The Combined Latissimus Dorsi-Scapular Free Flap in Head and Neck Reconstruction

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* Microvascular free tissue transfer techniques offer great versatility in the selection of tissue for reconstruction of head and neck defects. The system of flaps based on the subscapular artery and vein provides the widest array of composite free flaps. The possible flaps that can be harvested based on this single vascular pedicle include the scapular and parascapular skin flaps, the serratus anterior and latissimus dorsi muscle flaps, and the lateral scapular bone flap. In addition, a segment of vascularized rib can be transferred with the serratus anterior and latissimus dorsi muscles. Large cutaneous defects can be resurfaced by combining the latissimus dorsi and scapular flaps. Another advantage of this combined flap is the independent vascular pedicles of its components, which allow freedom in orientation of the various tissue segments. Thus, the combined flap can be helpful in reconstructing complex three-dimensional composite defects of the head and neck. In addition, by reinnervating the muscle portions of this flap, bulk can be preserved and an improved functional reconstruction of the oral cavity achieved. A review of the literature shows three previous reports utilizing this combination of flaps in five patients. We report the use of the combined latissimus dorsi-scapular free flap in six patients to reconstruct massive composite defects of the oral cavity, midface, and scalp/There was one flap failure, which was successfully reconstructed with the contralateral latissimus dorsi-scapular flap. The anatomy of this flap is reviewed, and the indications for its application are discussed.

Restoration of form and function to massive, composite defects of the scalp, midface, and oral cavity provides a challenge to the reconstructive surgeon. With the advent of microvascular free tissue transfer techniques, greater versatility in the selection of tissue for reconstruction of head and neck defects is possible. The system of flaps based on the subscapular artery and vein provides the widest array of composite free flaps. The flaps that can be harvested based on this single vascular pedicle include the scapular and parascapular skin flaps,[1,2] the serratus anterior and latissimus dorsi muscle flaps,[3] the lateral scapular bone flap,[4] the latissimus dorsi-rib flap,[5] and the serratus anterior-rib flap.[6] By combining the latissimus dorsi myocutaneous flap with the scapular or parascapular osteocutaneous flap, large composite defects in the head and neck can be resurfaced.

The latissimus dorsi myocutaneous flap was first reported by Tansini[7] in 1896 for breast and chest wall reconstruction. The application of the latissimus dorsi flap for head and neck reconstruction was described by Quillen et al[8] in 1978. studies on the scapular and parascapular free skin flaps preceded the description of the osteocutaneous scapular free flap by Teot et al[4] in 1981. Swartz et al[9] and Baker and Sullivan[10] popularized this composite flap for use in mandibular and maxillary reconstruction.

Batchelor and Sully[11] were the first to detail the combination of the latissimus dorsi myocutaneous free flap with the scapular and parascapular cutaneous free flaps. all based on the subscapular artery and vein, for reconstruction of a massive scalp defect in one patient. Swartz et al[9] used the combination of the latissimus dorsi myocutaneous free flap for the reconstruction of the floor of the mouth and anterior mandible in one patient. Subsequently, Granick et al[12] described the combination of the latissimus dorsi myocutaneous free flap with the scapular osteocutaneous free flap for reconstruction of massive lower facial composite defects in three patients. Jones et al[13] and Hardesty et al[14] used a combined latissimus dorsi myocutaneous flap with a scapular osteocutaneous flap for reconstruction of a large midface defect. However, the free flap failed.

The purpose of this article is to report the application in six patients of the combined latissimus dorsi-scapular free flap in the reconstruction of massive composite defects of the head and neck. The indications for use of this flap are reviewed.

Anatomy

The blood supply to the scapular bone, scapular and parascapular skin, and latissimus dorsi muscle is derived from the subscapular branch of the third portion of the axillary artery. The subscapular artery, which is 3 to 4 mm in diameter, passes inferiorly and slightly posteriorly before branching into the circumflex scapular artery and the thoracodorsal artery. The average length of the subscapular artery before it divides is 2.2 cm, with a range of 0.7 to 6.2 cm.[15]

The circumflex scapular artery, which is 1.5 to 7.0 mm in diameter, winds posteriorly around the subscapularis and passes through a muscular triangle created by the teres minor, teres major, and the long head of the triceps.[16] During its course, the circumflex scapular artery gives off muscular branches to the subscapularis, infraspinatus, and teres muscles. The circumflex scapular artery has two terminal branches: a descending branch, running deep to the teres major to supply the lateral border of the scapula, and a cutaneous branch.[17] The cutaneous vessel divides into a transverse branch and a descending branch, which provide circulation to the scapular and parascapular cutaneous flaps, respectively. The length of the circumflex scapular arterial pedicle is 4 to 8 cm.[18] The artery is accompanied by two venae comitantes, which drain the scapular and parascapular flaps. The venae comitantes join to form one vein in the triangular space[18] (Fig 1).

