Zygomatic Implants in Oncology Patients

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## Abstract

Zygomatic and modified zygomatic implants are emerging as a key adjunct in the management of patients presenting with maxillary and mid-facial benign and malignant diseases requiring radical resection to effect cure. Their popularity has gained momentum especially over the past 10 years and the evidence for their successful use continues to evolve and be presented by clinicians in high-volume cancer centres. From their inception, the zygomatic implant was conceived initially by Professor Branemark to support the maxillectomy patient by means of the remote anchorage that was available in the highly cortical zygomatic bone with the design incorporating the angle correction and reach into the oral cavity in order to provide the much needed support and retention for a subsequent prosthesis. This concept was taken up slowly around the world but now is becoming an area of huge interest amongst the multi-disciplinary teams who grapple with these challenge cases. This chapter will cover the application and evolution of the zygomatic implant and it’s associated techniques, both alone and in conjunction with microvascular free tissue transfer in the prosthetic and prosthodontic management of the oncology patient. It will discuss the evidence behind the treatments presented, the relevance of modified implant designs and illustrate the cutting edge new techniques such as the Zygomatic Implant Perforated Flap (ZIP Flap) technique which combines soft tissue reconstruction of the maxillary defect and full fixed dental reconstruction within weeks of surgery, irrespective of the need for adjuvant radiotherapy.

Challenges of the maxillofacial oncology patient

The maxillofacial oncology patient presents far more difficulties to the treating clinical team than any other patient who might benefit from the use of zygomatic implants. The central position of the maxilla within the face and it’s various relationships to important structures such as the orbits, the nose, the mouth, the oro-pharynx, the face, and the teeth, mean that the resection of any part of the maxilla and mid-face can have devastating consequences for the patient, even if their presenting disease is adequately controlled. The requirement to reconstruct and rehabilitate the patient is extremely high in order to effectively restore what was removed where at all possible, hopefully in a meaningful way that the patient can adapt to and continue to function successfully. The restoration of facial form, dental cosmesis and the preservation of functions such as speech, chewing, mouth opening and swallowing are paramount considerations in the management of these patients. The importance of the multi-disciplinary team including head & neck surgeons, oncologists, radiologists, pathologists, maxillofacial prosthodontists, speech and language therapists, anaplastologists and others is so important if patients are not going to be merely cured but effectively treated and rehabilitated to the highest levels possible. Ideally these patients should be managed in a high-volume head & neck cancer centre where significant inter-disciplinary care can be developed and provided as these tumours are relatively rare with maxillary and mid-facial cancers making up less than 6% of all head and neck cancers. Without this intensive combined multi-disciplinary approach, patients can be often left devastated, deformed and depressed with very poor quality of life. In addition, there is evidence that the long-term survival of this group of patients is lower than other sites within the head and neck(1) so the need for rapid and effective patient management is paramount. The emotional effects of this disease site should also not be forgotten with patients and their families often requiring significant emotional support and counselling prior to treatment.

## The Integrated Surgical Maxillofacial Prosthodontist

In the Merseyside Head & Neck Cancer Centre, we have developed a model of care for these group of patients with a strong emphasis on the incorporation a highly skilled surgical maxillofacial prosthodontist, whose main role is to emphasise the importance of prosthodontic and prosthetic implant-based rehabilitation for these patients and to deliver joint pre-prosthetic surgery and implant placement at the time of tumour resection. Our surgical team almost always includes a resective surgeon, a micro-vascular reconstructive surgeon and a surgical maxillofacial prosthodontist for patients with maxillary and mid-facial tumours. Following initial presentation and tissue diagnosis, the patients are seen for a team evaluation together with the supporting MRI, CT and dental radiographs to provide a comprehensive treatment plan and to decide whether the approach will be palliative, curative and/or rehabilitative. The patient’s overall medical fitness will be assessed especially if microvascular free tissue transfer is to be considered. A detailed dental assessment is undertaken to diagnose teeth of poor prognosis that should be removed as part of the patient’s treatment. Dental impressions and photographs are also taken to plan dental rehabilitation where required and to produce surgical templates or obturator prostheses.

## Ideal treatment goals

With all the available clinical information available, together with the input of the patient and their family, the aims of the proposed treatment will be explained. Primarily, patients are always concerned about the potential for cure and survival, but also the effect on cosmesis and post-treatment function has to be explained and understood. The potential need for post-operative (chemo-)radiotherapy is always discussed as well as it’s likely effect on the surgical/prosthetic reconstruction and other quality of life aspects.

Where a curative and rehabilitative approach is undertaken the ideal goals of treatment are;

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| Disease Control / Cure  Preservation / Restoration of Facial Form  Separation of the Oral Cavity from the Nose/Antrum  Dental Rehabilitation  Rapid Treatment & Rehabilitation  Low Prosthodontic Maintenance  Restoration of a Functional Quality of Life |

Disease control is beyond the scope of this chapter to discuss in detail, although needless to say is highly reliant on the presenting stage of disease, the particular tumour biology and behaviour as well as the adequacy of the initial resection and response to adjuvant chemo-(radiotherapy) where required. Where tumours are diagnosed at an early stage, outcomes and survival are generally better. The preservation or restoration of facial form is directly linked mainly to the vertical degree of the maxillary or mid-facial resection required. The greater the degree of bony resection required, the greater the impact on the post-operative facial form and the greater the need for micro-vascular bony reconstructive techniques. This is especially true when the orbital floor and/or zygoma are resected. In nasal / mid-facial resections, some patients may be managed with complex and often staged micro-vascular reconstructive surgeries, although the cosmetic outcome may not be as good as a prosthesis and the potential need for adjuvant radiotherapy often makes a prosthesis a more reliable option. The restoration of the teeth is also critical to lip support, which in turn also contributes to the final facial form following treatment.

