Reconstruction of the maxilla and midface: introducing a new classification

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Most patients requiring midface reconstruction have had ablative surgery for malignant disease, and most require postoperative radiotherapy. This type of facial reconstruction attracts controversy, not only because of the many reconstructive options, but also because dental and facial prostheses can be very successful in selected cases. This Personal View is based on a new classification of the midface defect, which emphasises the increasing complexity of the problem. Low defects not involving the orbital adnexae can often be successfully treated with dental obturators. For the more extensive maxillary defects, there is consensus that a free flap is required. Composite flaps of bone and muscle harvested from the iliac crest with internal oblique or the scapula tip with latissimus dorsi can more reliably support the orbit and cheek than soft-tissue free flaps and non-vascularised grafts, and also enable an implant-borne dental or orbital prosthesis. Nasomaxillary defects usually require bone to augment the loss of the nasal bones, but orbitomaxillary cases can be managed more simply with local or soft-tissue free flaps. We review the current options and our own experience over the past 15 years in an attempt to rationalise the management of these defects.

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Introduction

The most complex and controversial area in head and neck reconstructive surgery is the management of maxillary, midface, and skull-base tumours—not only in terms of disease control or cure but in the best methods of oral and facial reconstruction and rehabilitation. Ablative surgery of the midface involves a high level of psychological and physical trauma for a patient and their family. Although loss of an eye only affects binocular vision (patients can still read, watch television, and drive), the thought of losing a window to the soul seems frightening and final. Yet if the disease can be controlled, quality of life is acceptable and good speech and swallowing are often maintained. Traditionally, maxillectomy defects have been managed with a prosthetic option, but over the past 20 years the role of free-tissue transfer has become more important and the first partial facial transplant in the USA involved the midface.[1]

The published work is difficult to interpret since level 1 or 2 evidence for management of maxillectomy defects does not exist, and most studies are descriptive, highlighting one particular technique. Incidence of cancer involving the maxilla and midface is low, and the pathology is varied, therefore case-control studies are of limited value. There is also poor guidance for the best situations to use a prosthesis or a free-flap reconstruction. Hence, the proposal of a simplified algorithm to provide guidance in terms of the form of rehabilitation most likely to restore facial symmetry and give the best chance of good oral function is timely.

Management of maxillectomy patients is complicated by age and comorbidity, and, in some cases, reduction of the morbidity of surgery by avoidance of reconstruction is paramount in overall management. The importance of involvement of the prosthetic and surgical teams to explain the options to patients and provide appropriate informed consent cannot be overemphasised.

The aim of this Personal View is to describe our experience in the Regional Maxillofacial Unit in Liverpool, UK, since 1992, and report our current thinking, with due reference to the literature since 1998. We present a modification of our classification of the maxillectomy defect[2] and show how this relates to the method of rehabilitation. In this way, we aim to present a reasoned algorithm for management of patients that undergo ablative surgery for maxillary and midface cancer.

Classification

During the preparation of this Personal View, it became evident that none of the reported classifications adequately addressed the midface and maxilla. Therefore, we suggest a new classification based on our previously published classification,[2] which is expanded to include the midface and is clarified in terms of the horizontal or functional aspect of maxillary loss. Class I–IV describes the increasing extent of the maxillary defect in the vertical dimension. For the midface, we have added orbitomaxillary defects (class V) and nasomaxillary defects (class VI), most of which do not involve ablation of the palate or dental alveolus. Although Cordeiro and Santamaria[3] included orbitomaxillary defects in their classification, the nasomaxillary defect is more complex and requires a composite reconstruction if the nasal bones are lost. We have also clarified the dentoalveolar or functional side of the defect, as explained in figure 1. This classification provides a framework to explain the different problems and complexity of each defect, and indicates a rationale for reconstructive options.