The skin territories that can be harvested based on the scapular or parascapular vessels are centered on the triangular space and are bounded by the spine of the scapula superiorly and may extend well beyond the midline of the back medially.[19] The inferior edge of the vertically oriented parascapular skin territories can extend up to 30 cm.[2] The maximum width of the scapular and/or parascapular flap is approximately 15 cm[2,20] (Fig 2).

The latissimus dorsi is a superficial, flat muscle that originates medially from the sixth thoracic vertebra down to the superior sacral vertebrae and distally from the posterior outer surface of the iliac crest. The muscle becomes thin and tendinous as it inserts into the intertubercular groove of the humerus.[21] The dominant vascular supply is the thoracodorsal artery, with a secondary source derived from four to six perforators from the posterior intercostal and lumbar arteries. The latissimus dorsi is therefore a type V muscle according to the classification system of Mathes and Nahai.[22] The thoracodorsal artery is consistently accompanied by the thoracodorsal vein and the thoracodorsal nerve.

The distance from the axillary artery to the entry of the thoracodorsal artery into the latissimus dorsi muscle ranges from 9 to 11 cm, with the diameter of the artery varying between 2.0 to 5.0 mm.[21] Before entering the latissimus muscle, one to three smaller branches are given off to the serratus anterior muscle. The thoracodorsal vessels and nerve form a neurovascular hilum at their entry into the latissimus dorsi muscle. This hilum is located on the deep surface of the muscle, about 2 to 3 cm medial to the lateral border of the muscle and about 5 cm caudal to the inferior border of the scapula. The structure of the hilum is uniform, with the vein entering the muscle lateral to the artery and the thoracodorsal nerve situated between the vessels.[21]

Once the thoracodorsal artery enters the muscle, it bifurcates into a medial and lateral branch. The lateral, or vertical, branch runs parallel to the lateral border of the muscle. The medial, or transverse, branch runs toward the midline of the back, paralleling the upper free edge of the muscle. The thoracodorsal vein and nerve follow the same branching pattern as the artery.[18]

The upper border of the skin territory supplied by the thoracodorsal artery is the level of T6-7, which is 1 to 2 cm proximal to the upper muscle edge. Clinically, this corresponds to a line two finger breadths above the inferior scapular angle with the humerus adducted. The inferior border of the skin territory is about 3 cm proximal to the iliac crest, corresponding anatomically to the upper edge of the third lumbar vertebra. The lateral extent of the skin territory is the anterior axillary line for the proximal half of the muscle and the posterior axillary line for the distal half of the muscle. The medial bordser is 2 to 3 cm lateral to the vertebral spine.[21] The density of perforating vessels overlying the skin of the latissimus dorsi is greatest in the upper two thirds of the lateral aspect of the muscle and progressively decreases over the thoracolumbar facia.[23,24] Therefore, the skin paddle of a myocutaneous flap should be designed along the upper two thirds of the lateral portion of the muscle to capture the greatest concentration of perforators.

Surgical Technique

The patient is placed in a lateral decubitus position. The use of a bean bag facilitates intraoperative positioning. The muscular triangle is marked along with the spine of the scapula and the lateral border of the latissimus dorsi muscle. The techniques of latissimus dorsi and scapular osteocutaneous free flap dissection have been described in detail previously.[25,26] In harvesting the combined flap, the latissimus dorsi is usually elevated first. The latissimus dorsi dissection proceeds until the thoracodorsal pedicle joins with the circumflex scapular pedicle. At this point, the scapular osteocutaneous flap is harvested.