The separation of the mouth from the nasal or antral cavities is very important for patients and clinicians alike as it impacts so greatly on functions such as speaking and swallowing. It can be accomplished both with an obturator prosthesis or surgically via local flaps or free tissue transfer. The decision here is often based on the patient’s fitness for more advanced surgical techniques as well as the availability of local surgical expertise. There is no real consensus or strong evidence that one approach is better than the other in terms of functional outcomes as both can give good results for chewing and speech(2). However, there is no doubt that prosthetic obturation brings about the potential for fluid and air leakage, crusting and hygiene issues and has a negative impact psychologically on some patients. The dental rehabilitation of these patients is the main thrust of this chapter and there is no doubt that this has now been transformed by the advent and use of zygomatic implants. When maxillary obturators are employed in a carefully planned manner, dental rehabilitation can be immediate with the fitting of a surgical obturator with teeth being inserted on the day of surgery. However, when free tissue transfer is employed to close maxillary defects, the use of conventional prosthodontic rehabilitation is often not possible and the maxillofacial prosthodontist often has to rely on the insertion of osseointegrated implants to provide a useful dental rehabilitation.

The provision of rapid dental & facial prosthetic rehabilitation on the whole mandates the insertion of zygomatic and dental implants at the same time as the primary surgery. This provides the opportunity for their early use, often before radiotherapy is used and before post-treatment scarring and fibrosis has occurred. There is certainly a growing trend towards primary implant insertion in the mandible at the time of tumour resection(3) with all it’s advantages for this patient group and, in the author’s experience, the need for baseline zygomatic implant insertion in maxillary and mid-face patients is even greater. Fortunately, when zygomatic implants are used primarily, the high initial stability achieved by the anchorage into the zygomatic basal bone facilitates immediate and early loading protocols(4) that can provide effective support and retention for oral and facial prostheses within a short period of the initial surgical resection. This is one of the greatest advantages of using zygomatic implants rather than other techniques such as digitally planned composite flap reconstructions for patients with malignant diseases of the maxilla. Whilst this latter technique is a potential viable alternative, it generally does not allow prosthodontic restoration at an early timepoint if post-operative chemo-radiotherapy is to be used. A recent publication from the Alberta group(5) who use this technique extensively confirmed that their mean time to restoration is approximately 9 months, although the number of maxillary cases was small and it wasn’t clear how many of the 5 patients treated were for malignancy and how many had received post-operative radiotherapy. Whilst 9 months to restoration is still a great improvement on previous conventional prosthodontic rehabilitation approaches in general, it is still a long period to be without a restoration in an ideal sense and this is an area where zygomatic implants can facilitate a more rapid approach.

Prosthodontic maintenance can be a significant issue for patients treated for malignancies in these sites. Even when zygomatic implants are employed to provide in-defect support and retention for complex prostheses, multiple and regular clinic visits maybe required, especially where obturator or facial prostheses are employed. This adds to the patient’s overall burden of treatment. Where a screw-retained fixed zygomatic implant supported dental prosthesis can be employed, the requirement for maintenance can be very much reduced and the number of clinic visits reduced. This concept underpins the rationale for the maxillary ZIP Flap(6) which, as we shall see later, combines the use of surgical closure of the maxillary defect and a fixed dental prosthesis.

The restoration of a functional quality of life (QOL) is very much a composite outcome based on a large number of factors and in many respects is affected by the outlook of the individual patient and their experiences. However, it is important to state the importance of on-going work in this area, especially where new techniques are being adopted, in order to give a patient-centred input to validate both patient acceptance and the functional efficacy of the treatments used. Due to the small numbers of patients potentially treated each year, even in high-volume centres, it is highly unlikely that randomised controlled trials could ever be devised and so the inclusion of these quality of life outcome measures together with patient interviews is important in helping to understand the advantages and limitations of the treatments used. Whilst a number of validated patient questionnaires have been devised the most-commonly used ones in our unit are the University of Washington Quality of Life Questionnaire (version 4) and the Liverpool Oral Rehabilitation Questionnaire (version 3)(7). The combination of these QOL questionnaires allow evaluation specifically of functional aspects such as chewing, swallowing and speech as well as more detailed patient information regarding aspects of the prosthodontic reconstructions being employed. Whatever the treatments employed or questionnaires used, our ideal aim is restore a functional quality of life as rapidly as possible following treatment by addressing and managing the key patient clinical issues wherever possible.

## Disease Classification & Treatment Options

The use of anatomical classifications is a helpful adjunct when considering the different treatment approaches as there is a great deal of difference in the complexity of treating a small low-level maxillary alveolus tumour compared to a large mid-facial cancer invading the orbit. Whilst a number of classifications have been published, we favour the use of the Brown Classification(8) which distinguishes between the vertical component of the proposed surgical resection (Classes I to VI) and the horizontal component of the resection (Classes a to d). This classification (Figure 13.1) also helps to delineate 3 main groups of patients namely;

* Low- Level Maxillary resections (Classes I & II)
* High-Level Maxillary resections (Classes III & IV)
* Non-Alveolar Mid-facial resections (Classes V & VI)

The majority of this chapter will discuss the management of low-level maxillary tumours as these make up the majority of the presenting cases. In addition, these low-level resections favour the use of zygomatic and modified zygomatic on a much more regular basis. Later sections will explore the use of zygomatic implants together with composite free flaps for high-level tumours and we will also discuss the application of zygomatic implants to support and retain nasal and mid-facial silicone prostheses.