Literature review

The results of our literature review are presented in table 1. This review includes all reported cases of reconstruction of the maxilla and the midface since 1998. The cases have been studied and, if possible, allocated to the current classification. Full categorisation

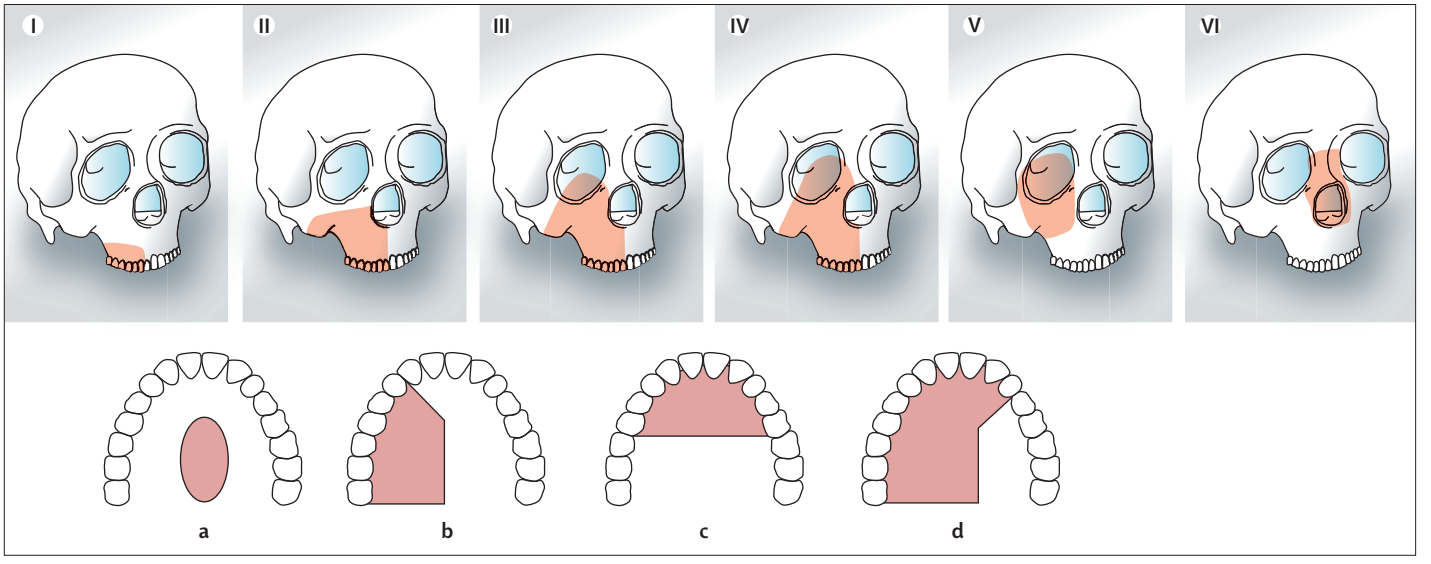

Figure 1: **Classification of vertical and horizontal maxillectomy and midface defect**
Vertical classification: I—maxillectomy not causing an oronasal fistula; II—not involving the orbit; III—involving the orbital adnexae with orbital retention; IV—with orbital enucleation or exenteration; V—orbitomaxillary defect; VI—nasomaxillary defect. Horizontal classification: a—palatal defect only, not involving the dental alveolus; b—less than or equal to 1/2 unilateral; c—less than or equal to 1/2 bilateral or transverse anterior; d—greater than 1/2 maxillectomy. Letters refer to the increasing complexity of the dentoalveolar and palatal defect, and qualify the vertical dimension.

	Classification of midface and maxillary defect							Total
	I	II	III	IV	V	VI	Unsure	
Pedicled flaps								
Pedicled flaps (unspecified)[4,5]	..	..	..	..	..	..	22	22
Temporalis, temporoparietal, buccal fat pad[3,6–12]	2	38	30	..	17	..	11	98
Soft-tissue free flaps								
Radial forearm[2–6,9,13–18]	20	67	14	..	1	3	11	116
Rectus abdominus[3–6,9,15,18–25]	1	14	65	53	16		45	175
Latissimus dorsi[4,5,13,15,17,26,27]	..	2	3	13	2	..	2	22
Anterolateral thigh[24]	..	..	3	..	..	..	..	3
Hard-tissue or composite free flaps								
Radial forearm[2,3,5,14–18,28,29]	2	21	7	5	11	..	15	61
Lateral arm[30]	..	1	..	..	..	..	..	1
Fibula[4,9,16,17,31–36]	4	63	25	..	..	..	2	94
DCIA/internal oblique[2,17,37–40]	2	24	18	12	..	..	..	56
Scapula[4,9,13,16,17,26]	..	8	12	6	6	..	3	35
TDAA/serratus anterior[41,42]	1	11	1	1	..	..	..	14
TDAA/teres major[43]	..	6	8	..	..	..	..	14
TDAA/latissimus dorsi[9,15,26,44,45]	..	2	1	28	..	..	7	24
Combined flaps[46]	..	..	..	1	..	..	..	1