The scapular osteocutaneous flap is raised as described previously,[26] with care taken completely to detach the teres major muscle from the lateral border of the scapula. This ensures adequate exposure to the scapular bone as well as to the proximal vascular pedicle, which is dissected to its vascular origin from the axillarv artery and vein. The is then transferred to the head and neck.

The donor site is closed by reattaching the teres muscles to the scapula. The wound are closed primarily over a suction drain and the patient turned supine to complete insetting and revascularization of the flap.

Clinical Data and Results

Six consecutive patients undergoing head and neck reconstruction with the combined flap were analyzed (Table). Five patients underwent primary reconstruction. Ablative procedures were performed for squamous cell carcinoma (four patients), eccrine carcinoma, and rhabdomyosarcoma. One patient underwent total palatal and bilateral maxillary reconstruction, and one patient underwent scalp and full-thickness skull reconstruction. Four patients underwent oromandibular reconstruction. Three cases will be described in detail to illustrate the use of this combined flap in reconstructing scalp, midface, and oromandibular defects.

Report of Cases

Case 2.- This 53-year-old woman, with an extensive defect of the scalp and full-thickness skull defect, underwent resection of the entire posterior scalp for a recurrent eccrine carcinoma (Fig 3). The composite defect involved approximately 600 cm^2 of skin and a 20x30-cm area of full-thickness cranium (Fig 4). A combined free latissimus dorsi myocutaneous flap and a scapular cutaneous flap were used for reconstruction (Figs 5 and 6). A secondary cranioplasty was pšlanned. The recipient vessels were the facial artery and the external jugular vein. The vascular pedicle was oriented subcutaneously posterior to the auricle. On postoperative day 1, due to placing the patient's head in a supine position, the flap became congested secondary to compression of the vascular pedicle. Numerous attempts to salvage the flap, including intravascular lytic therapy, were unsuccessful. The flaps were removed and the wound was treated locally for 4 weeks before a second reconstruction using the contralateral latissimus dorsi-scapular myocutaneous free flap.

In this procedure, the subscapular pedicle was tunnedled anterior to the auricle in the pretragal region. By orienting the pedicle anterior to the tragus, as opposed to the original pedicle position, compression of the pedicle by the supine position of the patient's head was avoided. The use of vein grafts allowed anastomosis to the facial artery and vein. To close the back wound primarily, only a portion of the back skin overlying the latissimus dorsi muscle was harvested. A meshed split-thickness skin graft was used for coverage of the bare latissimus dorsi muscle on the patient's scalp. The patient is alive with distant metastases 3 years after the procedure (Figs 7 and 8).

Case 3.- This case involved a defect of mandible from midramus to contralateral body, including the floor of the mouth and neck. A 56-year-old man had undergone a jaw-neck dissection for a large squamous cell carcinoma of the right anterior floor of mouth at another institution. The patient underwent primary reconstruction with a right-sided pectoralis major myocutaneous flap placed over a mandibular fixation plate. The pectoralis flap failed, and the defect was subsequently reconstructed with a right-sided latissimus dorsi myocutaneous flap. Near-total loss of the latissimus flap resulted in exposure of the fixation plate and oral incompetence secondary to an atonic lower lip and deficient left-sided neck skin from infection and scarring (Figs 9 and 10). Following transfer to the Mount Sinai Medical Center, New York, NY, the patient underwent reconstruction using a combined latissimus dorsi myocutaneous free flap with a scapular osteocutaneous free flap. The recipient vessels were the transverse cervical artery and vein. One ostectomy was made in the scapula to re-create the mandibular contour. The scapular skin was used to reconstruct the floor of the mouth, and the latissimus dorsi was used to resurface the anterior neck skin, allowing repositioning of the lower lip to restore oral competence (Fig 11). A bone scan on postoperative day 5 demonstrated good uptake in the revascularized scapular bone (Fig 12). Decannulation was performed and the patient was eating pureed food before leaving hospital. Following a vestibuloplasty, the patient is undergoing prosthetic rehabilitation with a tissue-borne denture. The patient remains free of disease 3 years after the reconstruction (Figs 13 and 14).

