Three Tumor Patients with Total Maxillectomy Rehabilitated with Implant-Supported Frameworks and Maxillary Obturators: A Follow-Up Report

Anders Örtorp, DDS, PhD*

ABSTRACT

Background: Few reports are available on treatment using implant-supported frameworks with maxillary obturators after total maxillectomy on tumor patients.

Purpose: To describe, evaluate, and report the clinical and radiographic performance of implant-supported frameworks and maxillary obturators after maxillectomy during the first years of function.

Materials and Methods: Three patients with cancer in the maxillary region treated by total maxillectomy were rehabilitated. Seventeen dental and two craniofacial implants were installed, and the patients each received implant-supported, screw-retained, three-unit frameworks with a U-shaped bar and obturators retained by four magnetic attachments. Clinical and radiographic data were collected up to 7 years of follow-up.

Results: The frequency of complications was low. Two craniofacial implants and one dental implant were loose and removed at abutment connection. No implants were lost after framework connection, and the mean marginal bone loss was small.

Conclusion: Within the limitations of this report, dental implants are useful for rehabilitation of total maxillectomy patients, and a three-unit, screw-retained, implant-supported framework with maxillary obturator retained by magnetic attachment is a successful treatment concept for this patient group.

KEY WORDS: complications, framework design, magnets, maxillary defect, zygoma implants

Cancer in the maxillary region is treated in many different ways. Despite improvements in separate treatment options or combinations of chemotherapy, radiation, and surgical techniques, some patients must undergo partial and total maxillectomy as part of tumor treatment.[1] Obturator therapy to restore oral functions has been used on patients with partial and total maxillectomy for many years.[2] This treatment involves a prosthetic challenge with a risk of many problems such as poor function that may include loosening of the obturator; mastication problems; fragile mucosa; leakage of saliva, liquid, and/or food; and problems with speech, aesthetics, and social integration, with psychological sequelae.[2–4] However, surgical techniques to rehabilitate patients with extensive soft and hard tissue loss have improved regarding tissue and bone augmentation, for example, autogenous fibula-free flap with or without dental implants and different prosthetic solutions.[5–8] In some patients, rehabilitation with surgical closure or distraction osteogenesis[9] of the defect is impossible because of factors such as irradiation, hospitalization, risk of advanced complications, treatment time, financial issues, and denial from the patients.[10,11]

Since the introduction of a method that also uses dental implants in the zygoma,[1,11,12] obturator retention has improved, with better stability and retention in the patient group that is not appropriate for vascularized

*Associate professor, prosthodontist, Department of Prosthetic Dentistry/Dental Materials Science, Institute of Odontology, The Sahlgrenska Academy, University of Gothenburg, Göteborg, Sweden

Reprint requests: Dr. Anders Örtorp, Department of Prosthetic Dentistry/Dental Materials Science, Institute of Odontology, Box 450, SE-405 30 Göteborg, Sweden; e-mail: anders.ortorp@vgregion.se

DOI 10.1111/j.1708-8208.2009.00164.x

bone-containing free flaps.[4,13] This report aimed to describe and evaluate the clinical and radiographic performance of implant-supported, screw-retained frameworks and maxillary obturators retained by magnetic attachment after maxillectomy in tumor patients during the first years of function.

MATERIALS AND METHODS

Three maxillectomy tumor patients provided with fixed screw-retained, implant-supported, three-unit frameworks and magnetic retained[14] obturators were followed-up at the Brånemark Clinic, Göteborg, Sweden by one prosthodontist. The patient characteristics are presented in Table 1. None of the patients were smokers.

Treatment planning was performed with a team of specialists in maxillofacial surgery, ENT, prosthodontics, and radiology; a dental technician; and an anaplastologist. Preoperative radiological examinations included orthopantomogram and computerized tomography for possible implant sites. Dental implant surgery was performed by three different surgeons according to standard two-stage surgical procedure with a healing period of 7 to 8 months before abutment connection.[15] For optimal fixture and framework design, the following parameters were analyzed: (1) location and number of implants required; (2) fixture number, position, length, and diameter; (3) attachment method; (4) framework design and material in terms of loading and cleaning access; and (5) shape of bar and number/location of attachments.

In addition, aesthetics, ethical problems, limited jaw movement, predictable mandibular treatment,[16] financial issues, and time schedules for prosthodontics, and retention after implant treatment were considered and analyzed. The prosthetic treatment aimed to restore and improve the oral functions and aesthetics.

