Osseointegrated Implant Applications in Cosmetic and Functional Skull Base Rehabilitation

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ABSTRACT

This study discusses the indications, outcomes, and complications in patients that underwent osseointegrated implantation for skull base rehabilitation. We conducted a retrospective review of eight patients with skull base defects who had undergone implantation of a facial prosthetic retention device $\pm$ bone-anchored hearing aid at a tertiary academic referral center. Descriptive analysis of applications, techniques, outcomes, and complications were reviewed. The majority of patients were males ($n=6$) with previously diagnosed skull base malignancy ($n=5$) with an average age of 46 (range, 14 to 77). All patients received an implanted facial prosthetic device either for an aural ($n=7$) or orbital ($n=1$) prosthesis. There were only two complications that included infection ($n=1$) and implant extrusion ($n=1$). Osseointegrated implantation of abutments for anchoring prosthetic devices in patients for skull base rehabilitation provides an excellent cosmetic option with minimal complications.

KEYWORDS: Craniofacial implants, facial prosthesis, skull base, bone-anchored hearing aid, rehabilitation

Osseointegration as a method of securing dental implants to the facial skeleton has existed in the literature since the late 1960s.¹ The bone-anchored hearing aid was the first application of a bone-anchored implant outside the oral cavity. Developed by Dr. Tjellström in Sweden in 1977, the device enables sound energy to be transmitted directly to the skull base via an attachable vibrator, and thus began a new era in hearing rehabilitation. Bone-anchored hearing aids have superior sound transmission and avoid painful pressure on the skin associated with traditional bone-conduction hearing aids.² In addition, the bone-anchored hearing aid is an excellent option for those with single-sided hearing loss in which a traditional hearing aid is not an option, (i.e.,

postradical temporal bone resection or canal oversewn procedure).

Two years after the implantation of the bone-anchored hearing aid, osseointegrated abutments were used to anchor prostheses for the ear, nose, orbit, and midface in the rehabilitation of patients with craniofacial defects from cancer surgery, congenital malformations, and traumatic amputations.³ Hairstyling can mask some skull base deformities but is often inadequate. Prostheses glued directly to the skin are useful in many patients, but mechanical and chemical irritation resulting from adhesives and solvents can result in skin and mucosal irritation.⁴ Orbital defects can be especially troubling for patients, and are often difficult to hide. Autogenous

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reconstruction is virtually impossible, masks are ineffective, and prostheses anchored on glasses are cumbersome. With significant improvements in prosthetic materials and implantation devices, prostheses attached via implanted abutments are now better tolerated, offer improved quality of life, and are often the best option.^{4,5} Osseointegrated implant application has changed many of the fundamentals of rehabilitation for those specialties working outside the oral cavity. The affected specialties include otolaryngology—head and neck surgery, maxillofacial surgery, and plastic surgery, all of which have reported excellent outcomes. In reverse order of technology, the U.S. Food and Drug Administration approved anchoring craniofacial prostheses on osseointegrated implants in 1985, and later approved the use of implants to anchor hearing aids in adults in 1995.⁶

The objective of this study was to evaluate and discuss the applications, techniques, outcomes, and complications in patients that underwent osseointegrated implantation for skull base rehabilitation at a tertiary care facility. Emphasis was placed on patients receiving osseointegrated implants for cosmetic reasons with or without functional rehabilitation utilizing osseointegrated bone-conduction hearing aids.

MATERIALS AND METHODS

Following approval by the Loyola University Institutional Review Board for human research, our medical records were queried for all patients that underwent osseointegrated implants by one of the senior authors (S.J.M.) from 2003 through 2010. This initial list of individuals ($n = 226$) was used to identify a unique subset of individuals that were of particular interest that only included a cohort of patients that received an osseointegrated abutment to anchor a facial prosthetic device $\pm$ bone-anchored hearing aid. The compiled list of eight patients underwent a retrospective review, and a descriptive analysis of the patient demographics, confounding variables, and pathologies was conducted. Furthermore, indications, outcomes, and complications were also assessed to better understand the utility of this technology. The facial prosthetic retention devices (VistafixTM) and bone-anchored hearing aid (BAHATM) implants were developed by Cochlear Americas Corporation (Centennial, CO).

