Review Article

JRAD Journal of Research and Advancement in Dentistry

J Res Adv Dent 2021;11:2:206-216.

Craniofacial Applications of Osseointigrated Implants

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ABSTRACT

Background: Maxillofacial Prosthodontics plays a significant role in rehabilitation of facial defects. Facial defects might be due to congenital or acquired. Osseointigrated implants proved to be successful and are a recent advancement in the field of maxillofacial prosthetics. Before the use of implants in restoration of craniofacial defects, they were retained using adhesives in which success rate was not up to the mark. Osseointigrated implants came into place restoring these defects. Retaining the prosthesis using these osseointigrated implants depends on some factors like bone density, soft tissue conditions, medical conditions of the patients, radiation therapy, social economic status and the cooperation of patient towards the treatment. Dental implants either intra oral or extra oral offers good stability, support and retention to the prosthesis which in turn gains confidence in patients to socialize. This article investigates current perspectives on the craniofacial applications of osseointigrated implants in the restoration of craniofacial defects.

Keywords: osseointegration, implants, bone anchored hearing aid, extra oral, defects, biomechanical model, prosthesis, craniofacial.

INTRODUCTION

Maxillofacial Prosthetics is defined as that branch of Prosthodontics concerned with the restoration, replacement, or both stomatognathic and associated facial structures by artificial substitutes that may or may not be removed.[1] The loss of facial structures through ablative or traumatic activities may produce significant psychological trauma in the patient that exceeds the actual physical injury. Although surgical procedures may fill in or close off significant defects, their results may be less than optimal in providing an acceptable function and aesthetics level. An alternative is the prosthetic restoration of their facial deformities.[2]

ETIOLOGY OF MAXILLOFACIAL DEFECTS

1. *Congenital defects*: Treacher Collins, Pierre Robins and Crouzon's are some of the syndromes associated with palatal clefts, facial deformities and significant malformation external ear. The microtia and agenesis of the ear are associated with several congenital syndromes. Congenital abnormalities are unlikely to result in the complete absence of the eyes or nose.

2. Acquired defects: Acquired defects may cause the loss of any facial part. The traumatic or

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pISSN 2278-0076
eISSN 2321-9270

neoplastic etiology is essential for determining the type of treatment.[3]

MAXILLOFACIAL OSSEOINTEGRATION

Osseointegration has been defined as a direct structural and functional connection between ordered, living bone and a load-carrying implant surface. The achievement of osseointegration requires biocompatibility of implant materials, an atraumatic and aseptic surgical technique, an initial healing period without loading, and optimal stress-reducing prosthodontic procedures.[2] Application of osseointegration in maxillofacial prosthetic reconstruction followed the positive results obtained by using osseointegrated implants for dental rehabilitative procedures of edentulous maxillae and mandibles. Several applications and clinical studies have been reported in the literature in which intraoral and extraoral defects have been restored with osseointegrated implants providing the prosthesis's necessary retention and stability. Osseointegrated implants are currently used in oncology and trauma patients with intraoral soft and hard tissue defects. Patients with facial deformities can support or retain prostheses.[2]

History of Maxillofacial Osseointegration

Osseointegration was first observed but not explicitly stated by Bothe, Beaton, and Davenport in 1940. Bothe et al. were the first to implant titanium in an animal and remarked how it tended to fuse with the bone.

Gottlieb Leventhal later described osseointegration in 1951. Leventhal described that "At the end of 6 weeks, the screws were tighter than when originally placed; at 12 weeks, the implant screws became difficult to remove when placed titanium screws in rat femurs. The screws were so tight that there was a fracture of the femur in one specimen when attempted at the end of 16 weeks.

These reactions described by Leventhal and Bothe et al. would later be coined into the term "osseointegration" by Per-Ingvar Branemark of Sweden.

