COMPARISON OF MINIPLATES AND RECONSTRUCTION PLATES IN MANDIBULAR RECONSTRUCTION

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Abstract: Background. The aim of this study was to compare complication rates of miniplates versus reconstruction plates in the fixation of vascularized grafts into segmental mandibular defects.

Methods. Retrospective analysis of 143 consecutive successful microvascular composite flaps performed between 1993 and 2001 was performed. Data were gathered from a computerized database, case notes, and pathology reports. Complications were classified as dehiscence, infection, and plate or bone removal.

Results. In the series, 49% of patients received miniplates, and 51% received reconstruction plates. No significant differences in complication rates were found between those grafts fixed with miniplates (27%) and those with reconstruction plates (30%). Plate choice was determined primarily by consultant preference. No significant differences were found in patient, defect, treatment, or follow-up characteristics between the plate groups. Twenty-nine percent of patients had at least one late complication at the reconstructed site, and this was higher (39%) in those who had postoperative radiotherapy.

Conclusions. No evidence was found in this study that the increased rigidity offered by reconstruction plates influences the rate of plate or bone removal, infection, or plate exposure. Thus, the decision to use reconstruction or miniplates is not dependent on the rate of plate complications.

Keywords: fixation; mandible; reconstruction; plates; vascularized

LITERATURE REVIEW

The use of free, vascularized, bone-containing composite flaps is established for reconstruction of the segmental mandibular defect.1,2 Various donor sites allow bone and soft tissue components to be tailored to the demands of the defect and patient.3 Subsequent oral rehabilitation, often using osseointegrated implants, is then achievable.4,5

Late complications at the reconstructed site are usually related to the plates used to provide graft-mandible union.6 Historically, alloplastic bridging reconstructions have used rigid plating systems7–10; however, with the advent of vascularized bone flaps, various types of reconstruction plates and miniplates have been described.
Boyd and Mulholland\textsuperscript{11} report a series of 132 flaps comparing 82 fixed with interosseous wires and 50 with various rigid techniques (including lag screws, OA reconstruction plates, and dynamic compression plates). They report rates of successful fixation of 94\% for rigid and 96\% for nonrigid systems. Comparing complications of rigid systems with the interosseous wire group, there were fewer infections or other soft tissue problems in the former. Within the rigid fixation group, fixation and complication rates were broadly similar. In conclusion, the authors recommend reconstruction plates for simplicity of use.

In Urken et al’s series\textsuperscript{6} of 210 cases of oromandibular reconstruction using microvascular composite flaps, rigid reconstruction plates were used in the “vast majority” of cases. They recommend a technique of contouring the reconstruction plate to the outer cortex of the mandible before resection. When possible, this facilitated maintenance of condyle position (and hence occlusion), restoration of facial form, and simplified fashioning of the vascularized graft by opening or closing osteotomies. Exceptions were made in certain scapula flaps, where miniplates were used to avoid excess muscle stripping. Most late complications relating to neomandible were associated with fixation hardware. Of particular note, extraoral plate exposure occurred in seven patients, and as a consequence, the authors have adopted a policy of removing all fixation plates 12 to 18 months after reconstruction. Other serious fixation-related complications included osteoradionecrosis, although in one of the three cases, this occurred by progression of the same pathology beyond the original resection margin.

Futran et al\textsuperscript{12} report a series of 95 reconstructions comparing three types of reconstruction plate. AO stainless steel, AO titanium, and THORP reconstruction plates were compared retrospectively with a follow-up period of 6 to 66 months. The stated advantages of rigid fixation were rapid resumption of oral function, avoidance of intermaxillary fixation, maintenance of occlusion, and ease of fashioning the graft. Plates were not routinely removed, but when an opportunity for reoperation arose, the plates were removed to prevent late complications and improve mandibular contour. Complications recorded were screw loosening, plate fracture, plate exposure, plate removal, and bony non-union. The total accumulation of complications was 25 in 48 patients for stainless steel, four in 25 patients for titanium, and three in 25 patients for the THORP system. The authors conclude that the stainless steel plates had a significantly greater complication rate ($p = .01$ for screw loosening and plate exposure). Because 74\% of complications occurred within the first year and the mean follow-up period for titanium (21 months) was shorter than for stainless steel (31 months), the authors comment that further problems may yet develop in titanium plates, perhaps reducing these differences. Only two patients with complications did not receive radiotherapy, but because 78\% of patients received either preoperative or postoperative radiotherapy, this precluded this trend from being statistically significant.

