Training in Flap Harvesting using Corrosion Casted Pig Latissimus Dorsi Muscle Flaps Choosing the Optimal Plastic Compound for Corrosion Casting

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Plastic compounds have been used for several decades to generate anatomical constructs for the training of new surgeons and medical students alike. The present study seeks to highlight the advantages and disadvantages of two different plastic compounds (Technovit 7143 and Epoxi BIODUR® E12) used to create corrosion casts of the vascular branching patterns in free muscle flaps. Porcine latissimus dorsi muscle free flaps were used in this study to create corrosion casts of their vascular branching tree by injecting the two different plastic compound into the main arterial supply. The casts generated by Epoxy BIODUR® E12 have superior qualities compared to the casts injected with Technovit 7143, because the injection process is smoother at all branching levels, without dilation, strictures or intramuscular extravasation of the injectable plastic compound. The corrosion casts resulted from injecting Epoxy BIODUR® E12 exhibit better elasticity and better resistance to mechanical handling compared to the ones injected with Technovit 7143.

Keywords: latissimus dorsi muscle flap, plastic polymers, corrosion casts, flap harvesting, flap dissection training

Plastic compounds have been used for several decades to generate anatomical constructs for the training of new surgeons and medical students alike. Previous publications show three main directions of study in this area: (i) corrosion casting designed to highlight the vascular-ductal systems of the parenchymal organs [1-4]; (ii) creating plastinated anatomical cross-sections, with computer aided three-dimensional reconstruction and modeling of the anatomical structures [5-9]; (iii) embedding of anatomical preparations in plastic mass [10,11]. In recent decades, the development of microsurgery has allowed the use of free muscle flaps (with or without fascio-cutaneous structures) to cover or fill important soft tissue defects. The latissimus dorsi muscle is one of the most used muscle structures in reconstructive microsurgery in human patients [12] and displays a type V pattern of vascular supply, according to Mathes and Nahai [13], with one dominant pedicle and secondary segmental pedicles. The porcine latissimus dorsi muscle displays the same patten of vascular supply as its human counterpart and thus harvesting a porcine vascularized free latissimus dorsi muscle flap simulates accurately the human counterpart, due to the almost identical anatomy of the swine and human muscle [14,15].

Currently, the most used plastics masses for creating anatomical corrosion casts are produced by Technovit (Heraeus Kulzer GmbH, Wehrheim, Germany) and BIODUR® (BIODUR Products GmBH, Germany) [16]. Injection of muscular vascular systems is the latest technique to highlight the vascular pattern [17]. The present research seeks to highlight the advantages and disadvantages of different plastic compounds used in the creation of vascular pattern corrosion casts of the porcine latissimus dorsi muscle.

Experimental part

Ten healthy pigs (*Sus scrofa domesticus*) of Landrace/ Large White/Duroc hybrid breed were obtained from Smithfield Ferme (Timisoara, Romania), both male and female (3 male, 7 female), weighing 28-36 kg. The experimental animals were used prior to flap harvesting for surgical training, carried out under general inhalatory anesthesia and were treated according to the *Policy for the Use of Animals in Teaching and Training* recommended by the Federation of European Laboratory Animal Science Associations (FELASA). The experiments were approved by the Ethics Committee of the Victor Babes University of Medicine and Pharmacy, Timisoara. After completion of the surgical training, the experimental animals were euthanized using intravenous injection of 0.3ml/kg embutamide (T-61©, Merck Animal Health, Germany).

Twenty latissimus dorsi muscle free flaps were harvested at necropsy, with the axial arterial supply traced proximally to the level of the subscapular artery and used to study the intramuscular diffusion proprieties of the plastic compounds. 10 harvested free muscle flaps, originating both left and right, were injected with Technovit 7143 plastic compound (Heraeus Kulzer GmbH, Wehrheim, Germany) and the other 10 free flaps with BIODUR® E 12 (BIODUR Products GmbH, Germany), seeking to compare the advantages and disadvantages of using these two plastic compounds in creating corrosion casts of the intramuscular vascular branching pattern in the procine latissimus dorsi free muscle flaps.

