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The In Vitro Evaluation of a Local Pedicled Osteomyocutaneous Mandibular Flap for the Reconstruction of Composite Mandibular Defects

Yadranko Ducic, MD, FRCS(C), Peter A. Hilger, MD,† and Michael D. Peters, MD‡*

Purpose: The purpose of this study was to develop and assess the potential feasibility of reconstructing composite defects of the mandible with a local pedicled osteomyocutaneous mandibular flap.

Materials and Methods: The flap design was established based on anatomic principles. A prospective evaluation of the flap was then performed in a fresh cadaver model, and, subsequently, its vascular integrity was documented with angiography.

Results: The pedicled osteomyocutaneous mandibular flap was technically simple to raise and had an exceptionally long arc of rotation, which should enable it to fill most compound segmental defects of the mandible. Angiographic studies of the harvested flaps done under fluoroscopic guidance confirmed that excellent vascularity of all components of the flap was present.

Conclusions: The pedicled osteomyocutaneous mandibular flap appears to have a sound anatomic basis. Clinical evaluation is needed to fully elucidate its potential role in head and neck reconstruction.

Segmental mandibular defects may arise from a wide array of different causes. Most such defects occur as a consequence of oncologic resection and trauma. The extent and location of the mandibular loss are important factors that must be considered when approaching reconstruction of these skeletal defects. However, one is often not dealing with an isolated discontinuity of bone. In addition, there is commonly loss of associated dentition and soft tissue coverage intraorally or externally. Thus, in considering the reconstruction of oromandibular defects, an approach needs to be used that will consistently result in the restitution of an acceptable aesthetic form, as well as provide for the rehabilitation of oral function.

A report by Komisar[1] has indicated that patients undergoing mandibular reconstruction consistently obtained better cosmetic results than their nonreconstructed counterparts. In addition to confirming Komisar's findings, Urken et al[2,3] noted significant improvement in terms of speech, dental rehabilitation, and swallowing ability in the reconstructed patient group.

A further consideration is the timing of any reconstruction. In the past, a significant decrease in morbidity was noted when the reconstruction was delayed as a secondary procedure.[4] However, this often resulted in unacceptable soft tissue contraction both intraorally and externally, compromising the aesthetic and functional outcomes in this patient population. Thus, it appears that for most patients, necessary mandibular reconstruction ideally should be performed as part of the primary procedure.

The wide array of reconstructive options available for restoring the form and function of mandibular defects leaves one realizing that an ideal method of reconstruction has not yet been devised. Until relatively recently, a free corticocancellous bone graft fixed with a reconstruction plate was the major reconstructive modality.[5,6] Problems with resorption of bone grafts, plate fracture and exposure, and the lack of any potential for dental rehabilitation with either this or other available modalities served as an impetus in the development and application of a broad range of pedicled bone-bearing flaps, none of which have withstood the test of time.[7-11]

As a result of the level of sophistication achieved

*Director, Otolaryngology and Facial Plastic Surgery at John Peter Smith Hospital, Forth Worth, TX.

†Associate Professor, Department of Otolaryngology, University of Minnesota, Minneapolis, MN.

‡Resident, Department of Otolaryngology, University of Minnesota, Minneapolis, MN.

Address correspondence and reprint requests to Dr Ducic: Director, Otolaryngology and Facial Plastic Surgery, 1500 S Main St, John Peter Smith Hospital, Fort Worth, TX 76104; email: YDucic@aol.com

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with microvascular free tissue transfer, oromandibular reconstruction can consistently result in adequate restoration of form and function.[12,13] However, the added operative time and expense, as well as the specialized training required to perform microvascular surgery, and the need for violation of a distant donor site are some of the drawbacks of this technique. An ideal flap would be simple to harvest, reliable, have consistent anatomy, and be readily transferable into the recipient bed without the need for a second surgical site. These factors led us to investigate the possibility of using a local pedicled osteomyocutaneous mandibular flap ("mandibular flap") in the reconstruction of certain combined defects of the oral cavity and mandible.

