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Review Article

Biomechanics of Extra Alveolar Anchorages in Implant Prosthetics - A Review

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Abstract

Dental implants are a common treatment for the loss of teeth. Alveolar anchorage is not sufficient for atrophic ridges intraorally. So, extra alveolar anchorage is an effective treatment option in the management of the atrophic edentulous maxilla as well as for maxillectomy defects and maxillofacial defects. In search of anchorage, cortical bone, zygomatic, pterygoid, and nasal regions provide anchorage intraorally whereas extra orally orbital, nasal, and mastoid region provides anchorage for facial defects which can be termed as extra alveolar anchorages. This article represents the biomechanics, cortical stabilization, and extra alveolar anchorage sites according to Zygomatic anatomy guided approach, Bedrosian, pterygoid anatomic radiographic prediction, Reiser's classifications, and custom surface implants intraorally. Extraorally craniofacial implant sites, biomechanics, and its complications.

Keywords: Extra Alveolar Anchorage; Dental Implants; Cortical Stabilization; Biomechanics

Abbreviations

ZAGA: Zygomatic Anatomy Guided Approach; PARP: Pterygoid Anatomic Radiographic Prediction; PFAST: Pterygoid Fixated Arch Stabilization Technique

Introduction

Dentistry nowadays has been improved advancement in technology, restorative material, and strategies for tooth loss. Among the many advancements, the restoration of dental implants is one of the advancement procedures and the technology like CBCT imaging undergoes parallel advancement in dentistry and is clinically evaluated. Dental implants are a remedy for the loss of teeth. The implant surgical procedures in dentistry are advised when the patient's bone is good for anchorage. The anchorage of the bone and the anchorage sites are some of the key successes of implantology. The anchorage sites are maxillary and mandibular alveolar ridges and/or the presence of extensive maxillary sinuses, leading to inadequate amounts of bone tissue for the anchorage of the implants. Various bone augmentation techniques, such as sinus floor augmentation and onlay bone grafting can be advised. Alternatively, the extra alveolar anchorage is an effective treatment option in the management of the atrophic edentulous maxilla as well as for maxillectomy defects and maxillofacial defects. In search of anchorage, cortical bone, zygomatic, pterygoid, and nasal regions provide anchorage intraorally whereas extra orally orbital, nasal, and mastoid region provides anchorage for facial defects which can be termed as extra alveolar anchorages. This article represents the extra alveolar anchorage sites, cortical stabilization, according to ZAGA [1], Bedrosian [2], Reiser's [3], PARP [4] classifications, biomechanics, and custom surface implants intraorally. Extra orally craniofacial implant sites, biomechanics, and its complications.

Extra alveolar anchorage

Conventionally, implants are placed into alveolar ridges which can be termed as alveolar anchorage. Alveolar anchorage is not sufficient for atrophic ridges intraorally. So, extra alveolar anchorage is an effective treatment option in the management of the atrophic edentulous maxilla as well as for maxillectomy defects and maxillofacial defects. The anchorage which can be used other than alveolar ridges can be termed as extra alveolar anchorage. The extra alveolar anchorage can be stabilized with cortical stabilization. In search for anchorage, cortical bone, zygomatic, pterygoid, and nasal regions provide anchorage intraorally whereas extra orally orbital, nasal, and mastoid region provides anchorage for facial defects which can be termed as extra alveolar anchorages.

Cortical stabilization

Primary stability of implants seen due to mechanical interlocking implant between bone to implant contact at cortical bone [5]. The primary stability of implants increases with an increase in anchorages of cortical plates. Based on the number of cortical plate anchorages, it is classified into 4 types.

MONOCORTICAL anchorage

Mono-cortical anchorages are implants with one cortical plate anchorage. This is observed in implants placed in the D2 bone density condition, the ZAGA 4 condition.