In 1952, Branemark conducted an experiment where he used a titanium implant chamber to study rabbit bone blood flow. By the end of the experiment, he discovered that the bone had entirely integrated with the implant. Branemark called this "osseointegration." In 1977, following the pioneering work by Branemark and his coworkers, the first clinical trial on skin-penetrating osseointegrated implants was conducted where specifically designed implants were placed in the mastoid region to support a bone conduction hearing aid at Sahlgren's Hospital in Goteborg, Swede. In 1979, the first implants were placed to retain an auricular prosthesis in the mastoid region. In February 1988, the Swedish National Social Welfare Board approved the use of Bone Anchored Hearing Aid (BAHA) within the Swedish health system. On January 13, 1995, the Food and Drug Administration (F.D.A.) provided clearance to Nobel Biocare U.S.A. to market the Branemark Maxillofacial implant system.[3]

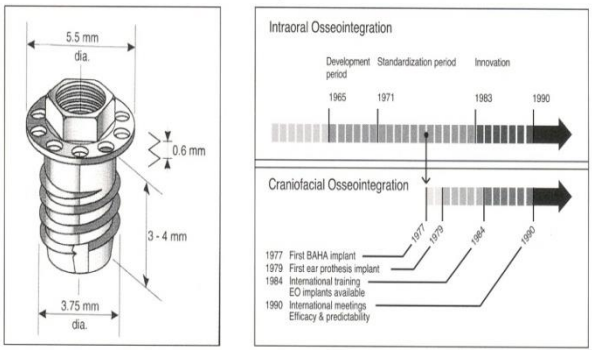


Fig 1: Historical development of Maxillofacial osseointegration to the development of intraoral osseointegrated implants.

Maxillofacial implants and their fixtures are fabricated from pure titanium, available in 3 mm or 4 mm lengths, and a 5-6 mm flange diameter. This flange facilitates the initial stabilization of the implant and prevents undue penetration into interior compartments.[4,5]

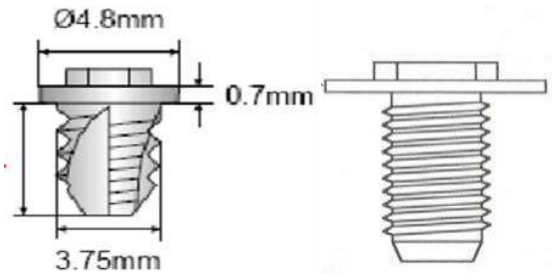


Fig 2: Maxillofacial implant fixtures.

The flange increases the implant surface area in contact with bone, facilitates initial immobilization

and prevents undue penetration of the implant intracranially. Perforations in the flange provide additional surface area and mechanical stabilization.[5]

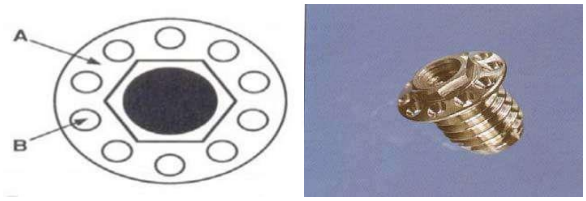


Fig 3: Perforations in the flange of extraoral implants.

Perforations in the flange create a protected environment for microbial colonization and accumulation of debris with ensuing infection.[5]

Extraoral implant systems

Solitary Implants

- Branemark system
- I.T.I. systems

Grouped Implants

Both Epitec system Epiplating system is used subperiosteally but fixed with bone screws.[5]

Fig 4: Implant systems for bone-anchored craniofacial prostheses. Left: Epitec system, back left: Brånemark system, back right: ITI system, front: a universal plate of the Epiplating system, right: titanium bone screws with lengths of 4, 5.5, and 7mm.

Advantage of Maxillofacial implants over conventional adhesives

- Improved retention and stability of the prosthesis.
- Elimination of occasional skin reactions to adhesives.
- Ease and enhanced accuracy of prosthesis placement.
- Improved skin hygiene and patient comfort.
- Decreased daily maintenance associated with the removal and reapplication of adhesives.
- Increased longevity of the prosthesis.
- Enhanced esthetics at the junction between the prosthesis and skin

BIOMECHANICAL ANALYSIS OF TYPICAL CRANIOFACIAL CASES

Auricular Case, Two Implants:

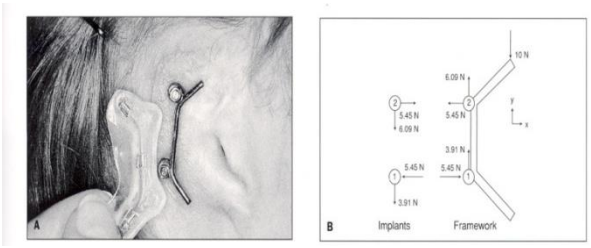


Fig 5: Auricular Case (A) Two implants with Hader bar (B) Biomechanical model using two implants

In this case, two titanium implants were used to support a metal framework that allowed a prosthetic ear to be clipped onto it using Hader clips. A biomechanical model of the case seeks to predict the two implants' loadings when a test load of magnitude 10 N is applied in the negative y-direction at a particular point on the framework. We will consider a horizontal load in the prosthetic bar's plane perpendicular to the two implants' long axes in the bone. Note that 10 N is used only as a standard test load; in in-vivo experiments, there is no data available on actual forces on this type of prosthesis.

