Microvascular flap reconstruction of the mandible: A comparison of bone grafts and bridging plates for restoration of mandibular continuity

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OBJECTIVE: **To compare the efficacy of vascularized bone grafts and bridging mandibular reconstruction plates for restoration of mandibular continuity in patients who undergo free flap reconstruction after segmental mandibulectomy.**

STUDY DESIGN AND SETTING. **A total of 210 patients underwent microvascular flap reconstruction after segmental mandibulectomy. The rate of successful restoration of mandibular continuity in 151 patients with vascularized bone grafts was compared to 59 patients with soft tissue free flaps combined with bridging plates.**

RESULTS: **Mandibular continuity was restored successfully for the duration of the follow-up period in 94% of patients who received bone grafts compared with 92% of patients with bridging mandibular reconstruction plates. This difference was not statistically significant. In patients who received bone grafts, most cases of reconstructive failure occurred during the perioperative period and were due to patient death or free flap thrombosis. In patients who received bridging plates, all instances of reconstructive failure were delayed for several months and were due to hardware extrusion or plate fracture.**

CONCLUSIONS: **Vascularized bone-containing free flaps are preferred for reconstruction of most segmental mandibulectomy defects in patients undergoing microvascular flap reconstruction. However, use of a soft tissue flap with a bridging mandibular reconstruction plate is a reasonable alternative in patients with lateral oromandibular defects when the nature of the defect favors use of a soft tissue free flap.**

SIGNIFICANCE: **Both bone grafts and bridging plates represent effective methods of restoring mandibular continuity following segmental mandibulectomy, with the former being the preferred technique for patients undergoing microvascular reconstruction.** (Otolaryngol Head Neck Surg 2003;129:48-54.)

Microvascular free flaps are a popular and frequently used method of oromandibular reconstruction. Vascularized bone grafts are widely recognized to be the most reliable method to achieve single stage, immediate reconstruction of the mandible, and therefore they represent the gold standard against which other methods should be compared. Considerable controversy exists regarding the utility of bridging mandibular reconstruction plates as permanent mandibular substitutes in patients with segmental defects of the jaw. In this series, patients who underwent free flap reconstruction of segmental defects of the mandible were analysed to compare the results achieved by vascularized bone grafts and bridging mandibular reconstruction plates for restoration of mandibular continuity.

MATERIALS AND METHODS

Two hundred ten cases of microvascular flap reconstruction were performed by the senior author (KEB) in patients with segmental defects of the mandible during a 6 year period (1995 through 2001). Data was collected prospectively using a personal computer-based database, including patient age, sex, comorbidity level, indication for surgery, history of radiation therapy, defect classification, free flap selection, hardware selection, occurrence of complications, and the length of follow up. Defect were classified according to the method described by Urken et al, while comorbid-

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ity was staged according to the method described by the American Society of Anesthesiology. Statistical analysis was done using the chi-squared test with an Internet-based statistical calculator (www.georgetown.edu/cball/webtools/web_chi.html).

There were 139 men and 71 women treated, ranging in age from 19 years to 88 years. Most of the defects arose as a result of the treatment of head and neck cancer (n=202), while the remaining patients underwent treatment of benign mandibular neoplasms (n=6) or severe mandibular trauma (n=2). The average follow up period in these patients was 20 months (range 1 to 70 months). Two distinct groups of patients were identified for comparison. One hundred fifty one patients (104 men and 47 women and hereafter referred to as the Bone Graft Group) underwent reconstruction using vascularized bone-containing free flaps, with the specific donor sites being fibula flaps (n=134), subscapular system flaps (n=11), iliac crest flaps (n=5), and an osteocutaneous radial forearm flap (n=1). Fifty nine patients (35 men and 24 women and hereafter referred to as the Bridging Plate Group) were identified who underwent soft tissue free flaps combined with bridging mandibular reconstruction plates, with the specific flap being fasciocutaneous radial forearm flaps (n=47), rectus abdominis myocutaneous flaps (n=10), and latissimus dorsi myocutaneous flaps (n=2). Patient comorbidity is reported in Table 1, while hardware selection is reported in Table 2. With regards to mandibular defect classification, 94 cases (62%) in the Bone Graft Group were lateral mandibulectomy defects, not extending beyond the midline of the mandibular symphysis, while the remaining cases were anterior or anterolateral defects that included more than half of the mandibular symphysis. All defects were lateral mandibulectomy defects in the Bridging Plate Group. One hundred fourteen patients (76%) of patients in the Bone Graft Group received either preoperative or postoperative external beam radiation therapy, compared to 51 cases (86%) who received radiation in the Bridging Plate Group. The mean length of follow up in the Bone Graft Group was 17 months (range 1 to 70 months), compared to a mean follow up of 26 months (range 1 to 60 months) in the Bridging Plate Group.