DCIA=deep circumflex iliac artery (supplies the iliac crest). TDAA=thoracodorsal angular artery (supplies the scapula tip).

Table 1: **Summary of published methods of reconstruction from 1998 to 2009, in number of reported cases**

of case series by Davison and colleagues,[4] Stavrianos and colleagues,[5] and Yamamoto and colleagues was not possible.[9] We present studies in terms of the type of defect and method of reconstruction. This approach gives an insight into the range of solutions that surgeons have used and the complexity of the maxillary and midface defect.

Retrospective review

We reviewed 147 cases of reconstructed midface and maxillary defects resulting from ablative surgery for head and neck cancer, done at the Regional Maxillofacial Unit in Liverpool, UK, since 1992 (table 2). Initially, the radial (fasciocutaneous and osteocutaneous) flap was used, but this technique is now less favoured apart from for class VI defects. The thoracodorsal angular artery (TDAA) flap with latissimus dorsi is now a useful alternative to the deep circumflex iliac artery (DCIA) with internal oblique, especially if facial skin is part of a complex defect.

Prosthetics versus reconstruction

Three reports have attempted to compare functional and aesthetic outcomes in terms of obturation and reconstruction, usually with free flaps.[47–49] These are retrospective non-randomised studies, but all indicate that reconstruction has advantages, which are more assured with larger defects. A recent study by Moreno and colleagues[49] reports on the largest comparative series (73 obturated and 40 reconstructed patients), and found that reconstruction provided a better outcome for swallowing and speech, particularly for larger defects in the horizontal or dental component of the maxilla. The results were not significant in the vertical dimension, but questionnaires were not used and aesthetics (more likely to be a problem in this dimension) were not measured.

Obturation has some obvious advantages: the surgery is relatively simple, the patient has an immediate new dentition with restoration of appearance, and there is the possibility of cavity surveillance (although this advantage has not been substantiated).[49] However, there are problems with radiotherapy and further surgical

operations are needed to change the obturator and refine it as the cavity heals and contracts. Reconstruction obliterates the defect and restores the facial profile, but there is no immediate dental solution; however, it is easier for patients in the short term since the mouth is more comfortable, especially if radiotherapy is added. The use of zygomatic implants to help retain the denture in larger defects has enhanced prosthetic options, but consensus has not been reached on when prosthetics will yield a poorer long-term result than reconstruction. A South African group has published the largest series (20 patients) on use of zygomatic implants and dental implants for immediate rehabilitation of maxillectomy defects.[50] Although the investigators report that almost all maxillary defects can be rehabilitated functionally and aesthetically, they only treated patients from class I–IIa–d (figure 1). In our own practice in Liverpool, obturation is offered for class I–IIa,b defects, but a composite free-flap option is preferred for larger alveolar (class IId) and class III–VI defects, when appropriate to the patient's medical fitness and informed choice.

	Classification of midface and maxillary defect						Total
	I	II	III	IV	V	VI	
Pedicled flaps							
Temporalis, temperoparietal	..	..	1*	..	3	..	4
Soft-tissue free flaps							
Radial	8	29	..	..	4	..	41
Rectus abdominis	..	..	..	1	1	..	2
Latissimus dorsi	..	..	..	6	..	..	6
Anterolateral thigh	..	3	..	..	2	..	5
Hard-tissue or composite free flaps							
Radial	..	14	4	4	1	5	28
Fibula	..	3	..	..	..	..	3
DCIA/internal oblique	..	19	15	17	..	..	51
TDAA/latissimus dorsi	..	..	..	6	..	1	7
Total	8	68	20	34	11	6	147

DCIA=deep circumflex iliac artery (supplies the iliac crest). TDAA=thoracodorsal angular artery (supplies the scapula tip). *The one class III case treated with a temporoparietal flap was an 11-year-old patient who needed restoration of the orbit and obturation, with a view to complete reconstruction on completion of growth.