Disadvantages of rigid reconstruction plates in this application have been discussed in the literature.\textsuperscript{6,12,13} Peroperative issues include increased cost, procedure complexity, difficulty applying large screws to thin cortices, interference with the vascular pedicle, and problems of metal fatigue when bending plates in the sagittal plane. In cases in which tumor invades the outer cortex, or when in-continuity resection with facial skin is required, it is then impossible to “precontour” reconstruction plates as has been recommended. Late complications include stress shielding of the neomandible, palpable hardware, aesthetic issues, and obstruction of endosseous implants complicating subsequent oral rehabilitation.

Stress shielding has been described as the absorption of functional stress by a rigid plate, resulting in “disuse atrophy” of the graft and subsequent osteoporosis.\textsuperscript{12} This has been investigated by Kennady et al,\textsuperscript{14} who discuss the effects of rigid reconstruction in an animal model. They confirm that a deterioration of bone volume and density can occur as a result of the stress shielding effect.

Monocortical miniplate osteosynthesis has found widespread application in facial reconstructive surgery, so, unsurprisingly, miniplate systems have been promoted in the fixation of vascularized bone flaps. Whereas the demands of bone grafts and alloplastic bridging techniques dictate rigidity, the excellent vascularity of free bone flaps allows use of semirigid plates. Not only are many of the problems described previously avoided, but also Hidalgo\textsuperscript{15} has enumerated additional advantages. In a series of 27 vascularized reconstructions, plate removal was necessary in four cases and non-union occurred in two of 107 osteotomy sites. Advantages included ease of application, decreased operation time, and avoidance of intermaxillary fixation. In addition, the low profile and
Malleability allowed precise contouring contributing to superior aesthetic results. Furthermore, it was believed that the 100% flap survival may have been facilitated by lower plate pressure on periosteum, thus avoiding circulation compromise. Barnard and Vaughan describe the evolution of a 32-hole titanium miniplate designed for use with the composite radial flap, 0.6 mm thicker than the standard Champy plate. In 28 consecutive successful flaps, plate fracture occurred in two cases, one patient later developing dehiscence, and fibrous (rather than full bony) union was seen in two cases. These complications occurred early in the series when Champy miniplates were exclusively used. In later cases, with the adoption of this larger miniplate, these complications were not seen.

Schmelzeisen et al describe a series of 19 vascularized bone grafts fixed with a variety of miniplates. The procedures were all secondary reconstructions, and the donor sites were iliac crest and scapula. Between two and four miniplates, some stainless steel and some titanium, were used, apparently without complications. In the same article, however, an animal study presenting mandibular angle defects in guinea pigs found that THORP reconstruction plates resulted in lower rates of plate fracture and screw loosening than 2.0-mm titanium miniplates. These authors state that rigid fixation systems should be used in larger defects including the condyle. For other defects, they conclude that fixation of graft with two titanium miniplates is the method of choice.

Whereas the literature describes various fixation systems used, there are no studies comparing miniplates and reconstruction plates within the same series. In this retrospective review, we aim to correlate complications at the reconstructed site with the plate system used.

METHODS
A series of segmental mandibular reconstructions with free flaps performed between 1993 and 2001

FIGURE 1. Composite scapula flap fixed with two miniplates reconstructing complex defect involving lateral mandible in dentate patient.

FIGURE 2. OPT of fibula flap fixed with AO reconstruction (2.4 mm) plate to reconstruct anterior defect in edentulous patient.

FIGURE 3. DCIA flaps reconstructing lateral defects fixed with miniplates. Oral rehabilitation has been facilitated by sectioning and removal of the miniplate at the time of implant placement. (Oral rehabilitation: Mr. J.I. Cawood, Consultant Maxillofacial Surgeon, Countess of Chester Hospital, and Mr. J. Howell, Consultant in Restorative Dentistry, Liverpool Dental Hospital.)
were identified using a computerized database. Confirmation of accuracy of data and some additional variables were sought from hospital case notes and histopathology reports.

A series of 149 consecutive patients undergoing mandibular reconstructions using 166 vascularized composite free flaps were identified from the database in the period 1993–2001. In the series, 18 flaps failed, the flap survival rate being 89% (148 of 166). In four patients, further resection necessitated a second bone flap, and in this situation, we took the second flap for analysis. The single case in which both radial and iliac crest bone inserted simultaneously was considered as an iliac crest graft for simplicity. This left 143 patients with successful flaps for analysis.

