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## Cadaveric comparison of two facial flap-harvesting techniques for alloplastic facial transplantation

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### KEYWORDS

Composite tissue  
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**Summary** *Background:* Functional and aesthetic reconstruction of severe facial deformities presents a major challenge, and the results are rarely satisfactory. Recent clinical success of composite tissue allograft transplantation and improvements in autoimmune regulation have initiated efforts to reconstruct severe facial deformities with alloplastic tissue. Few reports address the full facial flap dissection approach, where lengthy procedural times remain a limiting factor in achieving optimal graft survival. Extensive vascular anastomoses within facial tissues provide a unique opportunity to explore alternative graft harvesting strategies to optimise operative ischaemia.

*Objective:* The aim of the study was to shorten donor-graft harvesting time and reduce warm ischaemia. We evaluated alternative facial harvesting strategies through mock cadaveric facial transplantations.

*Methods:* Cadaveric dissections were performed to explore facial-scalp reconstruction alternatives. Six paired sub-superficial musculoaponeurotic system (SMAS) plane composite facial-scalp flaps were harvested using either a superficial temporal artery (STA) or a facial artery (FA) pedicle technique (Group I) or an external carotid artery (ECA) pedicle technique. Total harvesting times and lengths of vascular pedicles were measured.

*Results:* Harvesting time for a STA and FA pedicle total facial flap (mean = 113 min, range = 105–120 min, SD = 6 min) was shorter than that for an ECA pedicle flap (mean = 232 min, range = 225–240 min, SD = 6 min) ( $P < 0.01$ ). Mean pedicle lengths for the STA, the FA, the ECA, the external jugular vein, and the facial vein were  $37 \pm 2.1$ ,  $35 \pm 1.8$ ,  $26 \pm 1.4$ ,  $52 \pm 3.0$  and  $42 \pm 2.6$  mm, respectively. Mean pedicle lengths for the supraorbital, supratrochlear, infraorbital, mental, and facial nerve were  $15 \pm 1.5$ ,  $14 \pm 1.4$ ,  $24 \pm 1.2$ ,  $30 \pm 1.6$  and  $32 \pm 1.8$  mm, respectively.

*Conclusion:* Compared with previously reported ECA pedicle total facial allograft harvesting techniques, an STA and FA pedicle flap provides a shorter harvesting time and potentially safer dissection method for facial transplantation by avoiding interference with the complicated anatomy of the carotid and submental triangle. Early graft ischaemic damage can be minimised by this

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harvesting technique, which significantly shortens harvesting time compared with previously described approaches, while maintaining adequate full facial perfusion.

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Success with human composite tissue allograft (CTA) transplantations for hand, larynx, knee, and abdominal wall has been encouraging in the field of reconstructive surgery.<sup>1-4</sup> For most anatomical regions, the goal of the reconstructive procedures is primarily functional, and aesthetic outcomes remain secondary. In facial reconstruction, however, the static and dynamic appearance serves both aesthetic and functional purposes. Traditional reconstructive procedures include standard skin grafting, application of local flaps, tissue prefabrication, tissue expansion, and free tissue transfers.<sup>5-16</sup> Because of poor matching of tissue size, texture and colour, these methods are inadequate in restoring normal appearance and facial expression. In 2006, Siemionow et al.<sup>17</sup> performed cadaver studies to explore alternative sources for facial-scalp reconstruction and inferred that none of the conventional cutaneous autogenous flaps were adequate to cover total facial defects. They concluded that reconstruction by alloplastic facial transplantation would provide the optimal postoperative appearance.

Improvements in autoimmune regulation have permitted successful allograft transplantation and prolonged late graft survival. Early survival of the transplanted alloplastic tissue relies on prompt and adequate perfusion. Previously reported harvesting techniques are tediously slow due to the anatomic complexity of the facial tissues. Shorter harvest times would reduce warmer ischaemia, and improve graft viability.

In 2005 and 2006, Siemionow et al.<sup>17,18</sup> reported the results of mock facial transplantation in cadavers and their surgical strategy for harvesting the total facial-scalp flap.

