuri libere la nivelul mâinii, 15 transferuri la nivelul antebrațului și 4 la nivelul brațului.
Rezultate și discuții: Raportându-ne la cele 48 de cazuri, s-au înregistrat 4 eșecuri totale și 6 necroze parțiale care au fost rezolvate prin intervenții corective ulterioare. Transferul liber tisular a fost utilizat atât în situații în care reprezenta singura soluție chirurgicală, cât și în cazuri care puteau fi rezolvate și prin alte metode, dar transferul liber a fost o soluție calitativ superioară.

Cuvinte cheie: transplant tisular, reconstrucția membrului superior, transplantul de mână

Abstract
Introduction: The development of microsurgery allowed huge advancements in the reconstructive surgery of the upper limb. The use of free digital transfer started a true revolution for the reconstruction of the mutilated, functionally compromised hand, with multiple amputations. Slowly, surgeons started using free tissue transfers in other reconstructive procedures of the hand, forearm and arm. This way they avoided amputating a limb and they realized quality reconstructions in a single surgical step in cases in which classical methods did not apply. We shouldn't neglect to mention that free tissue transfers, along with hand replantation, represent an important step for microsurgery centers in preparing the hand transplant.
Material and methods: There have been 48 cases of free tissue transfers of the upper limb in the Plastic Surgery Department of the "Bagdasar-Arseni" Emergency Hospital between 2000 and 2010, of which 18 free digital transfers, 11 free tissue transfers of the hand, 15 transfers of the forearm and 4 of the arm.
Results and discussion: Of the total 48 cases we studied, 4 have been total failures and 6 cases presented partial necrosis of the

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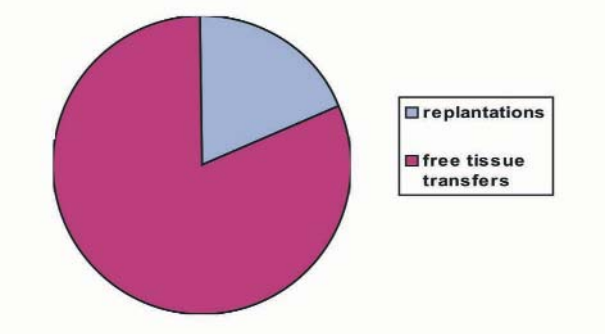
transferred tissue, all of which have been managed with ulterior corrective procedures. We used free tissue transfer in cases where there was no other surgical option and also in cases where other methods applied, but free tissue transfer provided a superior quality solution.

Key words: tissue transplant, upper limb reconstruction, hand transplant

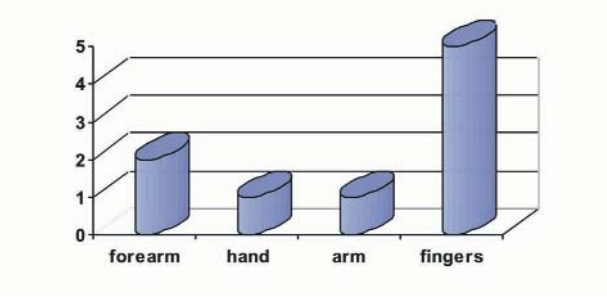


Graphic 1.

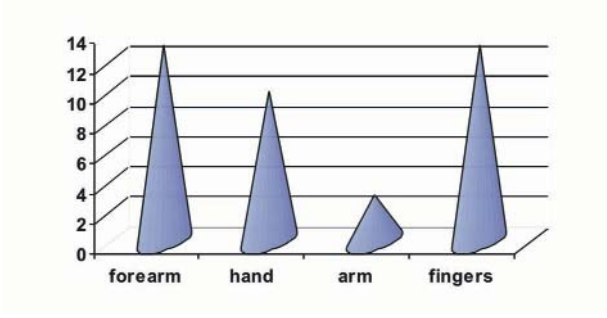
Introduction

Free tissue transfer represents harvesting a tissue unit (containing the skin, subcutaneous tissue and/or muscular, bone and nervous tissue) along with its vascular pedicle and transferring it to another region, where it will be attached through microsurgical anastomosis to the artery and vein of the receptive segment. The appearance of this procedure back in the '60s took reconstructive surgery to a new level, being used for the reconstruction of complex defects with very good aesthetic and functional results. In upper limb surgery free tissue transfer is sometimes, in the case of complex trauma with multiple amputations, the only solution for salving this very important functional segment (1). It is also worth mentioning that in International Microsurgery Centers, free tissue transfer, along with replantation, lead the way to hand transplantation, a true revolution in the reconstruction of amputated upper limbs.