Table 1. American Society of Anesthesiology (ASA) Preoperative Co-morbidity. Class 1: Normal patients. Class 2: Patients with a mild degree of systemic illness. Class 3: Patients with a severe degree of systemic illness which limits activities. Class 4: Patients with severe systemic disease that causes immobilization and may be life-threatening. Class 5: Patient who will not survive more than 24 hours whether or not surgical intervention takes place

	Bone Graft Group (N = 151)	Bridging Plate Group (N = 59)
ASA 1	18	5
ASA 2	84	30
ASA 3	37	19
ASA 4	11	5
ASA 5	0	0
MEAN ASA	2.3	2.4

Table 2. Hardware selection

	Bone Graft Group (N = 151)	Bridging Plate Group (N = 59)
2.7-millimeter titanium locking reconstruction plate	130	55
3.5-millimeter titanium locking reconstruction plate	3	4
2.4-millimeter titanium locking reconstruction plate	5	0
2.0-millimeter titanium miniplates	13	0

Successful reconstruction was defined as restoration of mandibular continuity. Because there is currently no consensus in the literature how a multitude of potentially important patient, treatment, and defect-related factors combine to effect outcome, no consideration was given to other relevant outcome measures, such as quality of life, mastication, speech, or swallowing. Early reconstructive failure was defined as failure to achieve and maintain mandibular continuity during the 30-day postoperative period. Late reconstructive failure was defined as failure to maintain mandibular continuity during the subsequent follow up period. Hardware extrusion or bone graft destruction that occurred as a result of cancer recurrence was not defined as reconstructive failure but was rather attributed to the nature of the patients' disease.

RESULTS

Chi-squared analysis of the level of patient comorbidity reported in Table 1 revealed no significant difference in the severity of comorbidity when comparing patients in the Bone Graft Group to patients in the Bridging Plate Group (chi-square = 1.65, $P \leq 1.0$). There was also no significant difference when comparing the sex distribution (chi-squared = 3.02, $P \leq 0.1$) or incidence of radiation therapy (chi-squared = 1.73, $P \leq 0.2$) between the two groups. The difference in hardware selection was significantly different between the two groups, with an increased use of miniplates in the Bone Graft Group compared to the Bridging Plate Group (chi-square = 10.20, $P \leq 0.025$). There was also a statistically significant difference in classification of mandibular defects when comparing the two groups, with an increased prevalence of anterior and anterolateral mandibular defects in the Bone Graft Group (chi-square = 30.57, $P \leq 0.001$).

There was 9 cases of failed mandibular reconstruction in the Bone Graft Group, for an overall success rate of 94%. Seven of the nine reconstructive failures were classified as early failures, occurring within 30 days of surgery. This included 4 instances of perioperative patient mortality, secondary to a myocardial infarction causing death on postoperative day 7, Adult Respiratory Distress Syndrome causing death on postoperative day 10, liver failure causing death on postoperative day 24, and death in a nursing home on postoperative day 24 which was attributed to a tracheostomy tube mucous plug. In addition, there were 3 instances of early reconstructive failure attributed to fibula flap microvascular thrombosis, consisting of cases of arterial thrombosis on postoperative day 1, venous thrombosis on postoperative day 2, and venous thrombosis on postoperative day 4.