The technique to fabricate all frameworks and obturators is presented for patient 1. After final tightening of the framework locking screws, the patients were scheduled for checkups after 6 months and once a year thereafter. Recalls on an individual basis were used when considered necessary, and the patients contacted the clinic whenever they had any problems. Radiographic examinations at prosthesis placement and annual checkups were performed in the Specialist Clinic for Oral and Maxillofacial Radiology (Göteborg, Sweden) by using intraoral apical radiographs,[17] orthopantomogram, or scanograms.

Data were collected on the number of clinical appointments from prosthesis insertion at the Brånemark Clinic to the last annual checkup, and all problems encountered after placement of the prostheses. Marginal bone loss was measured,[17] and frameworks were to be removed to test implant stability whenever radiograph signs and/or clinical symptoms were present to suspect that an implant had lost osseointegration.[18] However, because frameworks were not removed on a routine basis to confirm osseointegration, only survival criteria for implants have been used.[19]

Patient Presentations

Patient 1. A patient with cancer in the hard palate and nose (see Table 1) was admitted for surgical treatment of the tumor. Resection of the lower part of the nose, frontal part of the nose floor, maxilla, and central parts of the upper lip was performed. The patient received a conventional obturator in 2000. It did not feel secure, however, and implants (Nobel Biocare AB, Göteborg, Sweden; flange fixtures, Cochlear, Mölnlycke, Sweden) were inserted in 2001 (Table 2).

One-stage surgery was performed at the same time in the mandible with five implants and multi-unit abutments (Nobel Biocare AB), and the patient received a milled titanium bridge (Procera® Implant Bridge, Nobel Biocare AB) according to the early loading concept.[20,21]

TABLE 1 Patient Characteristics

Patient No.	Age at Tumor Surgery (Years)	Tumor Surgery (Year)	Sex	Tumor Diagnosis	Radiation Dose (Gy) Before Resection	Chemotherapy Before Resection	HBO	Free Iliac Crest Graft
1	64	2000	M	Carcinoma	No	No	No	No
2	52	1977	M	Squamous cell carcinoma	20	Yes	Yes	Pterygoid process
3	32	1992, 1996	F	Chondrosarcoma	No	No	No	No

HBO = hyperbaric oxygen therapy.

TABLE 2 Original Implants/Abutments Inserted in the Resection Area and Implant Site Distribution

Patient No.	No. of Implants	Length, Ø Implants (mm)	Implant System	Implant Site				No. of Abutments Length (mm)
				Zygoma	Tuber	Pterygoid Process	Nasal or Infraorbital Margin	
1	7	1 × 20; Ø3.75	Brånemark System	2	3	—	2*	2 × 9, mua
		2 × 15; Ø3.75						2 × 5 mua; 30°
		1 × 7; Ø3.75						1 × 4 st.; 30°
		1 × 10; Ø4.0						
		2* × 4; Ø3.75	Cochlear					
2	7†	1 × 7; Ø3.75	Brånemark System	2	—	4	1	1 × 4, st.
		3 × 13; Ø3.75						1 × 7, st.
		1 × 18; Ø3.75						3 × 10, st.
		2 × 20; Ø3.75						
3	5	4 × 17; Ø4,	Astra Tech TiOblast	2	3*	—	—	2 × 15; 45°
		1 × 15; Ø3.5						2 × 0; 45°

*Two craniofacial implants in the walls of the medial sinus maxillaries were nonintegrated and one implant in the tuber area. These were removed before prosthodontics.
†One implant in the infraorbital margin and one on the left side zygoma became sleeping implants.
mua = multiunit abutment; st. = standard.

Figure 1 Patient 1: impression copings seated and try-in of tray before final impression with polyether.