Materials and Methods

After formulating a theoretical basis for the mandibular flap based on accepted anatomic principles, a flap harvesting technique was developed. This technique allowed harvesting of eight consecutive flaps in four cadavers. The vascularity of the harvested flaps was subsequently analyzed by observing the pattern of iodinated contrast flow through the vascular pedicle under fluoroscopic guidance.

TECHNIQUE

The mandibular flap is based on the submental branch of the facial artery. The cutaneous portion of the flap is centered in the immediate inframandibular submental area and may include a section of skin measuring 10 by 18 cm (Fig 1). The skin portion is first circumferentially incised down through the subcutaneous and platysma layers. Limited subplatysmal flaps, as are typically used to provide access for oncologic resection, are then developed superiorly over the inferior aspect of the mandible to the level of egress of the mental nerve, posteriorly to at least the level of the facial artery crossing of the mandible, and inferiorly to at least the level of the hyoid bone. The marginal branch of the facial nerve should be identified at the inferior mandibular border, isolated, and preserved. At this point, the submental artery is identified as a consistent branch of the facial artery immediately superior to the submandibular gland. A like-named vein is also noted at this level (Fig 2). The arterial and venous pedicles are then dissected to the margin of the cutaneous paddle. Dissection of the remainder of the flap is simplified at this point by performing the osseous cut in the mandible with either an oscillating saw or osteotome (Fig 3). This cut should pass below the level of the mental nerves and teeth and not extend appreciably beyond the mandibular angle. To maintain the integrity of the periosteal branches of the submental artery, the periosteum must be included in the osseous portion of the flap. The muscular portion of the flap is now easily dissected from above by maintaining a plane of dissection immediately superficial to the mylohyoid muscle and including the

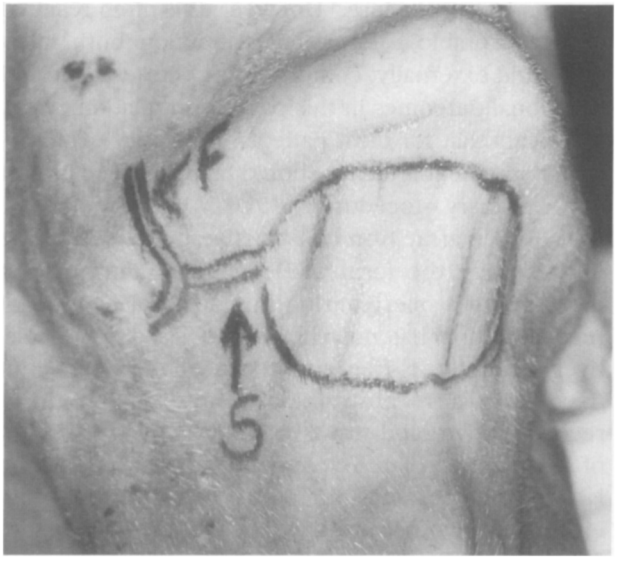

FIGURE 1. Fresh cadaver demonstration of skin markings for a planned mandibular flap. F, the facial artery palpated as it crosses inferior border of mandible; S, approximate position of submental artery in inframandibular area just superior to the submandibular gland.

FIGURE 2. View after identification of vascular supply to the mandibular flap. Note the black suture superiorly, placed at level of mental foramen for demonstration purposes. The arrow is pointing to the submental artery. The hook inferiorly is displacing the submental vein. The marginal nerve crosses the marker placed along the inferior border of mandible.