## Low-Level Maxillary Resections Class I

The class I resection is the smallest vertical resection of the maxilla and generally relates to a resection mainly of alveolar bone only rather than involving the basal bone of the maxilla or hard palate itself. The most common clinical presentation requiring a class I resection are malignant gingival tumours. In the anterior pre- maxillary region, it does not result in a communication to the nasal cavity (figure 13.2), but resection of the alveolus posterior to the canine region often results in the creation of a defect into the maxillary antrum (figure 13.3). The rehabilitative approach for a class I resection will depend on the residual dental status and the access and bone availability for implant placement. For limited anterior resections like that demonstrated in figure 13.2, there is no primary implant option and restoration with a well-made partial denture is very acceptable. Where the size of the resection in the horizontal dimension is greater and more teeth are removed (or the patient is edentulous), the use of primary zygomatic and/or dental implants is encouraged to provide the patient with an early loaded fixed dental prosthesis where possible. Where the maxillary antrum is exposed via a more posterior resection, the use of the buccal fat pad and a buccal advancement flap is generally utilised to close this defect primarily to avoid the need for prosthetic obturation. Whilst this often causes a degree of alteration in the local anatomy with loss of the buccal sulcus, the use of a precision-retained implant or tooth-supported prosthesis can overcome this issue with no on-going detriment to the patient. Figure 13.4 shows a patient presenting with a malignant gingival tumour in the pre-maxilla. The tumour necessitated the removal of the anterior teeth from canine to canine as a minimum together with a class I bony resection. In order to facilitate a fixed dental rehabilitation following this resection, the first premolars were also removed. Prior to surgery, impressions were taken to construct an interim partial denture to be fitted at the time of surgery to support mucosal healing over the resected alveolus.

Under general anaesthesia, the teeth were initially removed prior to the resection of the tumour specimen incorporating the gingival tissue and underlying bone which was resected utilising piezosurgery for improved cutting control. Following the resection, access was gained to the right and left zygomatic regions and buccal windows created in the lateral sinus walls in order to preserve the integrity of the sinus membrane throughout the procedure (figure 13.5). The bony window and sinus membrane were mobilised and allowed to fall in towards the antrum with reflection of the membrane from the alveolar aspect and also supero-laterally to allow identification of the best entry points to the zygomatic bone itself. Following this the initial pilot holes were made in the zygomatic bones and then via the residual alveolus prior to full drilling sequence along the desired implant path. In Class I alveolar resections, the path of the zygomatic implant is usually intra-sinus due to the significant loss of alveolar height. The author always ensures active management of the sinus membrane together with a localised lifting and grafting procedure at the alveolar end where the bone is often very limited. The additional grafting (with xenograft/autogenous bone scrapings) ensures that the bone around the head of the zygomatic implant is robust and that any bone loss here is unlikely to result in an oro-antral communication. Grafting is also undertaken between and over the threads of the zygomatic implants. A collagen or platelet rich fibrin (PRF) membrane is then used to cover the augmented region during the healing phase in an attempt to encourage further bone formation along the length of the implant. The final angulation of the implant heads is carefully evaluated once placed with respect to the opposing dentition by the use of direction pins screwed into the implant heads as a final check procedure. Once the implants had been installed and the sinus bone grafting completed, abutments were placed and torqued into position. A split-skin graft was harvested from the thigh and inset over the denuded bone surface in the anterior maxilla in and around the implant heads. Master impressions and a jaw registration were taken and final soft tissue closure was undertaken. Finally, the temporary denture prosthesis was relined with periodontal dressing material and fitted prior to recovery of the patient (figure 13.6). Two weeks later, the temporary denture prosthesis was removed and the surgical area cleaned. A try in procedure was undertaken on a cast cobalt chromium framework to ensure that the intra-operative records were accurate and that the final tooth position was appropriate. The definitive pathology was reviewed to ensure that adequate margins had been obtained prior to fitting the definitive prosthesis one week later (figure 13.7). The healing of the split skin graft was monitored and tailored oral hygiene measures instituted by the patient. The patient was kept under regular review on a 6 to 8 week basis for disease surveillance in the first year as per our oncology review protocol.

### Zygomatic Implant Designs

The author exclusively uses the range of zygomatic implants provided by Southern Implants Ltd (figure 13.8) as they provide a number of different advantages for different anatomical situations and especially for the oncology patient. The connections are the same as is the implant head angulation which is at 55 degrees to the long axis. Where possible, when placing zygomatic implants in a conventional manner, the author favours the use of the conventional zygomatic implant with it’s roughened surface along it’s entire length as, together with the active sinus management described above, the expectation is subsequent osseointegration along the length of the implant. Where the size of the zygoma is limited and a quad approach is necessary, the use of an implant with a narrower apex such as the Zygan**™** Implant is employed. As well as a narrow apex at 3.4mm with 15mm of threads, it has a coronal thread with a low surface roughness and a central machined polished surface. Where the zygomatic implant is to be placed in an oncology-defect situation, as we will see in the Class II defect next, the Zygomatic Oncology Implant provides an excellent solution for the clinician and patient alike. This implant has the same apical size to a conventional implant (4.8mm) and has 15mm of threads with the rest of the implant having a machined polished finish. This ensures that where the implant emerges into the maxillary or nasal defect, it promotes improved soft tissue health and is easier to clean compared to an implant with roughened threads. The Oncology Implant also functions well for conventional extra-maxillary placement where this is required on a non-defect atrophic maxilla.

## Low-Level Maxillary Resections Class II

The Class II defect is the most commonly dealt with defect in this group of patients and provides a number of significant challenges. One of the most significant issues is the resultant oro-nasal communication and how this is managed. Compared to Class I defects, the Class II defect is not easily closed with local tissue and generally the main decision lies between prosthetic obturation and free vascularised tissue closure. The horizontal component of the Class II defect is also critical and figure 13.9 illustrates three different Class II defects, the anterior maxillary resection (sub-class ‘c’), the unilateral maxillary resection (sub-class ‘b’) and the sub-total horizontal resection (sub-class ‘d’). The ‘a’ subclass is a central palatal defect (see figure 13.1), which isn’t often managed with zygomatic implants and for sake of simplicity will not be discussed any further.