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The Technovit 7143 injectable plastic compound, based on methacrylate copolymers, was prepared for injection by combining a partially polymerized monomer base (Technovit 7143, Heraeus Kulzer GmbH, Wehrheim, Germany) with a catalyst of Methyl methacrylate and N,N-dimethyl-p-toluidine (Technovit Universal Liquid, Heraeus Kulzer GmbH, Wehrheim, Germany) in a ratio of 1:1, with a hardening time of 10-15 min. The injected plastic compound was then allowed to polymerize for 24 h in the harvested anatomical construct.

The Epoxy BIODUR® injectable plastic compound (BIODUR Rathausstr.18, 69126 Heidelberg, Germany) was prepared by mixing: BIODUR® E12 (resin) / BIODUR® E6 (hardener), in ratio of 10:1 with a hardening time of 24h.

For each injectable plastic compound, a 50 ml syringe (Beckton Dickinson Luer-Lok™, New Jersey, USA) was used to inject the mixtures under hand pressure until the entire intramuscular arterial system was filled and the plastic compound could be seen to extrude from the edge of the anatomic specimen. Corrosion casting was performed in order to remove the muscular and fascial structures by submerging the anatomical specimens in sodium hydroxide solution 40% (w/w %) for 3 days. Corrosion with sodium hydroxide was interrupted by daily washing under running tap water to encourage the disposal of the organic tissues. The obtained vascular corrosion casts were rinsed 24 h in running tap water and finally photographed and analyzed.

Results and discussions

The porcine latissimus dorsi muscle is supplied in its dorso-caudal part by dorsal intercostal arteries (secondary segmental pedicles), while the remaining bulk of the muscle is supplied thorough the dominant pedicle – the thoraco-dorsal artery, a branch of the subscapular artery for the ventro-cranial part of the muscle [18].

The toracodorsal artery continues the path of the subscapular artery and penetrates the muscle on its posterior side, in a cranial to caudal direction in the muscle, some 2-3 cm distal from the muscle tendon. Inside the muscle bulk, the arterial trunk divides (branches of the second order) in a dorsal branch, running parallel to the dorsal edge of the muscle and a ventral, oblique branch, which runs parallel to the ventral edge of the muscular body. After a short path, the dorsal branch splits (branches of the third order) into a cranial branch (oriented to the dorso-cranial angle of the muscle) and a caudal branch (parallel to the dorsal edge of the muscular body). The ventral branch divides in its caudal path (branches of the third order), into dichotomic dorsal and ventral branches. Injections with Technovit 7143 (fig.1) and Epoxy BIODUR® E 12 (fig.2) allowed constant evidence of fourth and fifth order direct branches oriented towards the edges of the muscle body. Also, at the level of the cranial segment of the thoracodorsal artery, several branches similar to those of the third order with dichotomic dispersion were highlighted.

The corrosion casts generated from the anatomical specimens of harvested free latissimus dorsi muscle flaps were analyzed separately for each of the two plastics compounds used for injection (Technovit 7143 and Epoxy BIODUR® E 12). Analysis consisted in objective evaluation of: (i) the frequency with which branches of the vascular corrosion casts ruptured amongst the five orders of magnitude; (ii) uniformity of injected vascular diameter throughout the same order of magnitude; (iii) intramuscular extravasation of the injectable plastic compound.

The trunk of the thoracodoral artery showed complete rupture in 40% and of the dorsocervical branch in 30% of the corrosion casts injected with Technovit 7143. Compared to this, the casts injected with Epoxy BIODUR®

Table 1

LOCATION OF FRACTURES IN THE CORROSION CASTS BASED ON THE BRANCHING LEVEL AND ON THE PLASTIC COMPOUND USED

Branching level	Arterial level	Level of corrosion casts damage			
		Technovit 7143		Epoxy BIODUR® E 12	
		Damaged corrosion casts	Total damage	Damaged corrosion casts	Total damage
Order I	Thoracodorsal artery	4/10 pcs	40%	0/10 pcs	0%
Order II	Dorso-cranial branch and ventro-caudal branch	3/10 pcs	30%	0/10 pcs	0%
Order III	Third order dichotomic intramuscular branches	4/10 pcs	40%	2/10 pcs	20%
Order IV	Four order dichotomic intramuscular branches	7/10 pcs	70%	2/10pcs	20%
Order V	Marginal branches	10/10 pcs	100%	5/10 pcs	50%

