

# SERRATUS ANTERIOR MUSCLE FLAP FOR RECONSTRUCTION OF EXTREMITY INJURIES

## RETALHO DO MÚSCULO SERRÁTIL ANTERIOR PARA RECONSTRUÇÃO DE LESÕES EM EXTREMIDADES

GABRIEL SARDINI COVELLO<sup>1</sup> , DANILO VIDAL RIBEIRO MARTINS<sup>1</sup> , GIOVANI CAETANO PADILHA<sup>1</sup> ,  
CRISTINA SCHMITT CAVALHEIRO<sup>1</sup> , LUIZ ANGELO VIEIRA<sup>1</sup> , EDIE BENEDITO CAETANO<sup>1</sup> 

1. Pontifícia Universidade Católica de São Paulo, Faculty of Medical and Health Sciences, Sorocaba Campus, Sorocaba, São Paulo, Brazil.

### ABSTRACT

**Objective:** To report the use of the serratus anterior free tissue transfer in the treatment of traumatic injuries. **Methods:** Twenty-six free flaps or serratus pedicled flaps were performed for reconstruction of traumatic extremity injuries. **Results:** Complete flap survival was recorded in 20 limbs and 3 patients had circulatory complications. Even with the review of vascular anastomoses, partial flap necrosis could not be prevented and required a skin graft after debridement in the necrotic area. Another flap also required reexploration as a result of heavy congestion due to impaired venous return. Superficial wound infection was found in three patients and treated with conservative measures. Regarding the donor area, seroma formation was found in 8 cases; drainage was necessary in 2, and the others were resolved spontaneously. In 2, bruises formed and were later drained. In 1 limb there was long thoracic nerve injury and scapular winging. **Conclusion:** According to this study, the serratus anterior muscle flap is an excellent tool for treating small complex lesions in the extremities. **Level of Evidence IV; Case series.**

**Keywords:** Free Tissue Flaps. Upper Extremity. Hand Injuries.

### RESUMO

**Objetivo:** Relatar o uso da transferência de retalho livre do serrátil anterior no tratamento de lesões traumáticas. **Métodos:** Vinte e seis retalhos livres ou pediculados do serrátil anterior foram realizados para reconstrução de lesões traumáticas de extremidades. **Resultados:** A sobrevida completa do retalho foi registrada em 20 membros e 3 pacientes tiveram complicações circulatórias. Mesmo com a revisão das anastomoses vasculares, a necrose parcial do retalho não pôde ser prevenida e exigiu enxerto de pele após desbridamento da área necrótica. Outro retalho também necessitou reexploração em decorrência de forte congestão por dificuldade de retorno venoso. Infecção de ferida superficial foi encontrada em três pacientes, tratados com medidas conservadoras. Em relação à área doadora, a formação de seroma foi encontrada em 8 casos; em 2 foi necessária drenagem e os demais foram resolvidos espontaneamente. Em 2 houve formação de hematomas, que foram drenados. Em um membro havia lesão longa do nervo torácico e deformidade do tipo escapula alada. **Conclusão:** De acordo com este estudo, o retalho do músculo serrátil anterior é uma excelente ferramenta para o tratamento de lesões complexas e pouco extensas nas extremidades. **Nível de Evidência IV; Série de casos.**

**Descritores:** Retalhos de Tecido Biológico. Extremidade Superior. Traumatismos da Mão.

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### INTRODUCTION

Traumatic wounds of the extremities often result from serious and devastating injuries involving multiple components. Adequate coverage for complicated extremity injuries, especially the hands and feet, is a challenging problem, especially when structures such as bones, tendons, nerves and blood vessels are exposed. Several flaps have been described that are useful to cover these lesions.<sup>1,2</sup> Experimental and clinical studies have shown that muscle flaps are ideal in lesions with impaired vascularity and potential infection.<sup>3,4</sup> The serratus muscle presents a low risk of surgical complications, with a cosmetic scar in the donor area, without functional deficit,

