Jaw resection

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Resection of the mandible and maxilla

General principles

This chapter concentrates on the resection of squamous cell carcinoma arising in the oral cavity or the midface. A similar approach is required for the resection of bone invaded by malignant salivary tumours but the points on the patterns of tumour invasion and entry may be different. The principles of the resection techniques may be appropriate to the management of odontogenic tumours especially if these are recurrent. Resection of the jaws for osteoradionecrosis or osteonecrosis is more of a debridement requiring the resection of bone back to a bleeding base prior to reconstruction. Bone resection for osteosarcoma or primary intraosseous carcinoma requires a more radical removal of bone as the tumour will invade the bone preferentially.

Applied anatomy

Mandible

The mandible provides a bony framework to hold the teeth and sensation to the lip and chin is provided by the inferior alveolar nerve which enters at the mandibular foramen and exits at the mental foramen. Although there are often attempts to preserve this nerve in the treatment of benign disease, the loss of sensation to the lip and chin is an acceptable morbidity for most patients. The relationship of the teeth to the bone varies with patients and the molars run from a buccal position to a more lingual
position posteriorly. The temporomandibular joint articulates with the skull base and in some cases the condylar head may require resection. The loss of teeth results in the loss of the supporting alveolar bone. The inferior alveolar nerve will come to lie on the alveolar ridge and the relationship of the floor of mouth muscle insertions will alter with the loss of bone (Figure 39.1 and 39.2).

Maxilla

The maxilla is a complex structure which provides bone for the upper dental arch supports the alar base and facial curtain as well as providing the orbital floor, malar buttress and lateral nasal wall. The articulation with the rest of the skeleton is important to understand in tumour resection.

Medially, the lateral nasal wall is the least important structure, but care is required in maintaining the lacrimal system. The frontal process of the maxilla and the nasal bones articulate with the frontal bone and immediately behind these structures is the ethmoid sinus and then the sphenoid sinus. The cranium lies directly above these bones and experience in skull base resections is required to safely resect these structures. The lamina papyracea of the medial wall often requires resection and care must be taken to identify the anterior ethmoidal artery in particular. The maxilla provides much of the orbital floor as far as the inferior orbital fissure, and more laterally the lateral wall is made up of the greater wing of the sphenoid and the malar.

Mandibular resection for oral squamous cell carcinoma

Patterns of invasion and routes of tumour entry

Early or shallow invasion of the mandible from the oral cavity will often show an erosive pattern with a pushing front and a connective tissue layer separating the bone from the tumour. The more infiltrative pattern is related to deeper invasion in which the connective tissue layer is lost and separate islands of tumour infiltrate in a less favourable manner.1–3 It is not possible to predict the pattern of invasion so the judgment on how much bone to resect remains clinical and based on imaging. Various theories of the route of tumour entry to the mandible have been suggested but it seems most likely that the tumour enters the mandible at the point of contact. In the dentate mandible, this tends to be at the junction of the attached and reflected mucosa and in the edentulous mandible, this is more likely at the crest of the ridge due to the lowering of the floor of the mouth due to the loss of teeth.2,4 These are important issues if a marginal or more conservative resection of the mandible is being considered.

Pre-operative assessment

There are multiple papers looking at the accuracy of pre-operative imaging techniques and their accuracy in predicting the presence of tumour invasion of the mandible. A recent review article has summarized the findings which are included in Table 39.1.5

A widely accepted standard is to use a magnetic resonance imaging scan (MRI) as a standard image of the primary tumour and the neck nodes. This will usually provide 5-mm slices and will include T1, T2 and fat suppression sequences as well as gadolinium enhancement. The fat suppression sequence is the most sensitive in indicating tumour invasion of the mandible. The only additional image would be an orthopantomogram (OPG) if there is
clear invasion of the mandible or in which the mandible is unlikely to be invaded. For tumours in which it is unclear if the mandible is invaded a single photon emission computerized tomography (SPECT) scan is included to get a further sensitive imaging of the mandible. The combination of an image with a high specificity with one with a high sensitivity can provide a reasonably accurate prediction of the extent of mandibular invasion and therefore the most appropriate method of resection. Cawood and Howell published a widely accepted classification of the mandible following the loss of teeth and it is clear that in Class V and VI mandibles (Figure 39.2) there is insufficient height of bone to safely perform a marginal resection for malignant disease. As a result, a guide to mandibular resection has been published which relates to the size of the mandible and the results of the investigations predicting bone invasion (Table 39.2).