Their method used bilateral external carotid arteries (ECAs) and external jugular and facial veins as pedicles, and achieved a mean harvesting time of 236 min. To shorten donor-graft harvesting time and to reduce warm ischaemia, we propose a modified harvesting strategy of using the superficial temporal artery (STA) and the facial artery (FA) as pedicle, the STA and FA pedicle technique.

## Materials and methods

Twelve fresh human cadavers were dissected. Ten of the cadavers were males and two were females. The mean age of the cadavers was 71 years (range = 65–79 years). Cadavers were randomly divided into two groups defined by total facial flap harvesting technique; Group I cadavers were dissected using an STA and FA pedicle method, while Group II cadavers were dissected using the ECA as pedicle, an ECA pedicle technique. The harvesting technique for Group I began with a coronal incision, followed by subperiosteal dissection, down to the supraorbital rim where the supraorbital and supratrochlear nervi vasorum tract were ligated. Dissection was carried out at the superficial layer of the orbital septum, under the orbicularis muscles and downward to the suprarim of the tarsus, and the tarsus was kept on the flap. Bilaterally, the medial and lateral canthus tendon were separated and ligated. The lower eyelid was dissected at the same plane as the upper eyelid (Fig. 1) and dissection was continued in the sub-superficial musculoaponeurotic system (SMAS) plane to the infraorbital foramen, where the infraorbital nerve and artery were also ligated. At the region of the nose, the flap was dissected at the superficial layer of the periosteum of the

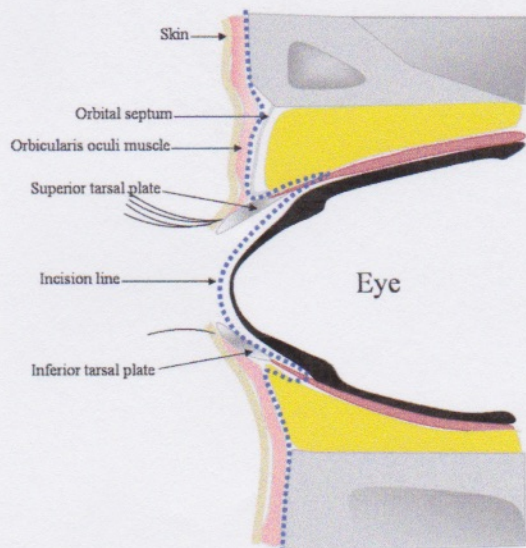


Figure 1 Dissection of the orbital area.