providing adequate quantity and quality of tissue with a consistent vascular-nervous pedicle of adequate length and easy to be dissected.<sup>5-9</sup> It can be transferred with the latissimus dorsi or scapular flap in very extensive lesions as they originate from a common vascular pedicle,<sup>5,6</sup> it can be incorporated into the last ribs in osteocutaneous losses.<sup>5-7</sup> It has been used in several transfers dynamics to restore thumb opposition, preserving segmental innervation of the long thoracic nerve. As a disadvantage, it may cause some asymmetry of the scapulae, formation of seromas or bruises are common, and blood transfusion may be necessary.<sup>5-7</sup>

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The study was conducted at Pontifícia Universidade Católica de São Paulo, Faculty of Medical and Health Sciences, Campus Sorocaba, Sorocaba, São Paulo, Brazil. Correspondence: Edie Benedito Caetano. Rua Joubert Wey, 290. CEP 18030-070 Sorocaba, SP, Brazil. [ediecaetano@uol.com.br](mailto:ediecaetano@uol.com.br)

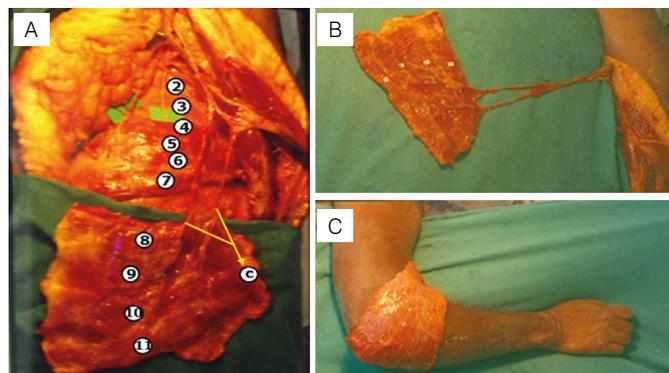
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Covering the lesion site with appropriate soft tissues is essential for the improvement of the functions of the extremities.<sup>5</sup> An optimum coverage must be stable, durable and capable of withstanding great work demands; it must preserve joint mobility and have an aesthetically acceptable appearance, but always prioritizing function.<sup>2</sup> The objective of this study was to present our experience and evaluate our results with the anterior serratus muscle flap in the reconstruction and recovery of the extremities in selected cases.

## MATERIALS METHODS

Twenty-six serratus muscle flaps were used to reconstruct the extremities between 1986 and 2014, 16 for the upper limbs and 10 for the lower limbs. The age group was 16 to 66 years old (of which 3 were younger than 18 years old), 20 male and 6 female patients. Causes of injury included 18 patients with mechanical trauma such as compressions, chains, and rolling machines, 4 patients with electrical and contact thermal burn, 4 crushing injury secondary to a motor vehicle accident. No patients had bony defects and 4 had extensor tendons injuries. In 11 cases, the last four digitations were used; in 12 cases, three digitations; in 3 two digitations. Each digitation averaged was 1.8 cm x 8 cm, varying according to the patient's height. The removal of only the three lower digitations can be performed without changes in the position of the scapula.<sup>10,11</sup> The muscle is easily removed through an incision in the medium axillary line and has a long and reliable vascular pedicle.<sup>12,13</sup> (Figure 1) The patient is placed in the supine position with a support on the back, raising the hemithorax from the operating table. The incision is made along the middle axillary line. The skin and subcutaneous tissue is elevated exposing the muscular layer. The thoraco-dorsalis vascular pedicle and the long thoracic nerve are visualized on the muscular layer. The lower digitations of the serratus muscle with its vascular branches are then identified. Marking the amount of muscle that will be used by sectioning the muscle immediately after the vessels and close to the scapula may be useful. Then, we anchor the sectioned end of the serratus muscle to the chest wall in order to prevent changes in the scapular position. The dissection continues proximally, up to the subscapular artery, depending on the length of the desired pedicle for the case. The pedicle is only detached from the donor area, when the recipient area was completely prepared. Anastomoses, preferably end to side, are performed outside the lesion area. In 3 limbs the skin graft was performed immediately after the flap and in 23 members the flap coverage with skin graft was performed 7 to 10 days after its application, with the confirmation of the flap's survival. The initial aspect of a bulky flap can be resolved by the subsequent atrophy of the denervated muscle, promoting