Methods of mandibular resection

In the past, the ‘commando’ operation in which the body of the mandible was sacrificed to remove potential lymphatics containing tumour and to facilitate the soft tissue reconstruction has now been discontinued and yet there are series published in which only 29% of the resected mandibles were invaded by tumour. As in all oncological surgery, the aim is to cure the patient of disease through adequate resection. At the same time, the skilled surgeon should be trying to reduce the morbidity of the operation to a minimum and maintain the best possible function. Good functional results for patients depend more on the tissue left behind than the method of reconstruction.

There are two basic methods of mandibular resection. In the marginal or rim resection, the integrity of the lower or upper border of the mandible is kept intact (Figures 39.1 and 39.2). In the full or segmental resection of the mandible, both the upper and lower border are included in the resection so that there is a loss of continuity of the mandible. There is clear evidence to show that functional and aesthetic results are poor if the continuity of the mandible is not restored. The need to reconstruct the mandible to achieve the best functional and aesthetic result will often involve composite-free tissue transfers for malignant disease which will add to the donor site morbidity and increase the risk of flap failure.

Marginal or rim resection

A marginal resection of the mandible can be performed in the coronal or the sagittal plane. In the majority of cases, a coronal marginal resection is used (Figure 39.2). This is the standard method for tumours in which a margin of normal bone is required. It can be used for smaller odontogenic tumours in which there is sufficient residual bone to maintain the lower border. A sagittal marginal resection cannot be used for bone pathology as preserving any kind of margin is not possible. It has been used for floor of mouth squamous cell carcinomas to obtain a clear margin when tumour is abutting the mandible but not obviously invading. This is a high-risk strategy as any invasion through the cortex will be reported as an involved margin. In addition, the angle of the mandible in the body region is difficult to judge (Figure 39.3). In this situation, it is a safer oncological approach to perform a segmental resection of the mandible. Rim resections that involve the ramus of the mandible can only be done in the coronal plane as the ramus is too thin to split for oncological reasons, and it is best to include the coronoid process as this may reduce trismus post-operatively.

If the lower border of the mandible is to be preserved then 10 mm of the depth of bone will be necessary for jaw continuity to be reliably maintained.

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**Table 39.1** Summary and comparison of the imaging techniques and clinical examination.

<table>
<thead>
<tr>
<th>Imaging technique</th>
<th>No of reports</th>
<th>Specificity (mean)</th>
<th>Sensitivity (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical examination</td>
<td>9</td>
<td>66</td>
<td>81</td>
</tr>
<tr>
<td>Plain radiography</td>
<td>18</td>
<td>81</td>
<td>76</td>
</tr>
<tr>
<td>Bone scintigraphy</td>
<td>15</td>
<td>74</td>
<td>93</td>
</tr>
<tr>
<td>SPECT</td>
<td>3</td>
<td>65</td>
<td>97</td>
</tr>
<tr>
<td>Computed tomography</td>
<td>7</td>
<td>88</td>
<td>78</td>
</tr>
<tr>
<td>DentaScan</td>
<td>3</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Magnetic resonance imaging</td>
<td>4</td>
<td>86</td>
<td>81</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>2</td>
<td>93</td>
<td>86</td>
</tr>
</tbody>
</table>

Abbreviation: SPECT, single photo emission computed tomography.

**Table 39.2** Results of the investigations predicting bone invasion.

<table>
<thead>
<tr>
<th>Mandible classification</th>
<th>OPG−, MRI−, BS−</th>
<th>OPG− MRI or BS+ early invasion (&lt;5 mm)</th>
<th>OPG+, MRI+, BS+ late invasion (&gt;5 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–2 (dentate)</td>
<td>Rim</td>
<td>Rim</td>
<td>Rim/segment</td>
</tr>
<tr>
<td>3–4 (&gt;20 mm mandibular height)</td>
<td>Rim</td>
<td>Rim</td>
<td>Segment</td>
</tr>
<tr>
<td>5–6 (&lt;20 mm mandibular height)</td>
<td>Rim/segment</td>
<td>Segment</td>
<td>Segment</td>
</tr>
</tbody>
</table>