The advantages of this method are stable, good quality coverage, in one operatory step of complex defects that cannot be resolved through other reconstructive techniques, with improvement of local vascularization, good aesthetic and functional results and low donor area morbidity. The disadvantage is that it's a difficult, lenghty procedure, which requires specialized medical personnel, with high costs and risk of vascular thrombosis and flap necrosis (2,3).



Graphic 2.



Graphic 3.

Material and Methods

This study presents the experience of the "Bagdasar-Arseni" Emergency Hospital's Plastic Surgery and Reconstructive Microsurgery Clinic for a period of 10 years (from 2000 until 2010). We included 48 patients and we used the following reconstructive techniques: 9 replantations and 39 free tissue transfers *(Graphic 1)*. The 9 replantations were 5 fingers, one hand, 2 forearm and one arm replantation *(Graphic 2)*, because replantation is very similar to a free composite flap. The free tissue transfers were: 13 digital transfers and 26 free flaps, of which 10 in the hand, 13 in the forearm and 3 in the arm area *(Graphic 3)*. We will present a few representative cases for our study next.

Case 1.

Female, 28 years old. Posttraumatic sequelae after a car accident at 9 years old *(Fig. 1A)* with a 90° elbow arthrodesis, muscular atrophy of the arm and forearm, fistulising osteitis of forearm and calcified myositis *(Fig. 2B)*. After the excision of the scar tissue from the anterior side of the elbow *(Fig. 1C)*, we used an inferior superficial epigastric free flap for the defect coverage *(Fig. 1D)*. The result was favorable, with complete integration of the free flap, minimal scarring of the donor area, good mobility and sensitivity of the elbow and forearm (*Fig. 1E* and *F*).

Case 2.

Male, 51 years old. Posttraumatic sequellae from a radius open fracture, complicated with infection of the forearm, radius osteitis and extensive musculo-tendinous necrosis *(Fig. 2A and B)*. For the reconstruction of the bone and musculo-tendinous elements we used a osteo-myo-cutaneous free flap, containing a fibula fragment and the solear muscle *(Fig. 2C)*. The result was very good, with good functionality and good anatomic integrity *(Fig. 2D, E and F)*.

Figure 1A. *Preoperatory aspect*

Figure 1B. *Radiological aspect*

Figure 1C. *Intraoperatory aspect*

Figure 1D. *Preoperatory drawing of donor area*

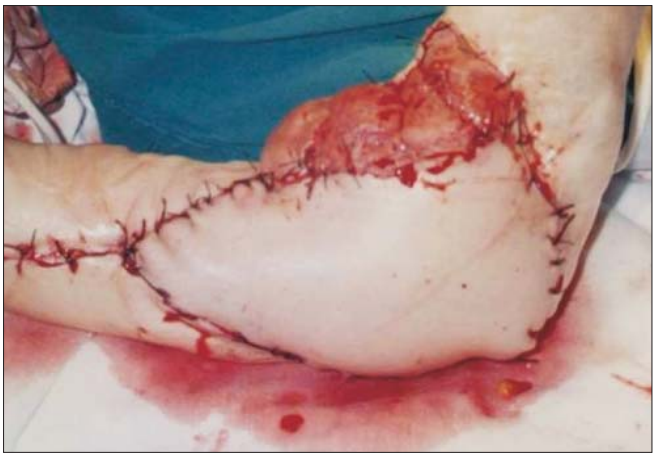


Figure 1E. *Immediate postoperatory aspect*

Figure 1F. *Postoperatory aspect (6 months)*

Case 3.