The Skalak or B.H. model of this case predicts the implant loadings. Concerning the coordinate system shown, both implants are loaded by x and y components of force. The y component of force on the second implant is slightly more than that on implant 1, whereas the x-components are equal. Another way to describe these results is to say that the x-components of force set up a counterclockwise couple moment equal but opposite to the clockwise moment produced by the 10-N force acting at a distance from the line connecting the implants. The forces on the implants

are quite small compared with any of the danger limits.[3]

Auricular Case, Three Implants:

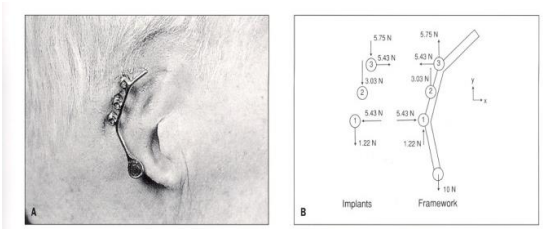


Fig 6: Auricular Case (A) Three implants with hader bar (B) Biomechanical model using three implants

This auricular case resembles the first case, except that three implants are used. For a 10N test load applied in the horizontal plane, the implant loads predicted by the Shalka or B.H. model are again rather small; none is larger than about 6 N, as in the first case. Still, there are no moments predicted about the axis of an implant.; there are just x and y forces. Note that implant 2, the middle implant in this arrangement, does not see any x-component of force because implants at positions 1 and 3 together supply the counterbalancing couple moment on the framework to resist the moment from the applied 10-N force.[3]

Orbital Case:

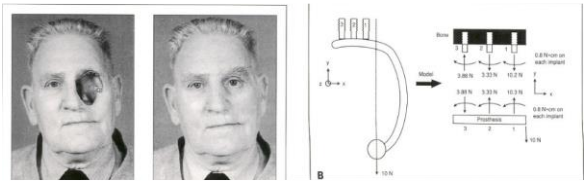


Fig 7: (A) Restoration of Orbital defect using implants (B) Biomechanical model

In this case, three implants support a framework on which an orbital prosthesis is attached. To enable a simple analysis, we assume that the three implants are in a straight line and aligned parallel to one another in an x-y plane parallel to the page. The inter implant spacing is about 4 mm. The framework is assumed to be attached to the implants by joints that can support vertical forces and moments about an axis perpendicular to the page's plane.

For a 10-N vertical load parallel to the implants' axes, the B.H. model predicts different axial forces on each implant but the same moment of magnitude 0.8 N.cm. The forces are tensile on the implants nearest the applied load, whereas implant 3 sees an axial compression. The force magnitude is 10.3 N on implant one nearest to the loading point of the prosthesis. As discussed earlier, none of these loadings on the implants appears large enough to cause concern, although no data on bone properties at this orbital site are readily available.[3]

Midfacial Case:

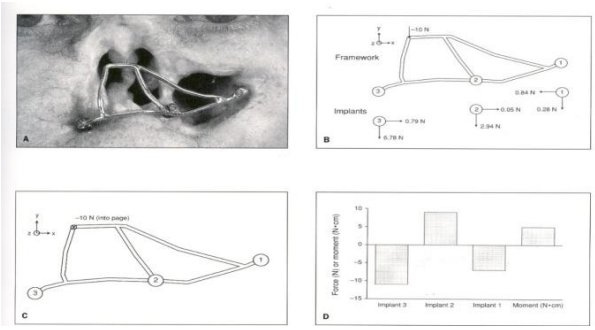


Fig 8: (A) Placement of implants in the mid-facial defect (B), (C) Biomechanical model (D) Graph depicting the loading force.