Bicortical anchorage [3,6]

Reducing extra-axial load can be achieved by strategically positioning implants and forming a polygon: To restore edentulous jaws with fixed prosthesis, the "supporting polygon" concept has been put out as an alternative to bone grafting. This includes the canines, tubero-pterygoid regions in the maxilla, and the zone of mylohyoid ridge in the mandible. The most distally positioned implants in the maxilla were placed at an angle of 30° to 45° along the pterygoid processes of the sphenoid bone and the posterior sinus wall. A similar technique was used to implant the medial and frontal implants, piercing the nasal floor and lower sinus wall to guarantee anchorage in the second cortical bone. With an angulation of 30°–45, the distal implants were positioned in the mandible's second and first molar regions, using the undercut for the mylohyoid muscle connection. Implants were positioned in the frontal region with the canines and lateral incisors angled laterally toward the highly mineralized portion of the mentum. Implants after extraction were positioned 1-2 mm below the crest, close to the palatal side. The manufacturer's guidelines were followed for the insertion of all implants to maximize cortical bone anchoring.

Tricortical anchorage

The tricortical stabilization technique represents a clinically efficient and predictable method for placing implants, bone graft material, and provisional restorations at anterior sites demonstrating severe buccal plate undercuts and recessed and exposed buccal bone in one surgical appointment. The technique enables dentists to provide patients with a single-surgery treatment that demonstrates stability, functionality, and esthetics, rather than requiring them to undergo multiple procedures or endure discomfort for an extended time. It is seen in severe atrophic buccal bone.

Quadricortical implants [7]

Implant with the stability of four cortical bone plates zygomatic implant crossing four cortices - alveolar crest, maxillary sinus floor, maxillary sinus roof, and zygomatic upper border particularly observed in ZAGA 0, ZAGA 1 and ZAGA 2 condition.

Extra alveolar achorage sites

Pterygoid implants were initially described by ITuslane and Tessier [8]. They are intended to be placed and engaged in the dense cortical bone that is made up of the sphenoid bone's pterygoid process, the palatine bone's horizontal process, and the posterior wall of the maxillary tuberosity. To avoid posterior prosthetic cantilevers and to provide anchorage in the maxilla's posterior region without the need for grafting procedures, pterygoid implants are necessary to traverse the maxillary tuberosity area and reach the dense pterygomaxillary plate.

A zygomatic region can also be used as an extra alveolar anchorage. The cortical plates of the zygomatic bone provide more anchorage. One of the classification related to this anchorage is ZAGA classification [1].

ZAGA classification [1]

ZAGA 0 is characterized by the anterior maxillary wall being very flat; the implant head is located on the alveolar crest and the implant body has an intra-sinus path.

ZAGA 1 is characterized by the anterior maxillary wall being slightly concave; the implant head is located on the alveolar crest; the drill has performed the osteotomy slightly through the wall and most of the implant body has an intra-sinus path.

ZAGA 2 is characterized by the anterior maxillary wall being concave; the implant head is located on the alveolar crest; drill has performed the osteotomy through the wall and most of the implant body has an extra-sinus path.

ZAGA 3 A drill has performed the osteotomy following a trajectory that goes from the palatal to the buccal alveolar bone. The implant body then leaves the concave part of the anterior sinus wall to penetrate the zygomatic bone so that the middle part of the implant body does not touch the most concave part of the wall. The anterior maxillary wall is very concave. The implant head is located on the alveolar crest.

ZAGA 4 The implant head is situated buccally of the alveolar crest; the maxilla and alveolar bone exhibit severe vertical and horizontal atrophy; the drill has reached the apical zygomatic entry after traveling beyond the sinus wall and most of the implant body.

According to Reiser [9]

He proposed the Classification of the Posterior Maxillary Implant Based on Anatomic Location

- Tuberosity
- Tuberosity/pterygoid process
- Tuberosity/pyramidal process
- Tuberosity/pyramidal process/pterygoid process
- Pyramidal process - pterygoid process

According to P. GEORGE, G. M. KURTZMAN [4]

The area of the posterior edentulous maxilla can be classified into two groups depending on the position of the maxillary sinus about the available tuberosity bone where a pterygoid implant will be placed.