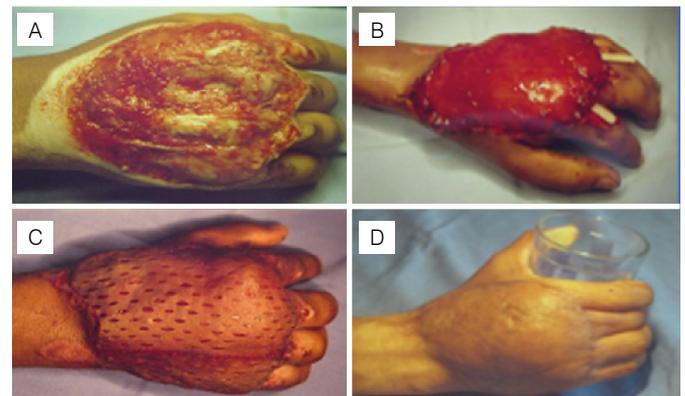


**Figure 1.** (A) Figure shows 11 digits of the serratus muscle, with two branches of the thoraco-dorsal artery destined for the anterior serratus muscle. (B and C) The last 4 digits with a long vascular pedicle, reaching the elbow region.

a very acceptable final contour a few weeks after its application. (Figure 2) Microsurgical instruments and with the aid of loupes and a stereoscopic dissecting microscope set at 16x magnification are the fundamental tools used by our staff in this procedure. CAAE: 37913420.8.0000.5373.

## RESULTS

In this study, we used the serratus muscle flap in 26 lesions of the extremities, 16 in the upper limbs and 10 in the lower limbs. Two of them were used as a pedicled flap to cover an area on the arm, one on the elbow, latter associated with ulnar nerve repair. (Figure 3) In three cases it was used as free flaps for the forearm, in two cases associated with fractures of the radius and ulna. (Figure 4) In 11 cases as free flaps for the hand, and in 4 of them for the palm. (Figure 5) We designed 7 to the dorsal aspect of the hand and wrist. (Figure 2) Only part of the muscle was used to cover the palmar aspect of the hand, with flexor tendon exposure in



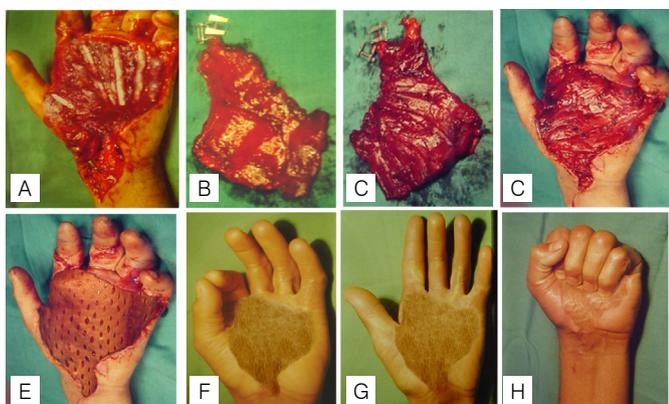
**Figure 2.** (A) Injury in the back of the wrist and hand. (B) The initial appearance of a bulky flap. (C and D) subsequent atrophy of the denervated muscle, promoting a very acceptable final contour a few weeks after the flap application.



**Figure 3.** (A) Loss of soft tissue associated with injury to the ulnar nerve. (B) pedicled flap of the anterior serratus muscle. (C and D) recent surgery. (E and F) Late postoperative.

