Open Reduction Internal Fixation for Midline Mandibulotomy
Lag Screws vs Plates

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IMPORTANCE  Midline mandibulotomy is a common approach for resection of head and neck oral cavity and oropharyngeal tumors; however, there are limited data available on the outcomes of lag screw vs plate fixation.

OBJECTIVE  To compare outcomes for midline mandibulotomy open reduction and internal fixation using plates vs lag screw technique.

DESIGN, SETTING, AND PARTICIPANTS  Retrospective cohort study at a tertiary care academic medical center of patients undergoing midline mandibulotomy for head and neck tumor resection over a 6-year period.

INTERVENTIONS  Mandibular fixation using lag screws or plates.

MAIN OUTCOMES AND MEASURES  The medical records and computed tomographic (CT) scans of patients undergoing midline mandibulotomy for head and neck tumor resection over a 6-year period were retrospectively reviewed. The postoperative CT scans were reviewed by a neuroradiologist who graded the fusion site on a scale of 0 to 2 using a 2-pass method. The rates and grades of union were compared, as well as several factors that affect healing, for fixations performed with plates vs lag screws.

RESULTS  Thirty-seven patients were included. The overall rate of radiologic union was 90% (9 out of 10) for lag screw technique and 41% (11 out of 27) for plates (P = .01). The average grade of radiologic union was 1.3 for lag screws and 0.67 for plates (P = .04). Hardware exposure occurred in 4 (15%) of the plate group and fistulae formed in 3 (11%); neither complication occurred in the lag screw group. In univariate analysis, both presence of dentition (odds ratio [OR], 5.50 [95% CI, 1.33-22.73]; P = .02) and plate technique (OR, 13.09 [95% CI, 1.45-11.62]; P = .02) were significantly associated with nonunion. In multivariate analysis, plate technique had an OR of 8.32 (95% CI, 0.85-81.75) for nonunion (P = .07).

CONCLUSIONS AND RELEVANCE  Fixation of midline mandibulotomy with lag screws results in a significantly increased rate of radiologic union compared with plates. Lag screws were also significantly better at achieving radiologic union in patients who underwent postoperative radiation, and the rates of fistula formation and hardware exposure were lower. Thus, lag screw fixation of midline mandibulotomy should be considered an excellent option, especially when patients will undergo postoperative adjuvant therapy and in patients at high risk for wound complications.
mandibulotomy is a common approach for resection of head and neck oral cavity and oropharyngeal tumors. This approach, known as the mandibular swing approach, involves a lip-splitting or visor flap incision, mandibular osteotomy (midline, paramedian, or lateral), and open reduction internal fixation (ORIF) of the mandible at the end of the operation. It provides excellent exposure of the posterior oral cavity and oropharynx, parapharyngeal space, as well as other areas of the upper aerodigestive tract. There are potential complications associated with the approach, including bone and wound infection, orocutaneous fistula, osteonecrosis, hardware exposure, malunion or nonunion, malocclusion, and plate and/or screw fracture or extrusion.

Multiple methods of mandibular fixation exist, including wires, plates, and lag screws. Wiring has largely been replaced by rigid fixation with compression plates and miniplates. Lag screw fixation was originally performed for trauma surgical procedures in 1970. In the 1990s, lag screw fixation was first described for ORIF of a stepped mandibulotomy, and later described a technique for transverse lag screw fixation for straight midline mandibulotomy. While there is no widely accepted gold standard for fixation after mandibulotomy, plate fixation is the most commonly performed technique.

We compared outcomes for midline mandibulotomy ORIF using plates vs lag screws. The primary end point was the rate of radiologic union as demonstrated by computed tomographic (CT) scan; this was correlated with preoperative and postoperative factors that may affect long-term union. Other outcomes including grade of radiologic union, hardware exposure, and fistula formation were also evaluated.