A primary impression of the upper jaw with alginate (Xantalgin® Select, Heraeus Kulzer, Hanau, Germany) at the time of implant surgery was performed, and an individualized open tray (Triad® Custom tray material, DENTSPLY De Trey GmbH, Konstanz, Germany) was constructed for an alginate impression at abutment surgery to register the tilting of the implants and for the final impression with polyether (Impregum™ Penta™ Soft, 3M ESPE, Seefelt, Germany) a few weeks later (Figure 1). For two of the implants, the impression was at implant level to make it possible for the dental technician to choose abutments. A master cast with replicas (Nobel Biocare AB) was fabricated, and a parallel bur (Figure 2) was used for laboratory verification of the parallelism during wax-up of the framework parts. Try-in of the three-piece cast gold alloy (Protor® 2, Cendres+Métaux SA, Biel/Bienne, Switzerland) implant retained framework with a U-shaped bar (System Macro, DCA 514, Nobel Biocare AB) and four integrated keepers was performed (Figures 3 and 4). The technique to fabricate the obturator followed the standard laboratory and clinical protocol, including determination of jaw relations up to completion of the try-in of tooth setup, which was followed by a reline impression (Xantopren® L blue, Heraeus Kulzer) and completion by heat-cured acrylic resin (Microdent, Esschem Ltd, Seaham, England) that also incorporated the four magnets (Magna-Cap MAXI, 7.2 N, 5.5 mm Ø, Technovent Ltd, Leeds, England).[14,22] Finally, the framework and obturator were refined and polished, and completed in 2001 by checking the fit of the framework to the obturator and to the five abutments clinically and

Figure 2 Patient 1: a parallel bur was used for laboratory verification of the parallelism during wax-up of the three-piece framework, made because of different tilting of the implants on the left and right sides. The two first bar sections have been waxed.

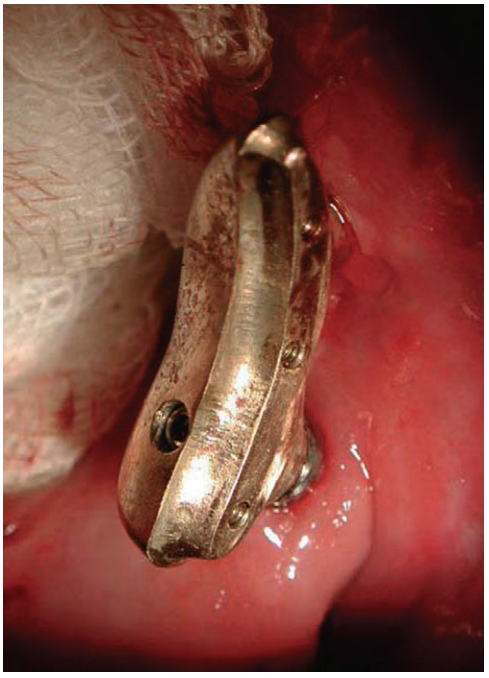

Figure 3 Patient 1: one section of the framework on the left side retained on two implants. Before connection of the supra bar of the three-piece gold alloy framework.

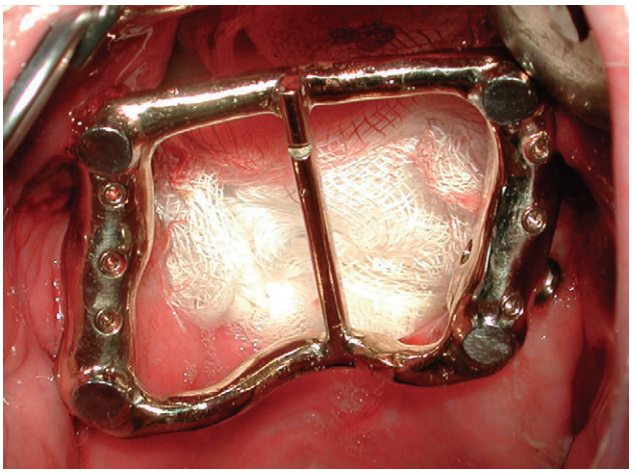

Figure 4 Patient 1: occlusal view of try-in of the three-piece screw-retained gold alloy implant retained framework.

radiologically (Figures 5 and 6). The silicone nose prosthesis (Realistic A588-2, Factor 2, Lakeside, AZ, USA) was fitted onto the obturator by one magnet (Multi-Purpose Magnet Attachment, 6.5 N, Ø 9.4 mm, Technovent Ltd)[14,23] and a cap (gold cap ball attachment, Nobel Biocare AB; Figures 7 and 8).

Patient 2. A patient with a tumor (see Table 1) in the right part of the maxilla underwent resection, and was given an obturator due to last until 1991. In 1991, a bone graft and implant installation (Nobel Biocare AB; see Table 2) were performed at another center. A framework and an obturator retained by clips were inserted on five implants (two implants became "sleeping implants").