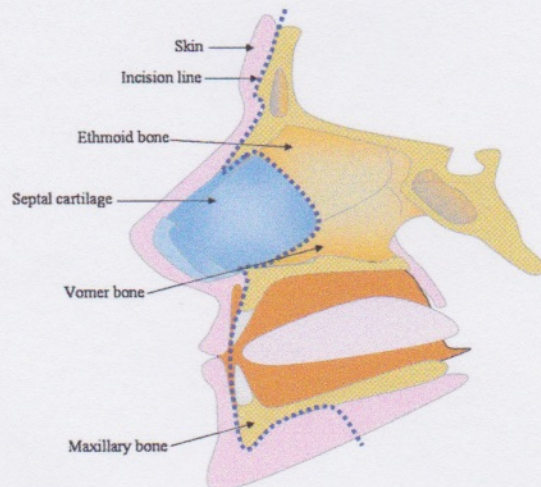
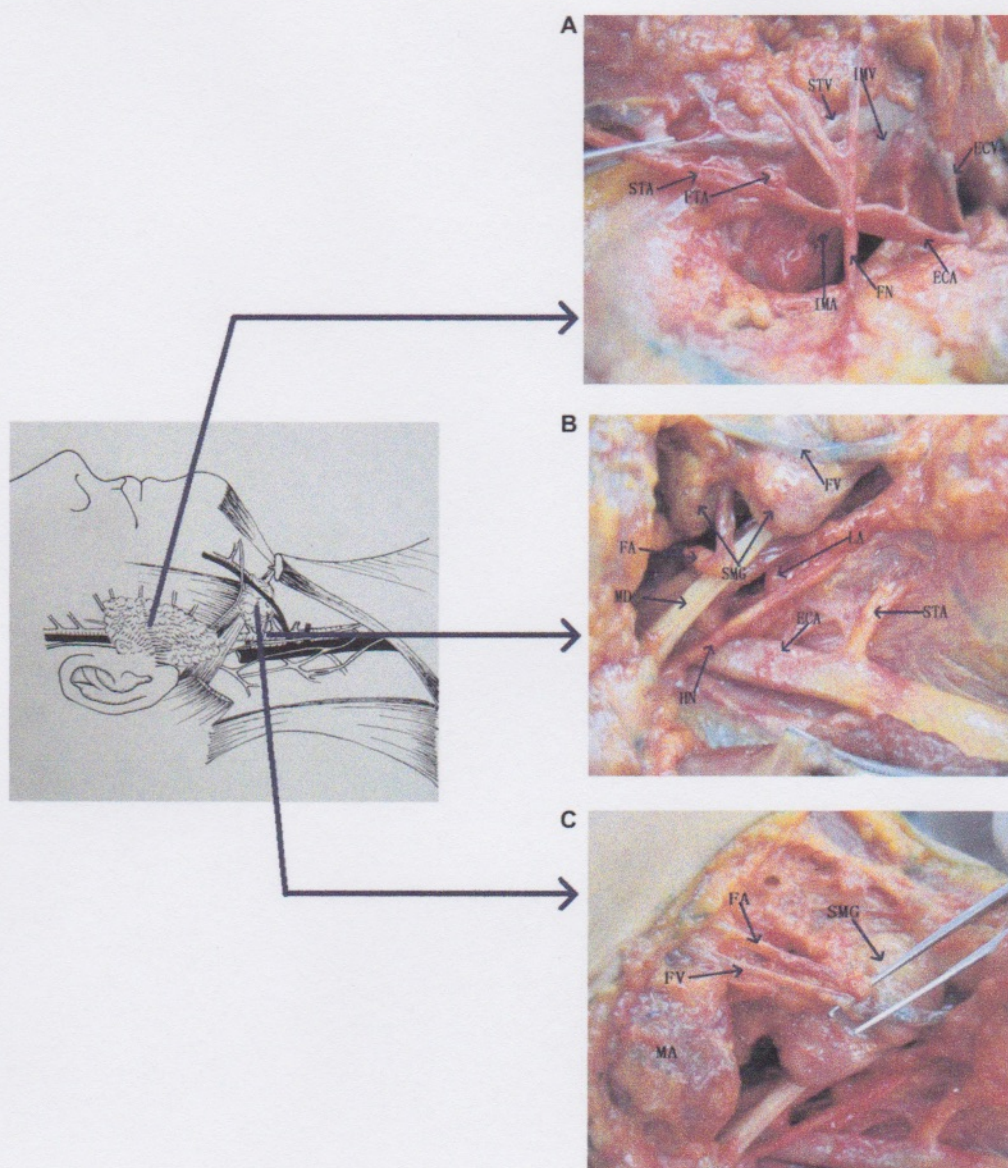


Figure 2 Dissection of the nose and oral region.