Table 2: **Summary of reconstructed midface and maxillary defects at the Regional Maxillofacial Unit in Liverpool, UK, since 1992 (number of cases according to method of repair)**

Reconstruction of the maxilla and midface

Class I

Most reconstructive techniques reported for class I defects are the fasciocutaneous radial forearm flap (table 1), typically used for midline hard-palate defects (class IIa), which reflects our own practice (table 2).

Class II

If the defect is less than half of the lateral alveolus and palate (class IIb), very good results can be achieved with either obturation or reconstruction. Any of the osteocutaneous free flaps will give excellent results in this class. Pedicled flaps such as the temporalis or temporoparietal will close the oroantral and nasal fistulae, but provide little option for a functioning dental prosthesis on the operated side. Even for larger dental defects (class IId), investigators have reported very good results with zygomatic implants to support the denture when the natural undercuts and retaining anatomy is also resected.[50]

For more posterior class IIb defects, it is not necessary to use bone as the ipsilateral incisors—canine can often be retained and a small sectional denture used to restore the dental aesthetics. For a soft-tissue reconstruction of the alveolus and palate, we now favour the anterolateral thigh, since the increased fat and thickness of the flap provides adequate filling of the dead space and reduces the risk of dehiscence.

The fasciocutaneous radial forearm (67 patients) is the most commonly reported flap for class II defects. A total of 121 patients (49%) have been reported using a soft-tissue option only, compared with 127 patients (51%) using vascularised bone from all the recognised donor sites (table 1). The most often reported composite flap for the class II defect is the fibula (63 cases; table 1), which provides most of the solutions and implants can be placed reliably. The pedicle is a favourable length and size, two-team operating is comfortable, and the donor-site complications are acceptable. Reconstruction with a composite fibula flap is ideal for class IIb defects, because the nose is well supported and midfacial collapse is unlikely. The main advantage of the DCIA with internal oblique or the TDAA flap is the use of muscle, which results in a more natural oral lining.

For class IIc defects, much depends on the loss of height of the perinasal maxilla. If there is loss of alar support, bones of smaller dimension such as the radius and fibula might not provide sufficient height to reliably support the oronasal region.

Class III

With class III defects, orbital support is lost as well as anterior support of the cheek and dental arch. This is the most difficult defect to restore and there is very little role for a prosthetic option. The results of failed obturation can result in midfacial collapse, which emphasises the need for choosing the correct option. Achievement of a good facial profile and orbital aesthetics with a secondary procedure is difficult once radiotherapy has resulted in scarred and contracted tissue.

Current opinion states that no single flap can provide reconstruction of class III defects.[51,52] Reconstruction must address support of the orbit and facial skin, and provide sufficient bone to ensure union from the alveolar remnant to the zygomatic buttress and close the oral and nasal defects. Restoration of the dental alveolus sufficiently for implant placement is also ideal.