Case 4.- In this patient, we treated a total palatal and bilateral maxillary defect. A 34-year-old man with a recurrent squamous cell carcinoma of the maxilla had undergone a left-sided total maxillectomy and orbital exenteration plus postoperative radiotherapy 1 year before admission. A recurrent tumor subsequently developed on the remaining right hemipalate, making it impossible to wear a palatal prosthesis and contributing to intractable pain and a 13.5-kg weight loss. In addition, skull-base osteoradionecrosis and maxillocutaneous fistulae developed over the left cheek. Following resection of the infrastructure of the right maxilla and the skin on the left cheek, the patient underwent reconstruction with a combined latissimus dorsi-scapular osteomyocutaneous free flap.

The resulting bony midface defect spanned from the right posterolateral maxilla to the left zygomatic buttress. The soft-tissue defect involved the left orbital cavity and the entire soft palate save a small strip of right-sided soft-palate muscle and mucosa. A V-shaped ostectomy in the middle of the scapular bone allowed re-creation of the hard-palate contour. Titanium craniofacial miniplates were used to fix the scapula to the left zygomatic buttress, to the right posterior maxilla, and to the vomer to create a neopalate.The scapular skin was used to resurface the bony palate, thereby providing intraoral coverage of the scapula. The scapular skin paddle was anchored posteriorly to the remnant of soft palate. The latissimus dorsi was used to fill the orbital cavity with a skin graft placed to close the cutaneous defect. The vascular pedicle was tunneled subcutaneously under the cheek into the neck. A saphenous vein graft was used to reach the recipient vessels, the lingual artery, and the external jugular vein. A bone scan on postoperative day 5 revealed good uptake in the neopalate. The patient did well postoperatively and was discharged home on the 10th postoperative day, having undergone decannulation and tolerating a pureed diet. The articulation of the patient was markedly improved relative to his preoperative state when he was functioning with a hemipalatal prosthesis.

Comment

An oncologic surgeon's approach to treating a patient with a massive tumor of the head and neck is limited not only by the extent of the lesion but also by the availability of reconstructive options. Local and regional reconstructive flaps have limited utility for large tumors of the scalp, midface, and oromandibular region because of the constraints of pedicle length and flap size, composite tissue availability, and three-dimensional maneuverability. Free tissue transfer techniques allow the surgeon an added series of options in reconstructing defects after ablative head and neck surgery. In addition, they provide the head and neck surgeon with a method to rehabilitate patients better following either radical curative or palliative resection so as to make them candidates for surgery when they may not have been so previously.

A wide variety of free flaps are currently in use for reconstruction of extensive, composite head and neck defects. Scalp reconstruction has been reported using omentum with skin grafts,[27] radial forearm,[28] rectus abdominis,[13] latissimus dorsi, and scapular free cutaneous and myocutaneous flaps.[13,29] Extensive midface defects have been reconstructed using scapular[9] and latissimus dorsi free flaps.[13] An array of free, vascularized bone flaps have been utilized in oromandibular reconstruction. The radius,[20,31] ulna,[32] humerus,[33] rib,[34] and metatarsus[35] have their place in reconstructing small defects. Howevermthe limited bone stock for dental rehabilitation using osteointegrated implants and the donor site morbidity of these flaps have relegated them to second-line choices. The iliac crest-internal oblique,36 scapula,[9,10] and fibula[37] are currently the primary choices for most oromandibular defects, especially when extensive mucosal and skin defects are present.[38]

The combined latissimus dorsi-scapular free flap offers the following advantages in reconstructing complex, composite head and neck defects. (1) It has the largest surface area of composite tissue based on one pedicle. Up to 875 cm^2 of tissue is reported to have been harvested.[11] (2) It has three-dimensional maneuverability of its component parts. (3) It offers independent vascular pedicles of its component parts so that almost any combination of skin, muscle, and bone is possible in planning a reconstructive procedure. (4) It offers the potential to transfer innervated muscle (latissimus dorsi) to maintain bulk or dynamic activity for use in facial reanimation.

The vast amount of tissue available in this combined free flap makes this flap an ideal choice for extensive scalp and midface defects.[9,13,29,39] Midface defects involving the palate are usually best rehabilitated with palatal prostheses. However, for a palatal or maxillary prosthesis to have support, retention, and stability, there must be at least an intact hemipalate.[40] For total palatal defects, wide, thin, contourable bone is desirable, and a scapular free flap can provide the necessary support, retention, and stability for palatal and velopharyngeal competence. In addition, by placing osteointegrated implants into the scapula, either primarily or secondarily, improved functional rehabilitation can be achieved.