As the horizontal component of the resection increases, the more difficulty the patients experience with conventional obturation due to the reduction in the amount of unaffected maxilla and/or retained teeth present to provide support and retention for the prosthesis. Where the residual teeth are poor or the patient is edentulous, the level of potential compromise with obturation increases still further and the need for implant insertion is greater in order to assist with retention and stability of the prosthesis. Where the resection involves the soft palate, effective prosthetic obturation is much more challenging due to the mobile cut-edge of the soft palate and ideally where the soft palate is affected, the author prefers surgical reconstruction. If the patient is deemed fit enough for free tissue transfer then this is a useful way of closing the surgical defect but the use of these techniques can significantly compromise the degree to which the patient can be rehabilitated dentally. Whilst the use of soft tissue flaps to close Class II defects is common, they don’t provide a suitable level of support for dental prostheses and often patients can be left without a good option for rehabilitation. The use of composite (bone-containing) flaps such as the fibula, scapula or DCIA can be employed in the larger low-level resections but the morbidity is greater and the technical difficulty increased for the surgeon. In smaller low level defects their use is difficult if not impossible. Whilst some units routinely employ digital planning for composite flap reconstruction together with primary implant insertion, this is far from ubiquitous and for most patients, the implant based rehabilitation will be a secondary consideration with significant delays for the patient especially if the patient is irradiated following their resective surgery.

All in all, a balance has to be struck between the medical fitness and motivation of the patient, the size of the resection, the involvement of the soft palate, the post-resection dental status and quality, the likelihood of post-operative trismus and the skill mix and resources of the treating multi-disciplinary team. The speed of dental rehabilitation will very much depend on the techniques employed and this should be discussed with the patient, especially if they have a high dental awareness and motivation.

### Class II Decision-Making Algorithm

Figure 13.10 illustrates the step-by-step approach taken by the author and his colleagues in the management of the Class II patient. The first step is the patient’s suitability and fitness for surgery preferably with free tissue transfer. Where possible, our preference is to move down the surgical arm of the algorithm unless the patient is medically unfit for this level of surgery or there is another surgical reason why obturation should be chosen, as ideally, we are looking to keep maintenance to a minimum.

The next step is to assess the dental status of the patient and particularly the position of the resection on the alveolus. The number and quality of the remaining teeth after the proposed resection should be carefully investigated by thorough clinical and radiographic examination together with an assessment of the opposing dentition, the vertical dimension, the occlusal plane and any degree of vertical maxillary excess.

Where patients present with a high-quality dentition, where possible, these may be retained especially where the resection is posterior to the canine tooth (figure 13.11). Most patients can cope well with this shortened arch functionally and additional units can generally be provided for improved appearance if required by means of a small removable denture.

Where the resection comes to the midline or beyond, the options will be to undertake a bony reconstruction to retain the residual high quality teeth and aim to provide a subsequent implant based rehabilitation into the composite flap or to undertake a ZIP Flap(6) by placing zygomatic oncology implants on the defect side and consider the elective removal of teeth on the non-defect side to facilitate the placement of immediate dental implants into sockets or to allow the placement of conventional zygomatic implants if socket implants are problematic (figure 13.12). As the ZIP Flap allows for much quicker post-surgical dental rehabilitation for malignant tumours than the techniques associated with composite flaps, it has become our treatment of choice for the Class II maxillary defect.

Where the dental status is poor or the patient is already edentulous but fit for a soft tissue flap reconstruction, the ZIP Flap will be the treatment of choice for those patients wishing to have a dental rehabilitation as part of their oncology treatment.

## ZIP Flap Technique(6)

The Zygomatic Implant Perforated Flap technique, first published in 2017 was developed by the author and combines the benefits conferred by both soft tissue free-flap reconstruction (usually a radial forearm flap) to close the oro-nasal defect with simultaneous zygomatic oncology implant placement into the residual zygomatic bone and allowing the immediate use of the implants by perforating the soft tissue of the flap with a long abutment at the time of flap insetting (figure 13.14). The prosthodontic impression and registration procedures are undertaken during the primary surgery and a definitive implant-supported fixed bridge is subsequently fitted in the weeks following surgery, even if adjuvant radiotherapy is required for on-going disease management.

Figures 13.13 to 13.18 illustrates the surgical and prosthodontic approach on an 82-year-old female patient who presented with a low level squamous cell carcinoma (SCC) of the right maxillary alveolus requiring a Brown Class IIb resection. On presentation, it was clear that her dental status was poor with generalised periodontitis, over-eruption in places together with an ill-fitting maxillary partial denture. Prior to surgery, dental casts were mounted and registered and an intermediate maxillary complete denture fabricated to be used as an interim registration device during surgery. On the day of surgery, the remaining teeth were extracted and a Class IIb resection undertaken taking care not to disrupt the pterygoid region and hence reduce the chances of post-operative trismus. Four standard endosseous implants were placed in the mandible. A right neck access procedure was completed to find vessels to supply the soft tissue free flap. Zygomatic Oncology implants were then inserted into the residual zygomatic bone on the resected side with conventional zygomatic implants being inserted on the non-defect side. The placement of the oncology implants takes a much more horizontal path than their conventional counterparts (figure 13.19) in order to reduce the chances of exposure of the implant shaft due to the action of the buccinator muscle at the margin of the flap. The radial forearm free flap is raised by the reconstructive team in parallel to the implant placement. Following implant placement and closure of the non-defect side, multi-unit abutments are placed and torqued. Longer 5mm abutments are usually placed on the oncology implants to facilitate the subsequent flap perforation procedure. Impression copings are attached to the abutments and splinted together utilising a light-cured acrylic material (Individo**®** Lux; VOCO Gmbh; Germany). Protective caps of known height were then placed onto the multi-unit abutments and the maxillary complete denture prosthesis was then relined with silicone impression material to provide a guide to the tooth position, lip support and incisal level.