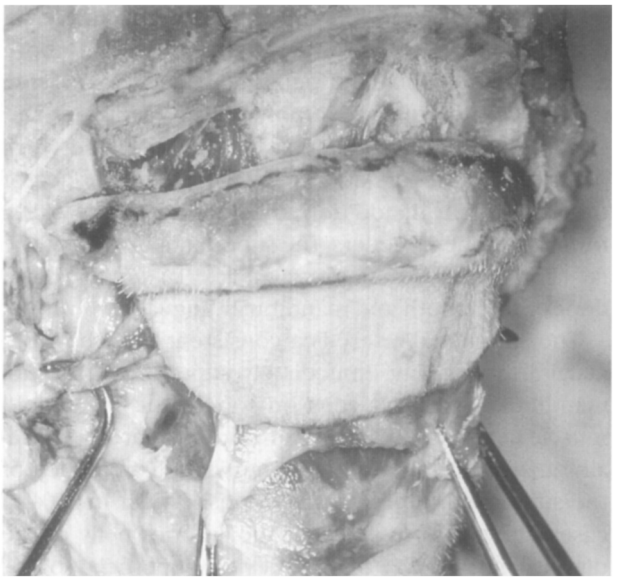

FIGURE 3. The mandible has been osteotomized. Note the inclusion of the anterior belly of the digastric in the flap. The hook is displacing the pedicle inferiorly.

ipsilateral (ipsilateral to the vascular pedicle) anterior belly of the digastric muscle in the flap. Nutrient branches of the submental artery to the floor of mouth and mylohyoid muscles should be ligated during this dissection. A substantial increase in flap reach may be attained by ligating the facial artery above the exit of the submental branch. This usually provides a minimum pedicle length of 8 cm (Fig 4). The mobility thus attained allows the mandibular flap to potentially easily reconstruct anterolateral defects of the mandible on the contralateral side (Fig 5). It also appears able to reconstruct ipsilateral ascending ramus and condylar defects (Fig 6). The cutaneous portion of the flap is mobile enough relative to the osseous portion to enable it to be used for both external and intraoral resurfacing. If required, a significant further increase in pedicle length may be achieved by dissecting the facial artery back to its origin from the external carotid artery. The cutaneous donor defect left after flap harvest is easily closed with advancement of the circumdonor skin achieved by wide undermining.

After flushing the fresh cadaver flap with a 3% hydrogen peroxide solution, the submental artery was injected with an iodinated contrast agent (Renografin-60, Bracco Diagnostics Inc., Princeton, NJ) and viewed under fluoroscopic guidance to determine the rapidity and adequacy of flow through the cutaneous, osseous, and muscular portions of the flap.

Results

The local pedicled osteomyocutaneous mandibular flap was noted to be simple and fast to harvest.

FIGURE 4. Ligation of the facial artery superior to its exit from the submental branch will consistently give a pedicle length in the range of 8 cm.

Seventy-five percent of the flaps were harvested in edentulous cadavers and 25% in dentate cadavers. No significant differences in flap harvest were noted between these two groups. The submental artery was a significant vessel (average internal diameter of approximately 1.5 mm) consistently noted to arise from

FIGURE 5. Demonstration of the potential reach of the flap for reconstruction of a contralateral anterolateral mandibular defect.

FIGURE 6. Demonstration of the potential reach of the flap for reconstruction of an ipsilateral ascending ramus or condylar defect.

the facial artery just superior to the level of the submandibular gland. The adequacy of donor bone stock available for harvest and remaining after harvest was more than sufficient in each specimen examined. Injection studies showed excellent vascularity, as evidenced by immediate and rapid flow through and perfusion of the entire extent of both the cutaneous and osseous portions of the flap (Figs 7, 8).

Discussion

The blood supply of the mandible is derived from three principal sources: the inferior alveolar artery, penetrating vessels, and a periosteal network. Free anastomoses are generally believed to exist in all human bones that have this pattern of vascular distribution.[14] In most individuals, with progressing age, the inferior alveolar vessels gradually sclerose to the point that they contribute a minority of the blood supply to the mandible beyond 50 years of age.[15,16] An elegant study by McGregor and MacDonald[17] confirmed that the facial artery is, in fact, a major source of blood supply to the body of the mandible. It distributes its nutrient supply to the jaw through both a multitude of unnamed penetrating vessels, passing through the cortex and supplying the medullary and cortical bone from the endosteal side, and a network of periosteal feeders emanating across the surface of the mandible.[17] In addition to being the source artery for most of these feeders, the submental branch of the facial artery is also the principal arterial supply to the floor of the mouth and mandibular lingual gingiva.[18]