There were two cases of late reconstructive failure in the Bone Graft Group. One occurred in a patient treated for mandibular osteoradionecrosis occurring after radiation therapy for parotid cancer. This patient underwent a lateral segmental mandibulectomy with preservation of the ipsilateral condyle and reconstruction using a fibula free flap. Four months after surgery, she experienced recurrent cheek ulceration with mandibular and hardware exposure secondary to residual osteoradionecrosis in the condyle. There was a nonunion between the fibula bone graft and the condyle, and a condylectomy had to be performed to achieve wound healing. A second case of late reconstructive failure occurred in a patient who experienced sudden infarction of a fibula flap 11 months after flap transfer. This patient had undergone an anterolateral segmental mandibulectomy and postoperative radiation therapy to treat squamous cell carcinoma of the floor of mouth. On examination 9 months after surgery, uneventful healing of the patients wounds and a healthy-appearing fibula flap were noted. He presented again 2 months later describing sudden onset of necrosis of the fibula flap skin paddle that resulted in intraoral extrusion of the fibula bone graft and fixation hardware. On evaluation, the osteotomies created to contour the fibula graft were fully healed, and there were solid bony unions between the fibula graft and the native mandibular remnant. However, at the time of debridement, the fibula bone graft was found to be devascularized and was removed. The etiology of this case of delayed fibula graft failure was never confirmed, although pre-existing vaso-oclusive disease involving the peroneal artery and postoperative radiation therapy were suspected to be contributory.

In addition to the two above noted cases of delayed reconstructive failure, there were 4 additional cases in the Bone Graft Group when the bone graft fixation hardware became extruded during the follow up period, at intervals of 4 months, 5 months, 6 months, and 28 months. However, in these four cases, bone graft healing was completed before the time of plate extrusion, and the extruded hardware was removed without resulting in mandibular discontinuity.

There were 5 cases of failed mandibular reconstruction in the Bridging Plate Group, for an overall success rate of 92%. In this group, there were no cases of early reconstructive failure and 5 cases of delayed reconstructive failure. Of the 5 instances of delayed reconstructive failure, 3 cases were due to impending or actual plate extrusion through the facial skin that occurred after postoperative intervals of 6 months, 6 months, and 12 months. In addition, there were 2 cases of delayed reconstructive failure that occurred secondary to plate fracture happening after intervals of 9 months and 36 months.

Overall, there was no statistically significant difference when comparing the 94% success rate achieved in the Bone Graft Group to the 92% success rate achieved in the Bridging Plate Group (chi-squared = 0.43, $P \leq 1$). To control for a possible discrepancy arising from the increased number of anterior and anterolateral mandibular defects reconstructed in the Bone Graft Group, a separate analysis was done of the rate of successful reconstruction in the 94 patients in the Bone Graft Group with lateral defects. In this subset of patients, the incidence of successful mandibular reconstruction using bone grafts was also 94%, not being significantly different than that achieved in the Bridging Plate Group (chi-squared = 0.24, $P \leq 1$). The pattern of reconstructive failure was significantly different when comparing the Bone Graft Group to the Bridging Plate Group, with a predominance of early failure in the Bone Graft Group and a predominance of late failure in the Bridging Plate Group(chi-squared = 7.78, $P \leq 0.01$). With regards to hardware-related complications, there was no significant difference in the incidence of hardware extrusion when comparing the Bone Graft Group (6 of 151 cases = 4%) to the Bridging Plate Group (3 of 59 cases = 5%)(chi-squared = 0.13, $P \leq 1$). However, in incidence of plate fracture (2 of 59 cases = 3%) was higher in the Bridging Plate Group when compared to the Bone Graft Group (0 of 151 cases) (chi-squared = 5.17, $P \leq 0.025$).