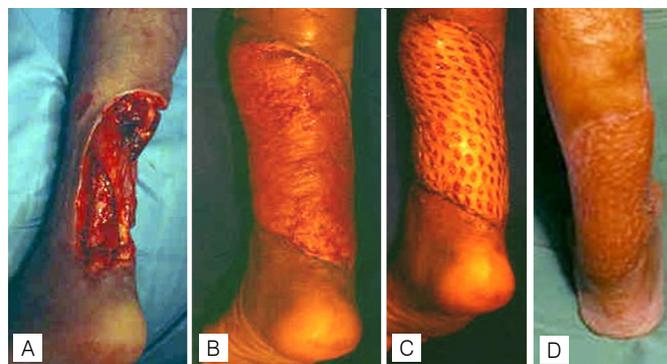


**Figure 4.** (A, B) injury associated with fracture of the forearm bones. (C, D and E, F) Free flap of the anterior serratus muscle, recent postoperative period. G, H - Late postoperative.

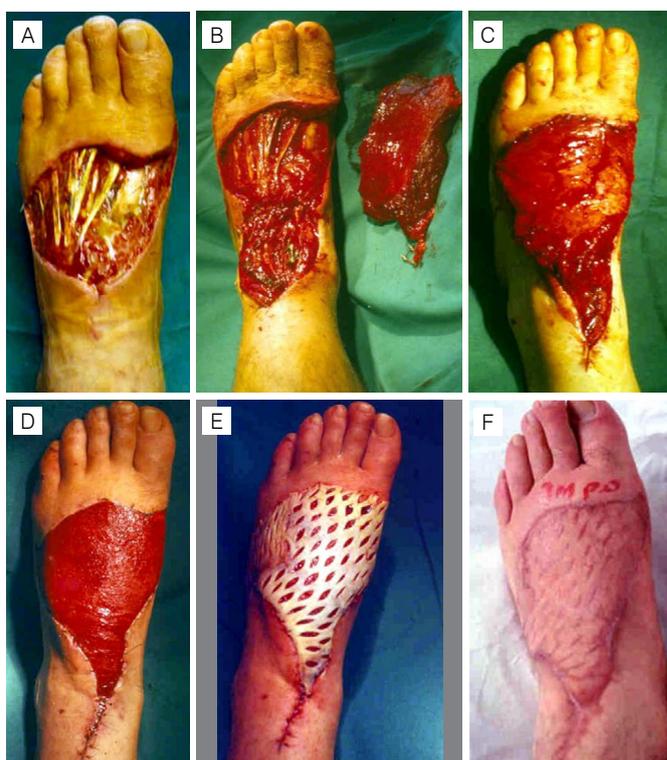


**Figure 5.** (A) Injury of the palmar surface of the hand with exposure of the flexor tendons. (B, C) Part of the thickness of the muscle, covered by the fascia, in contact with the flexor tendons to prevent their adherence to the musculature, leaving the bloody muscular area facing the surface. (D, E, F, G, H) Recent and late postoperative period.

4 limbs. The portion covered by the fascia in contact with the flexor tendons had the aim to prevent adhesences. The bloody muscular area facing the surface was grafted with partial skin. (Figure 5) Regarding the dorsal aspect of the hand, the same procedure was performed. In 3 limbs, we used silicone rod at the same time as the application of the serratus flap. (Figure 2) The serratus flap was used to cover the lower third of the leg in four cases, (Figure 6) for the dorsal aspect of the foot in 3 cases, (Figure 7) 2 for the calcaneus area (Figure 8) and one for the plantar surface of the foot. We considered the immediate good results, when the anastomoses were patent, there was diffuse bleeding of the muscle over the entire length of the flap, good color and normal turgor of the muscle. The result was considered bad, when the muscle remained ischemic, or excessive bleeding. We considered a good late result when, after two weeks, the muscle had a normal appearance, completely integrated with the receiving area, and regular when the part of the necrotic area, after debridement, was able to receive a skin graft. We considered the result to be bad when the flap or part of it was necrotic, requiring its removal and a new procedure for the same purpose. The results obtained were considered good when the patient was able to return to the functions he performed prior to the injury, or a briefly limited functional limitation; regular, when there is a greater limitation, however, the use of the extremity is useful for the patient; bad when the function has not been restored (Table 1).