Methods

Medical Record Review

Under a protocol approved by the University of Virginia Internal Review Board for Health Sciences Research, a retrospective review was performed of the medical records and CT scans of patients who underwent midline mandibulotomy for tumor resection between February 2008 and January 2014 at the University of Virginia Hospital. Patients meeting the following criteria were included: (1) midline mandibulotomy had been performed for tumor resection; (2) at least 1 posttreatment CT scan was available for review that demonstrated complete union or had been performed at least 6 weeks after the surgery. Patients were excluded if any form of mandibulectomy was performed.

Data collected from the medical record included age, presence of adverse wound healing factors (diabetes mellitus, chronic steroid use), preoperative or postoperative chemotherapy or radiotherapy (RT), type of mandibular fixation performed, preoperative albumin (if available), length of follow-up, presence of postoperative fistula, and presence of hardware exposure. Preoperative chemotherapy/RT (chemo-RT) was defined as any history of definitive or adjuvant RT and/or chemotherapy prior to mandibulotomy and ORIF. Patients in this situation underwent mandibulotomy either for surgical salvage or to address a second primary tumor. Postoperative chemo-RT occurred after the mandibulotomy procedure as adjuvant therapy for the same cancer. Hardware exposure was defined as visible fixation plates or screws through a wound dehiscence, and presence of fistula was defined as a purulent, mucoid, or salivary drainage tract from the oral cavity to the skin. Both hardware exposure and presence of fistula were determined by the attending head and neck surgeon during postoperative follow-up as documented in the medical record.

Surgical Technique

Decision for lag screw vs plates was an independent decision made by the operating surgeon. All mandibulotomies were performed vertically in the midline using a sagittal saw. For plate fixation, the 2 plates were bent to conform to the bone and corresponding holes were drilled prior to the osteotomy. At the conclusion of the operation, the 2 plates were placed: the inferior rim plate was fixed with bicortical screws, and the tension band was fixed inferior to the tooth roots with monocortical screws. At least 2 screws were used per mandibular segment to secure the plate to the bone. Lag screw fixation was performed as follows: after manual reduction of the mandible, superior and inferior lag screws were placed after the pilot hole and smaller hole were drilled on opposing sides of the mandible. Pilot holes were manually countersunk to limit projection of the screw head above the mandibular cortex.

Radiologic Interpretation

Nonunion was defined radiographically rather than clinically (mobility of mandibular segments). All CT scans were obtained helically on multidetector CT scanners with 0.6-mm acquisition, multiplanar reconstructions, and artifact reduction techniques per standard protocol. The CT scans were reviewed by a neuroradiologist who was blinded to the surgeon, original radiology interpretation, and clinical patient documentation. Scans with extensive artifacts from dental hardware, contrast material streak artifacts, as well as motion artifacts were excluded. The fusion site was graded as solid fusion (complete or near complete) (grade 2), partial fusion (grade 1), or nonunion (grade 0) based on a 2-pass method (Figure). First, the presence of any bridging trabecular bone across the osteotomy site was determined. Nonunion was based on (1) complete absence of any bridging trabecular bone and (2) a well-defined hypodense linear defect at the surgical defect. A second pass was then performed to quantify the amount of bridging trabecular bone in the rest of the cases. Partial fusion appeared as minimal amount of bridging trabeculae (extending across < 50% of the surgical defect) surrounding the fusion hardware. Solid fusion (complete or near-complete) was identified as bridging trabecular bone extending across more than 75% of the surgical defect. Union was defined as grade 1 or grade 2 fusion. Additional note was made of dentition and any findings of osteonecrosis. Dentition was defined as presence of teeth at the mandibular osteotomy site. If an additional postoperative scan was available, it was reviewed to determine any changes in grade of fusion or delayed union (if there was nonunion on the first postoperative scan).
Statistical Analysis
The rates and grades of radiologic union for both fixation methods were compared, as well as differences in any preoperative or postoperative factors that may have affected healing. Other outcomes, including presence of fistula and hardware exposure, were also investigated. Statistical analysis included unpaired t tests and Fisher exact tests for comparison of patient characteristics and outcomes between the lag screw and plate groups. Univariate and multivariate analysis of perioperative and patient variables and nonunion were performed using binary logistic regression (SPSS statistical software, version 22).