DISCUSSION

The advent of vascularized bone-containing free flaps have greatly increased the reliability of bone graft for immediate reconstruction of segmental mandibular defects.[2] In the previous era of immediate mandibular reconstruction using non-vascularized bone grafts, the rate of successful restoration of mandibular continuity was only about 50%.[3] A considerable experience with vascularized bone containing free flaps has shown that the rate of successful immediate mandibular reconstruction exceeds 90%.[4-6] However, it has long been recognized that the soft tissue components of composite free flaps that contain both soft tissue and bone may not be ideally suited for reconstruction of all patients with segmental mandibulectomy. This has led some authors to propose the use of two or even three simultaneous free flaps for certain complex composite oromandibular defects.[7-11]

Recognition of the shortcoming of the soft tissue components of vascularized bone containing free flaps led to the investigation of the combination of bridging mandibular reconstruction plates with soft tissue free flaps that were felt to we well suited for the soft tissue defect. This became possible shortly after the advent of the Titanium Hollow Screw Reconstruction Plate, which was the first mandibular reconstruction plate that provided a mechanism for osseointegration at the bone-to-screw interface as well as a locking mechanism at the screw-to-plate interface, resulting in superior hardware stability.[12] Subsequent studies analysed the potential roles of bridging reconstruction plates as permanent bone graft substitutes in patients with segmental mandibulectomies.[13-18] These showed that bridging plates were not suitable as permanent mandibular substitutes in patients with anterior mandibular defects, due to an unacceptably high incidence of intraoral plate extrusion. However, results were found to be more favorable when bridging plates were used to span lateral mandibulectomy defects, especially for those defects with a low volume and a short length of mandibular resection.

The current series confirms that bridging mandibular reconstruction plates can be used as bone graft substitutes in conjunction with a soft tissue free flap for lateral oromandibular defects, in cases where the nature of the soft tissue defect favors use of a soft tissue free flap. With regards to restoring mandibular continuity in lateral oromandibular defects, bridging plates proved to be of similar efficacy as to vascularized bone grafts when used to restore mandibular continuity. In the current series, most patients in the Bridging Plate Group underwent reconstruction using fasciocutaneous radial forearm free flaps combined with bridging mandibular reconstruction plates. The most common indication for reconstruction was composite defects of the lateral mandible and oropharynx, when the soft tissue resection included the base of tongue, lateral oropharyngeal wall and tonsillar fossa, and the soft palate. In this setting, it is possible to achieve anatomical reconstruction of this complex three-dimensional anatomy using a thin and pliable fasciocutaneous radial forearm free flap.[19] This is frequently not the case when using vascularized bone containing free flaps, as the soft tissue component of the composite free flap may be too thick to be folded appropriately, as is the case with iliac crest and subscapular system flaps. In other cases of composite flap reconstruction for lateral oropharyngeal mandibular defects, insetting of the soft tissues of a composite vascularized bone-containing free flap may be impaired by the physical attachment of the soft tissue component of the flap to the bone graft by their common vascular supply, as is the case with fibula osteomyocutaneous flaps, radial forearm osteocutaneous flaps, and iliac crest osteomyocutaneous flaps.

Another common surgical indication in patients in the Bridging Plate Group was reconstruction of lateral oromandibular defects which included significant portions of the tongue. Fasciocutaneous radial forearm flaps were used to restore missing tongue volume and preserve contralateral tongue mobility in patients who underwent hemiglossectomy and floor of mouth resection in conjunction with a short segmental lateral mandibulectomy. A less common indication for soft tissue flap/bridging plate reconstruction in the current series was reconstruction of lateral segmental mandibulectomies done in conjunction with total or subtotal glossectomy. In this case, a rectus abdominis myocutaneous free flap (or a latissimus dorsi myocutaneous free flap in patients with an unfavorable donor abdomen secondary to previous abdominal surgery) was used to provide for bulk in the reconstructed tongue, allowing for passive obturation of the oral cavity upon closure of the jaws. However, it should be recognized that this patient population might also be considered to undertake reconstruction using a vascularized bone-containing free flap that also contained an appropriately bulky soft tissue component harvested from the ilium or scapula, as such an approach might help to decrease to potential for delayed hardware-related complications as is seen with the bridging plate option.