Five implants (13 mm, Ø 3.75; Nobel Biocare AB) were installed in the mandible, and after a second-stage surgery five abutments were connected.[15,16] Finally, a cast gold alloy framework with resin teeth was fabricated for the mandible.[16]

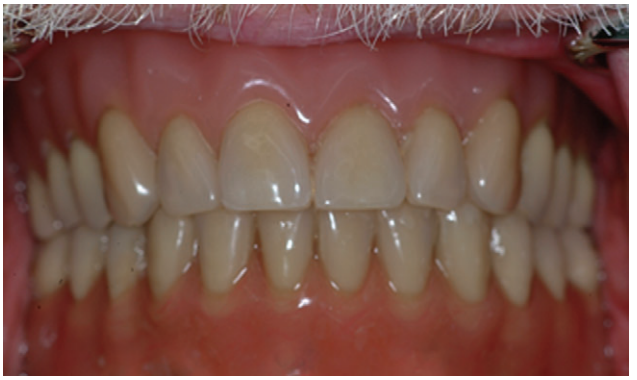

Figure 5 Patient 1: clinical view on obturator attached intraorally at the 5-year checkup.

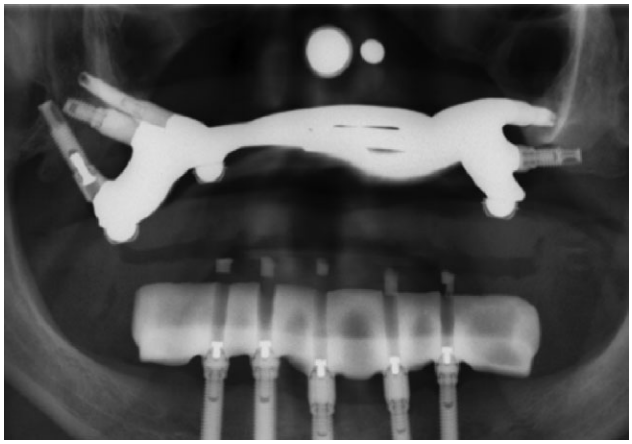

Figure 6 Patient 1: orthopantomogram with cast gold alloy framework and obturator connection on five implants at the 3-year follow-up. A milled fixed implant-supported titanium prosthesis in the mandible.

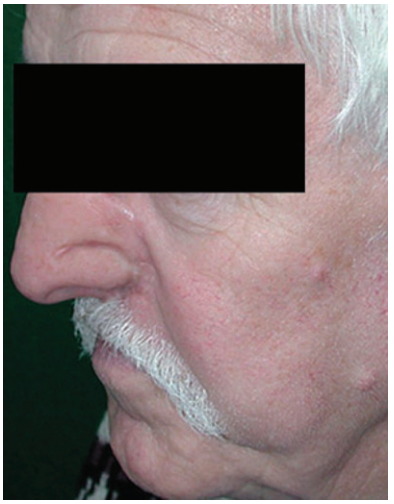

Figure 8 Patient 1: after the obturator was attached and the first silicone nose prosthesis fitted onto the obturator by a magnet and a cap.

In 1993, one implant in the left zygoma fractured and was removed. At reoperation, a new Brånemark implant (13 mm Ø 3.75 mm) was installed, and one "sleeping" implant was used. These two implants were connected with 10-mm standard abutments, and a second rigid cast gold alloy framework retained on six implants with a new clip retained obturator was constructed in 1993.

In 1999, the patient was referred to the Brånemark Clinic because of cleaning problems, liquid leakage, and repeated breakage of clips. He received a new implant-supported three-piece screw-retained cast gold alloy framework connected to six abutments (Figure 9) and an obturator retained by four magnets[14] as described for patient 1. It is from this point this prosthetic report begins; however, mean bone loss is calculated from first framework placement.

Patient 3. A patient with a tumor in the maxilla/nose cavity first underwent resection of the right nose cavity and 4 years later of the maxilla because of recurrence of the tumor (see Table 1). She had an obturator until 2003. Implant installation (Astra Tech AB, Mölndal, Sweden) was performed the same year (see Table 2;

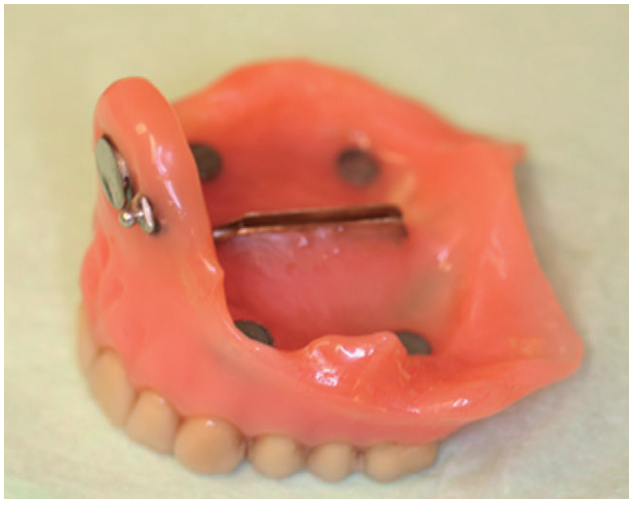

Figure 7 Patient 1: obturator with the U-shaped bar system and four magnets, for fitting the nose one magnet and a cap system integrated at the 7-year checkup.