For defects of the midface that involve the facial nerve, the latissimus dorsi muscle has been shown to be an excellent choice for use as a segmentally innervated muscle for facial reanimation.[41] Caution must be exercised, however, in applying free tissue transfer techniques for facial reanimation in patients with advanced squamous cell carcinoma. In such patients, static or dynamic muscle slings, such as described by Rubin,[42] [Conley et al,]43 and Baker and Conley,[44] may be more suitable. Yet, when the ablative procedure involves resection of the masseter and temporalis muscles, or their neurovascular supply, regional muscle rehabilitation is not possible. Under those circumstances, using a free segmentally innervated muscle with its motor nerve supply anastomosed to the facial nerve stump provides a good method for restoration of mimetic facial expression.

For oromandibular reconstruction, the iliac crest-internal oblique and fibular free flaps have advantages when compared with the combined latissimus dorsi-scapular flap. One advantage is related to patient positioning and accessibility for a two-team approach. Another is that ilium and fibula offer a superior stock of bone for functional mastication.[45] To date, however, the ilium is the only donor site where implant-borne dental prostheses have been reported.[46] Nevertheless, there are times when patients are nopt good candidates for oromandibular reconstruction with the iliac crest-internal oblique or fibular flaps. For instance, in patients with massive skin defects that extend cephalad to the level of the oral commissure,[38] the iliac crest and fibula are not good options. Also, in patients with previous vascular surgery involving the femoral vessels, the groin is to be avoided as a donor site. In addition, in patients with a preoperative gait disturbance, the scapular bone is better choice than ilium or fibula.

The combined latissimus dorsi-scapular free flap has several disadvantages, most important of which is that the patient is in a lateral decubitus position for flap harvesting. When access is needed to both sides of the neck or face, then the patient must be turned during the procedure. For temporal bone and unilateral scalp reconstruction, the entire procedure can be performed in a lateral decubitus position. Donor site morbidity is another potential disadvantage. This has been addressed in some detail with regard to the scapular osteocutaneous flap,[47] and to the latissimus dorsi myocutaneous flap,48 but not to the combination of these flaps. Adduction and internal rotation of the arm are the important actions of the latissimus dorsi. These movements are assisted by the pectoralis major and teres major muscles. Scapulohumeral rotation can be severely limited after a scapular osteocutaneous flap, so physical therapy is essential for the rehabilitation of these patients. Therefore, patients are treated by shoulder immobilization for 5 days postoperatively, followed by supervised range-of-motion exercises with gradually increased activity.

A new frontier in microvascular head and neck reconstruction is developing in the area of restoring sensation to oral and pharyngeal defects with sensate free flaps. Sensory restoration in these regions has been described with the radial forearm flap[49] and the lateral arm flap.[50] There are a variety of other flaps that have been described, including the lateral thigh, ulnar, and dorsalis pedis flaps. Sensory reinnervation has not been reported in the scapular or latissimus dorsi skin.

CONCLUSION

The combined latissimus dorsi-scapular free flap provides an unmatched variety and surface area of composite tissue based on a single vascular pedicle. Because of the three-dimensional maneuverability of the component parts of this flap, its independent vascular pedicles, and the potential to transfer innervated muscle, form as well as function can be restored to large defects of the scalp, midface, and oromandibular region. The combined latissimus dorsi-scapular free flap increases the reconstructive options available to the head and neck surgeon in treating patients with extensive, often disfiguring, tumors. These reconstructive options may allow a greater chance for palliative or curative resection of select lesions and may ultimately result in better care for the patient with head and neck cancer.

References

dos Santos LF. Retalho escapular: Um novo retalho livre microcirurgico. Rev Bras Cir. 1980;70:133.

Nassif TM, Vidal L, Bovet JL, Baudet J. The parascapular flap: a new cutaneous microsurgical free flap. Plast Reconstr Surg. 1982;69: 591-600.

Harii k, Yamada A, Ishihara K, Miki Y, Itoh M. A free transfer of both latissimus dorsi and serratus anterior flaps with thoracodorsal vessel anastomosis. Plast Reconstr Surg. 1982;70: 620-629.

Teot L, Bosse JP, Moufarrege R, Papillon J, Beauregard G. The scapular crest pedicled bone graft. Int J Micro. 1981;3:257-262.