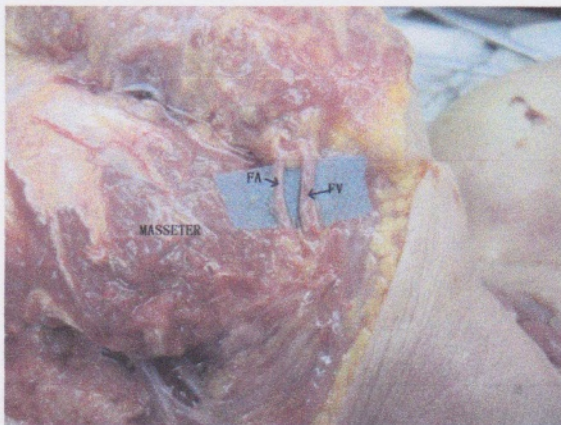


**Figure 3** The anatomic structure of complicated areas during the procedure of harvesting of the facial flap. (A) The anatomy of the region of the parotid gland. STA, superficial temporal artery; IMA, internal maxillary artery; FTA, transverse facial artery; ECA, external carotid artery; STV, superficial temporal vein; IMV, internal maxillary vein; ECV, external carotid vein; FN, facial nerve. (B) The anatomy of the carotid artery triangle: FV, facial vein; FA, facial artery; SMG, submandibular gland; MD, musculus digastricus; HN, hypoglossal nerve; LA, lingual artery; ECA, external carotid artery; STA, superior thyroid artery. (C) The anatomy of the submandibular triangle: FV, facial vein; FA, facial artery; SMG, submandibular gland; MA, masseter.

nasal bone, and the cartilages, septum and upper lateral cartilages were separated from the nasal bone and the vomer bone, and then harvested using the scissor. The cartilages with the mucous membrane of the nasal vestibule were kept on the flap. Dissection was carried out downward to the perioral region, where the flap was dissected at the superficial layer of the maxillary bone, and the mucous membrane of the mouth was also kept on the flap (Fig. 2). Dissection was performed temporally, above the

superficial layer of deep temporal fascia, down to the zygomatic arches and mandibles, and then separated between the superficial and the deep portion of the parotid gland. Further dissection isolated the facial nerve, branches of the ECA (internal maxillary, transverse facial, STA, and the nutrient artery of the parotid gland), and the branch of the external carotid vein (Fig. 3A). The internal maxillary artery and the branch that enters the deep part of the parotid gland were then ligated. The facial nerve was





**Figure 4** The isolated length of the facial artery (FA) and facial vein (FV) show they are suitable to be anastomosed and used as pedicles.

followed proximally to find the facial nerve stem at the point of the stylomastoid foramen, where the facial nerve was severed. Dissection was carried out downward to the deep part of the facial nerve. The STA was dissected and ligated, and the external carotid vein and FA were separated at the lower margin of the parotid and anterior border of the masseter (Fig. 4). These were used as the vascular pedicles. The plane at the rear of the mandibular angle was performed superficial to the ECA and the sternocleidomastoid. The mental nervi vasorum tract was also ligated at the mental foramen. The incision was performed approximately 2 cm from the lower margin of the submaxilla. The composite graft involves bilateral auricles, all mimetic muscles, facial nerves, palpebral conjunctiva, upper and lower lips, and nasal cartilage (Fig. 5).

Group II cadavers were dissected with an ECA pedicle method, similar to that described by Siemionow et al.<sup>18</sup> First, the skin was incised and along the body surface

**Table 1** Total time for harvesting the graft for group I and group II

	Time (min)						Mean $\pm$ standard deviation
Group I	120	120	115	110	110	105	113 $\pm$ 6
Group II	240	235	235	230	225	225	232 $\pm$ 6

$t = -33.8479$ ,  $P = 0.0000$ .

projective line of the external carotid artery, the external carotid vein was isolated and ligated superficial to the platysma at the posterior border of the sternocleidomastoid. We then separated the sternocleidomastoid inner from the anterior border, where the common carotid artery was found. After the bifurcation of the common carotid to the internal and external carotid arteries, the ECA was transected to become the arterial pedicle of the flap and, tracing the ECA, its branches were found (Fig. 3B): the ascending pharyngeal, the superior thyroid, and the lingual arteries were ligated close to their branching from the ECA, and dissection was carried out further cranially. The hypoglossal nerve was also exposed and transected. The FA, branching from the anteromedial side of the ECA, was carefully dissected in a cranial direction as it entered the submandibular gland. The artery was traced and separated from the gland with tedious dissection (Fig. 3C), and the gland was not incorporated in the flap, and dissection was continued laterally upward deep in the ECA, keeping the part of the sternocleidomastoid on the graft. The posterior auricular artery was then ligated at the junction with the ECA. Dissection was continued caudally along the ECA through the parotid region, similar to the method followed in Group I. The total facial graft was harvested within the same plane as in Group I. Procedural time was noted, and the main ramous communicans between the ECA and the internal carotid artery system was marked.