Abbreviations: BS, bone scan; MRI, magnetic resonance imaging; OPG, orthopantomogram.
For marginal resections involving malignant disease (all osteosarcomas and primary intraosseous carcinomas require segments), it is possible to assess the extent of tumour invasion into the mandible from the surrounding soft tissues and estimate the extent of the resection required. This technique is illustrated through Figure 39.4. Note that periosteal stripping to assess the presence of mandibular invasion and its extent has been used. The use of periosteal striping is an essential part of the technique in the decision-making process for mandibular resection. It has been shown to be a reliable technique and in a large series from the unit in Liverpool our involved bone margin rate is very low compared to the soft tissue margin rate.

Figure 39.3 This is a partial sagittal rim resection but this diagram illustrates the angle of the body of the mandible from medial to lateral if the full sagittal rim is required.
Segmental resection of the mandible

This is a basic procedure in the management of malignant disease once the decision has been made not to preserve any part of the involved mandible. The decision as to where the bone cuts are made will depend on the assessment of mandibular invasion and the entry and exit points of the inferior alveolar nerve. In benign disease, it is often possible to keep the nerve intact and allow it to lie in the soft tissues overlying the reconstructed bone.

Periosteal stripping is also an important factor in the segmental resection of the mandible in malignant disease. Periosteum can be stripped back from the undamaged bone until it becomes adherent, or the tumour is seen entering the bone. Once this is established, the margin can be decided and the bone cuts planned. It is also important to examine the specimen to ensure that the bone margins are clear of disease by direct inspection (Figure 39.5). This is much less reliable in a malignant tumour arising in bone such as a primary intraosseous carcinoma or an osteosarcoma. In these cases, the periosteum and the cortex of the bone may look clear of invasion as the tumour spreads along the marrow space. As a result, it is necessary to be much more aggressive in mandibular resection and frozen sections should be performed if possible.

It may be necessary to excise the overlying skin in mandibular resection. In most cases, it is possible to preserve the skin cover but care must be taken in the buccal aspect of the resection to take sufficient tissue. It is seldom necessary to use an access procedure with segmental mandibular resection. The overlying skin is raised or excised depending on the needs of the oncological ablation and once the bone cuts have been made the mandible can be delivered into the neck and any further resection lingual

Figure 39.4  (a–d) Pre-operative clinical photograph, OPG, SPECT scan and MRI scan showing early tumour invasion of the mandible. (e) The resection of the buccal side of the mandible. (f) Completion of the planned coronal rim resection. (g) Turning the bone over to inspect the lingual side of the rim resection and ensure clearance of invaded mandible. (h) The resulting defect post resection. (i) The specimen with lingual periosteal stripping to confirm clearance of resection. (j) and (k) Post-operative OPG and clinical photograph of anterolateral thigh flap reconstruction.
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to the jaw can be undertaken as the last part of the resection prior to the delivery of the specimen (Figure 39.6).

Maintaining the occlusion in mandibular resection

There are various methods used to maintain the occlusion prior to mandibular reconstruction. Some surgeons will use a form of external fixation of the nonresected part of the mandible but this is very cumbersome and the device impedes accurate oncological resection. Templates have been devised using stereolithographic models but again these are often impractical in surgery for malignant disease. The simplest technique is to pre-bend a plate if the tumour does not involve the buccal aspect of the mandible. In this way, the harvested bone can be grafted into position with the plate already in place. I usually move the plate back by a screw-hole in the edentulous situation to take the pressure off the soft tissues and reduce the risk of dehiscence. If the use of a pre-bent plate is not possible then the condylar position can be fixed with a miniplate from the part of the ramus that does not require resection to the maxilla prior to the resection with the mandible in occlusion. Once the mandible has been resected, the position of the ipsilateral condyle remains fixed and the collateral mandible can be located with the residual occlusion. A plate can then be bent into position prior to the placement of the graft. This can be carried out bilaterally for extensive mandibular resections. The length of the plate may need to be estimated but at least the condyles will be in the correct position relative to each other.