The radial forearm flap was then inset to the maxillary defect and it’s pedicle tunneled beneath the skin into the neck. Once the periphery of the flap had been sutured into position, the flap is carefully incised over the implant abutments which are carefully pushed through the flap ensuring a tight fit around the abutment. A small piece of polyvinyl mouth guard material was then used to stop the flap covering the abutments during the healing period. It was trimmed to encompass both implants and perforated with a 4mm tissue biopsy punch to ensure a tight fit on the implant abutments. New tapered abutment caps were then placed in order to retain the polyvinyl sheet during the healing period (figure 13.15). The flap pedicle was then anastomosed to vessels in the right neck prior to final neck wound closure and subsequent patient recovery.

Approximately two weeks later, the patient was seen in clinic for review and for the try-in of her fixed hybrid bridge prosthesis with a cobalt chromium metal framework. The plastic shield was removed and the tooth position examined. Minor changes were made to the tooth position and incisal level and the finalized metal-acrylic bridgework was fitted one week later. The definitive pathology was favourable and post-operative radiotherapy was not required. The patient was subsequently provided with a mandibular implant overdenture 2 months later. The soft tissue response around the oncology implant abutments was monitored and patient specific oral hygiene measures instituted. The patient reported a high degree of satisfaction with the results of her treatment. She reported high scores on follow-up QOL questionnaire evaluation with preservation of speech quality and a significant improvement in her masticatory ability compared to her pre-surgical state. Her facial appearance is unaffected by the surgery (figure 13.18).

The ZIP Flap can also be employed for the larger Class IId defects (figures 13.20 to 13.22) as well as the more anterior Class IIc defects (figures 13.23 to 13.26). In addition, we have utilized the thicker Antero-lateral thigh (ALT) flap in the larger defects but have found it harder to perforate on the day of surgery than the radial forearm flap due to the bulk and the increased risk to the very small perforating vessels. For the ALT case, we elected to come back 3 weeks post-surgery with a completed prostheses and to perforate at that time with some flap debulking (figure 13.21). The prosthesis rectified the sagging of this large flap and the patient went through post-operative radiotherapy with no adverse events to the flap or implant restoration. The dental and facial appearances were preserved well and the patient’s speech was extremely clear. He struggled to eat initially due to the bulk of the flap and his significant xerostomia which caused the food particles to stick to the flap. He continues in follow-up and a recent 18-month review demonstrated very acceptable facial and intra-oral appearances with some further shrinking of the flap (figure 13.22). The importance of post-radiotherapy shrinkage of soft tissue flaps in the maxilla should also be highlighted, as if too small a flap is harvested initially and the tissue is subsequently inset with some tension as well as implant perforation, there is a risk that it will pull away from the palate and create a fistula. Our approach has always been to take a generously proportioned soft tissue graft which can be inset into the maxillary defect without tension and have some scope for further shrinkage if radiotherapy is required. One of our early cases experienced flap breakdown at the palate margin but since adopting a more generous size graft approach, we have not had any cases of flap breakdown.

For the IIc anterior defect (figure 13.23), some controversy exists about whether bone is required to support the anterior part of the nose although in our experience, this has not been a major issue as we feel that the addition of extra soft tissue bulk in this region and the lip support provided by the fixed dental prosthesis provides a good facial result (figure 13.26).

The ZIP flap, in our opinion, is an elegant technique which combines not only disease control but provides a rapid functional rehabilitation for patients with low-level Class II maxillary tumours with low prosthodontic maintenance and preservation of QOL. It has allowed more patients to be dentally rehabilitated than in previous years and has simplified the treatment flow for many of our patients. Further longitudinal research is currently in place within our unit examining it’s efficacy in the longer term.

## Obturation of the Class II Maxillary Defect

Where patients are unfit for complex surgical approaches, prosthodontic obturation is mandated in order to preserve the patient’s speech, chewing and swallowing functions. This form of treatment has been in existence for decades and is the mainstay of Class II defect management in many parts of the world. A myriad of techniques exist for the fabrication of both simple single-part and highly complex multi-part obturators to solve the bespoke problems of patients requiring this form of treatment. The main support for a conventional obturator relies on the amount of remaining hard palate and the quality of the remaining teeth, whilst the retention is provided mainly by direct clasping of the undercuts associated with the teeth. If these undercuts don’t exist, some clinicians undertake extensive restoration of the remaining teeth to improve these aspects for the obturator prosthesis. Some retention can be provided by the maxillary defect as long as it is carefully prepared at the time of surgery with adjunctive procedures such as split-skin grafting to the cheek and removal of the inferior turbinate. Even with such modifications, conventional obturators always lack support on the major defect side and have a tendency to displace into the defect during function. Where the remaining teeth are poor or absent on the non-defect side, there is always a tendancy for the obturator to move during speech and chewing and this movement can cause soft tissue trauma and ulceration for some patients. In the Class IId situation, especially following total maxillectomy (figure 13.27) all the support is provided by the sensitive internal structures of the nose and patients find these prostheses extremely difficult to tolerate and function with.

The assessment of the patient’s dental status and motivation is extremely important at the pre-operative stage in formulating a treatment plan. The plan should encompass the extraction of any teeth with poor prognosis, the retention of strategic teeth which will contribute to the support and retention of the obturator together with the placement of dental and/or zygomatic implants to provide additional support and retention.