Results
Thirty-seven patients met inclusion criteria. All but 1 patient underwent resection of an oral cavity and oropharyngeal tumor with free or pedicled flap reconstruction. One patient underwent mandibulotomy for a large carotid body tumor and did not require flap reconstruction. Patient characteristics are listed in Table 1. Plates were used in 27 patients, and lag screws were used in 10. There were no statistically significant differences in patient age, preoperative albumin, mean length of follow-up, presence of diabetes mellitus, use of chronic steroids, preoperative or postoperative chemotherapy or RT, or presence of osteonecrosis between the plate and lag screw groups. Patients who underwent plate fixation had dentition more often than those who underwent lag screw fixation (56% vs 10%), and this difference was statistically significant (P = .01). Although it did not achieve statistical significance, patients in the plate group had a higher rate of postoperative treatment with chemotherapy (48% vs 20%; P = .12).

As shown in Table 2, the overall rate of radiologic union (grades 1 or 2) was 90% for lag screw technique and 41% for plates (P = .01). One patient with lag screws and 1 with plates had delayed radiologic union noted on the second postoperative scan. The average grade of radiologic union was 1.3 for the lag screw group and 0.67 for the plate group (P = .04). The rate of radiologic union for edentulous patients (57% fixed with plates) was 67% and for patients with dentition (94% fixed with plates) was 31% (P = .04). When considering edentulous patients alone, the rate of union for lag screw technique was 89% and for plates was 58% (P = .15). Compared with plate fixa...
tion, rates of radiologic union were higher with the lag screw technique in patients who were treated with preoperative or postoperative chemotherapy and/or RT. The difference between the 2 groups achieved statistical significance only in patients who were treated with postoperative RT (88% vs 42% union, respectively; \( P = .04 \)), likely owing to the more substantial number of patients in this group (Table 2). No patients in the study were noted to have clinical instability of mandibular segments.

Hardware exposure and fistula at the mandibulotomy site occurred in 15% and 11% of the plate group, respectively; neither complication occurred in the lag screw group (\( P = .27 \) and \( P = .38 \), respectively; Table 3). Two patients required hardware removal, both of whom had plate fixation.

Patient and perioperative variables were assessed for association with mandibular radiologic nonunion using univariate (Table 4) and multivariate (Table 5) logistic regression analyses. The only variables that were significantly associated with radiologic nonunion were dentition and plate technique, with ORs of 5.5 and 13.09, respectively. These 2 variables were then assessed in multivariate analysis for prediction of radiologic nonunion. Dentition was no longer significant in the multivariate model, and plate technique was also not significant (OR, 8.32; \( P = .07 \)). The outcomes of hardware exposure and fis-

### Table 2. Rates of Radiologic Union

<table>
<thead>
<tr>
<th>Patients</th>
<th>All Fixations</th>
<th>Lag Screw</th>
<th>Plates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All, No.</td>
<td>Union, No.</td>
<td>%</td>
</tr>
<tr>
<td>All</td>
<td>37</td>
<td>20</td>
<td>54</td>
</tr>
<tr>
<td>Edentulous</td>
<td>21</td>
<td>14</td>
<td>67</td>
</tr>
<tr>
<td>Preoperative group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemo</td>
<td>6</td>
<td>2</td>
<td>33</td>
</tr>
<tr>
<td>RT</td>
<td>11</td>
<td>7</td>
<td>64</td>
</tr>
<tr>
<td>Chemo-RT</td>
<td>6</td>
<td>2</td>
<td>33</td>
</tr>
<tr>
<td>Postoperative group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemo</td>
<td>15</td>
<td>10</td>
<td>67</td>
</tr>
<tr>
<td>RT</td>
<td>27</td>
<td>15</td>
<td>56</td>
</tr>
<tr>
<td>Chemo-RT</td>
<td>13</td>
<td>8</td>
<td>62</td>
</tr>
</tbody>
</table>

Abbreviations: Chemo, chemotherapy; RT, radiation therapy.

\* Fisher exact test.

\* Patients receiving chemo-RT are included in both chemotherapy and radiation therapy groups.