Female, 26 years old. Complex left hand trauma, with extensive distruction of the III-V fingers' extensor tendons, of the metacarpophalangeal and proximal interphalangeal joints of the index finger, of the extensor pollicis longus tendon, of the interphalangeal joint of the thumb, complicated with ulcerations and osteitis *(Fig. 3A)*. We used a serratus anterior musculo-cutaneous free flap for the coverage *(Fig. 3B)*. Even though the aesthetic aspect is not ideal, our focus was on salving the hand and the possibility of further corrections sustains our choice as a very good one.

Figure 2A. *Preoperatory aspect*

Figure 2B. *Radiological aspect*

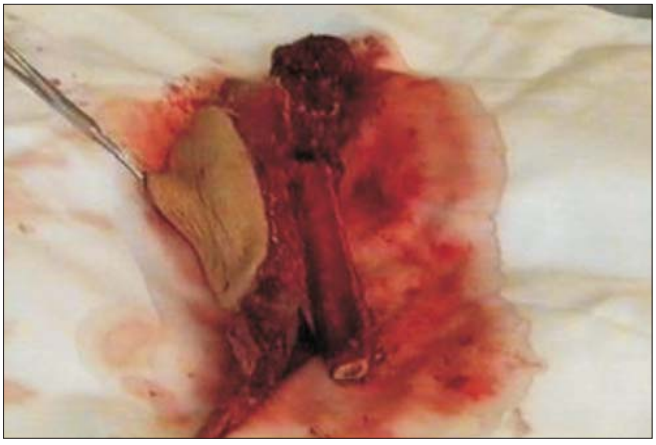


Figure 2C. *Composite flap*

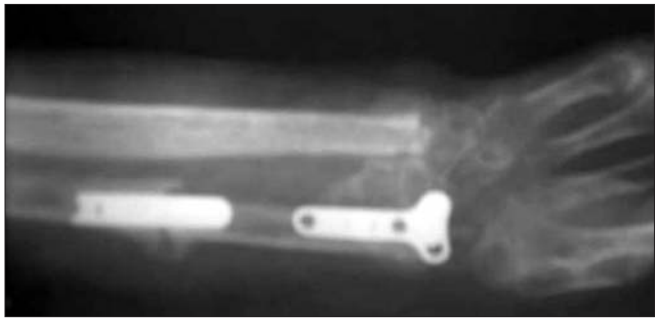


Figure 2D. *Postoperatory radiological aspect*

Figure 2E. *Postoperatory aspect (14 days)*

Figure 2F. *Postoperatory aspect (6 months)*

Case 4.

Female, 27 years old. Left hand crushing trauma with amputations of the thumb, 2nd and 3rd fingers and serious posttraumatic sequellae of the fourth finger *(Fig. 4A)*. We decided to trasnfer the second toe *(Fig. 4B and C)*, performing the microsurgical anastomosis between the pedious artery and radial artery and also between the great saphenous vein and cephalic vein *(Fig. 4D)*. The functional result was very good, 9 months after the surgery prehension and digital grips were possible *(Fig. 4E and F)*.

Case No. 5

Male, 27 years old. Electric saw trauma 7 years before,

Figure 3A. *Preoperatory aspect*

Figure 3C. *Postoperatory aspect (3 months)*

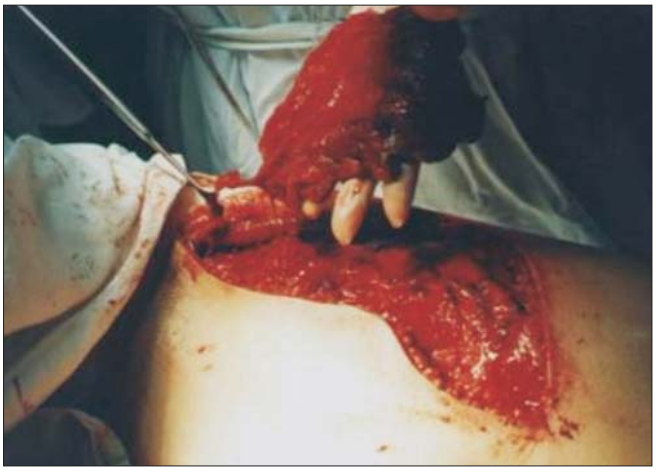


Figure 3B. *Serratus anterior flap*

Figure 3D. *Postoperatory aspect of the donor area*

Figure 4A. *Preoperatory aspect*

Figure 4B. *Preoperatory drawing of the donor area*

with amputations of the 2-5 metacarpals of the right hand, the thumb being intact *(Fig. 5A, B and C)*. We decided a block transfer of the second and third toe, fixated to the third and fourth metacarpals and the vascular anastomosis was performed between two plantar digital arteries and branches from the palmar arch and also between the great