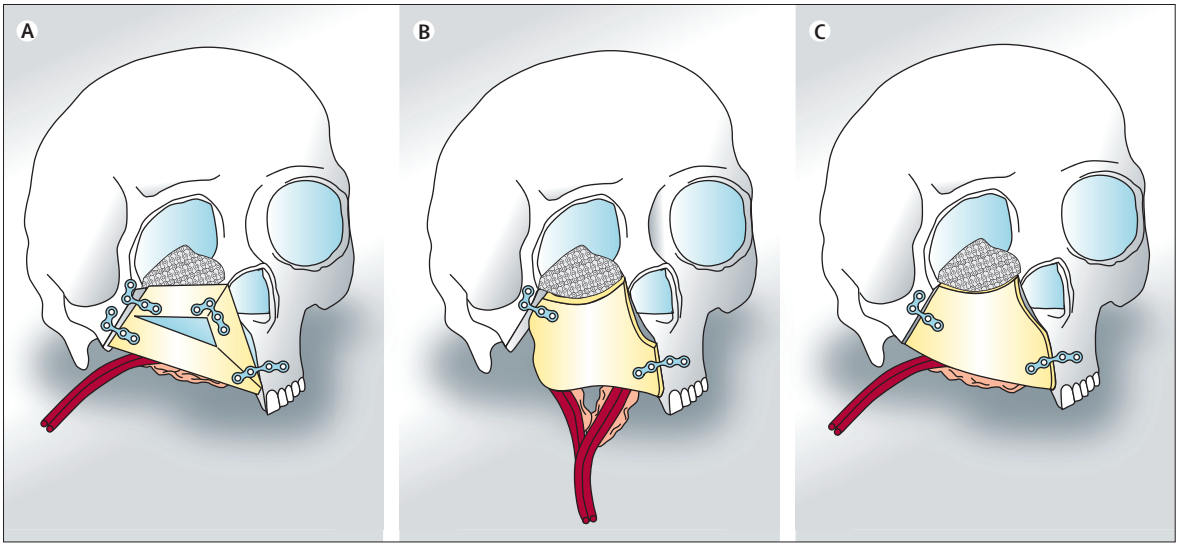

Figure 2: **Class IIIb defect created in a plastic skull model and reconstructed with fibula, TDAA flap, and DCIA flap, with use of titanium mesh for the orbital floor**
(A) Fibula flap. This figure shows the acute angles and illustrates the difficulty of planning skin islands. (B) TDAA flap. The flap is oriented so that the lateral thicker bone forms the alveolus. (C) DCIA flap. Fills the defect and allows the best option for an implant-retained prosthesis. TDAA=thoracodorsal angular artery. DCIA=deep circumflex iliac artery.

Previous reports have established the advantages of use of muscle to obturate the oroantral or nasal fistula and line the lateral nasal wall, since it epithelialises and leaves a natural oral and nasal mucosa.[43,53] Additionally, the implant and soft-tissue interface is favourable, requiring minimal preparation compared with a skin island.

Although class III defects involve a substantial loss of bone, 58% (114 of 197) of cases reported in the literature have been reconstructed with soft-tissue-only flaps. The rectus abdominus is the most often reported soft-tissue flap, but this requires non-vascularised bone to restore the orbital rim and floor, and in some cases the dental alveolus. The use of non-vascularised bone risks wound breakdown and graft loss, since postoperative radiotherapy is inevitably required. In both large series of repair of class III defects by use of rectus abdominus with (non-vascularised) iliac crest, no loss of primary-placed bone grafts was reported.[6,25] However, the ectropion rate was reported as 77% (ten of 13)[6] and 23% (five of 22),[25] and the provision of a dental prosthesis (only reported in the first series) was 54% (seven of 13),[6] which was presumably not implant-retained.

For this report, we created a class IIIb defect on a model, then reconstructed the defect using scaled models of the fibula, scapula, and iliac crest, as shown in figure 2. Although it is possible to support the orbital floor and provide a dental solution with a fibula flap, this approach requires two osteotomies and severe angles between the bone ends, as well as positioning of the skin islands which require separate perforators. A double-barrelled fibula might also be considered, but orientation of the skin islands remains a challenge. Surgeons proposing the fibula flap have highlighted this problem and suggested different solutions. Perhaps the best option involves two osteotomies and taking out a section of the bone, so that a single segment reconstructs the orbital floor; the space spans the nasal lining and the remaining two segments complete the alveolus and connect to the residual zygomatic buttress.[36] The investigators in both of largest series of fibula flap for maxillectomy concluded that this flap was inadequate for class III and IV defects, complicated by the problem of correct orientation of skin islands and soleus insertions.[32,34]

In our own practice, the DCIA with internal oblique satisfies most of the requirements mentioned above. The iliac crest is harvested as a block that can be shaped into the defect and contoured to replace the orbital rim, restore facial form, and provide sufficient bone for dental rehabilitation, even with more extensive resections of the alveolus (class IIId) if required (figure 3). Articulation with the residual nasal bones might not be possible, and in the case pictured, non-vascularised bone from the iliac crest was used to restore nasal support and was vascularised by the underlying muscle. The block of bone is of a sufficient size to form a union with the residual zygomatic buttress, and the muscle naturally obturates the remaining dead space, closing the oral fistula and lining the nasal airway. We have reported on the reliability of the DCIA with internal oblique in terms of dental prosthesis, and an implant-retained prosthesis is usually an option; good results have been achieved with full dentures supported by epithelialised muscle.[37]