Resecting the ramus and condyle

In most cases of squamous cell carcinoma, it is possible to maintain the condyle and the condylar neck sufficiently to maintain a plate so that this important part of the joint is left in function. The need to resect the condyle makes the subsequent reconstruction more difficult as the condyle cannot be fixed and it is not possible to pre-bend a plate. The resection of the condyle with the ramus and body of the mandible is relatively straightforward but care must be taken to protect or tie off the maxillary artery and avoid damage to the facial nerve. The facial nerve can be damaged by inappropriate retraction in this region. It is often necessary to use some form of intermaxillary fixation if the patient is dentate to help the patient maintain a functioning occlusion in the post-operative period.

Figure 39.5 (a and b) Periosteal stripping postresection to ensure that the buccal and lingual surfaces are clear of tumour in the distal part of the resection in the region of the lower right canine.

Figure 39.6 (a-b) There is no need for access surgery such as a lip split in segmental surgery as the tumour can be delivered into the neck to complete the resection.
Resecting the maxilla

Pathology and pre-operative imaging

There is much less controversy over the more conservative approach to maxillary resection than the mandible. It is possible to preserve the bone of the maxilla with a limited resection of the palatal or alveolar mucosa and place a dressing plate and await the pathology report. If there is an involved or close margin then bone can be resected at a second procedure. This process is also possible in more extensive resections of the maxilla in which an obturator can be placed and again the margins checked and more tissue taken at the time of the obturator change.

There is little discussion on the role of pathology either in terms of the pattern of spread in the bone or the pathway of entry. Most accept that the route of entry in the maxilla is at the point of contact and thus the maxillary resection is guided by the extent of the soft tissue mass.

For the assessment of bone invasion in the maxilla, most prefer a computed tomography (CT) scan. In our practice, both MRI and CT scans are used to fully assess the tumour when there is concern over the involvement of the orbit, skull base or the infratemporal or pterygoid fossa. The CT scan is probably best for the skull base, and the MRI to assess the infratemporal fossa and both contribute equally to the invasion of the orbital contents.

The methods of resection are based on the classification illustrated in Figure 39.7.12

Class I (alveolectomy)

For Class I defects (Figure 39.1), there is no need to use an access procedure, as the tumour can usually be visualized with ease. This classification includes a medial maxillectomy often used for inverted papillomas but resection for this pathology is not included in this chapter.

Class II (low-level maxillectomy)

In this situation, the orbital floor is not involved with the resection and if the lesion is below the level of the infra-orbital nerve then no access procedure may be required.

Either a lip-split combined with a lateral rhinotomy or a midfacial degloving procedure may be used for access with equal effect.13,14 There are four osteotomies required to deliver the low-level maxilla in ablative surgery:

1. Vertical alveolar (Figure 39.9a)
   In the dentate maxilla, it is best to remove a tooth in the line of the osteotomy which is continued to the floor of the nose. Maintaining bone adjacent to the remaining tooth helps the stability of the adjacent tooth to the bone cut for obturated cases. Ensure there is sufficient soft tissue to cover the exposed bone.

2. Le fort I level
   A further osteotomy is required at the required height which may include the infraorbital nerve if required. This is carried through to the pterygoid plates.

3. Pterygoid plates
   If the tumour is contained in the antrum, the pterygoid plates can be split from the maxilla with a chisel. If the tumour is through the antrum posteriorly it is essential to make a bone cut through the pterygoid plates superior to the position of the tumour and then resect the through the pterygoid muscles to obtain a margin of resection.

4. Palatal
   The alveolar osteotomy is continued into the palate. If possible, the soft tissue incision should allow some of the redundant mucoperiosteum to cover the bone cut especially if obturation is the method of rehabilitation.

Once these osteotomies have been carried out the hemimaxilla can be mobilized and any soft tissue attachments released.

Class III (high-level maxillectomy maintaining the orbit)

The midfacial degloving technique reaches its limit if the orbital floor requires resection or there is extension into the medial orbital region of the ethmoids. In this situation, the lip split and lateral rhinotomy may be sufficient or it may be necessary to extend the incision as a blepharoplasty incision or sub-ciliary incision (Weber-Ferguson). In most situations, it is possible to reach the lateral orbital wall and malar without this extension reducing the risk of ectropion.