To simplify the analysis of this complicated case, we assume that the three implants are parallel to one another and perpendicular to the x-y plane of the (infinitely rigid) framework. A test load loads the framework with two components; a horizontal force of 10 N in the x-y plane of the framework and a vertical force of 10 N in the negative z-direction, perpendicular to the framework.[3]

The B.H. model predicts that implant three nearest to the loading point is loaded by the most significant x and y components of force for horizontal loading only. In contrast, implants 1 and 2 see relatively inconsequential forces. For vertical loading of N at x, implant two is subjected to tensile loading, whereas implants 1 and 3 see compressive forces. This force distribution is consistent with the slightly staggered (noncollinear) arrangement of the implants, which tends to make the framework rotate about a line between the three implants when the loading acts at x. According to the model, each implant is also subjected to a moment of a magnitude of 5.4 N.cm.[6]

Patient assessment and selection

Maxillofacial reconstruction is based on osseointegration principles because it must be done

only under selected patients' optimum conditions. The potential benefits have been compared carefully against the known possible complications and risks. Many factors need to be considered, like age, presence of any disease, significance of any previous therapy, available alternative treatments and the patient's wishes. Special care should be taken while evaluating children.[2]

EVALUATION OF SYSTEMIC DISEASES

Medical conditions, whichever gives rise to delayed healing and propensity to infection is given importance like uncontrolled diabetes, immune depression, large doses of steroids—existing degenerative bone conditions like Paget's disease, Osteomalacia, osteoporosis, hyperparathyroidism.

Adrenal disorders: Hyperfunctioning or hypo functioning of the adrenal gland cannot produce increased steroid levels during stressful situations and cardiovascular collapse.

Recent Myocardial Infarction (MI): If the surgery is done within three months of MI, another MI's risk is 30%, and it is 15% within six months.

Hypertension: Hypertension is treated with medications, many of which impact implant therapy because of its numerous side effects. These include dehydration, sedation, and xerostomia, gingival hyperplasia around teeth and implants and depression.

Pregnancy: Implant surgery procedures are contraindicated and should be postponed till childbirth.

Smoking Habits: Tobacco smoking decreased neutrophil count leading to reduced phagocytic activity, decreased calcium absorption, and delayed secondary healing. It also contaminates a bone graft and contributes to early bone loss during initial healing.[2]

Radiological Investigations:

Plain radiographs, tomography, C.T., M.R.I., and ultrasonography.[7]

TREATMENT PLANNING

Each case must be evaluated based on individual requirements; however, a number of fundamental considerations are relevant to all cases. On occasion, bone morphology will not permit the ideal configuration of fixtures, and as a result, there will be variations in the retentive system.

The auricular prosthesis:

In congenital cases, removal of the developmental remnants in the line of the prosthesis is done. In contrast, they can be reshaped to simulate a tragus to help mask the prosthesis anterior border. Implants are positioned in a semilunar fashion beneath the ear's thickest parts to provide space for the prosthesis with minimal over contouring of the part.[8]

One-Stage Surgical Technique for Auricular Implant Placement

Implant Site Selection: The ideal placement is 18 to 22 mm from the center of the external auditory meatus. For the upper cranial implant, it is placed between 1-0,' and 2-0'clock position, and for the caudal implant, it is between the 3:30 and 4:30 positions on the left-hand side. This is because the implants and the bar construction will then be located underneath the antihelix ridge to achieve the prosthesis's adequate depth and contour.

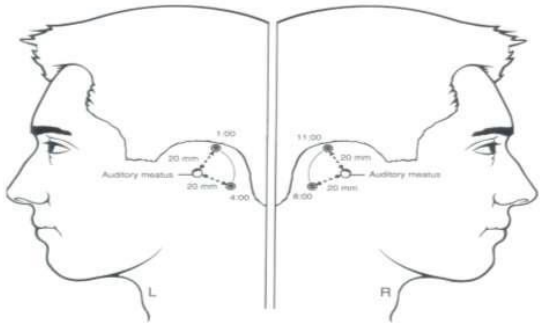


Fig 9 – Ideal implant placement is 18 – 22 mm from the center of the external auditory meatus

The area is cleaned and marked with surgical ink for the placement of implants. The incision line, which is 7 to 10 mm behind the intended implant sites, is marked. Local anesthesia is injected, and the incision is made down to the periosteum, where the flap is folded anteriorly and kept in place with two self-retaining retractors.

Fig 10: Incision line given 7 – 10 mm behind the implant site and the distance between the two implants is 15 – 20 mm.