The TDAA flap is gaining in popularity;[43] this flap also provides an adequate block of bone and plenty of muscle, since latissimus dorsi can be harvested with the scapula tip in true chimeric fashion, as originally described by the team in Zagreb, Croatia.[26] Although two-team harvesting is difficult, the main advantage

over the DCIA is the longer pedicle, which increases the options for anastomosis and will probably increase the reliability of the flap. Addition of skin supplied by the thoracodorsal artery is also possible if required, either as a musculocutaneous or a perforator flap.[44] The orientation of the flap in figure 2 shows the lateral part of the scapula tip articulating with the zygomatic buttress, which slightly shortens the pedicle length but retains the thickest bone for the dental alveolus[43,54] This technique was originally described for provision of support in the buttress region for class IV defects,[31] and more recently orientated with the tip of the scapula replacing the dental alveolus,[45] which is relatively thin bone and unlikely to be implantable. The TDAA and scapula tip has been described with serratus anterior,[42] or teres major,[43] but we prefer use of latissimus dorsi, which can be trimmed to the size of the fistula and provides reliably vascularised muscle to support non-vascularised orbital or titanium grafts.[54]

The loss of facial skin in class III defects is rare, since such an extensive tumour often requires orbital exenteration, but in this scenario we have used a DCIA perforator flap with internal oblique,[55] and still believe that for good orbital support and dental rehabilitation with implants, the DCIA option is better than the thinner bone of the scapula.

Class IV

Class IV defects involve patients with stage IV disease and poor prognosis, and this should be taken into account when choosing the most appropriate reconstructive option. Often the most difficult decision is whether to perform surgery at all, but if surgery is oncologically the most appropriate option, either the DCIA with internal oblique or the TDAA with latissimus dorsi provide excellent results. We now favour the more reliable TDAA flap, since dental rehabilitation is less important with a poor prognosis and the option of skin cover is less problematic. The problems of orbital support are no longer an issue with this reconstruction, and the use of latissimus dorsi muscle to obliterate the oral fistula and line the nasal cavity is ideal. Additionally, use of muscle to obturate the orbit allows planned favourable contraction to provide space for an orbital prosthesis, and provision of vascularised muscle to support repaired dura and prevent cerebrospinal fluid leaks.

Class V

Tumours arising in the orbitomaxillary regions are relatively simple to treat; exenteration of the orbit is necessary, but the palate remains intact and bone is generally not required. The aim in these cases is to prepare the orbit with sufficient depth to provide an orbital prosthesis, although we have used a composite radial flap to restore the lateral orbital wall. The prosthesis can disguise any loss of bone in the forehead region or cheek. Use of temporoparietal and temporalis flaps is ideal if the case is unilateral. For larger areas of skin loss, the anterolateral thigh or radial forearm can be a good option (figure 4), whereas the rectus or latissimus dorsi musculocutaneous option will obliterate the orbital defect and make the construction of an orbital prosthesis difficult, with a likely poorer appearance.