Statistical significance was analysed using the SAS 6.12 Student's *t*-test. The harvested flaps of Group I were bisected down the midline. The left STA and right FA of the



**Figure 5** The harvested composite facial flap. Left: the anterior view. Right: the opposite view.



**Table 2** Vessels were ligated during the operation in group I and II

Vessels Group	Supra-orbital	Infra-orbital	Supra-trochlear	Internal maxillary artery	Occipital artery	Posterior auricular artery	Nutrient artery of PG	Mental
I	+	+	+	+			+	+
II	+	+	+	+	+	+	+	+

cadaver were isolated and cannulated. Arteries were flushed with 0.9% normal saline until the retrograde flow from the vessels was clear. Methylene blue was then infused through the left STA and the right FA to confirm the vascular distribution of each of these arterial supplies.

## Results

Total facial flap harvesting time by the STA and FA pedicle method was significantly shorter than that by the ECA pedicle method ( $P < 0.01$ ). The mean harvesting time in Group I was  $113 \pm 6$  min compared with  $232 \pm 6$  min for Group II (Table 1). Fewer vessels required ligation using the STA and FA pedicle technique than the ECA pedicle technique (Table 2). The pedicle lengths are shown in Table 3. Perfusion of the STA revealed nearly complete semifacial flap distribution, except for the nasal and the perioral region (Fig. 6). The FA supplied the midface and extended into the region of forehead; it also retrograded to the region of the temple (Fig. 7).

## Discussion

The structural complexity and functional sophistication of the human face make it difficult and tedious to perform a safe and precise facial dissection in order to harvest a viable graft. Numerous clinical studies and experiments have explored the feasibility of the facial allotransplantation. Early survival of transplanted tissue requires adequate perfusion to be achieved within a timely fashion to minimise warm ischaemia. Fortunately, generous anastomoses between the various arterial territories offer an opportunity to explore alternative dissection planes and vascular pedicle sources to simplify procedural complexity and to shorten procedure time. Although microanastomosis of bilateral facial arteries and veins would most likely be

sufficient for facial flap viability, additional venous anastomoses should improve transplant success. Postoperative facial expression depends on very complex coordination of nerves and muscles.

In 1998, the first scalp and facial autograft was replanted.<sup>19</sup> The authors described anastomosing the medial canthal vein followed by the facial vein and artery. The buccal branch of the facial nerve was also reapproximated. The left labial artery with its vein and the STA and two adjoining veins of the scalp were subsequently anastomosed. The separate left-sided scalp fragment was then reattached, anastomosing two veins and the left STA. The patient recovered satisfactorily except for a partial loss of her right ear and a 1 cm marginal loss of skin edges on the left side of the face. At about 4 months, the patient was able to open and close his/her eyelids satisfactorily, as the existing orbicularis oculi muscles regained their function. The orbicularis oris began to regain function at approximately 13 months; however, animation of the oral musculature and the ability to blow and drink without drooling required 3 years of recovery. In 2003, Wilhelmi et al. reported a successful replantation of an entire scalp and ear by microvascular anastomoses of only one artery and one vein.<sup>20</sup> Jiang et al. reported alloplastic partial head and neck compound tissue transplantation, which included both ears.<sup>21</sup> Their allograft was dissected deep to the periosteum in calvaria, deep to the superficial layer of the deep temporal fascia temporally, close to the zygomatic bones and mandibles, including masseter and auricles upon the face, and cervical soft tissues, including sternocleidomastoid muscles. Cervical and external jugular vessels of both sides were excised simultaneously. The ECA was anastomosed with the superior thyroid artery of the recipient, and the donor external carotid vein was anastomosed with the internal carotid vein of the recipient. In 2005, French surgeons performed the first partial facial transplant, using the nose, lips, and chin from a brain-dead living donor to repair the face of a 38-year-old woman who