Implant Placement:

After the implant site positions are checked and marked in the periosteum, a 6 mm wide incision is made, and the drilling with a guide drill is started. During drilling procedures, generous cooling with saline solution is important. The minimum distance between the two implants should be 15 to 20 mm. The cranial implant position will often be in the temporal bone, dense and thicker, and started with a 3 mm guide drill.[3]

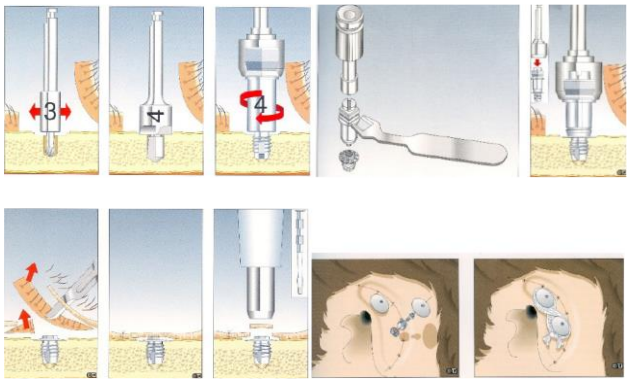


Fig 11: Stepwise surgical procedure and soft tissue management of placing implants in the auricular region.

With the connector placed in the slow speed handpiece, the titanium cap is picked up, and the direction is checked carefully. With a fork-shaped instrument and screwdriver, the implant mount is picked up and screwed on top of the implant. The implant can find its way into the threaded hole using slight pressure with the drill at low speed.[3]

When the implant is down, the handpiece is turned slightly counterclockwise to release the implant mount from the connector. The implant mount is then removed and covered with the thin skin and sutured in place.

Soft Tissue Management:

1) The skin's immobility is achieved by making a subcutaneous tissue reduction at the implant site.

2) There should be no hair follicles present on the skin at the implant site. These goals can be achieved by reducing the flap's thickness or using a split-thickness skin graft.

Abutment Connection: A hole is made over the implant with a 4mm disposable skin punch. With the help of an internal screw, the abutment is fitted tightly. After which, healing caps are attached to the abutments. To avoid post-operative swelling and hematoma, ointment soaked gauze down towards the skin is placed and finished with mastoid dressing.

Post-operative Care: After one week, the healing caps are removed, and the surgical field is left open. Three weeks after the surgery, the patient is allowed to clean the area with soap and water. There is no load on the implants for three months.[8]

Orbital prosthesis

Skin adhesives or double-sided tape is capable of adequate retention but may lead to loss of prosthetic margin integrity, skin irritation, misalignment and discoloration. Mechanical devices such as eyeglasses have limitations, such as the movement of facial muscles independent of the glass frames. The success rate for non-irradiated patients has ranged from 92% to 100%, and for irradiated, it is 45% to 79% when the implants are placed in the orbital bone.

Patient Selection:

The exenteration procedure consists of removing the entire soft tissue contents of the orbit, extraocular muscles, fat, and periorbita. Only the inferior, superior and lateral orbital rims are suitable for osseointegration of titanium implants as the orbital walls are thin.

Surgical Procedure:

Stage 1

Under anesthesia, a skin incision is made just anterior to the rim. The periosteum is elevated to expose the bony rim marked with gentian violet

along the orbital rim at the designated locations. Three to four sites are typically chosen for implantation, with the superolateral and the inferolateral rim the more frequent sites. The initial drill orientation should be directed towards the orbit's center, which allows space for the future prosthesis. If an adequate bone is present, a 3-4 mm spiral drill is used to form the final hole. Next, the threading is done at a slow speed of 8 to15 rpm, allowing the precise cutting of bone with the threading tap.

The titanium implant is screwed into the threaded hole with an implant mount on the drill. The implant screw is placed, and a topical antibiotic is applied with a pressure dressing. If the orbital rim continuity is disrupted, several options are available for bony reconstruction to create a bed for implant placement like iliac crest, fibula and calvarial bone.

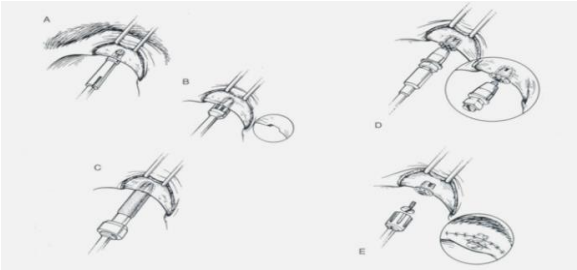


Fig 12: (A) Initial drill (B) Spiral drill used to form final hole (C) Threading of hole done with threading tap (D) Implant placed (E) Placement of cover screw.