All plate complications requiring readmission or reoperation were classified as follows:

1. plate removal,
2. bone removal,
3. intraoral or extraoral plate exposure,

FIGURE 4. (A) Series illustrating anterolateral, reconstruction of defect with DCIA flap fixed with reconstruction plate (free cortical bone grafts were used to fill the opening osteotomies). (B) OPT after reconstruction, extraoral hardware exposure after radiotherapy and wound infection. (C) After removal of the plate and bone grafts, the DCIA flap appeared healthy, and the wounds subsequently healed without further complications, OPT demonstrating successful osteosynthesis. Oral rehabilitation is planned after hyperbaric oxygen.
(4) infections around the plate (as documented in the case notes). It was permissible to record more than one complication per patient.

Dental status was classified as edentulous, fully dentate, or partially dentate. The position of the mandibular defect was classified as anterior, lateral, anterolateral combined, or anterior and bilateral. A defect in the intercanine region was defined as anterior, whereas a defect distal to the canine was defined as lateral.

Various defects and methods of plate fixation used are illustrated in Figures 1 and 2. Complications of fixation hardware are illustrated in Figures 3 and 4.

All plate types and manufacturers used over the period in each group were as follows:

**Miniplates**
- Howmedica Luhr vitallium 2 mm (max, 29 holes)
- Wurzburg titanium 2 mm (max, 16 holes)
- Osteomed titanium 2 mm (max, 40 holes)
- Surgical Technology titanium 2 mm (max, 32 holes)

**Reconstruction plates**
- Stratec/Synthes AO 2.4-mm titanium reconstruction
- Martin/Albert Waeschle 2.4-mm titanium reconstruction

Statistical analysis was performed using SPSS version 11. We regarded statistical significance as $p < .05$.

### RESULTS

Of the 143 flaps analyzed, miniplates were used as fixation in 49% ($n = 70$) and reconstruction plates in 51% ($n = 73$). The pathology leading to defect was oral squamous cell carcinoma in 87% ($n = 124$), other tumors in 7%, osteoradionecrosis in 4%, and trauma in 1%. The donor sites used were the radius in 36% ($n = 52$), iliac crest in 31% ($n = 44$), fibula in 23% ($n = 33$), and scapula in 10% ($n = 14$).

Plate complications are summarized in Table 1. No statistically significant differences in complication rates were found between miniplates (27%) and reconstruction plates (30%). Also, little difference was found with respect to plate removal, bone removal, infection, or plate exposure.

### Comparison of Groups.

The amount of follow-up, to death or to June 15, 2002, was similar in each group: miniplates (median, 2.2 years; interquartile range [IQR], 0.9–4.3 years), reconstruction (median, 2.3 years; IQR, 1.2–4.8 years). Survival

### Table 1. Plate type versus complication rate.

<table>
<thead>
<tr>
<th>Complication</th>
<th>Miniplates ($n = 70$)</th>
<th>Reconstruction Plates ($n = 73$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Plate removal</td>
<td>14 (20)</td>
<td>15 (21)</td>
</tr>
<tr>
<td>2. Bone removal</td>
<td>5 (7)</td>
<td>3 (4)</td>
</tr>
<tr>
<td>3. Plate exposure</td>
<td>4 (6)</td>
<td>6 (8)</td>
</tr>
<tr>
<td>4. Infection</td>
<td>14 (20)</td>
<td>16 (22)</td>
</tr>
<tr>
<td>Any plate complication</td>
<td>19 (27)</td>
<td>22 (30)</td>
</tr>
</tbody>
</table>