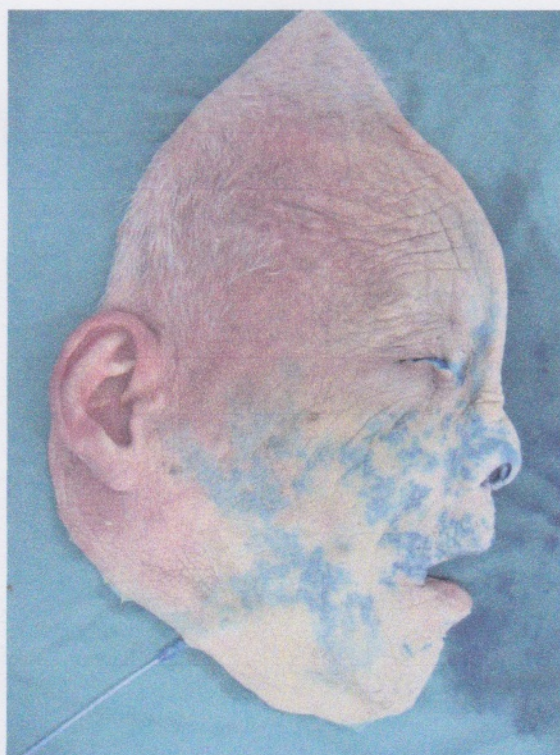
**Table 3** Length of the pedicle in group I

	Length (mm)	Mean $\pm$ standard deviation
Superficial temporal artery	35 37 37 36.5 38 42 40 36 35 35 36 37	$37 \pm 0.2$
Facial artery	35 36 35 34 35 36 35 37 30 35 34 36	$35 \pm 0.18$
External carotid artery	25 26 27 27 26 25 26 25 24 28 29 27	$26 \pm 0.14$
Facial vein	40 42 39 45 43 42 38 45 40 38 45 43	$42 \pm 0.26$
External carotid vein	50 56 55 49 48 52 56 53 49 50 50 55	$52 \pm 0.3$
Supra-orbital nerve	13 14.5 15 16.5 18 17 17 16 15 13.5 14 15	$15 \pm 0.15$
Supra-trochlear nerve	14 12 12.5 13 13 14 16 15.5 15 14 16 13	$14 \pm 0.14$
Infra-orbital nerve	25 26 23 23.5 24 26 25 24.5 23 26 23 24	$24 \pm 0.12$
Mental nerve	32 31 30 32 31.5 29 29.5 31 27 29 28 31	$30 \pm 0.16$
Facial nerve	32 31 31 33 34 30 3.2 31 30 30 35 29	$32 \pm 0.18$





**Figure 6** The Methylene blue staining of the left superficial temporal artery territory.



**Figure 7** The Methylene blue staining of the right facial artery territory.

was mauled by a dog. Initial reports indicate that the recipient is doing well.<sup>22</sup> Those reports suggested various pedicle types could be chosen for the facial flap transplantation, as the facial region has an abundant blood supply system.

In 2006, Siemionow et al.<sup>18</sup> reported an ECA pedicle technique in which the flap was designed to incorporate the entire facial skin, including the skin over the nose, eyelids, vermillion of the lips, ears and scalp. The created composite facial flap included SMAAS of the face, the inferior and superior tarsal plates of the eye, and the great auricular, supraorbital, infraorbital, and mental nerves. This composite facial-scalp flap was based bilaterally on the ECAs serving as the arterial pedicles and on the external jugular and facial veins serving as the venous pedicles, which did not include the nasal cartilage. Harvesting total facial and scalp flaps in cadavers required an average of 236 min. Although this method has the advantage of providing a more extensive perfusion, the additional complexity requires dissecting within the carotid artery and submandibular triangles, which significantly slows down the harvest procedure, and can prolong intraoperative graft ischaemia. Our study aimed to evaluate the feasibility of a potentially safer transplantation technique, using superficial temporal and facial arteries, and external carotid vein as the vessel pedicles.