Stage 2:

The second stage of surgery involves the placement of titanium abutments after 3 to 4 months. A trephine is used, and an abutment is placed 3 or 4 mm in height, which is covered with a healing cap left for four to five weeks, after which the patient is ready for prosthesis fitting.[3]

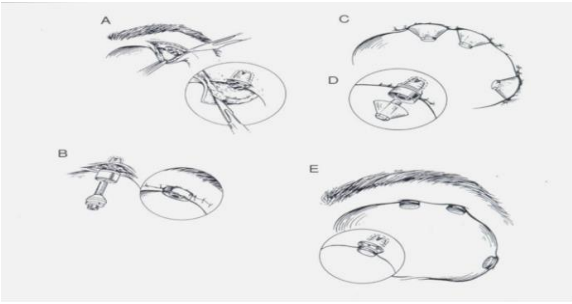


Fig 13: Placement of abutments on the implants

Nasal prosthesis

The maxillary dentition and the presence or absence of anterior teeth can be important diagnostic factors in selecting fixture type, length, and location. Ventilation for nasal prostheses is facilitated via perforations within the artificial nares. Suppose the nasal defect involves only the lower portion of the nose; only two implants inferiorly in the maxilla are placed. Glabella and lateral maxillary areas are poor choices for implants because the framework will interfere with the nose's aesthetic formation.

Stage I

An incision is made, and the periosteum, skin are elevated together. The implants' location is marked, and a 4 mm implant is placed in the lower piriform aperture and 3 mm implants in the nasoethmoidal area. It is extremely important to use the minimally traumatic technique, low-speed drilling, and copious irrigation.

Stage II

After three months, cover screws are removed during second-stage surgery, and abutments are placed along with healing caps. The wound is allowed for two weeks to heal before the prosthetic work is started.

Attachments: A metal bar to connect the abutments or individual magnets can be used. Metal bars work well in the nose area; it limits rotational forces on the implants.

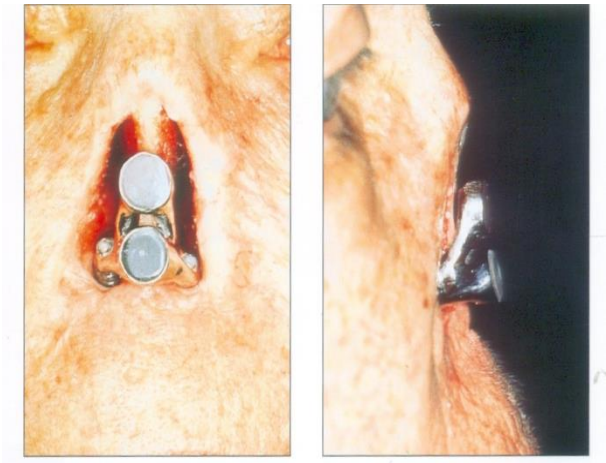


Fig 14: Metal bar connecting to magnets.

Framework Design

A midline clip and framework retention are used in most cases. An inverted Y shape with a cross brace between the widest part of the Y near the abutments is designed in cast metal.

Advantages include:

1) Allows maximum bilateral airflow.

2) Provides vertical and horizontal clip orientation, preventing the misapplication of the facial prosthesis; and

3) Provides access to the nasal cavity and periabutment tissues for hygiene maintenance.

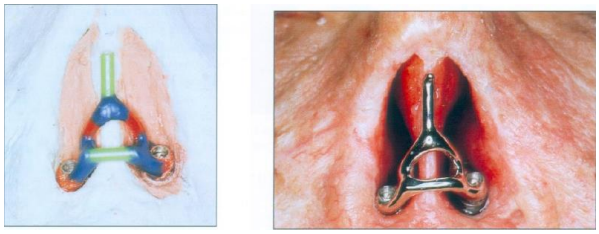
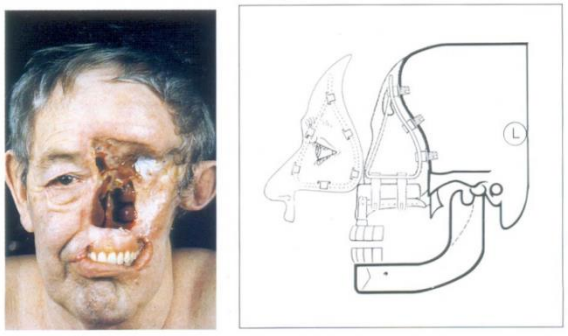


Fig 15: Wax framework model and metal framework in inverted Y shape.