Depending on the position and size of the maxillary resection, the final obturator can be supported and retained by the teeth alone (figure 13.28), a combination of teeth and implants (figure 13.29-30) or be entirely implant supported (figure 13.31-32). As the horizontal component of the palatal resection increases there is a greater need for zygomatic implant placement to provide in-defect support and retention. The oncology zygomatic implant is the main implant used to support maxillary obturators in the defect and the author’s preference is to place them at the time of primary resective surgery. The primary stability, angulation and final implant head position is critical for successful prosthodontic use. Generally they should emerge in the canine and second premolar regions with the heads being at about the level of the previous root apices. It is also helpful to angulate the implant heads anteriorly to provide improved prosthodontic access in the case of post-operative trismus, which is not uncommon. Where possible, two oncology implants are placed on the defect side and where the patient has good quality teeth remaining on the non-defect side, this can be enough to provide a well supported and retained one-piece obturator. The implants are always splinted together with a cast bar incorporating precision attachments to retain the final prosthesis. There is no need for adjuvant split-skin grafting in these cases and the final obturator bung can be a “low-profile” polished acrylic design with only enough engagement into the defect to affect a peripheral seal as the retention of the prosthesis is being provided by the implants. Where only a single oncology implant can be placed on the defect side, additional implants should be placed on the non-defect side, with the sacrifice of additional teeth if required. In the edentulous patient, additional implants should always be placed on the non-defect side to provide splinting to the defect implants and additional retention and support on the non-defect side. In the total maxillectomy situation, bilateral oncology implants can be placed ideally in a quad configuration.

Following the resection and implant placement, an abutment level impression should be taken including the remaining teeth and palate and the superficial component of the defect. Significant undercuts within the defect and around the oncology implants should be blocked out with surgical gauze. An approximate jaw registration can be undertaken using a pre-made appliance and following this, the surgical obturator can be placed. The author’s preference is to use silicone putty to reline the surgical obturator in the defect with some material entering the undercuts around the implant abutment heads to provide temporary retention on the defect side. The patient is usually returned to the operating room, two weeks later to remove the surgical obturator, clean the defect and fit the interim implant supported obturator. The author often uses large magnets housed within a cobalt chrome cast bar as the main means of retention as it requires much less dexterity from the patients (who are often elderly) in order to ensure the correct seating of the prosthesis. This patient group require a significant level of clinical support in the early months following treatment especially if adjuvant radiotherapy is required. The dental hygienist can be a useful resource in supporting the patient’s hygiene measures around the implant superstructures. As the defect changes post-treatment, further modifications to the prosthesis to ensure an adequate peripheral seal may be required.

## High-Level Maxillary Resections (Class III/IV)

In addition to the removal of the maxillary alveolus and palate, high-level Class III resections involve the removal of additional structures such as the zygoma and the orbital floor. In Class IV resections, the orbital contents are removed in addition. These are often required due to large maxillary sinus tumours that present late and can be difficult to treat, usually requiring combined treatment with radiotherapy. The dental rehabilitation of this group of patients is extremely difficult and is poorly reported on in the literature. The ideal management of these defects from a rehabilitation point of view is with the use of composite free tissue transfer, which can provide bone for facial support and implant placement. In our unit, the vascularised hip graft based on the deep circumflex iliac artery (DCIA) is the first choice flap certainly for a class III defect although this is a highly technique sensitive reconstruction. The challenge for the reconstructive surgeon is placing the bone to provide both facial support and bone for implant placement. Figure 13.33-34 illustrates the management of a patient requiring a Class IIIb resection for SCC with a DCIA reconstruction and secondary implant-based rehabilitation. The CT scan demonstrates how the bone tends to flare out more posteriorly away from the dental arch. In this case, the use of a quad zygomatic approach not only dealt with the very atrophic non-defect side but was also used to bring the heads of the implants into the correct position on the reconstructed side to support the subsequent metal/acrylic fixed bridgework. The use of zygomatic implants directly into the DCIA flap is helpful as the bone is often of low-density. The use of longer implants together with some under-drilling allows the insertion of the implant with good primary stability.

## Non-Alveolar Mid-Facial Resections (Classes V & VI)

The final group of oncology patients benefitting from the placement of zygomatic implants are those presenting with orbito-facial (Class V) and mid-facial (nasal)(Class VI) malignancies that require radical surgery and a subsequent facial prosthesis. Of the two classes, the Class VI resection is much more common and is usually required for nasal tumours arising internally from the mucosa or externally arising from the skin. The use of zygomatic implants in mid-facial resections was reported in 2006 by Bowden et al.(9) and involves the placement of zygomatic implants in a horizontal manner across the face with the head of the implant emerging on the lateral aspect of the nasal defect with the prosthetic axis facing anteriorly. Published case series report high levels of success with this technique(10). Figure 13.35 demonstrates the surgical procedure favoured by the author with the implant running within the anterior wall of the maxillary sinus. Once the nasal resection has been undertaken, the skin is reflected from the anterior surface of the maxilla and the zygomatic body in a sub-periosteal plane. The infra-orbital nerve is identified and protected. Care is taken not to perforate the mucosa leading into the oral cavity on the inferior aspect of the dissection. A bony window is cut along the anterior wall of the sinus without perforating the sinus membrane. The sinus membrane is elevated from the anterior piriform region across to the medial internal aspect of the zygomatic body. An initial pilot hole is made into the zygoma to ensure ideal placement and maximal primary stability. The entrance hole for the osteotomy is then made through the thin bone of the lateral nasal wall and the path of the implant follows along the slot window created in the lateral maxillary wall and connects with the pilot hole in the zygomatic body. The drill sequence is followed with the osteotomy traversing the body of the zygomatic bone through to it’s external surface. The appropriate length implant is then placed in this extra-sinus but intra-maxillary path. Xenograft bone is utilised over the exposed threads together with a collagen based membrane prior to wound closure. The implant procedure is repeated on the contralateral side and where bone exists in the nasion region, a short dental implant can be placed. Split-skin grafts are placed on the lateral aspects of the wound and over the superior surface of the lip to provide a robust environment for a prosthesis and to reduce scar contraction of the upper lip (figure 13.36). Abutments are placed/torqued and the impression copings splinted into place with light-cured acrylic material to ensure an accurate pick up. The excess undercut within the nasal cavity is blocked out with gauze and a facial impression is then carried out using a combination of silicone impression materials (medium/heavy body). Fragments of wooden tongue spatulas are used to reinforce the impression and prevent distortion and a final alginate impression is taken to capture the wider facial field including the eyes. The whole impression is supported and backed by a modified plastic facial shield normally used by hairdressers. This removes the need to back the impression with plaster of paris and makes the impression process much quicker. The nose is packed and the patient is fitted with a temporary nasal shield whilst waiting for the their first silicone prosthesis. The impression is cast and this allows the fabrication of a cast metal bar incorporating precision attachments or a magnet as well as the initial was nasal template. The try in visit is usually scheduled for 4 weeks post-operatively to allow time for healing with the initial implant retained prosthesis being fitted around 6 weeks (figure 13.37). Patients requiring radiotherapy usually start treatment around the same time and every effort is made to fit the initial prosthesis beforehand.