The High PTG (left) permits a more vertical placement going through tuberosity and reaching pterygoid plates but not passing through the pyramidal process.

The Low PTG (right) requires placement angled posteriorly which passes from tuberosity, pyramidal process, and finally reaches the pterygoid plates.

PARP classification

The PARP classification allows working only in the pterygomaxillary region with retromolar implants by *Luis., et al.* [5].

PARP 1. It is the simplest scenario when there is no sinus invasion and we have a bone in all its route. In these cases, the length of the implant depends on the bone density.

PARP 2. The patient presents with a sinus invasion but still has >10 mm of the remaining bone. In case of having good bone density, it would be more appropriate to place a conventionally conceptualized retromolar implant.

PARP 3. This is a case of medium-high difficulty, with sinus invasion leaving a bone surface between 5 mm and 9 mm of remaining bone. Due to the scarce remnant of alveolar bone and the air of the sinus invasion, the pterygoid anchor will always be used in the apophasis of the same name, with a suitable density.

PARP 4. In the majority of cases of a large sinus invasion, leaving only a remaining bone smaller than 5 mm, the possibility of using long pterygoid implants or opting for other surgical approaches will be evaluated.

The implant location

The implant placement procedure begins with determining the intraoral coronal entry location, which is determined by prosthetic, biomechanical, and anatomical considerations.

Bedrossian classification [2] of the maxilla to identify zones that implants may be placed into. The Bedrossian classification gives a guideline for the surgical approach to be adapted. This is done by reviewing the patient's panoramic radiograph. The maxilla is divided into different zones

- Zone I - Between canine to canine,
- Zone II - bicuspids,
- Zone III– molars and
- Zone IV – zygoma.

The presence or absence of bone in these zones determines the surgical approach to be adapted.

Type 1

A type 1 maxillary arch presents with a premaxilla (zone II) with a height of 10 mm or greater and a width of 5 mm or greater. This will allow placement of 2–4 regular platforms axial or tilted dental implants in zone I with no grafting needed as the implant can be placed into the native bone and no biological complications are expected requiring grafting. Posteriorly, a single zygomatic implant is placed bilaterally with its platform at the 1st molar position providing a good A-P spread and no distal cantilever prosthetically.

Type 2

The type 2 resorbed maxillary arch is divided into subcategories A and B depending on the degree of resorption. Long-term survival of the anterior implants may be questionable due to the native anatomical limitations related to the bone quantity and quality availability and thus the possibility of surgical modification in case of failure should be predicted.

Type 2A

This type and subcategory presents with an atrophic premaxilla with a height of 10 mm and a width between 3 and 5 mm. This allows the placement of 2 narrow diameter axial positioned implants, Vomer implants. Bone grafting can be expected at the time of the implant surgery due to possible fenestration and dehiscence. Posteriorly, a single zygomatic implant is placed with its platform in the 2nd premolar position. Pterygoid implants are placed to allow support in the molar area without the need for sinus augmentation and improve AP spread while voiding a posterior cantilever. Should in the future the anterior axial implants fail, a second zygomatic implant may be placed. The disadvantage to this approach is patient hygiene is more difficult to reach around the restored pterygoid implants as their position is at or distal to the natural 2nd molar position. Impression capture during the restorative phase may also present some challenges due to the position of the pterygoid implant. The position of the pterygoid implants provides maximized A-P spread and occlusion with whatever teeth or implants are present in the mandibular arch.