Figure 4C. *Harvesting the second toe*

Figure 4D. *Postoperatory aspect (24 hours)*

Figure 4E. *Digital grip*

Figure 4F. *Prehension*

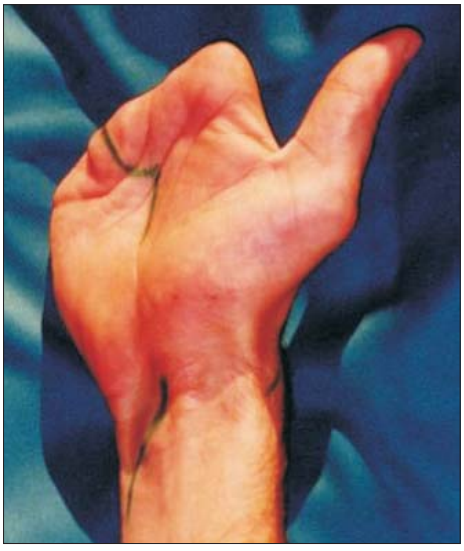


Figure 5A. *Preoperatory aspect*

Figure 5B. *Radiological aspect*

Figure 5C. *Arteriography*

saphenous vein and cephalic vein *(Fig. 5D and E)*. 6 months after the surgery we did a flexor tenolysis and 9 months after the surgery the fingers were sensitive, our patient was professionally reintegrated and can use his hand in common activities like writing or getting dressed *(Fig. 5F and* G*)*.