**Figure 6.** (A) Musclocutaneous loss, transfer of the fibular brevis muscle to replace the Achilles tendon, (B) Free flap of the anterior serratus muscle. (C and D) Recent and late postoperative period.



**Figure 7.** (A) Injury to the dorsum of the foot. (B, C, D) free flap of the anterior serratus muscle. E -Recent postoperative period. (F) - late postoperative.

Complete flap survival was recorded in 20 limbs, 3 abstracts circulatory problems, even with a revision of vascular anastomose and partial flap necrosis cannot be avoided and required a skin graft after debridement. Another also requires re-exploration as a result of intense congestion due to difficulty in venous return, this has been fully recovered. In two cases, we used the serratus fascia flap. In these there was partial loss in the first case and total loss in the second, due to venous insufficiency. Superficial wound infection occurs in three patients, who were treated with conservative measures. Regarding the donor area, in 8 cases the formation of seroma occurred, in 2 cases drainage was necessary and in the other cases it was resolved spontaneously. In two instances hematoma formation that was drained. In a limb that has 4 digits to cover an extensive lesion on the back of the wrist and hand, there was an injury to the long thoracic nerve and deformity in the scapula lata (Table 2 – A and B).

## DISCUSSION

The transfer of the free anterior serratus muscle flap was first described by Takayanagi and Tsukie.<sup>13</sup> They reported two cases of plantar surface coverage, with good results and minimal morbidity at the donor site. The flap's popularity increased after Whitney and al<sup>6</sup> published a series of 100 cases of use of the anterior serratus muscle free flap, highlighting the low morbidity at the donor site. Derby et al.<sup>12</sup> report that they performed 34 transfers of serratus flaps to cover lesions in several places, blood transfusion was necessary in 24% of cases. The rate of early complications was 21%, consisting of 6% hematomas and 15% seromas. Scar appearance, pain, numbness, strength and mobility of the shoulder were acceptable. Gordon et al.<sup>14</sup> analyzed the result in their patients, 50 months postoperatively, inform that the removal of the flap did not affect the strength and mobility of the shoulder, even those who had some scapular deformity did not have difficulty to perform their activities of daily living. In our cases, complete flap survival was recorded in 20 of the 26 limbs, 3 patients had circulatory complications, even with revision of vascular

anastomoses, partial necrosis of the flap cannot be avoided requiring skin grafting. Another flap also required re-exploration as a result of intense congestion due to difficulty in venous return, this was fully recovered. In two cases, we used the serratus fascia flap. In these, there was partial loss in the first case and total loss in the second, due to venous insufficiency, so we prefer to associate a muscular portion about one centimeter thick to facilitate the venous return. In cases of use of the only fascia, or even when associated with a very thin muscular portion, the venous return can be compromised and complications occur. Superficial wound infection occurred in three patients, who were treated with conservative measures. Regarding the donor area, in 8 cases there was a seroma formation, in two cases drainage was necessary. In the others, it was resolved spontaneously. Hematoma formation occurred in two limbs that was drained. In a case where we removed four digits to cover an extensive lesion on the back of the wrist and hand, there was an injury to the long thoracic nerve and deformity in the scapula lata. Blood transfusion was not necessary in the cases that are part of this study. Ronswel et al.<sup>9</sup> in an anatomical study showed that at least one branch of the thoracodorsal artery for serratus is present in 99% of the cases and in 24% registered two branches of the thoracodorsal artery for the serratus muscle.<sup>9</sup> In the 26 members that are part of this study, in only 5 (23%), more than one branch of the thoracodorsal artery was registered for the serratus muscle.