Many previous authors have proposed use of two simultaneous free flaps for reconstruction of the types of defects reconstructed using soft tissue flaps and bridging plates in the current series.[7-10] In dual free flap oromandibular function, a soft tissue free flap that is well suited for the soft tissue defect is selected, and then a vascularized bone-containing free flap is used to restore mandibular continuity, maintain dental occlusal relationships, and restore the contour of the lower third of the face. The current series brings into question the necessity to perform a second vascularized-bone containing free flap for lateral oromandibular defects, as this series demonstrates that bridging plates achieve these goals of reconstruction with a similar success rate without incurring the increased complexity and donor site morbidity of dual free flap transfer.

Shortcomings of the current series need to be considered carefully when weighing the conclusions derived from this analysis. This series showed that early postoperative complications were the most common etiology of failed reconstruction using vascularized bone grafts, while delayed complications related to hardware fracture or extrusion accounted for the majority of failures in cases of bridging plate reconstruction. As the mean length of follow up in the Bridging Plate Group was only 26 months, it is likely that an increased incidence of reconstructive failures will be noted with longer follow up, so the difference in reconstructive failure between the two groups may eventually become statistically significant as more delayed complications occur in the Bridging Plate Group. However, it should also be noted that the relatively high success rate noted in the Bridging Plate Group is in part attributable to the overall poor prognosis for long-term survival in patients treated for advanced stage cancer of the oral cavity and oropharynx. It is well documented that most patients who undergo treatment of advanced oral/oropharyngeal cancer die of recurrent cancer, with the majority of cancer recurrences occurring within two years of therapy.[20] Despite a relatively short average follow up period of 20 months in the current series of 210 patients, it is sobering to note that 67 patients (32%) have already experienced cancer recurrence or died of intercurrent disease. This in part helps to explain why the overall average length of follow up in this 6 year study was less than 2 years. The poor prognosis for long-term survival no doubt increases the utility of the bridging plate reconstruction method, as many patients do not survive long enough to experience delayed hardware-related complications.

Another shortcoming which merits consideration is the imperfect definition of successful mandibular reconstruction used in this series, as defined by restoration of mandibular continuity for the duration of the follow up period. This approach fails to consider other more important outcome measures, including as masticatory, swallowing, speech, and quality of life outcome. With regards to mastication, a previous series has documented the efficacy of implant-borne dentures to restore chewing in patients with vascularized bone graft reconstruction,[21] and this approach is less likely to be an option in patients with bridging plate reconstruction due to a paucity of suitable bone for placement of endosteal implants. In addition, while many authors have strong opinions on the subject,[22] there is little objective data in the literature to support the authors' contention that a soft tissue flap reconstruction is likely to result in a superior functional outcome when compared to that achieved by composite vascularized bone-containing flaps.

CONCLUSIONS

The current series demonstrates that bridging mandibular reconstructions plates combined with soft tissue free flaps result in restoration of mandibular continuity with a similar frequency to that achieved by vascularized bone-containing free flaps. The pattern of reconstructive failure differed markedly between the two methods. With vascularized bone grafts, most failures occurred during the early postoperative period and were secondary to patient death or free flap thrombosis. With bridging plates, failures were delayed and were secondary to hardware-related complications, including plate extrusion or plate fracture. This series demonstrates that most segmental oromandibular defects are successfully reconstructed using a single vascularized bone-containing free flap, and this method of reconstruction may prove to be more durable than the bridging plate method after a longer period of follow up. However, a soft tissue free flap combined with a bridging mandibular reconstruction plate is a reasonable alternative to vascularized bone-containing flap reconstruction for select lateral oromandibular defects when the nature of the defect favors use of a soft tissue free flap.

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