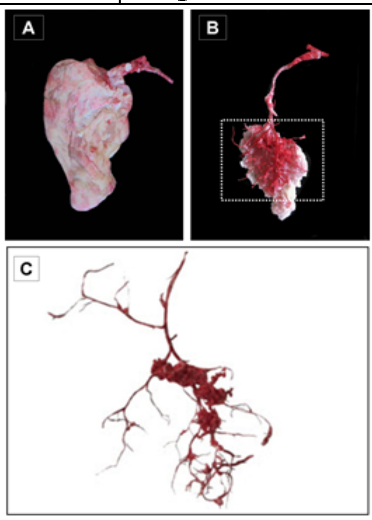

Fig. 1. A. Harvested left latissimus dorsi muscle flap with thoracodorsal pedicle, injected with Tehnovit 7143. B. Partial corrosion cast of the anatomical specimen injected with Tehnovit 7143, having the vascular network partially exposed. C. Detail of the corrosion cast showing the branching system (order II-V) and the damage to the injected plastic compound after corrosion with sodium hydroxide. Branches of order IV and V show extensive damage [Color figure can be viewed in the online issue, which is available at www.revmaterialeplastice.ro].

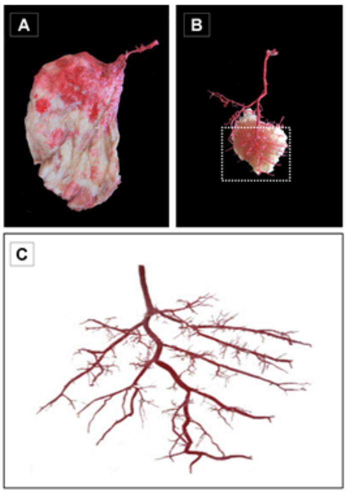

Fig. 2. A.Harvested left latissimus dorsi muscle flap with thoracodorsal pedicle, injected with Expoy BIODUR® E12. B. Partial corrosion cast of the injected anatomical specimen, with the vascular network partially exposed after injection with Expoy BIODUR® E12. C. Detail of the corrosion cast showing the branching system (order II-V) and the damage to the injected plastic compound after corrosion with sodium hydroxide. Branches of order IV and V show extensive damage [Color figure can be viewed in the online issue, which is available at www.revmaterialeplastice.ro]

E12 showed no rupture in the first and second order of branches (table 1). Third and fourth dichotomic intramuscular branches showed ruptures in the case of both plastic compounds, but significantly more frequent when using Technovit 7143 (fig. 1). The casts injected with Epoxy BIODUR® E12 (fig. 2) displayed a better preservation of the vascular branching pattern. The more frequent ruptures of order V marginal branches (100% damage for casts injected with Technovit 7143 and 50% damage for Epoxi BIODUR® E12 injected casts) was correlated with the accentuated adhesion of saponified residues resulting from the sodium hydroxide corrosion process. The rapid polymerization process of Technovit 7143 makes the injected vascular trinisations uneven and low-diameter areas are more commonly associated with ruptures of corrosion casts. The 24h period required for Epoxy BIODUR® E12 polymerization leads to a uniformity in the appearance of the injected arterial trunks, without dilation or strictures. The rapidly increasing viscosity of the intravascular injected Technovit 7143 requires an increase of the injection pressure in order to keep the plastic compound advancing, which causes extravasation of the plastic compound in the third and fourth order arterial branches.

Linear and total shrinkage of Epoxy BIODUR® E12 plastic compound is minimal compared to Technovit 7143 [19].

Conclusions

Porcine muscle free flaps provide an easy teaching and training model for surgeons aiming to better understanding the vascular architecture of free flaps. Injecting anatomical specimens and creating plastic corrosion casts facilitates the educational process and the understanding of intramuscular tridimensional distribution of the arterial pattern. For these purposes, Epoxy BIODUR® E12 has superior qualities compared to Technovit 7143 because the injected plastic compound is uniform at all levels of magnitude without signs of dilation, strictures or intramuscular extravasation. The corrosion casts made with Expoy BIODUR® E12 have a better elasticity and good resistance to mechanical handling compared to the ones obtained by injecting Technovit 7143.

Acknowledgements: This work was supported through a grant financed by the Victor Babes University of Medicine and Pharmacy Timisoara (Grant PII-C1-TC-2013-15250/19.12.2012, Acronym ANGIOPERF).

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Manuscript received: 15.02.2017