There are few reports of the use of this flap to cover the palm of the hand. Gordon et al.<sup>14</sup> report the experience in 34 cases of covering lesions in the hand with the anterior serratus flap, in 11 to cover the palm of the hand. Our results are in line with the statement by Gordon et al.,<sup>14</sup> that no type of flap is more suitable for covering the palm of the hand. Other muscle flaps are more bulky, and fasciocutaneous



**Figure 8.** (A) Injury in the calcaneal region. (B) flap of the anterior serratus muscle. (C and D) Recent and late postoperative

**Table 2.** Complications associated with flaps.

Complication	Number of Cases	Percentage
Anastomosis Reexploration	4 of 26 cases	15,38%
Total Flap Necrosis	1 of 26 cases	3,85
Partial Flap Necrosis	4 of 26 cases	15,38%

**Table 3.** Complications related to the donor area.

Complication	Number of Cases	Percentage
Nerve Injury	1 of 26 cases	2,6%
Seroma	8 of 26 cases	21%
Bruise	2 of 26 cases	5,2%
Superficial Infection	3 of 26 cases	7,8%
Osteomyelitis	0 of 26 cases	0%

**Table 1.** Distribution of lesions according to affected segment, associated lesions, simultaneous surgeries and immediate and late results.

Affected Segment	Number of Lesions	Associated Lesions	Simultaneous Surgeries	Immediate Results	Late Results
Arm and Elbow	2	Ulnar Nerve Lesion (1)	Ulnar Nerve Neurotaphy	Good (2)	Good (2)
Forearm	3	Radio and Ulna fracture (2); Tendon Injury (2)	Osteosynthesis (2)	Good (2) Regular (1)	Good (3)
Wrist and Hand (Palmar)	4	Tendon injury (2); Digital Nerve Injury (3)	External Fixation (1)	Good (4)	Good (4)
Wrist and Hand (Dorsal)	7	Tendon injury (5); Digital Nerve Injury (3)	Tendon spacer (3), tendon transfer (2); skin graft (2)	Good (4) Regular (1) Bad (2)	Good (5) Bad (2)
Lower third of the leg	4	Achilles Tendon Injury (1); Sural Nerve Injury (1)	Osteosynthesis(1) External Fixation (1)	Good (3) Regular (1)	Good (4)
Foot (Dorsal)	3	Tendon injury (2); Nerve Injury (1)	Tenodesis (1)	Good (2) Regular (1)	Good (1)
Foot (Plantar)	1	-	Skin Graft (1)	Good (1)	Good (1)
Calcaneus	2	Fracture	-	Good (2)	Good (2)

flaps have little adherence and subcutaneous mobility makes it difficult to grasp. Unlike these authors in the four cases we operate, we do not transfer serratus to the palm of the hand, with all its thickness, we prefer it with partial thickness, which in addition to a smaller volume, allows us to place the surface portion covered by loose, less adherent areolar tissue, in contact with the exposed flexor tendons, facilitating their sliding to perform digital flexion. (Figure 5) Gordon et al.<sup>14</sup> believe that plantar reconstruction requires a stable and adherent flap, similar to the palmar surface of the hand. We used the serratil flap to cover the calcaneal region in two cases and the plantar region in one case. Logan et al.<sup>5</sup> used the serratil flap in 15 patients, In six additional procedures were performed in the same act as the flap. In two as a functional flap to restore the opposing of the thumb, both patients recovered the opposition of the thumb between 12 and 18 months postoperatively. They also report another case that used the serratil flap, simultaneously with the politization of index finger. In another, a tendon graft was performed at the same time as the flap. Gordon et al.,<sup>14</sup> reported a case in which they used the serratus flap, simultaneously with the transplantation of the second toe. In this study, we do not use the serratil flap as a functional flap.