The submental artery is a consistent branch of the facial artery arising immediately superior to the submandibular gland. It runs on top of the mylohyoid muscle in the immediate inframandibular area, eventually anastomosing with communicating branches of the submental artery on the opposite side. In 70% of cases, the artery runs below the anterior belly of the digastric and in 30% of cases it runs superficial to it.[19] It is for this reason that it was thought that the anterior belly of the digastric muscle should be included in the flap. Its constant anatomy and average measured internal diameter in the range of 1.5 mm (as compared with 2.4 mm for the facial artery) have led a number of surgeons to devise submental artery cutaneous island flaps for various uses in head and neck reconstruction.[19-21] The cutaneous flap is based on perforators arising from the submental artery and passing through the platysma to supply the overlying skin of the submental region.[22] The venous drainage is from the submental vein that empties into the facial vein. As was noted in these dissections, others also have found the submental artery and vein to be simple to dissect

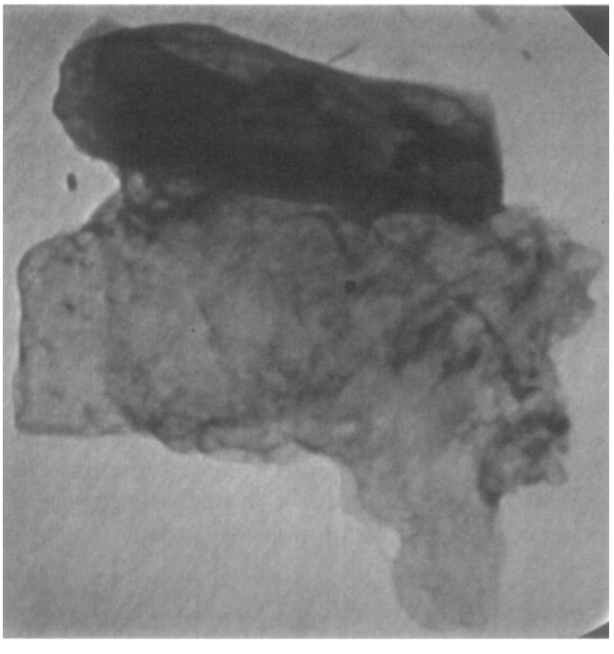

FIGURE 7. Angiographic documentation of flap vascularity after injection of the submental artery.