The plastic sprues 2 mm in diameter are cut and positioned as the vertical stem in the wax framework with a transverse brace of the inverted Y. Triangular segments of the Y should be as far as away from the nasal cavity walls, so access for cleaning of septal surfaces of the internal nose is achieved. The inverted Y stem should be as short as possible but still, allow the attachment of a vertically oriented clip.

MIDFACIAL PROSTHESIS



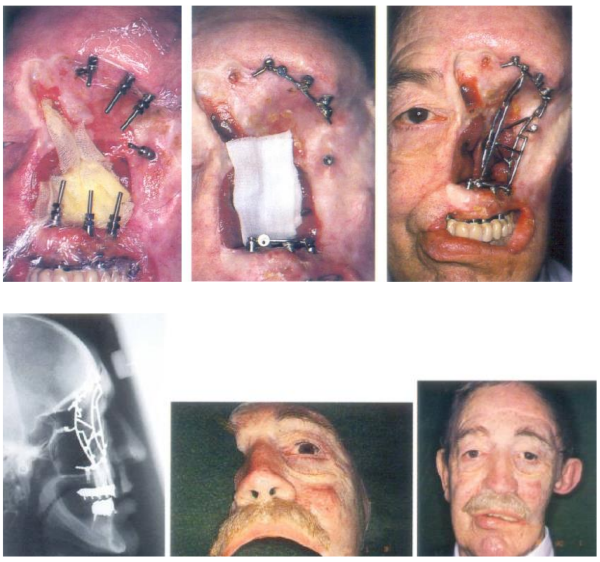


Fig 16: Biomechanical model and restoration of the craniofacial defect using osseointegrated implants and prosthesis in position giving a natural appearance to the patient using implants and bar attachments

Framework:

Two conventional bar constructions were made to retain the facial prosthesis, and the third part connects the two bar constructions. These fittings were then soldered and connected, which are of low weight. Stiffness is achieved, and the entire framework is made of pre-machined gold alloy clasp wire of 2 mm diameter bent and soldered into conventional 3mm gold cylinders.[9,10]

SKIN RESPONSE AT ABUTMENT SITE

Skin response to Percutaneous abutments has also been considered an indicator of success; rating it on five-point scale results from Holgers et al. in 1987.[11]

Class	Description
0	No irritation ,epithelial debris removed if present
1	Slight redness, temporary local treatment
2	Red and slightly moist tissue; no granuloma formation, local treatment; extra controls.
3	Reddish and moist; sometimes granulation tissue , revision surgery is indicated
4	Removal of skin-penetrating implant necessary as a result of infection.
R	Removal of implant for reasons not related to skin problems

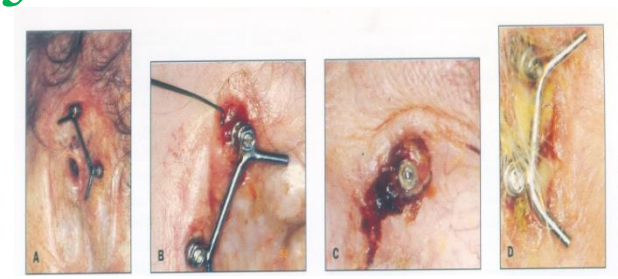


Fig 17: Soft tissue reactions (A) Slight redness (B) Red and moist tissue (C) Granulation, red and moist (D) Infection.

Osseointegration in irradiated patients

It is important to be aware of different factors influencing osseointegration, healing of the soft tissues, and the risk of side effects in the compromised tissues. Side effects considering the factors like - healing of soft tissue over the implants, rupture of major vessel, flap necrosis, fistulation, skin or mucosa infections, loss of implants denuded bones around implants, and even osteoradionecrosis.[12,13]

Complications In Irradiated Patients

Complication	Patients %
Loss of implant	35
Slow wound healing	18
Wound dehiscence	12
Fistula	15
Soft-tissue infection	10
Osteoradionecrosis	2
Rupture of major vessel	0
Flap necrosis	0

A study showing the possible effects of different irradiation procedures found that many implants were lost in the region where the high dose is above 120 Gy. More implants were lost in the low dose region, whereas osseointegration in the medium-dose region showed minor effects.[14]

COMPLICATIONS AROUND PERCUTANEOUS IMPLANTS

Marsupialization: Encapsulation of implant by proliferating epidermis forming a sinus tract and the implant is due to the epithelial cells free edge effect.