### Table 2. Plate type versus patient/defect characteristics.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Miniplates ($n = 70$)</th>
<th>Reconstruction plates ($n = 73$)</th>
<th>Overall ($N = 143$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age &lt; 65</td>
<td>40 (57)</td>
<td>44 (60)</td>
<td>84 (59)</td>
</tr>
<tr>
<td>Sex: Male</td>
<td>40 (57)</td>
<td>47 (64)</td>
<td>87 (61)</td>
</tr>
<tr>
<td>Diagnosis/stage: SCC and T4</td>
<td>44 (63)</td>
<td>52 (71)</td>
<td>96 (67)</td>
</tr>
<tr>
<td>Dental status</td>
<td>n = 64</td>
<td>n = 68</td>
<td>n = 132</td>
</tr>
<tr>
<td>Dentate</td>
<td>21 (33)</td>
<td>28 (41)</td>
<td>49 (37)</td>
</tr>
<tr>
<td>Partially dentate</td>
<td>19 (30)</td>
<td>21 (31)</td>
<td>40 (30)</td>
</tr>
<tr>
<td>Edentulous</td>
<td>24 (38)</td>
<td>19 (28)</td>
<td>43 (33)</td>
</tr>
<tr>
<td>Defect</td>
<td>n = 69</td>
<td>n = 72</td>
<td>n = 141</td>
</tr>
<tr>
<td>Anterior</td>
<td>16 (23)</td>
<td>29 (21)</td>
<td>39 (21)</td>
</tr>
<tr>
<td>Anterolateral</td>
<td>20 (29)</td>
<td>17 (24)</td>
<td>37 (26)</td>
</tr>
<tr>
<td>Lateral</td>
<td>31 (46)</td>
<td>40 (56)</td>
<td>71 (50)</td>
</tr>
<tr>
<td>Lat-Ant-Lat</td>
<td>2 (3)</td>
<td>2 (3)</td>
<td>4 (3)</td>
</tr>
<tr>
<td>Median (IQR) length defect, mm</td>
<td>71 (60–91)</td>
<td>70 (61–80)</td>
<td>71 (61–90)</td>
</tr>
</tbody>
</table>
rates from operation were similar at 1 year (77% miniplates vs 85% reconstruction) and after 3 years (61% vs 55%).

To consolidate the finding that plate types have similar complication rates, we compared patient and defect characteristics, treatment parameters, and follow-up data between the two groups (Tables 2 and 3).

Table 2 demonstrates that there was little difference in patient and defect characteristics between the two groups.

Table 3 shows that despite a similar case mix, consultant A had a preference for miniplates and consultant B had a preference for reconstruction plates. Miniplates were used more often for iliac crest flaps and less often for scapula flaps ($p < .001$ for association between flap type and type of plate). The differential use of plates for scapula flaps was explained by most (11 of 14) of these scapulas being performed by consultant B.

Other Factors Influencing Plate Complications. Further analysis of the data revealed no obvious differences between complication rates and flap type or defect position (results not shown). However, radiotherapy was strongly correlated with complications. Plate complications were seen in 39% of those who had postoperative radiotherapy but only 16% of those who did not (Fisher’s exact test, $p = .003$). Patients who had an osteotomy of the bone graft (30% vs 18%) or age less than 65 years (33% vs 22%) seemed to have more complications, although these associations were not statistically significant. There were small numbers in the nonosteotomized group. Dentate (26%) or partially dentate patients (42%) also had more complications, although the difference was not statistically significant. Radiotherapy was used more often in younger patients (61% of those <65 years vs 47% of those >65 years), and age was strongly associated with dental status (20% of those <65 years vs 53% of those ≥65 years were edentulous). No evidence of associations was found between flap osteotomy and age, dental status, or radiotherapy, or of radiotherapy with dental status. For those having radiotherapy, the infection rate for miniplates was 29% (10 of 35) and for reconstruction plates was 30% (13 of 44). Without radiotherapy, the infection rate for miniplates was 11% (four of 35) and for reconstruction plates was 10% (three of 29). Consultants A (28%, 20 of 72) and B (28%, 17 of 60) had similar overall complication rates.

DISCUSSION

Most previous studies on mandibular reconstruction with vascularized bone grafts are retrospective reviews of one fixation method. Many surgeons clearly judge that rigid reconstruction plates are indicated, although some believe that these plates should routinely be removed after bony union. In presenting a large series of mandibular reconstructions carried out in the same unit and within demonstrably similar patients and defects, we feel uniquely able to comment on the relative merits of miniplates versus reconstruction plates.

For major head and neck surgery, it is unit policy to allocate cases between the consultants on the basis of the next operation list available rather than by case type. Consultants A and B, who carried out most surgery, however, do have a clear distinction in their preference of graft fixation. In light of this, the absence of significant differences between plate groups in terms of patient characteristics, defect, flap used, or postoperative radiotherapy is not surprising.

Although a randomized controlled trial would be the “gold standard” in evaluating best outcome in two treatment groups, no such study exists in this field. The limitations of this retrospective study are apparent. Certain patient and treatment characteristics were retrieved from our prospectively completed computerized database; however, others were sought from case notes, operation notes, and pathology reports, none of which were recorded in a completely standardized way over the decade in question. Postoperative radiographs and radiographs of complications would yield extra information of interest. Unfortunately, these films were not always available because many
were destroyed after the death of the patients and others were mislaid.