Case No. 6

Male, 54 years old. Electric saw trauma with amputation

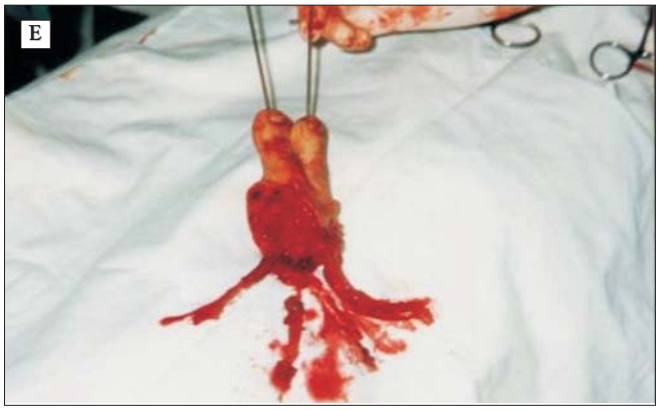


Figure 5D, E. *Hharvesting the second and third toes*

Figure 5F. *Immediate postoperatory result*

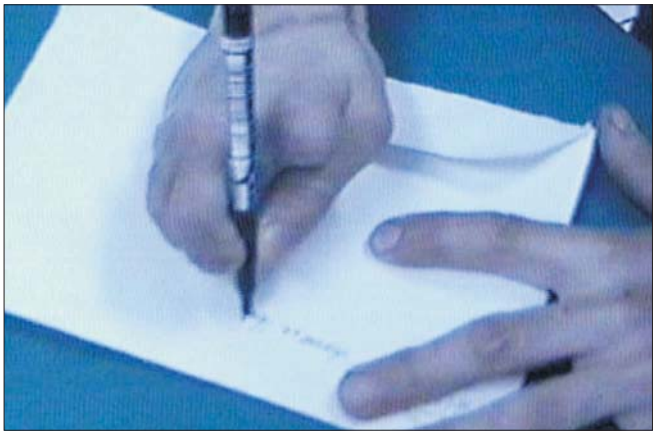


Figure 5G. *9 months postoperatory result*

Figure 6A. *Forearm amputation in the distal third*

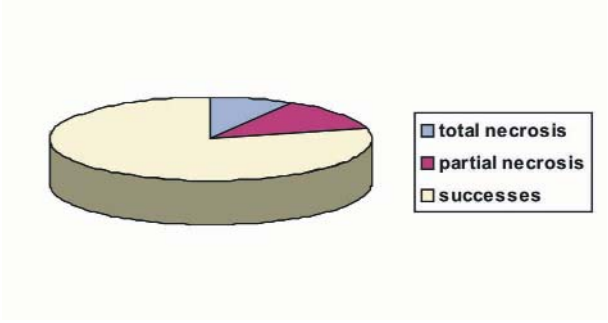
Figure 6B. *Immediate postoperatory aspect*

of the forearm in its distal third *(Fig. 6A)*. We performed emergency surgery, replantating the forearm *(Fig. 6B)*, with its complete postoperative integration *(Fig. 6C and D)*.

Results

Of the 48 patients who benefitted from free tissue transfers, in 38 cases the transfered tissues survived integrally, in 6 patients there was partial necrosis of the flaps and 4 of them total necrosis *(Graphic 4)*. Total necrosis was seen in the gracilis musculo-cutaneous flap, the radial flap, scapular flap and in one case of free digital transfer. We performed corrective surgeries in both partial and total necrosis. In the cases where partial necrosis appeared, we used skin grafts and for the total necrosis, axial flaps combined with skin grafts.

Figure 6 C,D. *3 months postoperatory aspect*



Graphic 4.

Table 1. *Most frequently used free flaps in different upper limb areas*

Fingers	Free digital transfers from the foot to the hand	
Hand	Coverage	Radial, fascial parieto-temporal, brachial fasciocutaneous
	Infection management	Serratus anterior, pectoralis minor
Forearm	Coverage	Radial, latissimus dorsi, gracilis, fibular, scapular and parascapular
	Functional free transfer	Gracilis, rectus femoris, latissimus dorsi
Arm	Radial, latissimus dorsi, gracilis, fibular, scapular and parascapular	

Discussion

Free flaps represent an important method for the coverage and reconstruction of complex defects in the arm and forearm. In defects of the arm and forearm there can be used virtually every fasciocutaneous or musculocutaneous flaps. Functional free flaps in the forearm deserve a special mentioning for using distant muscular elements for the repair of the digital flexion and extension. In hand defects smaller flaps are required, either fasciocutaneous (radial or lateral brachial flap) or muscular (serratus anterior muscle) (3). In finger amputations digital transfers from the foot are preferable, especially in thumb reconstruction.

In arm and forearm reconstruction, the most frequently used flaps are radial, latissimus dorsi, gracilis, fibular, scapular and parascapular flaps. The most commonly used flaps in the upper limb can be seen in *Table 1*.

The radial flap can be transfered from the other upper limb in case there are no other local coverage possibilities. It can be used as a fasciocutaneous flap or as a composite myo-cutaneous, osteo-cutaneous, tendino-cutaneous flap in bone, muscular and tendon reconstruction of the hand and forearm (4).

The latissimus dorsi free flap is one of the most versatile flaps and can be used as a muscular, musculocutaneous or composite osteo-musculo-cutaneous flap. Along with rectus abdominis muscle and the radial flap, it's one of the most frequently used flaps in plastic and reconstructive surgery and when it is harvested with the thoracodorsal nerve it can be used as a functional transfer (5). Its utility is most obvious in large defects of the arm and forearm (6,7).

The gracilis muscular flap can be used for the coverage of soft tissue defects or functional muscular reconstruction of the forearm. It can be transfered as a muscular flap and covered with a skin graft, or as a musculo-cutaneous flap. It is especially helpful in reconstructing volar antebrachial defects, but also in arm defects (8).

The fibular free flap has brought a revolution for the reconstruction of bone defects. Its indications are mostly posttraumatic defects in the upper limb (9,10). It can be harvested together with the solear muscle or with skin, as a composite flap.

The scapular and parascapular free flaps are surgical techniques frequently used for the coverage of arm and forearm defects (11).

The most commonly used flaps in hand reconstruction are radial, serratus anterior, fascial parieto-temporal and fasciocutaneous brachial flap.