Type 2B

This type and subcategory present with a severely atrophic premaxilla (zone I) with insufficient height, width, and angulation issues to permit implant placement. The premaxillary resorption extends to the nasal floor and thus dental implants without prior grafting are not indicated. The resorptive presentation due to angulation issues may not allow implant placement to permit restoration even following grafting. Bilateral double zygomatic implant placement is indicated with implant platform placement at the canine/lateral positions and 2nd Premolar positions allowing stability of the planned prosthesis but termination of the prosthetics at the 1st molar with a resulting cantilever. Quad zygomas have been reported to have comparable success rates as bilateral single zygomatic implants but offer better implant platform spread in those cases that will not permit anterior implant placement. Pterygoid implants may be added to improve the AP spread and reduce the cantilever depending on the opposing dentition and occlusion. As with type 2A, hygiene is more difficult for the patient due to the position of pterygoid implants if they are added and the cantilever if they are not added. Additionally, impression capture during the restorative phase may also present some challenges due to the position of the pterygoid implant, as well as the insertion of the prosthesis at placement.

Extraoral implant anchorages

The placement of implants for retaining prosthesis depends on several factors such as the presence of bone, the proximity of vital structures the dexterity of the patient, soft tissue conditions, prognosis, patient's health, radiation therapy, and economic conditions. The use of extraoral implants provides excellent support and retentive abilities to improve aesthetics as well as quality of life.

Craniofacial implant classification [9]

Based on the amount of bone available for the placement of implant fixtures craniofacial implant sites are classified as (1) alpha, (2) beta, and (3) gamma sites

- **Alpha sites:** There is more bone accessible in these areas, with a minimum of 6 mm. Regular fittings and heavier loads are not a problem for bone. These can be utilized to hold onto intricate dental or facial prostheses. The mandible, anterior maxilla, and zygoma are the craniofacial region's alpha sites.
- **Beta sites:** These can be located in the temporal, zygomatic, anterior nasal fossa, and periorbital regions. These make use of phalange fixtures (4mm) or short dental fixtures (5mm).
- **Delta sites:** include the buttress, pyriform, zygomatic arch, medial orbit, temporal and frontal bones, and zygomatico-frontal process. Implant fixtures used are 3mm or less.

Auricular prosthesis location

Auricular defects are typically the result of trauma, congenital anomalies, or surgically removed cutaneous cancers. easiest techniques: glue, hair bands, or eyeglasses.

Location and number of implants for auricular prosthesis: - As per the accepted protocol, the implants are to be placed in the mastoid area 15mm apart keeping a distance of 20mm from the auditory canal opening. Two 4 mm EO implants (Straumann, AG, Switzerland) were placed for each temporal bone. After soft tissue healing and osseointegration are confirmed, 5.5-mm abutments were inserted [10] and they should be placed at 8 and 11'o clock positions on the left side and 1 and 4'o clock positions on the left side. The retentive mechanisms used are bar and clip, ball clips, and magnetic retentive cap systems. The current treatment, CBCT facilitated the capture of greater osseous detail than could conventional CT; this, in turn, facilitated contingency planning of eight viable sites, only four of which were used.

Orbital prosthesis location

These are recommended for patients who have congenital defects, irreversible damage, tumors, painful blind eyes, or sympathetic ophthalmic conditions that result in the loss or absence of one eye.

The length of the implant used is usually 3-4 mm. There should be 10 – 12 mm space between the implants to allow access for hygiene [11].

Location and placement of implant

Outer canthus or inner canthus and superior orbital rim. An additional implant or two was often placed in the inferior orbital rim or zygoma. The implant should not be angled facially as it may interfere with the prosthesis contour.

Nasal prosthesis

The primary site for implant placement is the floor of the nose, piriform ridge, or inferior orbital foramen. Another site suitable is glabella [12].

Other anchorages like custom surface implants [13].