Maruyama Y, Urita Y, Ohnishi K. Rib-latissimus dorsi osteomyocutaneous flap in reconstruction of a mandibular defect. Br J Plast Surg. 1985:38:234-237.

Richards MA, Poole MD, Godfrey AM. The serratus anterior/rib composite flap in mandibular reconstruction. Br J Plast Surg. 1985;38:466-477.

Tansini I. Nuovo processo per l'amputazione della mammaella per cancre. Riforma Med. 1896;1: 3-5.

Quillen CG, Shearing JG, Georgiade NG. Use of latissimus dorsi myocutaneous island flap for reconstruction in the head and neck area. Plast Reconstr Surg. 1978;62:113-117.

Swartz WM, Banis JC, Newton ED, Ramasastry SS, Jones NF, Acland R. The osteocutaneous scapular flap for mandibular and maxillary reconstruction. Plast Reconstr Surg. 1986;77:530-545.

Baker SR, Sullivan MJ. Osteocutaneous free scapular flap for one-stage mandibular reconstruction. Arch Otolaryngol Head Neck Surg. 1988;114:267-277.

Batchelor AGG, Sully L. A multiple territory free tissue transfer for reconstruction of a large scalp defect. Br J Plast Surg. 1984;37:76-79.

Granick MS, Newton ED, Hanna DC. Scapula free flap for repair of massive lower facial composite defects. Head Neck Surg. 1986;8:436-441.

Jones NF, Hardesty RA, Swartz WM, Ramasastry SS, Heckler FR, Newton ED. Extensive and complex defects of the scalp, middle third of the face and palate: the role of microsurgical reconstruction. Plast Reconstr Surg. 1988;82:937-950.

Hardesty RA, Jones NF, Swartz WM, et al. Microsurgery for macrodefect: microvascular free-tissue transfer for massive defects of the head and neck. Am J Surg. 1987;154:399-405.

Rowsell AR, Davies DM, Eisenberg N, Taylor GI. The anatomy of the subscapular-thoracodorsal arterial system: study of 100 cadaver dissections. Br J Plast Surg. 1984;37:574-576.

Bartlett SP, May JW, Yaremchuk MJ. The latissimus dorsi muscle: a fresh cadaver study of the primary neurovascular pedicle. Plast Reconstr Surg. 1981;67:631-635.

Gilbert A, Teot L. The free scapular flap. Plast Reconstr Surg. 1982;69:601-604.

dos Santos LF. The vascular anatomy and dissection of the free scapular flap. Plast Reconstr Surg. 1984;73:599-603.

Thoma A, Heddle S. The extended free scapular flap. Br J Plast Surg. 1990;43:709-712.

Barwick WJ, Goodkind Dj, Serafin D. The free scapular flap. Plast Reconstr Surg. 1982;69:779-785.

Friedrich W, Herberhold C, Lierse W. Vascularization of the myocutaneous latissimus dorsi flap. Acta Anat. 1988;131:97-102.

Mathes G, Nahai F. Classification of the vascular anatomy of muscles: experimental and clinical correlation. Plast Reconstr Surg. 1981;67:177-187.

Tobin GR, Schusterman M, Peterson GH, Nichols G, Bland KI. The intramuscular neuroanatomy of the latissimus dorsi muscle: the basis for splitting the flap. Plast Reconstr Surg. 1981;67:636-641.

Maves MD, Panje WR, Shagets FW. Extended latissimus dorsi myocutaneous flap reconstruction of major head and neck defects. Otolaryngol Head Neck Surg. 1984;92:551-558.

Hidalgo DA. Latissimus dorsi free flaps. In: Shaw WW, Hidalgo DA, eds.Microsurgery in Trauma. London, England: Futura Publishing Co Inc; 1987:251-254.

Manktelow RT. Scapular flap. In: Manktelow RT, ed. Microvascular Reconstruction: Anatomy, Applications and Surgical Technique. New York, NY: Springer-Verlag NY Inc; 1986:32-34.

Mclean DH, Buncke HJ. Autotransplant of omentum to a large scalp defect with microsurgical revascularization. Plast Reconstr Surg. 1972;49:268-274.