### Table 3. Other Outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Patients, No. (% of Group)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Fixations (n = 37)</td>
</tr>
<tr>
<td>Fistula</td>
<td>3 (8)</td>
</tr>
<tr>
<td>Hardware exposure</td>
<td>4 (11)</td>
</tr>
</tbody>
</table>

\* Fisher exact test.

### Table 4. Univariate Logistic Regression Analysis of Predictors of Radiologic Nonunion

<table>
<thead>
<tr>
<th>Variable</th>
<th>( \beta ) (SE)</th>
<th>( P ) Value*</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemo</td>
<td>1.02 (0.94)</td>
<td>.28</td>
<td>2.78 (0.44-17.46)</td>
</tr>
<tr>
<td>RT</td>
<td>−0.56 (0.74)</td>
<td>.45</td>
<td>0.57 (0.13-2.43)</td>
</tr>
<tr>
<td>Chemo-RT</td>
<td>1.02 (0.94)</td>
<td>.28</td>
<td>2.78 (0.44-17.46)</td>
</tr>
<tr>
<td>Postoperative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemo</td>
<td>−0.88 (0.70)</td>
<td>.21</td>
<td>0.42 (0.11-1.63)</td>
</tr>
<tr>
<td>RT</td>
<td>−0.22 (0.74)</td>
<td>.76</td>
<td>0.80 (0.19-3.42)</td>
</tr>
<tr>
<td>Chemo-RT</td>
<td>−0.47 (0.70)</td>
<td>.50</td>
<td>0.63 (0.16-2.47)</td>
</tr>
<tr>
<td>Dentition</td>
<td>1.71 (0.72)</td>
<td>.02</td>
<td>5.50 (1.33-22.73)</td>
</tr>
<tr>
<td>Miniplate technique</td>
<td>2.57 (1.05)</td>
<td>.02</td>
<td>13.09 (1.45-118.62)</td>
</tr>
</tbody>
</table>

Abbreviations: Chemo-RT, chemotherapy and radiation therapy; OR, odds ratio; RT, radiation therapy; SE, standard error.

\* Binary logistic regression analysis.

### Table 5. Multivariate Logistic Regression Analysis of Predictors of Radiologic Nonunion

<table>
<thead>
<tr>
<th>Variable</th>
<th>( \beta ) (SE)</th>
<th>( P ) Value*</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dentition</td>
<td>1.19 (0.78)</td>
<td>.13</td>
<td>3.29 (0.71-15.19)</td>
</tr>
<tr>
<td>Miniplate technique</td>
<td>2.12 (1.17)</td>
<td>.07</td>
<td>8.32 (0.85-81.75)</td>
</tr>
</tbody>
</table>

Abbreviations: OR, odds ratio; SE, standard error.

\* Binary logistic regression analysis.
tula formation could not be assessed by logistic regression analysis owing to the low rates of these complications.

Discussion

Mandibulotomy has been shown to be a safe and effective method for surgical access to most of the upper aerodigestive tract. The location and cut of mandibulotomies vary, with sites including the median (midline), paramedian, and lateral positions and cuts including straight, notched, or stair-step. Midline mandibulotomy has the advantage of preserving the inferior alveolar and mental nerve, in addition to submental muscle attachments, potentially improving postoperative functional results. Multiple mandibular fixation procedures have been devised ranging from interosseous and K wires, to compression plates, noncompression plates, and lag screws.

In general, the decision for type of fixation after mandibulotomy is based on surgeon preference and experience. Fixation with plates requires precise plate contouring along the surface of the mandible, which can be time consuming. As midline mandibulotomy is associated with a small loss of bone at the osteotomy site, fixation of prebent plates offers maintenance of normal occlusion in dentulous patients and prevention of mandibular segment dislocation as the plates are contoured prior to the loss of bone that occurs during the osteotomy. However, the bony gap that is present after fixation must eventually be closed with bone to achieve union, which may be more difficult in patients with wound-healing problems. In this study, in which most of the patients had the presence of at least 1 poor wound healing factor, there was a statistically significant lower rate of union overall with plates compared with lag screws, possibly owing to the presence of this bony gap after fixation. Lag screw fixation allows for primary bone healing because it allows bone-to-bone contact and provides rigid fixation, while plate fixation using prebent plates requires secondary bone healing to occur given the presence of the small bony gap. Secondary, or indirect, bone healing does not require complete anatomic reduction or rigidly stable conditions. Secondary healing involves formation of a cartilaginous callus that later undergoes mineralization, resorption, and replacement with bone. Thus, while it is logical that radiographic union would be higher when the type of fixation closes and compresses the osteotomy gap, secondary bone healing would predict that the gap would close under normal conditions and should not lead to radiographic nonunion. The present study suggests that perhaps patients with head and neck cancer have impaired secondary healing owing to the presence of factors such as prior RT, and as such may be better suited for complete reduction and rigid mandibular fixation, such as occurs with lag screws.