Over the study period, there have inevitably been changes in the type and manufacture of hardware used. In pursuit of simplicity and clarity, we have grouped all 2-mm screw diameter semirigid systems under the miniplate heading. This may be at the expense of identifying differences in complications between different types of miniplates.

Difficulties were also found in defining and discriminating between complications recorded in case notes. For example, whereas one surgeon may believe an intraoral plate exposure is due to infection, another may only describe the dehiscence. To simplify our data, we have collected all complications requiring readmission or reoperation under the term “plate complications” and believe this simple classification gains in reliability and utility what it loses in detail.

When evaluating these techniques, a cost analysis encompassing hardware costs and procedure length might be considered helpful. In our unit the miniplates currently cost £50 to £150 ($80–$240) per plate (depending on length of procedure length), and the reconstruction plates cost £320 ($500) per plate. The costs of screws also show proportionate differences (approximately £15 [$24] vs £40 [$64]). This apparent cost savings in the use of miniplates is lessened because, more than one miniplate is often used in the fixation of a single graft. Although this study has not specifically measured operation times with the two systems, it is the opinion of the authors that either system can be applied, by experienced hands, in approximately 30 minutes. In summary, it is believed there are minimal overall cost differences between the two techniques.

This composite flap survival rate (89%) was similar to the overall flap survival rate (90%) in our regional oncology database (although composite flap survival rate has improved to 95% since 1998). Failures are concentrated in the early years of use of each flap, and we speculate the learning curve in raising, positioning, and anastomosing technique is highly relevant. Neither reconstruction plates (91%) nor miniplates (89%) show significant flap survival advantage. This finding does not support the theories described by Futran et al\textsuperscript{12} and Hidalgo\textsuperscript{15} that reconstruction plates might compromise bony blood flow.

Proponents of rigid fixation claim significant advantages in maintenance of condyle positioning. As described by Urken et al\textsuperscript{6}, contouring the reconstruction plate to the outer cortex of the mandible prior to resection maintains condyle position, occlusion, facial form, and simplifies flap fashioning. When possible, this technique works well with reconstruction plates and some longer miniplate systems; however, alternative methods are available in the use of short miniplates or when tumor breaches the lateral cortex: (1) use of temporary long miniplate, spanning the defect while resection occurs; (2) fixation of proximal mandibular segments to maxillary tuberosities with temporary supramucosal miniplates while resection occurs; (3) in substantially denatured patients with anterior segment resection, temporary peroperative intermaxillary fixation (eg, eyelet wire IMF) can be used; and (4) use of temporary intraoperative external fixation systems.\textsuperscript{18}

By tailoring the technique to the individual circumstances, condyle positioning is usually satisfactorily maintained. This study does not specifically evaluate plate palpability, but the authors are unaware of any particular trend between systems. The possibility that rigid fixation systems offer superior restoration or stability of occlusion and facial form exists. Our research has, however, not addressed these issues, so we are unable to comment further. It has, however, been noted that during oral rehabilitation with endosseous implants, reconstruction plates or screws need to be removed more frequently and that this sometimes necessitates greater exposure than would be the case with miniplates. We speculate that the use of osseointegrated screws with THORP plates may further compromise implant positioning in these challenging rehabilitation cases.

The deleterious effect of radiotherapy on complications in this series is of note. We have demonstrated a statistically significant increase ($p = .003$) in complications where Futran et al\textsuperscript{12} did not. Thirty-nine percent of irradiated patient versus 16% of nonirradiated patients had at least one complication develop, although this difference was mostly accounted for by plate infections. The even proportion of irradiated versus nonirradiated patients in a larger series (55% vs 45% in 143) allows greater confidence in this correlation than in the earlier study (Futran et al, 78% vs 22% in 95). We are not able to comment on the relative effects of preoperative and postoperative radiotherapy because a negligible number of patients, were treated with the former.

In summary, the selection of fixation system depends not only on complications but also on the effects on postoperative occlusion, bone position,
and facial profile. We did not address these issues in this study. Our main finding was that there are no significant differences in complication rates between 2-mm miniplates and rigid reconstruction plates. Developments in hardware such as locking plates, resorbable plates, and hybrid systems offering rigid plates with small-caliber screws are now commercially available. Although these advances await evaluation, this study shows that healing of the graft and the need for intervention for complications is not influenced by the choice of fixation in mandibular reconstruction.

REFERENCES