Figure 39.7 Classification of the maxillectomy defect.11 The need for reconstructive options increases from Class 1 to 4.
This is the most complex resection because of the need to preserve the orbit and the lacrimal apparatus. A guide to the osteotomies is as follows (Figure 39.10):

1. Vertical alveolar and nasal
   The previously described vertical alveolar bone cut is extended to include the nasal piriform fossa and extended to the level of the lacrimal crest. Care must be taken to expose the lacrimal sac and to preserve this structure.

2. Orbital
   In this situation, the orbital floor is included as far as the inferior orbital fissure. This horizontal bone cut can be extended to the lateral orbital wall or the frontal process of the malar bone as required.

3. Malar
   The orbital bone cut is linked to the malar buttress cut which is made lateral to the position of the tumour.

4. Pterygoid plates
   This often requires the plates to be sectioned higher than in the low maxillectomy close to the skull base. A chisel can be used to fracture off the pterygoid plates with a tumour contained within the antrum.

In these more extensive tumours, this part of the maxillectomy can be delivered intact. In most situations, there will be extension into the ethmoid sinuses or superior to the lacrimal sac which will make delivery of the en bloc specimen more difficult. It is still essential to attempt to deliver the main part of the maxillectomy intact and carry out further resection of the medial orbital wall and ethmoid and sphenoid sinuses as required. If it has not been possible to maintain the lacrimal system, the punctum is stented with a silastic tube and delivered into the nose and tied off. The silastic tube can be cut between the upper and lower punctum at about 3 weeks. It may be possible to repair parts of the lacrimal sac and duct at the time of the resection but the placement of silastic...
obtain adequate access to the anterior skull base. Craniotomy and frontal bar osteotomy may be required to create a coronal flap, which will require removal after the delivery of the main specimen. Tumour extending into the skull base, the ethmoids and sphenoid sinuses may be possible to deliver the specimen. Tumour extending into the skull base. The ethmoids and sphenoid sinuses may require removal after the delivery of the main specimen. Tumours involving the skull base require a multidisciplinary team approach. In this situation, a coronal flap, craniotherapy and frontal bar osteotomy may be required to obtain adequate access to the anterior skull base.

Class IV (radical maxillectomy with orbital exenteration)
If the orbit requires resection with the maxilla then the approach includes the upper and lower lids if there is no attempt to reconstruct the defect with a prosthetic eye. This operation is much easier to perform as no orbital structures need to be preserved.

In this operation, it is better to release the optic nerve after exenterating the superior part of the orbit after the access procedure.

The same vertical bone cuts are made in the alveolus and nasal bones but no special attention is required regarding the medial canthal ligament and the lacrimal apparatus. The lateral bone cut is made from the inferior oblique fissure to the malar buttress prior to the release of the pterygoid plates. The palatal bone cuts link with the vertical alveolar and nasal cuts and at this stage the specimen can be mobilized. The soft tissue resection at the base of the orbit is completed and now it should be possible to deliver the specimen. Tumour extending into the skull base, the ethmoids and sphenoid sinuses require removal after the delivery of the main specimen.

Tumours involving the skull base require a multidisciplinary team approach. In this situation, a coronal flap, craniotherapy and frontal bar osteotomy may be required to obtain adequate access to the anterior skull base.

**References**


**Top tips**

**Resection of the mandible**
- Pre-operative imaging should include a sensitive (bone scan, MRI) and specific (OPG) technique.
- Pre-operative imaging, clinical examination and the use of perioperative periosteal stripping all help to decide the type and extent of resection.
- Remember that the tumour will invade the mandible at the point of contact which may be below the dental line or the crest of the ridge.
- Early invasion is more likely to be the erosive pattern and late invasion infiltrative, requiring a wider margin.
- The option of a rim resection decreases with the extent of mandibular resorption following the loss of teeth (Class V and VI).

**Resection of the maxilla**
- Pre-operative imaging will include an OPG and a CT scan and often an additional MRI will be useful to assess the skull base.
- The main issues in maxillary resection involve the removal of the orbit and the extent of the disease into the infratemporal fossa.
- Using a saw to resect the pterygoid plates above the tumour will ensure a safer resection at the posterior maxilla.
- Close cooperation with the restorative dentist is essential in the planning of maxillary resection.