Avulsion: Skin around implants subjected to forces that lead to mechanical disruption of the interface, with microhematomas and subsequent macro-foci of acute inflammation, which is considered a mechanically induced failure mode.

Permigration: Immature connective tissue cannot nourish the epidermis, which will permigrate deeper down around the skin, penetrating the implant. The failure mode is related to implants with a porous surface.

Infection: When there is a presence of infection around an implant, it may have serious effects and usually leads to the implant's failure, where the major pathogen is Staphylococcus aureus.[15]

FOLLOW UP AND MANAGEMENT

Follow up management begins once the abutments have been placed. After the initial healing period, the patient is instructed to clean this area daily to remove cellular material on the abutment or the skin, which can arise from the epithelium and abutment interface. The cleaned area should be moistened with an even mixture of hydrogen peroxide and water to soften any dried debris. A soft end nylon bristle toothbrush, a cotton swab or interproximal dental brush is used to facilitate cleaning.[16,17]

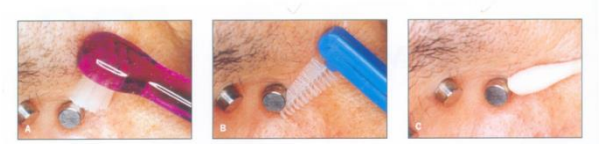


Fig 18: Toothbrush, floss, cotton swab used to clean around abutments

The prosthodontist should monitor the abutment stability and soft tissue condition during the visit for prosthesis fabrication. An abutment clamp is used to check abutment tightness. If the abutment is loosened, complete seating should be verified before retightening, done with an abutment holder.[17]

When placing the prosthesis, the patients should be aware that the retentive elements are engaged completely so that the prosthesis is seated fully. For nasal or auricular prosthesis, proper removal is done by grasping the prosthesis's thick portion and slowly disengaging the retentive elements. For an

orbital prosthesis, the outer margin should be lifted carefully until a thicker portion can be grasped to lift the prosthesis.[17]

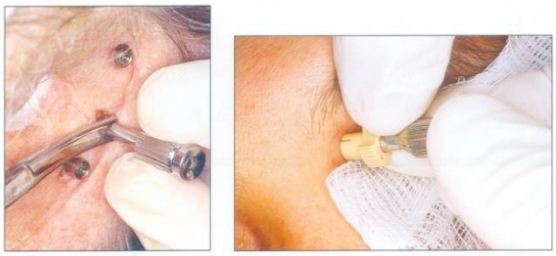


Fig 19: Checking for abutment tightness and tightening loosened abutment with abutment holder

BONE ANCHORED HEARING AID

Hearing through bone conduction means that the sound reaches the skull's inner ear vibrations' hair cells.[18] This is a natural way of hearing. In normal conditions, one's voice reaches the inner ear through 2 routes.

Air conduction:

Sound waves go out of the mouth into the air and the external ear canal. The eardrum starts to vibrate, and by the transmission of vibrations through malleus, incus, and stapes in the oval window, the sound is transferred to the cochlea's fluid.[19]

Bone conduction:

The sound is produced in orofacial cavity vibrations surrounding bone, skull base, maxilla. The sound is propagated through the bone of the inner ear and mandible. These sound waves cause the deformation of the enchondral bone of the inner ear spaces. Because the inner ear compartments have different dimensions, the scala media's hair cells are stimulated. The mechanical energy is transformed into an electrical impulse in the same way as when stimulated through air conduction.[20] Indication for BAHA requires a bone conductor in chronic ear disease and bilateral ear canal atresia. The amplification range of double BAHAs is five dB. [21]

CONCLUSION

During the last decade, the advent of tissue-integrated prostheses has significantly improved treatment results in managing congenital, surgical, and traumatic defects of the craniofacial region. The implant team must develop a coordinated treatment plan that is delivered efficiently. The highest standards of aesthetics and retention should be met. Much attention should be paid to soft tissue fitting and care regarding hardware articulation and registration issues. A commitment to follow up for the clinical evaluation of implant tissues and the maintenance and periodic replacement of the facial prosthesis are team responsibility and the patient's best interests.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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