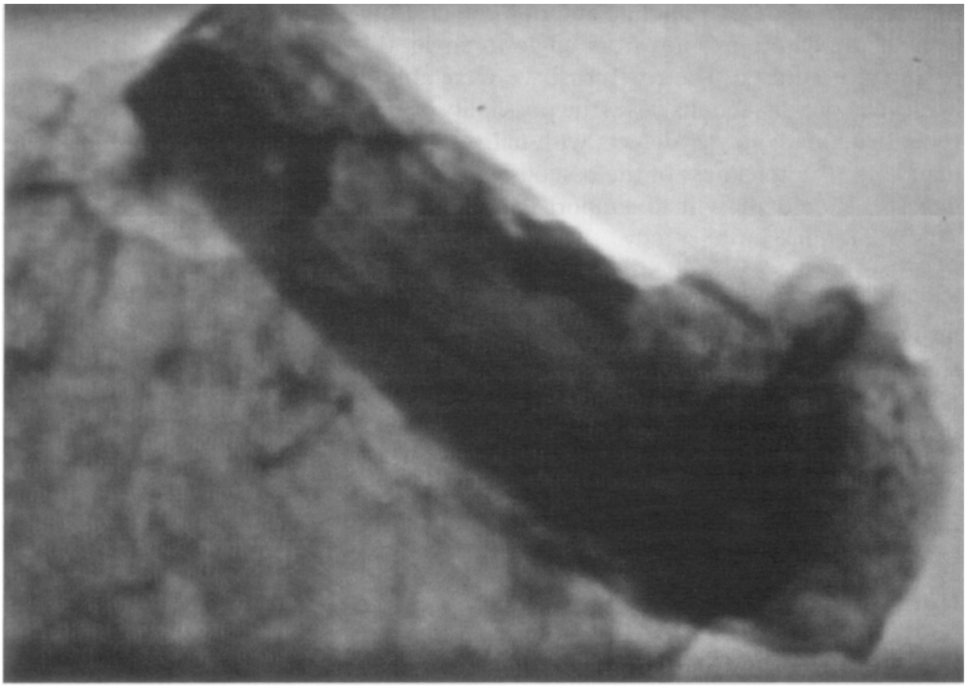

FIGURE 8. Coned-down view of the vascular supply to the osseous portion of the flap. Direct penetrating vessels provide rapid filling of the marrow space.

and of adequate caliber to supply an area of submental skin measuring up to 10 by 18 cm.[19-21] Although the submental artery cutaneous island flap appears to have been successful in limited clinical practice, no one until now has specifically demonstrated the vascularity, viability, design, harvest, or potential use of an osteomusculocutaneous flap based on the submental artery and incorporating the full thickness of the mandible.

The concept of harvesting a full-thickness horizontal section of mandible uses some of the same principles used in performing a marginal mandibulectomy for oncologic resection. The goal in using the mandibular flap described in this article is to osteotomize enough of a full-thickness horizontal section of mandible to allow for reconstruction of a local adjacent segmental mandibular defect, while preserving an adequate amount of donor site mandible to maintain its structural integrity. In studying the biomechanical profiles obtained in a large series of mandibles after horizontal resection, Ariyan et al[23] determined that there was no significant decrease in the strength as long as more than 9 mm of mandible remained at the resection site. They further noted that preservation of a minimum of 11 mm of mandibular height was generally necessary to assure maintenance of adequate blood supply to the remaining segment.[23] The mandibular flap would thus theoretically be feasible as long as there was a minimum of 22 mm of donor site mandibular height present (11 mm for the recipient and 11 mm remaining at the donor site). Severely atrophic mandibles are thus likely a contraindication to the use of the mandibular flap.

In the mandibular flap, pedicled vascularized full-thickness mandible is transferred. Therefore, there should be maintenance of the osteogenic potential in the transferred segment, allowing primary bone healing to occur. This is advantageous in terms of the eventual biomechanical stress and strain tolerances evident in the neomandible. Healing times for vascularized bone grafts have been consistently shorter, with improvement in their ability to resist both infection and extrusion.[24]

There is a mild cosmetic deformity at the donor site noted after flap harvest. This should not be a major problem in the patient undergoing oncologic resection. It may, in fact, contribute to better symmetry between the resected and nonresected sides. Closure of the cutaneous donor site should, likewise, not pose a significant problem. In using extensive submental cutaneous island flaps for closure of pharyngostomes, Mazzola et al[21] were able to achieve primary closure of the donor site in each case. Wide undermining is the key to achieving adequate mobilization of adjacent tissue to allow for donor site skin closure.

A basic premise of head and neck surgery is that one should never allow the reconstruction method used to limit the adequacy of the oncologic resection. The ability to maintain the integrity of the facial artery and vein, and their submental branches, on the side of the planned mandibular flap elevation are obvious requirements if this flap is to be used. Contralateral radical neck dissection or ipsilateral submandibular gland resection, mylohyoid resection, or any other dissection that does not compromise these vessels should not pose a problem. Bilateral flaps may be harvested

for reconstruction of a midline anterior defect. However, if the defect extends from angle to angle, this flap cannot be used. The reach that we were able to achieve in our dissections raises the possibility of even reconstructing condylar defects with native pedicled mandible. The thickness of the osseous aspect of the flap also should allow it to support dental implants. This will require further study.

No problems were encountered in raising these flaps in fresh cadavers. The blood supply appeared to be constant and reliable. Based on this preliminary study and anatomic review, we believe that the potential feasibility of a local pedicled osteomyocutaneous mandibular flap has been demonstrated. However, clinical evaluation is necessary before the mandibular flap can be recommended as a standard technique in head and neck reconstruction.

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