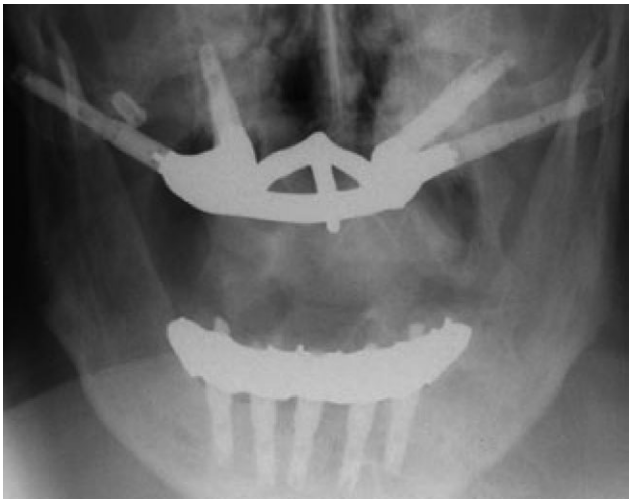

Figure 9 Patient 2: scanogram after three-piece gold alloy framework connection on six implants (1999). One implant is a "sleeping implant." In the mandible, the patient had an implant-supported gold alloy prosthesis.

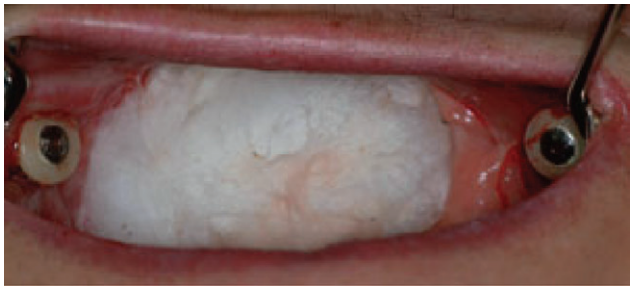

Figure 10 Patient 3: after abutment connection, the abutments were protected by customized larger healing caps to prevent overgrowth of soft tissue around the abutments.

Figure 10). Two titanium frameworks were cast as two separate bars on the four abutments,[24] and because of the need for a rigid supra framework in limited space, the third piece of framework was cast in cobalt chromium (Wirobond® C, Brego, Bremen, Germany). The construction was completed by laser welding of four keepers (Maxi Insert Keeper, Technovent Ltd) to the supra bar, and it was connected in 2004 as described for patient 1. The patient had natural teeth and fixed dental prostheses in the mandible.

RESULTS

One implant was found loosened in patient 3, and two facial implants in patient 1 were lost. These three implants were removed before prosthetic connection. The mean bone loss for all three patients after 5-year follow-up was 0.52 (SD 0.73) mm.

The patients required few appointments to maintain the obturators with exception of the first year, and the frequency of problems during follow-up was low (Table 3; Figure 11). The patients reported no complaints about persistent pain, speech, air leakage, or mastication.[12,13] Good oral hygiene access was obtained, and mucosal problems were rare. No framework or obturator failed during follow-up. During the 7-year follow-up, patient 1 changed his nose prosthesis once a year because of wear and color changes.

Patient 2 died 9 years after the first implant retained construction was delivered, and 17 months after the three-piece gold alloy bar and magnetic retained obturator was inserted. Patients 1 and 3 are functioning well 85 and 57 months, respectively, after completion of the prosthodontic treatment.