OPERATIVE TECHNIQUE

We used a linear incision implantation technique similar to that described by Cass.⁷ For infection prophylaxis, one perioperative dose of antibiotics was given to cover skin flora. An incision was made ~ 1 cm from the projected implantation location. Significant subcutaneous dissection and soft tissue reduction down to the periosteum was performed to create a thin skin flap that maintained a

Figure 1 Osseointegrated implantation for auricular prosthesis and bone-anchored hearing aid: intraoperative exposed periosteum with implants in place.

robust vascular supply. This critical step enables the skin flap to adhere to the underlying periosteum. The fixture placement site was prepared by elevating the periosteum to ~ 1 cm in diameter. A guide hole was created at a right angle from the skull using the provided 1.8-mm drill bit with the 3-mm stop under continuous irrigation. A lacrimal probe was used to determine if bone cortex remains, and if so the guide hole was drilled to a depth of 4 mm. The guide hole was widened to 3.8 mm and a 360-degree countersink was created using the widening/countersink bit. The self-tapping implant was then secured to the bone using a slow drill taking caution not to touch the portion of the screw that is to be implanted as this can affect osseointegration. The screw was tightened using the manual wrench being careful not to strip the bone (Fig. 1). The skin incision was then closed using 3-0 Vicryl sutures in an interrupted fashion. A 4-mm skin punch was used to excise the skin over the implant, and the skin was tucked under the outer portion of the implant (Fig. 2). Antibiotic-impregnated gauze was placed around

Figure 2 Osseointegrated implantation for auricular prosthesis and bone-anchored hearing aid: intraoperative skin closure with implants in place.

Table 1 Patient Characteristics

Patient No.	Age	Gender	Pathology	Follow-Up
1	77	M	SCCa, T bone	15 mo
2	59	F	Adeno Ca, T bone	27 mo
3	50	M	BCCa, T bone	16 mo
4	72	F	Melanoma, conjunctiva	15 mo
5	36	M	Traumatic auriclectomy	16 mo
6	25	M	Aural atresia	9 mo
7	15	M	SCCa, T bone	6 mo
8	28	M	Aural atresia	17 mo

Adeno Ca, adenocarcinoma; BCCa, basal cell carcinoma; SCCa, squamous cell carcinoma; T-bone, temporal bone.

the implant and the supplied healing cap was placed. A mastoid dressing placed over the wound, which was removed 24 hours later. The healing cap was changed 1 week later, and the implant was allowed to bear weight via a bone-anchored hearing aid or prosthesis at 3 months' time.

RESULTS

A total of eight patients underwent osseointegrated implantation for skull base rehabilitation with or without bone-anchored hearing aid (Table 1). The majority of patients were males ($n = 6$, 75%) with an average age of 46 years (range, 15 to 77). The majority of patients were previously diagnosed with a skull base malignancy ($n = 5$, 63%). Two patients (25%) had congenital aural atresia and one patient (13%) suffered a traumatic avulsion of his auricle.

Preimplant confounding variables that could affect the outcomes of osseointegration are shown in Table 2. Relevant comorbidities were found in only three patients that included vascular disease ($n = 2$, 25%) and previous autogenous reconstruction surgery at the implant site ($n = 1$, 13%). Surprisingly, none of the patients was smoking at the time of implantation, and only one patient was a former smoker.

Of the patients with skull base malignancy, four patients underwent an ablative lateral temporal bone resection and one patient underwent an orbital exenteration for conjunctival melanoma. All four patients with lateral temporal bone malignancy had postextirpation defects reconstructed immediately with a vascularized flap. The majority had an anterior lateral thigh free tissue transfer (75%), and one had a temporoparietal fascial flap. All four patients had postoperative intensity-modulated radiation therapy in doses greater than 5625 cGy (range, 5625 to 11,040 cGy; average, 8486 cGy). Two patients received concomitant chemotherapy. One of these patients received chemotherapy with an initial radiation dose of 4680 cGy followed by a boost of 6600 cGy. The other patient had tumor recurrence after initial surgery and radiation (6000 cGy) requiring additional resection that was followed by chemotherapy and additional radiation (5040 cGy). Prosthesis abutment implantation was performed into the irradiated bone an average of 15 weeks (range, 8 to 18 weeks) after completion of treatment.

In total, 27 implants were placed in 8 patients for either an auricular ($n = 7$, 88%) or orbital ($n = 1$, 12%) prosthetic ± bone-anchored hearing aid (Table 3). Four patients underwent hearing aid placement either at the

Table 2 Preimplant Variables

Patient No.	Comorbidity	Smoker	Preimplant Adjuvant Tx	Surgical Defect Reconstruction
1	PVD, CAD	No*	XRT	Temporoparietal fascia flap
2	None	No	XRT, chemotherapy	ALT free flap
3	None	No	XRT	ALT free flap
4	CAD, HTN	No	None	None
5	None	No	None	None
6	Autogenous aural repair	No	None	None
7	None	No	XRT × 2, chemotherapy	ALT free flap
8	None	No	None	None

*Former smoker.

ALT, anterior lateral thigh; CAD, coronary artery disease; HTN, hypertension; PVD, peripheral vascular disease; XRT, external radiation therapy.

Table 3 Osseointegration Implant Data

Patient No.	Prosthesis	Baha	No. of Abutments	Complications
1	Auricular	+*	4	None
2	Auricular	+*	4	Skin reaction
3	Auricular	+ [†]	4	None
4	Orbital	N/A	2	Cellulitis
5	Auricular	-	3	None
6	Auricular	+ [†]	4	None
7	Auricular	-	3	One implant extrusion
8	Auricular	-	3	None

*Baha placed at the same time as implants for prosthesis.