When considering each subgroup of patients alone (dentulous, preoperative or postoperative chemotherapy, or RT; Table 2), lag screw fixation had higher rates of radiologic union compared with plates. In both univariate and multivariate analysis, plate fixation was the variable most significantly associated with radiologic nonunion.

The placement of a metallic stabilization device, such as a plate under the gingivolabial suture line, leads to increased tension, wound dehiscence, and infection owing to exposure of the hardware to saliva. As a result, one of the most common complications of plate fixation is plate exposure. In the present study, all cases of fistula and wound dehiscence with hardware exposure occurred in patients who underwent plate fixation, and 2 patients required plate removal. The differences in hardware exposure and fistula formation between the plate and lag screw group were not statistically significant; however, this is likely due to the low number of these complications.

The lag screw technique avoids several of the aforementioned problems associated with plates. There is very little exposure of the hardware outside of the bone, avoiding the additional tension on the suture line, and the small portions that are exposed are situated away from the mucosal incision. As discussed in the Results section, there were no instances of fistula formation or hardware exposure in patients who underwent lag screw fixation in this study. Lag screws compress bone fragments, allowing for primary bone healing. The holes for lag screws can be drilled prior to osteotomy or after, as in the present study. While lag screws have been purported to lead to malocclusion in dentulous patients owing to the closure of the gap created by the osteotomy and subsequent dislocation of the bony segments, they have been shown to be both safe and successful in terms of both union and occlusion in patients with dentition. The maintenance of normal occlusion after lag screw fixation in dentulous patients has been attributed to the use of a thin saw blade and the adaptable nature of teeth within the alveolus to adjust to minute changes of the mandibular segments. The dentulous patient in this study who underwent lag screw fixation had normal subjective occlusion on postoperative follow-up. Another option for fixation is the use of a reconstruction plate. Reconstruction plates provide compression similar to lag screws but can be contoured prior to osteotomy. However, there is still concern for fistula formation and hardware exposure given the presence of hardware under the suture line.

While fixation with plates seems to be the most common method for mandibulotomy ORIF, studies to date have not shown clear superiority of one method over another. Review of the literature yielded only 1 study comparing mandibular fixation using lag screw technique vs miniplates after midline mandibulotomy: Dediol et al concluded that the lag screw approach is at least as safe as fixation with plates. While most patients in their study received postoperative RT, only 1 patient had recurrent disease, and no patient was documented as having had preoperative RT or chemotherapy. Union was determined by postoperative orthopantomogram, and the 2 techniques were found to have similar rates of union and numbers of complications. However, owing to the low number of salvage cases in the study, it is unclear whether these findings are applicable to patients who have had preoperative chemotherapy and/or RT, or the presence of other factors that impair wound healing.

Reconstruction after extirpation of head and neck tumors often involves several decisions based on factors such
Open Reduction Internal Fixation for Midline Mandibulotomy

Original Investigation Research

Open Reduction Internal Fixation for Midline Mandibulotomy

ARTICLE INFORMATION

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Study concept and design: Danan, Mukherjee, Shonka.

Acquisition, analysis, or interpretation of data: Danan, Jameson, Shonka, Drafting of the manuscript: Danan, Shonka, Critical revision of the manuscript for important intellectual content: All authors.

Analysis and interpretation of data: Danan, Jameson, Shonka.