DISCUSSION

This communication reports an overall good treatment result, and despite the limitations of implant positioning, the aesthetic and functional demands were fulfilled. Effective obturation requires close cooperating and

TABLE 3 Patient-Related Complications and Maintenance Requirements During Follow-Up After Placement of Magnetic Retained Obturators (Number of Occasions)

Year	Patient	Visits	Leakage Liquid	Acrylic/Veneer Fracture*	Mucosal Compl.†	Soft Tissue Ulcers‡	Reline Clinic	Reline Laboratory	New Magnets
1	1	5	2	—	1	—	—	—	—
	2	11	7	—	2	3	7	1	—
	3	9	1	1	1	1	—	2	—
2	1	1	1	—	—	—	—	—	—
	2	1	1	—	—	—	—	—	—
	3	5	—	2	—	—	—	—	—
3	1	1	—	—	—	—	—	—	—
	3	4	—	1	1	—	—	—	—
4	1	1	—	—	—	—	—	—	—
	3	3	—	1	1	—	—	—	—
5	1	1	—	—	—	—	—	—	—
	3	2	—	—	—	—	—	—	—
6	1	3	—	—	—	—	—	1	1
7	1	1	—	—	—	—	—	—	—

*Treatment: laboratory mending of the acrylic (four occasions) and a new tooth (one occasion).
†Treatment: cleaning instructions and/or chlorhexidine treatment.
‡Treatment: grinding the acrylic on the obturator.
Number of visits each year is also presented.

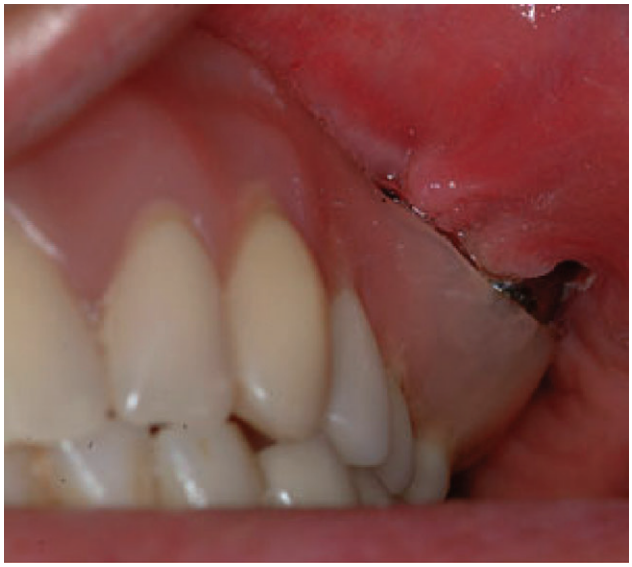

Figure 11 Patient 3: mucosal inflammation around an abutment, treated with chlorhexidine.

careful planning between the very well-trained specialized surgical and prosthetic teams[1] to guarantee successful treatment. However, research on maxillofacial prosthodontics contains few strictly scientific studies in the prosthetic field.[1,4,10,12,25] The great variety of maxillectomy defects and low patient numbers are usually presented as "case reports," as in this report.[5,22,23,26–28] Therefore, prosthetic treatment decisions on this patient group must be based on low levels of evidence, mainly from case reports, expert statements, and consensus conferences. The two-stage surgery[15] protocol was the first treatment alternative because of no available scientific literature on the early loading concept in this patient group. Furthermore, implant survival rates[10,29] in oral tumor patients are lower due primarily to five causes: lack of primary osseointegration, acute inflammation, bone loss, biomechanical overload, and tumor recurrence.[29] This report presents early loss of one dental implant, probably because of lack of primary osseointegration in very thin bone. However, no implant was lost after rigid framework connection, and the risk of biomechanical overload of tilting implants decreased.[29–31] More knowledge about the time for loading in this specific patient group is needed, especially as several studies report increased implant failures in patients with tumors, radiation, and zygomatic implants.[10,12,32–35]

Because of over-projection of the implants and the cranial base, the bone loss was difficult to register. With available methods, however, low levels of bone loss were registered for all three patients, and few implant sites had mucosal problems.

Patient 2 had a history of a fractured implant, and it is reasonable to assume that the risk is higher with external bending load on the implant and the frameworks than in conventional treatment.[36] Therefore, all biomechanical considerations[25,31] must be performed, and the weakest point should be the attachments, veneers, or an internal (framework) screw joint, not the implant itself.