In Class V defects, the overall zygomatic implant strategy is the same with implants being oriented in a horizontal fashion although the extent of the resection often allow the use of oncology implants where the lateral maxillary wall has been resected. In addition to horizontal zygomatic implant placement, standard dental implants can be placed into the superior orbital rim and the combination of these implants can be used to support a one-piece metal framework with embedded retaining magnets to retain the usually much more extensive facial prosthesis. Figure 13.38-41 illustrates the management of a recent case presenting with an extensive class V facial SCC.

## Zygomatic Implant Survival in Oncology Patients

The use of zygomatic implants in oncology patients reported in the literature is quite limited to date but is a growing area of publication. The initial reports from the work inspired by Professor Branemark were presented briefly in a paper by Parel(11) in 2001 and referenced a small series of approximately 24 patients who received implants into the zygomatic bone following maxillectomy. The implants inserted were between 25 and 60mm in length and generally the assumption from the paper that they were placed at a secondary time-point following maxillectomy in order to assist with obturator prosthesis retention. The implants inserted were allowed 5 to 6 months to achieve osseointegration prior to restoration. No data was presented on other risk factors such as radiotherapy or smoking although it was clear that some patients had been irradiated. No failures were reported with a follow-up from 1 to 12 years. Subsequent reported case series (Table 13.1) were not quite as promising with implant survival ranging from 79% to 100% with the vast majority of centres still placing zygomatic implants at a secondary time-point.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Study** | **Cohort / Approach** | **Radiotherapy** | **N** | **Follow-up** | **Zygomatic Implant survival** |
| Parel *et al* 2002(11) | Maxillectomy/cleft defects - Secondary placement | Not stated | 27 patients  65 zygomatic Implants | 1-12 years | 100% |
| Schmidt *et al* 2004(12) | Large Maxillary defects mainly malignant – 2 primary placement; 7 secondary placement | 4 Post implant placement;  1 Pre Implant placement | 9 patients  28 zygomatic implants; 10 dental | Not stated | 79% *(only 5 patients restored)* |
| Zwahlen *et al.* 2006(13) | Mix of patients including 5 pts with maxillary defects (secondary placement & 6month integration period) | Not stated | 5  patients  9 zygomatic Implants; 42 dental | Not stated | 100% |
| Boyes-Varley *et al.* 2007(4) | Maxillectomy defects. Primary Placement. Immediate Loading | 5 post implant placement; 1 pre-implant placement | 20 Patients;  40 oncology implants; 66 dental | 6-96 months | 100% |
| Landes *et al.* 2009.(14) | Mixture of Pts including maxillary defects; 2 primary placement; 10 secondary placement; delayed loading | 7 post-implant radiotherapy; 7 pre-implant chemotherapy | 12 patients  26 Zygomatic; 18 dental | 15-100 months | 77% |
| Huang *et al.(15)* | Maxillary resection +/- composite reconstruction; secondary placement | No radiotherapy | 24 patients; 9 zygomatic; 79 dental | 18-137 months | 89% |
| Pellegrino *et al.* 2015(16) | Maxillectomy defects. Secondary placement.  Immediate loading (4pts); delayed loading (1 pt.) | 1 patient post-implant placement | 5 patients;  17 Zygomatic implants | 10-29 months | 94% |
| Butterworth 2018 *(In Press)* | Mid-facial & Maxillary Oncology Patients; primary vs secondary placement; early & delayed loading | 9 pre-implant placement; 15 post-implant placement | 49 patients;  135 Zygomatic implants; 33 dental | 2-110 months | 94% 12 month survival estimate.  92% 60 month survival estimate |

Table 13.1 Main published evidence regarding the use of zygomatic implants for dental rehabilitation in maxillary oncology patients.

The study of Boyes-Varley *et al.(4)* in 2007 however reported the highly successful placement of the first zygomatic oncology implants in 20 patients at the time of primary maxillectomy surgery together with additional dental implants placed on the non-defect side. They also reported the immediate loading of these implants in the 2 weeks following surgery to support precision retained obturator prostheses. They reported 100% implant survival over 6-96 months follow-up with this protocol whilst acknowledging the large prosthodontic burden of visits especially associated with adjustments around speech.

The apparent disparity between survival rates for primary placed vs secondarily placed zygomatic implants led to a prospective study by the author over a ten-year period from 2006 to 2016 to examine the survival and usability of implants placed at our centre together with an analysis of any differences due to timing of placement or anchorage concept (*publication in press 2018*). The study population included 49 patients and 131 zygomatic implants. Only 9 implants have been lost during this study period and the 12-month and 60-month survival estimates were 94% and 92% respectively. Half the patient group received radiotherapy prior to or immediately following implant placement. Interestingly there were no statistically significant differences in respect to the timing of implant placement or whether the implant was placed conventionally or with the remote anchorage concept. These data demonstrate the high promise of the zygomatic implant technique for patients with mid-facial and maxillary malignancy irrespective of the need for radiotherapy and support the concept of early placement and early restoration as the emerging standard of care.