Prior to the experiment, we harvested the total facial flap without ligating the vessels, which took  $46 \pm 11$  min in Group I and  $111 \pm 7$  min in Group II, but took more time to ligate the vessels during irrigation of the flap with the saline before being transplanted to the recipient. In this study, using a

mock clinical procedure, we harvested the total facial flap by ligating the vessels with silk suture during the operation, thus reducing the time for trimming the flap. The result showed that the STA and FA pedicle method might offer several advantages over the previously reported ECA pedicle technique, including a simpler and potentially safer dissection and a significantly shorter harvest time. Taking advantage of the extensive facial vascular anastomosis, and avoiding the carotid artery and submandibular triangle regions, the average harvesting time could be reduced by half, which significantly reduces operative ischaemia.

Unlike Group I, Group II cadavers received carotid artery and submandibular triangle dissection. First, we separated the external carotid artery, its branches, the FA and the occipital artery in the carotid artery triangle, as well as separated and ligated the occipital artery. Second, along the FA, we explored the submandibular triangle to the anterior border of the masseter muscle where the FA enters the face. Nervi vasorum of the supraorbital, infraorbital, mental, and supratrochlear were also ligated. Mean harvesting time for the six facial flaps harvested in Group I was  $113 \pm 6$  min, compared with the  $236 \pm 6$  min required for the six facial flaps of Group II. Paired *t*-testing, using SAS analysis, indicated ( $P < 0.01$ ) that Group I STA and FA pedicle technique was significantly shorter than Group II ECA pedicle technique.

In addition to harvesting time, host preparation for implantation also significantly impacts potential graft ischaemia. Within the face, extensive anastomotic networks connect the external and internal carotid arterial



systems, both ipsilaterally and across the midline. These include the frontal branch of the superficial temporal, supraorbital, supratrochlear, and the angular artery, and the communication between the upper and lower lip arteries. Although Wilhelmi et al.<sup>20</sup> reported that a total face and scalp flap can survive on only one artery and two veins, to avoid the risk of necrosis when transplanting a total facial flap, we explored arterial supplements. In a clinical procedure, if we anastomose the superficial temporal and the facial arteries and bilateral external jugular veins, both can guarantee blood supply to the graft and also save operation time. In addition, the anatomic study showed the average length of the STA to be  $37 \pm 2.1$  mm, the FA as  $35 \pm 1.8$  mm, and the ECA as  $26 \pm 1.4$  mm, the mean pedicle of the external jugular vein as  $52 \pm 3.0$  mm and the facial vein as  $42 \pm 2.6$  mm. The mean pedicle of the supraorbital nerve was  $15 \pm 1.5$  mm, the supratrochlear nerve was  $14 \pm 1.4$  mm, the infraorbital nerve was  $24 \pm 1.2$  mm, the mental nerve was  $30 \pm 1.6$  mm, and the facial nerve was  $32 \pm 1.8$  mm. We have shown that with our dissection technique, vessel and nerve pedicles are of adequate length for anastomosis.

Postoperatively, recipients of alloplastic grafts require a life-long immunosuppressive regimen to prevent rejection and must bear the risks of rejection and life-long immunosuppression. We have developed an experimental immunomodulatory regimen for our facial alloplastic transplantation experiments on dogs (unpublished data). To date, the longest surviving canine facial allograft has exceeded 1 year without rejection.

In conclusion, harvesting a total facial flap is a time-consuming procedure because of the complex tissue anatomy. Prolonged dissection may cause unnecessary warm ischaemia to the flap. To take advantage of the extensive vascular anastomosis within facial circulation, we present a safe and efficient method of harvesting a total facial flap for alloplastic facial transplantation. This STA and FA pedicle method avoids treating the complicated anatomy of the carotid artery triangle and submandibular triangle. This technique significantly shortens donor-graft harvesting time with no appreciable sacrifice to vascular perfusion.