Chicarilli ZN, Ariyan S, Cuono CB. Single-stage repair of complex scalp and cranial defects with the free radial forearm flap. Plast Reconstr Surg. 1986;77:577-585.

Pennington DG, Stern HS, Lee KK. Free flap reconstruction of large defects of the scalp and calvarium. Plast Reconstr Surg. 1989;83:655-661.

Vaughan ED. The radial forearm free flap in orofacial reconstruction: personal experience in 120 consecutive cases. J Cranimaxillofac Surg. 1990;18:2-7.

Soutar DS, Widdowson WP. Immediate reconstruction of the mandible using a vascularized segment of radius. Head Neck Surg. 1986;8:232-246.

Lovie MJ, Duncan GM, Glasson DW. The ulnar artery forearm free flap. Br J Plast Surg. 1984;37:486-492.

Martin D, Mondie J, Bebiscop J, Schott H, Peri G. The osteocutaneous outer arm flap: a new concept in microsurgical mandibular reconstruction. Rev Stomatol Chir Maxillofac. 1988;89:281-287.

Serafin D, Riefkohl R, Thomas I, Georgiade NG. Vascularized rib-periosteal and osteocutaneous reconstruction of the maxilla and mandible: an assessment. Plast Reconstr Surg. 1980;66:718-727.

MacLeod AM, Robinson DW. Reconstruction of defects involving the floor of mouth ny free osteocutaneous flaps derived from the foot. Br J Plast Surg 1982;35:239-246.

Urken ML, Vickery C, Weinberg H, Buchbinder D, Lawson W, Biller HF. The internal pblique-line crest osseomyocutaneous free flap in oromandibular reconstruction: report of 20 cases. Arch Otolaryngol Head Neck Surg. 1980;115:329-349.

Hidalgo DA. Fibula free flap: a new method of mandible reconstruction. Plast Reconstr Surg. 1989;84:71-79.

Urken ML, Weinberg H, Vickery C, Buchbinder D, Lawson W, Biller HF. The internal oblique-iliac crest free flap in composite defects of the oral cavity involving bone, skin, and mucosa. Laryngoscope. 1991;101:257-270.

Earley MJ, Green MF, Milling MAP. A critical appraisal of the use of free flaps in primary reconstruction of combined scalp and calvarial cancer defects. Br J Plast Surg. 1990;43:283-289.

Desjardins RP. Obturator prosthesis design for acquired maxillary defects. J Prosthet Dent. 1978;29:424-435.

Mackinon SE, Dellon AL. Technical considerations of the latissimus dorsi muscle flap: a segmentally innervated muscle transfer for facial reanimation. Microsurgery. 1988;9:36-45.

Rubin LR. The anatomy of a smile: its importance in the treatment of facial paralysis. Plast Reconstr Surg. 1974;53:384-387.

Conley J, Baker DC, Selfe RW. Paralysis of the mandibular branch of the facial nerve. Plast Reconstr Surg. 1982;70:569-576.

Baker DC, Conley J. Regional muscle transposition for rehabilitation of the paralyzed face. Clin Plast Surg. 1979;6:317-331.

Urken ML, Buchbinder D, Weinberg H, et al. Functional evaluation following microvascular oromandibular reconstruction of the oral cancer patient: a comparative study of reconstructed and nonreconstructed patients. Laryngoscope. 1991;101:935-950.

Urken ML, Buchbinder D, Weinberg H, Vickery C, Sheiner A, Biller HF. Primary placement of osseointegrated implants in microvascular mandibular reconstruction. Otolaryngol Head Neck Surg. 1989;101:56-73.

Sullivan MJ, Baker SR, Crompton R, Smith-Wheelock M. Free scapular osteocutaneous flap for mandibular reconstruction. Arch Otolaryngol Head Neck Surg. 1989;115:1334-1340.

Quillen CG. Latissimus dorsi myocutaneous flaps in head and neck reconstruction. Plast Reconstr Surg. 1979;63:664-670.

Urken ML, Weinberg H, ickery C, Biller HF. The neurofasciocutaneous radial forearm flap in head and neck reconstruction. Laryngoscope. 1990;100: 161-173.

Matloub HS, Larson DL, Kuhn JC, Yousif J, Sanger JR. Lateral arm free flap in oral cavity reconstruction. Head Neck. 1989;11:205-211.