The present patient group needed few appointments for maintenance during the first follow-up years. However, liquid leakage was a problem the first year, with several relining appointments. This is required more often for patients with maxillary defects than for complete denture patients, because of the large defects in which tissues are subject to change.[1] Acrylic fractures were also common[1] in one patient because of limited space for the material. Magnets were used as attachments because of their small size and strong attractive forces which allowed their incorporation into the obturators without being obtrusive in the mouth, as discussed by others.[22] Furthermore, a rigid bar[25] attachment spanned the implants, and the magnets were placed in contact with the bar instead of individual keepers on the implants.[14] Accordingly, the magnets were changed only once in one patient at year 6, because of loosening,[14] a favorable result compared to damaged clips or technical complications with matrix retainers.[25,26]

Retrievability for repair and visual inspection was ensured through the screw access in the three-piece framework. This is discussed elsewhere[37] as an important consideration for delivering quality and patient-based treatment outcomes.

Current, rapid digitization means that future treatment concepts for this patient group will probably involve virtual three-dimensional planning recently described.[27,28]

CONCLUSION

Within the limitations of this report, dental implants are useful for rehabilitation of total maxillectomy patients, and a three-unit, screw-retained, implant-supported framework with maxillary obturator retained by magnetic attachment is a successful treatment concept for this patient group.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Prof Per-Ingvar Brånemark, Prof Karl-Erik Kahnberg, and Prof Ulf Lekholm who performed the dental implant installations. Thanks also to dental technician Vagn Poulsen, anaplastologist Kerstin Bergström, and the Specialist Clinic for Oral and Maxillofacial Radiology (Göteborg, Sweden), and to Prof Gunnar E. Carlsson for comments on this article.

REFERENCES

1. Boyes-Varley JG, Howes DG, Davidge-Pitts KD, Brånemark P-I, McAlpine JA. A protocol for maxillary reconstruction following oncology resection using zygomatic implants. Int J Prosthodont 2007; 20:521–531.
2. Parr GR, Gardner LK. The evolution of the obturator framework design. J Prosthet Dent 2003; 89:608–610.
3. Umino S, Masuda G, Ono S, Fujita K. Speech intelligibility following maxillectomy with and without a prosthesis: an analysis of 54 cases. J Oral Rehabil 1998; 25:153–158.
4. Fukuda M, Takahashi T, Nagai H, Iino M. Implant-supported edentulous maxillary obturators with milled bar attachments after maxillectomy. J Oral Maxillofac Surg 2004; 62:799–805.
5. Chiapasco M, Biglioli F, Autelitano L, Romeo E, Brusati R. Clinical outcome of dental implants placed in fibula-free flaps used for the reconstruction of maxillo-mandibular defects following ablation for tumors or osteoradionecrosis. Clin Oral Implants Res 2006; 17:220–228.
6. Kramer F-J, Dempf R, Bremer B. Efficacy of dental implants placed into fibula-free flaps for orofacial reconstruction. Clin Oral Implants Res 2005; 16:80–88.
7. Schmelzeisen R, Schliephake H. Interdisciplinary microvascular reconstruction of maxillary, midfacial and skull base defects. J Craniomaxillofac Surg 1998; 26:1–10.
8. Ferri J, Caprioli F, Peuvrel G, Langlois JM. Use of the fibula free flap in maxillary reconstruction: a report of 3 cases. J Oral Maxillofac Surg 2002; 60:567–574.
9. Won-suck O, Roumanas E. Dental implant-assisted prosthetic rehabilitation of a patient with a bilateral maxillectomy defect secondary to mucormycosis. J Prosthet Dent 2006; 96:88–95.
10. Roumanas ED, Nishimura RD, Davis BK, Beumer J 3rd. Clinical evaluation of implants retaining edentulous maxillary obturator prostheses. J Prosthet Dent 1997; 77:184–190.
11. Schmidt BL, Pogrel MA, Young CW, Sharma A. Reconstruction of extensive maxillary defects using zygomaticus implants. J Oral Maxillofac Surg 2004; 62:82–89.
12. Landes CA. Zygoma implant-supported midfacial prosthetic rehabilitation: a 4-year follow-up study including assessment of quality of life. Clin Oral Implants Res 2005; 16:313–325.
13. Fujimoto T, Niimi A, Ueda M. Implant-supported prostheses after maxillary cancer resection: preliminary report. Implant Dent 1997; 8:295–298.
14. Riley MA, Walmsley AD, Harris IR. Magnets in prosthetic dentistry. J Prosthet Dent 2001; 86:137–142.
15. Susarla SM, Chuang SK, Dodson TB. Delayed versus immediate loading of implants: survival analysis and risk factors for dental implant failure. J Oral Maxillofac Surg 2008; 66:251–255.
16. Ekelund J-A, Lindqvist LW, Carlsson GE, Jemt T. Implant treatment in the edentulous mandible: a prospective study on Brånemark system implants over more than 20 years. Int J Prosthodont 2003; 16:602–608.
17. Hollender L, Rockler B. Radiographic evaluation of osseointegrated implants of the jaws. Dentomaxillofac Radiol 1980; 9:91–95.
18. Gröndahl K, Lekholm U. The predictive value of radiographic diagnosis of implant instability. Int J Oral Maxillofac Implants 1997; 12:59–64.
19. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long term efficacy of currently used dental implants: a review and proposed criteria of success. Int J Oral Maxillofac Implants 1986; 1:11–25.
20. Randow K, Ericsson I, Nilner K, Petersson A, Glanz P-O. Immediate functional loading of Brånemark dental implants. An 18-month clinical follow-up study. Clin Oral Implants Res 1999; 10:8–15.
21. Örtorp A, Jemt T. Clinical experiences of CNC-milled titanium frameworks supported by implants in the edentulous jaw. A 5-year prospective study. Clin Implant Dent Relat Res 2004; 6:199–209.
22. Sunil Chandra T, Sholapurkar A, Joseph RM, Aparna IN, Pai KM. Prosthetic rehabilitation of a complete bilateral maxillectomy patient using a simple magnetically connected hollow obturator: a case report. J Contemp Dent Pract 2008; 9:1–7.
23. Takahashi T, Fukuda M, Funaki K, Tanaka K. Magnet-retained facial prosthesis combined with an implant-supported edentulous maxillary obturator: a case report. Int J Oral Maxillofac Implants 2006; 2:805–807.
24. Abrahamsson I, Berglundh T, Glantz P-O, Lindhe J. The mucosal attachment at different abutments. An experimental study in dogs. J Clin Periodontol 1998; 25:721–727.
25. Nelson K, Heberer S, Glatzer C. Survival analysis and clinical evaluation of implant-retained prostheses in oral cancer resection patients over a mean follow-up period of 10 years. J Prosthet Dent 2007; 98:405–410.
26. Stegersjö G, Kahnberg KE. Prosthetic restoration following maxillary resection without an oroantral defect: a case report. Int J Prosthodont 1999; 12:391–394.