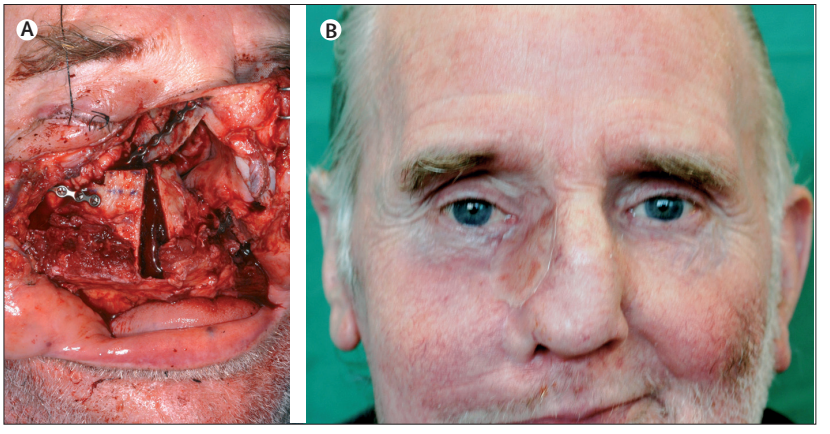

Figure 3: **T4a squamous-cell carcinoma requiring class IIId maxillectomy with excision of facial skin**
(A) Peroperative photograph showing osteotomised iliac crest (DCIA) to span the extensive alveolar defect, and free iliac crest to reconstruct the lateral nasal bones. (B) Some perinasal dehiscence patched with silastic but good orbital support and options for implant-retained dental prosthesis. DCIA=deep circumflex iliac artery.

Class VI

A nasoethmoid defect that does not include the palate or nasal bones does not generally require reconstruction, unless there is resection of a large area of dura and a high risk of a cerebrospinal fluid leak. Nasomaxillary defects that involve the nasal bone with or without skin require reconstruction. In this situation, the osteocutaneous radial forearm flap is our first option, and we had very acceptable results for the five patients we have treated (figure 5). The purpose of the bone is to provide support for the flap. The split radius provides a rounded graft on the outside, and the inner cut bone can be covered in fascia harvested from the arm to prevent exposure to air. The loss of nasal support is best reconstructed with vascularised bone, since grafts in this region do not survive well if radiotherapy is required. The risk of radial fracture has been greatly reduced by the use of a supportive plate, allowing more confidence with this donor site.[56] The combination of a forehead or glabellar flap with the composite radial is ideal, and allows the radial skin to be used for the inner nasal lining.

Conclusion

Trends in the provision of prosthetic devices and reconstructive options for maxillary defects will continue to be opinion-based rather than evidence-based. This Personal View attempts to bring together the latest opinions and detect patterns and trends in treatment choice. We comprehensively searched for reports published in English from 1998 to incorporate into the new classification. We also presented the experience of the Liverpool team,

Figure 4: **Lacrimal gland adenoidcystic carcinoma resected to leave class V defect**
Facial (A) and lateral (B) views after reconstruction with a composite radial forearm flap, showing sufficient space for a prosthesis.

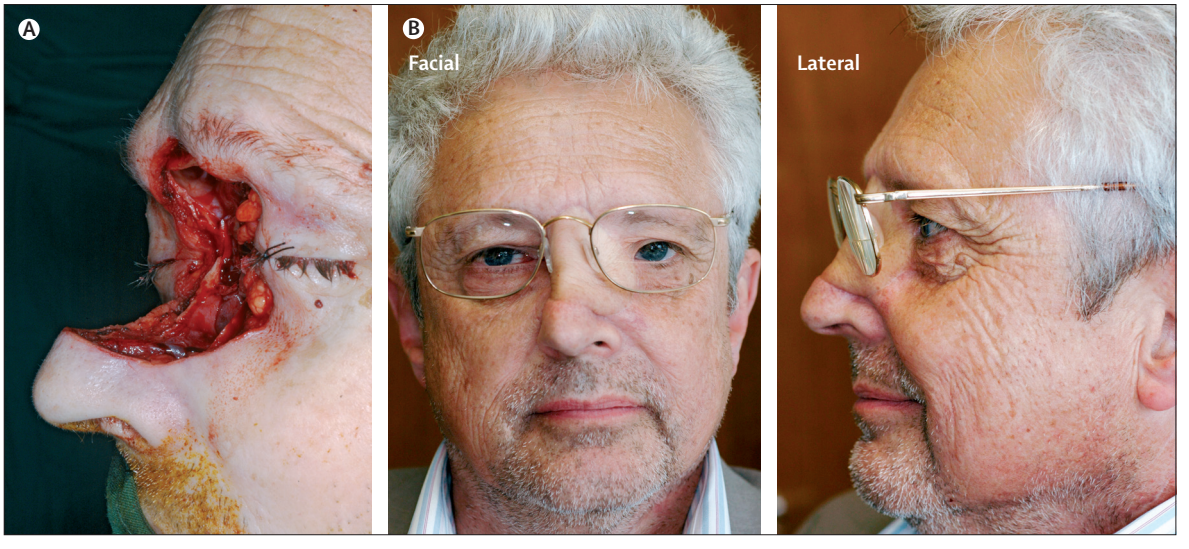

Figure 5: **T4a squamous-cell carcinoma requiring removal of nasal bones and overlying skin**
(A) Preoperative defect. (B) Postoperative facial and lateral view showing good nasal profile.