Lin and Yazar<sup>15</sup> performed 24 serratil flaps, including ribs in 22 patients for osteocutaneous reconstruction of the extremities in single-stage procedures. Two patients underwent bilateral costal arch flaps associated with the anterior serratus for bilateral tibial and fibular exposed fractures. In nine cases, the latissimus dorsi muscle was also included in the flap. In 17 limbs, two ribs were included in the flap. Two members included three ribs. In five limbs, only one costal arch was included in the flap. They report that in 21 members the flaps survived. They report that 11 of the 24 members had morbidity in the donor area; these included pneumothorax (one patient), pleural fibrosis (one patient), chest wall deformities (two patients) and chronic chest pain (10 patients). Some patients had more than one morbidity at the donor site. Kurokawa et al.<sup>16</sup> report a case of reconstruction of loss of soft tissues on the dorsal surface of the foot, with bone loss of four metatarsals, using free osteomyocutaneous flap of the serratil muscle associated with costal arches reconstructed osteocutaneous loss, inform that the structure of the foot arches was rebuilt using the curvature of the

costal arches. Long-term follow-up has shown good results, the patient can walk and run without support.

Trignano et al.<sup>17</sup> report a series of 12 reconstructions, associating the latissimus dorsi, serratil and ribs, indicating this procedure, in case of bone loss, associated with extensive soft tissue injuries. The flaps survived, however, 6 patients (50%) had postoperative complications. They consider that, in fact, this procedure has a very high percentage of complications, being an alternative option to amputation. Lin et al.<sup>18</sup> performing this same procedure had complications, in 6 of 9 patients 66.7%, and Kim and Blackwell<sup>19</sup> in 14 of 29 patients (48%).

Elia et al.<sup>20</sup> treated 47 patients with osteocutaneous loss, the latissimus dorsi muscle flap associated with ribs were used in 13 limbs. The latissimus dorsi flap associated with the serratil muscle flap and ribs in 25 members as a free flap, in nine as a pedicled flap. In cases of association only of the latissimus dorsal, the eighth and tenth ribs were incorporated into the flap. In cases where serratus was also included, they used the fifth and seventh ribs, inform that they prefer to remove intercalated ribs, in order to preserve the stability of the chest.<sup>20</sup> Yamamoto et al.<sup>21</sup> prefer the removal of the last ribs that are floating and do not alter the dynamics of the rib cage. In this study we used the anterior serratil muscle flap exclusively for traumatic injuries not very extensive in the extremities, we do not use this flap associated with ribs, or as a functional flap innervated by the long thoracic to restore the function of paralyzed hand muscles. We also do not associate the latissimus dorsal and paraescapular muscle flap that originates from a common vascular pedicle. In two cases, we used the serratil muscle flap to cover a lesion on the arm, another on the elbow, by dissecting the vascular pedicle to its origin in the axillary artery, so it was possible to cover these lesions just by transposing the flap, without the need performing microvascular anastomoses. (Figure 3)

## CONCLUSION

According to this study, the serratus anterior muscle flap is an excellent tool for treating complex lesions that are not very extensive in the extremities. The dimensions of the vascular pedicle length allow microanastomoses to be performed in vessels distant from the recipient area.