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Correction: This article was corrected online December 18, 2014, to fix an error in the Results section of the Abstract.

REFERENCES


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as patient age, general health condition, problems with wound healing, and the need for postoperative RT. Patients with head and neck cancer often present with persistent disease after RT and require surgical salvage. Preoperative RT is a significant factor in head and neck reconstruction because ionizing radiation causes both an acute and delayed effect on skin and subcutaneous tissue and negatively affects wound healing. Patients who receive preoperative RT in the months prior to surgery experience more wound-healing difficulties because irradiated tissue is less pliable and has reduced vascularity. A study of mandibulotomy ORIF with plates found that patients who received preoperative RT were more likely to develop nonunion and osteoradionecrosis. Similarly, postoperative RT has been associated with complications of bony healing in patients undergoing mandibulotomy in 14% to 37% of cases. A small study by Altman and Bailey reported nonunion in 100% of patients who underwent RT to a minimum dose of 60 Gy. While it is unclear in the present study what amount of radiation was received by the mandibulotomy site itself (as opposed to the surrounding soft tissue during preoperative or postoperative RT), it has been reported that there is no difference in complication rates despite varying dosages of radiation received by the osteotomy site during RT for head and neck cancer. In addition, diabetes mellitus and nutrition have been shown to negatively affect wound healing.

Thus, it is critical to consider these factors because they are relatively common in patients with head and neck cancer and may be of relevance in determining the best method of fixation after midline mandibulotomy. This study is unique from prior studies in that it is the first to investigate wound-healing factors, such as preoperative RT and/or chemotherapy, diabetes mellitus, nutritional status (as indicated by preoperative albumin), and chronic steroid use in comparing the rates of radiographic union and complications in patients undergoing mandibulotomy fixation with lag screw vs plates. With consideration of all of these preoperative and postoperative variables, ORIF with lag screw technique resulted in a significantly increased rate of radiologic union compared with ORIF with plates and should be considered an excellent method for achieving mandibular union for patients who require midline mandibulotomy for tumor resection.

Limitations of this study include its retrospective nature and relatively small number of patients, particularly in the cohort treated with lag screw ORIF. While there were many additional patients undergoing mandibulotomy ORIF at our institution, the sample size was limited by the number of patients with suitable postoperative CT scans. Another limitation is the selection bias in the choice of treatment. Historically, treatment decisions for lag screw or plate fixation at our institution were often determined by dentition. While our practice is evolving, of the patients included in this study, edentulous patients underwent lag screw fixation more commonly than dentulous patients, leading to low numbers of patients with dentition and lag screw fixation: only 1 patient with dentition who underwent lag screw fixation had a postoperative scan available. As indicated in Table 1, there is a correlation between dentition and fixation approach, which likely had an impact on the multivariate analysis and precluded a thorough analysis of the comparison of lag screws vs plates in patients with dentition.

Future studies should include a prospective study in which long-term union and complication rates are compared for ORIF with preosteotomy and postosteotomy bent plates vs lag screws. Further analysis can then be performed on the outcomes of patients with dentition who have lag screw vs plate fixation. A study that includes postosteotomy bent plates in addition to preosteotomy bent reconstruction plates will help to clarify whether it is (1) the lack of bony gap after osteotomy and fixation, (2) the compression achieved by lag screws, or both of these factors that are responsible for higher rates of radiologic union in patients undergoing ORIF for midline mandibulotomy. The cause of additional complications, such as fistula and hardware exposure, can also be compared between prebent plates, postosteotomy bent plates, and lag screws.

Conclusions

Lag screw fixation is an excellent method of ORIF for midline mandibulotomy. For all patients studied, lag screw fixation was associated with a statistically significant increased rate of radiologic union compared with plates. Lag screws were also significantly better at achieving radiologic union in patients who underwent postoperative radiation. While not statistically significant owing to the small number of events, the rates of fistula formation and hardware exposure were lower for lag screw fixation compared with plates. Thus, lag screw fixation of midline mandibulotomy should be considered when patients will undergo postoperative adjuvant therapy and in patients at high risk for wound-healing complications.