## References

1. Francois CG, Breidenbach WC, Maldonado C, et al. Hand transplantation: comparisons and observations of the first clinical cases. *Microsurgery* 2000;20:360.
2. Hofmann GO, Kirschner MH. Clinical experience in allogenic vascularized bone and joint allografting. *Microsurgery* 2000;20:375.
3. Strome M, Stein J, Esclamado R, et al. Laryngeal transplantation and 40-month follow-up. *N Engl J Med* 2001;344:1676–9.
4. Levi DM, Tzakis AG, Kato T, et al. Transplantation of abdominal wall. *Lancet* 2003;361:2173–6.
5. Eguchi T, Nakatsuka T, Mori Y, et al. Total reconstruction of the upper lip after resection of a malignant melanoma. *Scand J Plast Reconstr Surg Hand Surg* 2005;39:45–7.
6. Marck KW, Van der lei B, Spijkervet FKL, et al. The prefabricated superficial temporal fascia flap in noma surgery. *Eur J Plast Surg* 2000;23:188–91.
7. Heitland AS, Pallua N. The single and double-folded supraclavicular island flap as a new therapy option in the treatment of large facial defects in noma patients. *Plast Reconstr Surg* 2005;115:1591–6.
8. Pallua N, von Heimburg D. Pre-expanded ultra-thin supraclavicular flaps for (full-) face reconstruction with reduced donor-site morbidity and without the need for microsurgery. *Plast Reconstr Surg* 2005;115:1837–44.
9. Kuzon Jr WM, Jejurikar S, Wilkins EG, et al. Double free-flap reconstruction of massive defects involving the lip, chin, and mandible. *Microsurgery* 1998;18:372.
10. Futran ND, Farwell DG, Smith RB, et al. Definitive management of severe facial trauma utilizing free tissue transfer. *Otolaryngol Head Neck Surg* 2005;132:75–85.
11. Copcu E. Trilobed skin flap on the face: for reconstruction of full-thickness or commissural defects. *Dermatol Surg* 2004;30:915–21.
12. Angrigiani C, Grilli D. Total face reconstruction with one free flap. *Am Soc Plast Surg* 1997;99:1566–75.
13. Mureau MA, Posch NA, Meeuwis CA, et al. Anterolateral thigh flap reconstruction of large external facial skin defects: a follow-up study on functional and aesthetic recipient- and donor-site outcome. *Plast Reconstr Surg* 2005;115:1077–86.
14. Pribaz JJ, Fine N, Orgill DP. Flap prefabrication in the head and neck: a 10-year experience. *Am Soc Plast Surg* 1999;103:808–20.
15. Pribaz JJ, Weiss DD, Mulliken JB, et al. Prelaminated free flap reconstruction of complex central facial defects. *Am Soc Plast Surg* 1999;104:357–65.
16. Posch NA, Mureau MA, Flood SJ, et al. The combined free partial vastus lateralis with anterolateral thigh perforator flap reconstruction of extensive composite defects. *Br J Plast Surg* 2005;58:1095–103.
17. Siemionow M, Agaoglu G, Unal S. A cadaver study in preparation for facial allograft transplantation in humans: part II. Mock facial transplantation. *Plast Reconstr Surg* 2006;117:876–85 [Discussion 886–8].
18. Siemionow M, Unal S, Agaoglu G, et al. A cadaver study in preparation for facial allograft transplantation in humans: part I. What are alternative sources for total facial defect coverage? *Plast Reconstr Surg* 2006;117:864–72.
19. Thomas A, Obed V, Murarka A, et al. Total face and scalp replantation. *Plast Reconstr Surg* 1998;102:2085–7.
20. Wilhelmi BJ, Kang RH, Movassaghi K, et al. First successful replantation of face and scalp with single-artery repair: model for face and scalp transplantation. *Ann Plast Surg* 2003;50:535–40.
21. Hui-qing Jiang, Xin-bao Hu, You-sheng Li, et al. Allograft transplantation with compound tissue of two ears and skin of head and neck. *Chin J Plast Surg* 2003;19:416–9.
22. Editorial: the first facial transplant. *Lancet* 2005;366:1984.