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## REFERENCES

1. Miller EA, Friedrich J. Soft Tissue Coverage of the Hand and Upper Extremity: The Reconstructive Elevator. *Journal of Hand Surgery*. 2016;41(7):782-92.
2. Bashir MM, Sohail M, Shami HB. Traumatic Wounds of the Upper Extremity: Coverage Strategies. *Hand Clinics*. 2018;34(1):61-74.
3. Mathes SJ, Feng LJ, Hunt TK. Coverage of the infected wound. *Annals of Surgery*. 1983;198(4):420-9.
4. Chang N, Mathes SJ. Comparison of the effect of bacterial inoculation in musculocutaneous and random-pattern flaps. *Plastic and Reconstructive Surgery*. 1982;70(1):1-10.
5. Logan SE, Alpert BS, Buncke HJ. Free serratus anterior muscle transplantation for hand reconstruction. *Br J Plast Surg*. 1988;41(06):639-43
6. Whitney TM, Buncke HJ, Alpert BS, Buncke GM, Lineaweaver WC. The serratus anterior free-muscle flap: Experience with 100 consecutive cases. *Plast Reconstr Surg*. 1990;86(3):481-90.
7. Brody GA, Buncke HJ, Alpert BS. Serratus anterior muscle transplantation for treatment of soft tissue defects in the hand. *J Hand Surg*. 1990;15(2):322-7.
8. Dumont CE, Domenghini C, Kessler J. Donor site morbidity after serratus anterior free muscular flap: a prospective clinical study. *Ann Plast Surg*. 2004;52(02):195-8
9. Rowsell AR, Davies DM, Eizenberg N, Taylor GI. The anatomy of the subscapular-thoracodorsal arterial system: study of 100 cadaver dissections. *British Journal of Plastic Surgery*. 1984;37(4):574-6.
10. Salles FA, Ribak S, Dalapria R, Resende MR, Andrade D, Toledo CS. Estudo anátomo-radiológico do retalho do músculo serrátil anterior. *Rev Bras Ortop*. 1994;29(5):351-6.
11. Caetano EB, Brandi S, Nunes JS, Itano AT, Balera E. Retalho do músculo serrátil anterior: considerações anatômicas e aplicações clínicas. *Rev Bras Ortop*. 1991;26(6):205-10.
12. Derby L, Bartlett S, Low D. Serratus Anterior Free-Tissue Transfer: Harvest-Related Morbidity in 34 Consecutive Cases and a Review of the Literature. *Journal of Reconstructive Microsurgery*. 1997;13(06):397-403.
13. Takayanagi S, Tsukie T. Free serratus anterior muscle and myocutaneous flaps. *Ann Plast Surg*. 1982;8(4):277-283.
14. Gordon L, Levinsohn DG, Finkemeier C, Angeles A, Deutch H. The serratus anterior free-muscle transplant for the reconstruction of the injured hand: An analysis of the donor and recipient sites. *Plast Reconstr Surg*. 1993;92(1):97-101.
15. Lin CH, Yazar S. Revisiting the serratus anterior rib flap for composite tibial defects. *Plastic and Reconstructive Surgery*. 2004;114(7):1871-7.

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16. Kurokawa M, Yamada N, Suzuki S, Muneuchi G. Long-term follow-up of reconstruction of four metatarsal bone and soft-tissue defects using a serratus anterior muscle rib osteomyocutaneous free flap. *Plastic and Reconstructive Surgery*. 2004;114(6):1553-5.
  17. Trignano E, Fallico N, Nitto A, Chen HC. The treatment of composite defect of bone and soft tissues with a combined latissimus dorsi and serratus anterior and RIB free flap. *Microsurgery*. 2013;33(3):173-83.
  18. Lin CH, Wei FC, Levin LS, Su JI, Fan KF, Yeh WL et al. Free composite serratus anterior and rib flaps for tibial composite bone and soft tissue defect. *Plast Reconstr Surg*. 1997;99(6):1656-65.
  19. Kim PD, Blackwell KE. Latissimus-serratus-rib free flap for oromandibular and maxillary reconstruction. *Arch Otolaryngol Head Neck Surg*. 2007;133(8):791-5.
  20. Elia R, Di Taranto G, Amorosi V, Ngamcherd S, Alamouti R, Liao L et al. The versatility of the thoracodorsal artery based composite flaps with vascularized rib and a systematic review of the literature. *Journal of Surgical Oncology*. 2019;120(3):527-39.
  21. Yamamoto Y, Sugihara T, Kawashima K, Qi F. An anatomic study of the latissimus dorsi-rib flap: an extension of the subscapular combined flap. *Plastic and Reconstructive Surgery*. 1996;98(5):811-6.