	I	II	III	IV	V	VI
Obturation	+	+	–	–	–	–
Local pedicled flaps						
Temporoparietal, temporalis	+	+ (b)	–	–	–	–
Soft-tissue free flaps						
Radial, anterolateral thigh	+	+ (a,b)	–	–	+	–
Rectus abdominus, latissimus dorsi	–	–	–	+	–	–
Hard-tissue or composite flaps						
Radial	+	+ (b,c)	–	–	+	+
Fibula	–	+	–	–	–	–
DCIA/internal oblique	–	+	+	+	–	–
Scapula	–	+	+	+	–	–
TDAA (with scapula tip)	–	+	+	+	+	+

Letters (a,b,c) refer to the horizontal classification (figure 1). +=recommended. –=not recommended. DCIA=deep circumflex iliac artery (supplies the iliac crest). TDAA=thoracodorsal angular artery (supplies the scapula tip).

Table 3: **Recommended method of reconstruction, according to classification of midface and maxillary defect**

consisting of four surgeons with a similar philosophy working with two restorative dentists with a special interest in this specialty. With so many options for this problem, development of a team-working relationship between the prosthetic and surgical side is essential.

Some trends are detectable from the studies summarised in table 1. Since 1998, Cordeiro and colleagues[3,6] have put forward the principle of non-vascularised bone-grafting techniques combined with the rectus abdominus flap for larger maxillary defects (class III–IV), but since 2000, there is a preference for the vascularised bone option of the TDAA flap, and some consolidation in opinion regarding the iliac crest with internal oblique. The advantage of both of these vascularised bone options is that the provision of a reasonable height of bone allows good bony adaptation, to promote healing and union at the alveolus and zygomatic remnant. The iliac crest with internal oblique is more difficult to raise than the TDAA flap, but the patient does not need turning or tilting and

Search strategy and selection criteria

References for this Personal View were obtained from a search of Embase and Medline, by use of the search terms "maxilla", "resection", "reconstruction", "rehabilitation", and "obturation", and from the reference lists of relevant reports. Only reports and abstracts published in English between January, 1998, and December, 2009, were included.

two-team operating is much more comfortable and possible. Both flaps provide adequate muscle to obturate the oral, nasal, and orbital defects, and the subsequent epithelialisation provides a very natural and functional result. The fibula flap can be skilfully adapted to provide a solution for class III defects,[36] but skin-island planning is difficult and problems increase if the lateral nasal bones require resection. This point is made by both large series reporting on use of this flap,[32,34] but reliable results are achieved for class IIa–d defects.

Table 3 presents an opinion on the use of the various flap options in relation to the suggested classification. The use of a combination of flaps is not recommended because the subscapular system provides chimeric options, and recipient vessel choices are limited by the increased distance from the midface to the neck. The DCIA can be used with internal oblique as a true chimeric option to include facial skin if the cutanous element is raised as a perforator flap.[55]

The DCIA with internal oblique is the gold standard for maxillary reconstruction because oral rehabiliation can be achieved with implant-retained dental options and good orbital support. The TDAA (with latissimus dorsi, teres major, or serratus anterior) also provides a muscle and bone alternative, but the bone stock is restricted, and the reliability of the blood supply to the bone for class II–IVd defects is in question. Class V defects can be restored with soft-tissue flaps and the composite radial forearm flap is an excellent option in the class VI defect.

Contributors

JSB did the literature search, wrote and revised the report. RJS provided advice on the report.

Conflicts of interest

JSB declared that he has no conflicts of interest. RJS is a consultant for the advisory board on head and neck oncology to GlaxoSmithKline.

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