The serratus anterior muscle is useful in the coverage of

tissue defects of the hand, especially when there are complications such as infection (osteitis, arthritis). As a composite osteo-myo-cutaneous flap, it is used for the reconstruction of hand bone defects (12).

The free transfer of the fascial parieto-temporal flap assures a suple, slim coverage and is especially used for metacarpal, digital or retinacular reconstruction.

The fasciocutaneous brachial flap is also indicated in hand reconstruction because of the colour and texture similarity.

Choosing a reconstructive method in the case of free digital transfers for the restauration of the hand functionality (prehension, especially) must fulfill the following conditions (13):

- Good functionality in the transplanted finger, which means careful nervous anastomosis for obtaining a sensitive finger and the existance of motor musculotendinous elements to allow active movements of the transfered finger.
- Anatomical similarity between the transfered finger and the one it will substitute. In thumb reconstruction, the hallux is most suited, both functionally and anatomically.
- In the case of multiple amputations, obtaining a 3 digit hand will assure, aside from fine grips, hand stability and the possibility for obtaining more forceful grips.
- The morbidity of the donor area must be minimal. In total thumb reconstruction (including the first metacarpal) it is prefered to harvest the second toe along with the second metatarsial bone, because the loss of the first metatarsal would produce severe functional disturbance in the foot.

The free digital transfer cases presented here have had very good functional long term results. 9 months after the surgery, the transplanted fingers are sensitive and both fine and forceful grips are possible. As can be seen in the pictures, the patients use their hands in common domestic activities (grabbing and using objects), feeding and writing. We should also mention that the patients from this study managed to find work. There are still some aesthetic deficiencies, but the very good functional result is compensatory.

The free flaps used in arm, forearm and hand reconstruction were used especially for defects coverage, not so much for functional reconstructions, as opposed to those used for the fingers and thumb, which generally intend to repair their function.

We believe that in the decision making process regarding the reconstruction of hand and forearm defects, the main factor to be considered is the quality of the coverage and reconstruction, from an anatomical, functional, but also aesthetic point of view. We must choose the optimal surgical technique, even though this means a more complex procedure. Free tissue transfer shouldn't be avoided when its utility is obvious, but its usage shouldn't also be forced.

Even though a basic plastic surgery principle is the choose the simplest reconstructive method, complex procedures shouldn't be avoided. The cases we presented prove that high technical surgical methods, when they are carefully chosen, can lead to very good functional and aesthetic results. The functional result always outweights the aesthetic appearance in hand and forearm reconstructions.

Replantation of the amputated segments of the upper limb (fingers, hand, forearm and arm) can be quite similar to a composite free flap transfer. When performing a replantation, the reconstructive procedure adresses all anatomical elements of the amputated limb: bones, muscles, tendons, joints, nerves, vessels and skin (14). Their accurate repair will assure both the survival of the limb, but also its long term high quality recovery (15).

Training a microsurgical team in free tissue transfers and especially in upper limb replantations, associated of course with optimizing the surgical steps through cadaver dissections have a special role in the preparation of a top hand surgery procedure, the hand transplant. Aside from mastering the microsurgery techniques, there are other important conditions that must be attained, but the existance of a trained microsurgery team is the ground stone in preparing the hand transplant (16,17).

Conclusions

- Free tissue transfers represent, in some cases, the only surgical technique available for the functional reconstruction of the hand.
- There are several reconstructive methods that use free tissue transfers and choosing the right one should take into account the anatomical conditions of the traumatized hand, but also the functional altering that may appear in the donor area.
- If all technical details are respected, free digital transfer can provide a quality reconstruction, with the obtaining of sensitive fingers with good mobility that will allow fine and power grips. Patients who benefit from this procedure can be socially reintegrated and find work easier.
- The advantages of free tissue transfer are: a stable, high quality coverage of the defect, in a single surgical step, improving local vascularization, good functional and aesthetic results with low donor area morbidity, allowing the reconstruction of complex tissue defects that cannot be resolved through other plastic surgery methods.
- Last, but not least, we must underline the role that developing these microsurgical interventions will have in the preparation for future hand transplant centres.

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