27. Kreissl ME, Heydecke G, Metzger MC, Schoen R. Zygoma implant-supported prosthetic rehabilitation after partial maxillectomy using surgical navigation: a clinical report. J Prosthet Dent 2007; 97:121–128.
28. Ekstrand K, Hirsch JM. Malignant tumors of the maxilla: virtual planning and real-time rehabilitation with custom-made R-zygoma fixtures and carbon-graphite fiber-reinforced polymer prosthesis. Clin Implant Dent Relat Res 2008; 10:23–29.
29. Kovács AF. Clinical analysis of implant losses in oral tumor and defect patients. Clin Oral Implants Res 2000; 11:494–504.
30. Krekmanov L, Kahn M, Rangert B, Lindström H. Tilting of posterior mandibular and maxillary implants for improved prosthesis support. Int J Oral Maxillofac Implants 2000; 15:405–414.
31. Brunski JB, Skalak R. Biomechanical considerations for craniofacial implants. In: Brånemark P-I, Tolman DE, eds. Osseointegration in craniofacial reconstruction. 1st ed. Chicago, IL: Quintessence Publishing, 1998:15–35.
32. Mericske-Stern R, Perren R, Raveh J. Life table analysis and clinical evaluation of oral implants supporting prostheses after resection of malignant tumors. Int J Oral Maxillofac Implants 1999; 14:673–680.
33. Schliephake H, Neukam FW, Schmelzeisen R, Wichmann M. Long-term results of endosteal implants used for restoration of oral function after oncologic surgery. Int J Oral Maxillofac Surg 1999; 28:260–265.
34. Granström G. Osseointegration in irradiated cancer patients: an analysis with respect to implant failures. J Oral Maxillofac Surg 2005; 63:579–585.
35. Colella G, Cannavale R, Pentenero M, Gandolfo S. Oral implants in radiated patients: a systematic review. Int J Oral Maxillofac Implants 2007; 22:616–622.
36. Eckert SE, Meraw SJ, Cal E, Ow RK. Analysis of incidence and associated factors with fractured implants: a retrospective study. Int J Oral Maxillofac Implants 2000; 15:662–667.
37. Gervais M, Wilson P. A rationale for retrievability of fixed implant-supported prostheses: a complication-based analysis. Int J Prosthodont 2007; 20:13–24.