## Summary

Conventional and modified zygomatic implants provide a highly effective platform in the support of oral and facial prosthetic rehabilitation in oncology patients. Whether they are used in isolation or in conjunction with other surgical reconstructive techniques, the remote anchorage concept is robust, providing high primary stability and the opportunity for early prosthetic rehabilitation of this unfortunate and deserving patient group. The rehabilitation-focussed multi-disciplinary head & neck cancer team would be well advised to embrace zygomatic implants as part of their extensive armamentarium of treatment options.

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## Figure Captions

Figure 13.1

The Brown Classification of maxillary & mid-facial resections.

Figure 13.2

A Class I resection of the anterior maxilla for a small gingival tumour.

Figure 13.3

A Class I resection of the posterior maxilla with subsequent oro-antral defect.

Figure 13.4

Clinical and radiographic views of a patient presenting with a gingival SCC in the anterior maxilla.

Figure 13.5

Intra-operative views demonstrating anterior maxillary rim resection and conventional zygomatic implant placement with management of the maxillary sinuses.

Figure 13.6

Temporary partial denture re-lined with periodontal dressing and radiographic view of zygomatic implant placement.

Figure 13.7

Palatal and facial views of definitive zygomatic implant supported bridgework.

Figure 13.8

Conventional (left), Oncology (middle) and Zygan™ (right) zygomatic implants designed for differing anatomical conditions (Southern Implants Ltd).

Figure 13.9

Class II maxillary with different horizontal sub-classes; class b (top), class c (middle); class d (bottom)

Figure 13.10

Class II defect treatment decision-making algorithm.

Figure 13.11

Posterior class IIb resection in a patient with good quality residual dentition managed with resection and ALT soft tissue reconstruction only (courtesy Prof R Shaw).

Figure 13.12

Hemi-maxillectomy in a patient with high quality remaining teeth on the non-defect side with decision to sacrifice teeth to facilitate contra-lateral zygomatic implant placement.

Figure 13.13

An elderly patient with poor residual dentition requiring a class IIb maxillary resection.

Figure 13.14

Following resection and dental clearance, conventional and oncology zygomatic implants are placed. Abutments are placed and an abutment level impression is undertaken using light cured acrylic material.

Figure 13.15

The incisal level and occlusal plane are registered with a pre-made acrylic denture before the soft tissue flap is inset and perforated over the defect side abutments. The soft polythene sheet is placed to prevent soft tissue overgrowth over the abutments during initial healing.

Figure 13.16

Intra-oral appearance 18 days post surgery before and after removal of the soft polythene sheet together with panoramic radiograph.

Figure 13.17

Definitive metal-acylic fixed prosthesis fitted at 6 weeks following surgery. Note the excellent soft tissue reconstruction and slight soft tissue excess on the defect side.

Figure 13.18

Facial appearance and prosthetic occlusion 6 months post-surgery.

Figure 13.19

The zygomatic oncology implant is placed is a more horizontal fashion when compared to the conventionally placed zygomatic implant.

Figure 13.20

A large class IId maxillectomy treated with the ZIP Flap approach.

Figure 13.21

The large ALT flap placed at primary surgery was perforated at 3 weeks post-operatively with the fitting of the initial metal-acrylic fixed prosthesis which helped to lift up the sagging soft tissue flap.

Figure 13.22

Facial and intra-oral appearance 18 months following radical surgery and post-operative radiotherapy.

Figure 13.23

New anterior maxillary malignant tumour requiring class IIc maxillectomy. This patient previously had a left class IIb resection and soft tissue flap previously.

Figure 13.24

Quad zygomatic implant placement, registration and inset of radial forearm flap with perforation and use of polythene membrane.

Figure 13.25

Implant supported fixed bridgework fitted within 6 weeks of primary surgery. Note the accurate 3-dimensional placement facilitating ideal screw positions on the prosthesis.

Figure 13.26

Excellent preservation of facial appearance 6 months post-operatively. No adjuvant radiotherapy was required.

Figure 13.27

The Class 2d total maxillectomy defect provides a poor foundation for the support and retention of a conventional obturator.

Figure 13.28

A posterior class IIb resection in a patient with good quality remaining teeth which can effectively support an obturator.

Figure 13.29

A class IIb malignant resection in a paediatric patient with the primary insertion of oncology zygomatic implants.

Figure 13.30

A low-profile simple acrylic obturator supported by teeth and zygomatic implant bar with precision attachments for retention.

Figure 13.31

A class IId total maxillectomy for SCC. Four oncology zygomatic implants were placed at the time of the resection.

Figure 13.32

Complete Maxillary obturator supported by cross-arch splinted bar magnet apparatus.

Figure 13.33

Class IIIb maxillectomy reconstructed with DCIA composite flap with bone volume and location shown on the CT reconstruction. Zygomatic implants placed in quad formation into atrophic left maxilla and directly into the vascularised hip bone.

Figure 13.34

Restored case with healed vestibuloplasty and plain film showing the extent of implantation within the DCIA graft.

Figure 13.35

Horizontal placement of conventional zygomatic implants following rhinectomy with preservation of the sinus lining and peri-implant grafting.

Figure 13.36

Clinical & radiographic views of healed situation following rhinectomy, implant placement and split-skin grafting.

Figure 13.37

Zygomatic Implant retained bar-magnet and silicone nasal prosthesis with high retention and stability.

Figure 13.38

Large facial tumour requiring a class V orbits-facial resection with primary horizontal zygomatic and orbital rim implants.

Figure 13.39

Abutments and impression copings placed with rigid splinting with light-cured acrylic material prior to facial impression.

Figure 13.40

Multi-phase full facial impression utilising heavy body silicone and alginate backed with plastic facial shield.

Figure 13.41

One piece cobalt-chrome bar with 2 embedded magnets to retain initial closed-eye silicone prosthesis.