Prosthetic applications of extra alveolar anchorages

Quad zygoma Prosthesia [14]

Impressions are taken just a few hours after surgery, and the patient must be completely cognizant throughout this phase of the procedure. It will be more challenging to capture impressions when the patient is still unconscious (under intravenous sedation or general anesthesia). The transparent surgical guide is utilized for impression-transfer, implant placement, and implant joining using general-purpose acrylic resin. After abutment placement, impression copings are fastened to the implant abutments. The patient's jaw relationship and occlusion are recorded using the same guide. The space between the surgical guide and the impression copings is filled with fluid silicone after the occlusion has been registered and the guide has been fastened. The transepithelial abutments are covered with protective covers and the copings are removed together with the guide as soon as the material has solidified. The temporary prosthesis is made using the standard process, which involves casting a model and joining laboratory counterparts. It may be possible to use the patient's existing conventional denture, which satisfies all prosthetic standards, as a reference for the surgical template and to facilitate the conversion to an all-acrylic bridge for instant loading. The mouth picks up two or three of the imprint copings. Next, an imprint tray is used to make an impression. The intaglio surface is filled in after the final implants are detected on the model. Before creating the final prosthesis, implant integration is confirmed six months following surgery, and the soft tissues are evaluated. To achieve sufficient anterior and posterior support, implants in the maxillary arch must be distributed somewhat evenly. Implants ought to be placed with a secure anchorage in the zygomatic bone on the maxillary crest.

With a quad zygoma cross-arch stabilization system, implant stabilization is provided by the provisional prosthesis right away following surgery. While it is always desirable to achieve an insertion torque of more than 35 Ncm for each implant, it is not required. Some implants may experience a small bending (but not rotating) movement because there is frequently a lack of implant integration at the crest. As soon as the prosthesis is linked, this stops. The implants are submerged if sufficient primary stability cannot be attained, which is not common. Implants should never be loaded in a free-standing configuration.

Pterygoid implant prosthesis

All on Four and Six with the pterygomaxillary complex is a recognized anchorage site for dental implants, according to Holtzclaw., *et al*. [15] it is usually saved for use in challenged circumstances. This region's thick bone has been linked to great survival rates in delayed loading scenarios and offers superior insertion torque for dental implants.

When pterygoid implants are used for immediately loaded full-arch scenarios, the Pterygoid Fixated Arch Stabilization Technique (PFAST) procedure is utilized to determine implant insertion features and success. Using the PFAST technique, the pterygoid process of the sphenoid bone and the thick cortical bone of the pyramidal process of the palatine bone is engaged. For patients [16,17], the author was able to significantly expand the A-P implant spread, guaranteeing a restoration with a sufficient distal extension for chewing ability and buccal corridor aesthetics. Severe pneumatized maxillary sinuses are rarely discovered during surgery and are often straightforward to detect and plan for with a standard CBCT pre-surgical assessment. On the other side, low bone density and its impact on All-On-4 surgical planning may be more difficult to identify beforehand. A few factors need to be taken into consideration when assessing CBCT scans for bone density and pre-surgical planning of possible implant placement locations when executing All On-4 style dental implant treatments. Above all, it should be kept in mind that before the implantation of dental implants, most On-4 style surgeries necessitate alveolar bone reduction. After such bone reduction, the crestal cortical bone is often removed, leaving less thick trabecular bone to serve as the implant recipient site. The buccal and lingual walls of dental implants can be engaged by the implant's threads in the majority of patients.

All on four [18,19]

As previously discussed in the literature, pterygoid implants are a reliable and beneficial tool for the rehabilitation of the posterior atrophic maxilla. To the best of the author's knowledge, however, no work has addressed full arch rehabilitation with rapid loading of the upper jaw with four implants, two of which are conventional implants in the front region and two of which are pterygoid implants in the posterior. Pterygoid implant placement prevents direct vision of the finishing point. Standard protocols were followed for implant insertion, but certain strategies such as under preparation, osseodensification, and bi-corticalization were applied to boost primary stability. Using Misch's denture conversion technique, a previously removable provisional denture was transformed into a fixed, screw-retained complete acrylic FP-3 prosthesis that was delivered six hours after the procedure. Four months following surgery, the final acrylic prosthesis with titanium milling was put in place.