[†]Baha placed after implants for prosthesis.

time of prosthetic device placement or in a delayed fashion. Complications were minimal with only one extrusion in the patient who was treated with radiation therapy two times before implantation. Loss of the implant did not cause destabilization of the prosthesis and was not replaced. There was one skin infection treated successfully with systemic antibiotics and one skin-metal reaction causing granulation tissue treated successfully with more aggressive wound care. The overall implant survival rate was 96%. No cases of cerebral spinal fluid leak, loss of skin flap, or hematoma occurred in this series, and all implantations occurred as a single-stage procedure even in those with previous irradiation. Hyperbaric oxygen (HBO) therapy was not employed in any patients.

DISCUSSION

Craniofacial defects can be considered a severe social disability. Procedures such as an auriculectomy and orbital exenteration leave patients with inherent craniofacial morbidities and can have significant cosmetic, functional, and emotional consequences. However, the know-how, artistic skills, materials, and techniques are available today to provide these patients with lifelike implant-fixed facial prostheses.

The main application for the use of osseointegrated implants at our institution is reconstruction of the auricle. Autologous reconstruction is a major challenge requiring multiple stages.⁸ Reconstructive procedures can also be hampered by patient comorbidities such as vascular compromise of the surgical bed due to postsurgical scarring and radiation therapy following ablative oncologic surgery.

Prosthesis Use with Baha

Osseointegrated implants play a significant role in many patients after lateral temporal bone resection with the potential for both cosmetic and functional deficits ad-

dressed in one procedure. In this small series of patients, we were able to afford several patients with the dual benefit of improved cosmesis and functional rehabilitation through applications of the Vistafix and Baha (Fig. 3). In our series, no patient received adjuvant therapy after implantation and all underwent single-stage surgical technique versus the two-stage surgical technique with delayed implant exposure.

Complications

Although craniofacial implantation is a relatively simple procedure requiring only minimal operative time, each patient provides his or her own risk factors for complications. Granström in his recent review of craniofacial osseointegration states that previous irradiation is a significant risk factor for failure, that is, implant extrusion.⁶ Risk for induction of osteoradionecrosis (ORN) is always present in previously irradiated patients, and the use of HBO therapy has been proposed to reduce that risk.⁹ In the 1980s, Marx delineated the physiologic changes that occur in irradiated tissue described as a radiation-induced hypovascular-hypocellular-hypoxic tissue environment.¹⁰ Furthermore any trauma-induced or spontaneous tissue breakdown can result in nonhealing wound that leads to ORN. Although our limited series of eight patients precludes any meaningful statistical analysis, we found that the only failure was in a patient who had been irradiated twice due to tumor recurrence. In another series of 107 patients undergoing osseointegration in cancer patients that had undergone adjuvant therapy either before or after implantation, Granström found that radiotherapy and chemotherapy before and after implants were significant risks for failure when compared with historical controls (nonirradiated). Gender, age, smoking habits, and tumor size and type were noncontributing factors.¹¹ Controversy exists as to the benefit of HBO treatment before implantation. Two opposing views were presented in 2006 on dental implants.^{12,13} In this series none of the patients underwent HBO treatment, and no cases of ORN were observed. Granström states that despite multiple risk factors in cancer patients, the overall implant survival is high and outcomes are so favorable that it should be recommended.¹¹

One possible reason that our success rate was so favorable, 96%, when compared with others is that all patients that received adjuvant radiation therapy also had vascularized tissue placed for reconstruction that presumably served to protect the underlying bone from the harmful effects of radiation. In many of these cases that utilized free-tissue transfer, the soft tissue of the free flap had to be reduced to accommodate the implant. We advocate using vascularized tissue to cover the projected implant site either with a local flap or a free-tissue transfer flap at the time of extirpation when postoperative adjuvant therapy is indicated.

Figure 3 Osseointegrated implant application in cosmetic and functional skull base rehabilitation.

All osseointegrated implants can develop local skin reactions around the implant, which can influence the success or failure of the entire system.³ All of our patients underwent a single-staged procedure using a linear-incision implantation technique, as opposed to a skin grafting technique. Skin reaction was observed in only one patient, grade 1–2, and this was controlled with local skin care. Skin infection was only seen in one patient undergoing orbital prosthetic rehabilitation. Incidentally this was the only patient without vascularized tissue transfer following orbital exenteration for melanoma. Neither of these patients had loss of implants despite these minor complications.

CONCLUSION

This study supports the reported evidence as to the safety and application of osseointegrated implantation for both functional and cosmetic rehabilitation after skull base surgery. Implantation is particularly useful in the reconstruction for cosmetic and functional deficits following a lateral temporal bone resection. We show a low complication rate in both irradiated and nonirradiated patients without the use of HBO treatment. We attribute our high success rate in part to the use of vascularized tissue flaps for postablative reconstruction, especially in those patients undergoing radiation treatment.

NOTE

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