Biomechanical considerations of implants in maxillofacial prosthesis [8]

- **Design of craniofacial and intraoral implant:** Compared to intraoral implants, craniofacial implants are less varied. Because there is a limited supply of bone, they are only accessible in shorter lengths of 3–4 mm. Its perforated flange helps prevent the implant from tilting when lateral stresses and moments operate on it. It also enhances the surface area of the implant, improving its initial mechanical stability during the healing period.
- **Micromotion at the Bone-Implant Interface:** For optimal osseointegration, implants should be largely stationary when they are implanted. Any micromotion in such a location results in the fibrous tissues forming and osseointegration failure.
- **Stress Transfer from implants to bone:** Never put an implant under more stress than it can handle. Whereas craniofacial implants are stressed between 0.1 and 1N, intraoral implants are stressed between 50 and 200 N.10 The implant screw's design, mainly by compression on its angled faces, transfers an axial tensile or compressive force to the surrounding bone.
- **Load distribution to several screws:** Depending on the relative stiffness and geometry of the arrangement of the components, a prosthesis supported by many screws results in a composite structure that functions as a single unit in which any applied load is distributed equally across all the members.
- **Impact of implant stiffness on stress distribution:** The diameter of the implant determines how stiff it is. Implant stiffness will rise fivefold with a 30% increase in diameter, resulting in a significant reduction in stresses around the implant neck.
- **Impact of the implant shape on stress distribution:** Implants exhibiting rational symmetry are considered regenerative aids because force transfer into bone should be as uniform as possible.
- **Impact of the implant surface on stress distribution:** The maximum implant surface area that can be utilized for force transfer is recommended. The implant surface can be made larger by adding threads, covering with plasma flame spray, roughening the surface, or acid etching to reduce compressive pressures.
- **Measurement of implant stability and Osseointegration:** Histological examination, percussion testing, reverse and vibration testing (perio test and radiofrequency analysis test) are techniques used to assess implant stability. When an implant is placed, the radiofrequency analysis technique assesses the quality of the bone and any changes in stiffness at the implant-tissue interface that may be related to bone development during the healing process. If fibrous tissue growth at the interface causes an implant to fail to integrate, resonance frequency decreases, and damping increases.

The method which is used to detect the biomechanics of implant and bone is the finite element analysis method [20-22].

Complications

Complications of zygomatic implants [14]

Penetration into the Orbital Cavity.

Peri-Implant Mucositis, Peri-Implantitis, and Retraction of Buccal/Labial Peri Implant Tissue.

Pterygoid complications [15]

Multiple studies have noted that pterygoid dental implants have a high learning curve and are technically challenging due to difficult surgical access and proximity to vital anatomic structures. Vascularity such as the pterygoid venous plexus and descending palatine artery are in propinquity to the pterygomaxillary fissure and pose a risk for excessive hemorrhage should they be damaged during implant placement.

Prosthetic complications

These include loosening of the transepithelial abutments, loosening of the prosthesis fixation screws, and fracture of the prosthetic teeth or prosthetic structure.

Custom-made subperiosteal implants

Their main problems could relate to 1, material fracture due to fatigue, 2, peri implants, 3, implant exposure, 4, implant mobility, 5, lack of osteointegration, and 6, length of the connection pillars used.

Extraoral implant complications

From several studies conducted it is found that the implant survival rate is high for auricular prosthesis followed by nasal and orbital areas, the most common complication seen is peri-implantitis which is related to hygiene maintenance around the implant site.

Conclusion

The current implants are adaptable, have success rates, and have boosted patient acceptability and comfort. The cortical stabilization technique represents a clinically efficient and predictable method for placing implants. By engaging the dense cortical bone, the additional insertion torque can be added to full arch cumulative torque values which increases the chances for immediate loading. There are numerous advantages for extra-oral implants including consistent retention, enhanced stability, improved patient confidence, improved aesthetic due to the possibility of forming fine featheredge prosthesis, and extended functional life of prosthesis. There is still potential for advancement and research in this area.

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