APPRAISAL OF FUNDAMENTALS IN CONTEMPORARY IMPLANT SYSTEMS

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ABSTRACT

Rapid advancement in science and technique of dental implantology has resulted in preamble and development of an extensive assortment of implant systems. This has widened the clinical applicability and adaptableness of dental implants according to the presenting condition. In turn, this has also resulted in newer considerations in treatment planning and challenges in clinical decision making. The selection of an appropriate implant system in accordance with the clinical stipulations, the first and foremost step in implant dentistry which dictates the treatment outcome, has become more taxing. Consequently, a comprehensive awareness of the contemporary trends and implant systems is obligatory for accomplishing the intended outcome with dental Implantology. This article discusses the present-day generic implant systems based on their scientific and diametric fundamentals.

Key words: *Osseocoalescence, Grit blasting. Submerged placement. Additive, Ablative*

INTRODUCTION

The rapid growth in the dental implant research has lead to development of several new implant systems.[1] Manufacturers are coming up with a new design and system of implant almost every fortnight. Considering the variety of materials, surface treatments, shapes, lengths and widths available, clinicians can choose from more than 2000 implants during treatment planning.

As many as 220 implant brands manufactured by 80 different manufacturers have been identified.[2] Although having these many options is beneficial, this has also made the selection of an implant system and treatment plan more complex and challenging. Because no implant system is appropriate for all patients, choosing the implant that is best suited for a particular case is a critical part of the treatment. When a practitioner has training only from the manufacturer's course, there is a tendency to fit the patient to that system of implant rather than choosing the appropriate system.

Each implant system and its manufacturer provide a different design, shape, form, dimension and surface characteristic. The implant systems can be classified and described based on these different features (Tables 1 to 6).

Subperiosteal implants

Subperiosteal implants gain support from the outer aspect of the cortical plate. The subperiosteal implants originated from the design of Gerschoff and Goldberg[3]. They are used when no enough bone is available to place implants within the bone. These implants consist of a metal framework which is placed over the alveolar crest. The projecting posts on the framework are left uncovered by the mucosa which are used to support the prosthesis. The subperiosteal implants are not used widely nowadays because of the development of better systems of implants. However, circumstances when the subperiosteal implants can be considered include:

1. If anatomically the osseous support is inadequate in the mandibular posterior region for endosseous implants and the patient wants to keep his/her natural teeth in the anterior region.

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2. If no enough alveolar bone is available above the inferior alveolar nerve
3. If the ridge is too narrow bucco-lingually to support an endosseous implant

Endosseous implants

The endosseous implants have gained more acceptances and are more widely used because they gain support analogous to that of a natural tooth. The endosseous implants differ in shape and size. The most widely used being the screw-type design which has become more common than the blade vent type of implants. These 'root-form' implants can be either cylindrical or tapered.

A stepped screw implant is a relatively newly developed type of screw implant. The finite element analysis have proven that the stepped screw implants induce comparatively lesser maximum stress levels on the peri-implant bone (17.9% lesser) than the screw type implants, especially for the normal cortical bone quality and oblique bone conditions. It has also been suggested that the stepped screw implants are more bio-mechanically suited for cortical bone with an elastic modulus from 10 to 13.4 GPa whereas screw type implants are suitable only for cortical bone with elastic modulus of above 13.4GPa.[4]

The endosseous cylinder of root form implants are the most widely used implants nowadays because of their increased stability due to direct bone anchorage. They are used for single tooth replacements, multiple tooth replacements and also to support overdentures. The endosseous cylindrical implants can be either threaded or non-threaded in type. Light microscopic evaluations of the retrieved implants by some authors have revealed that the bone-implant contact is more in case of the threaded implants (33%) than in non-threaded implants (23%).[5] The hollow-type implant is a type of endosseous implant that has hollow spaces within the body. It is being widely accepted that increased stability can be achieved with these implants as it has been proved that there is osseous spreading within these hollow spaces.

Based on the dimensions, endosseous implants are available in three widths and corresponding platforms

1. Regular platform: This is the most commonly used. This type of implant has a 4.1 mm diameter platform and a 2.7 mm hex. This platform corresponds to the implant body of 3.75 and 4 mm diameter.
2. Wide platform: This type has a 5.1 mm diameter platform corresponding to 5 mm implant body. The hex diameter is 3.4 mm. This type is recommended for posterior areas where additional loading is anticipated in the molar crowns. They are also useful in areas of softer or poorer quality bone as increased diameter also increases the implant-bone contact area and thereby increasing the primary stability of the implant
3. Narrow platform: A platform diameter of 3.5 mm corresponding to a 3.3 mm diameter body. The hex diameter is 2.4 mm. They are recommended for areas of limited space - either because of tooth proximity or narrow ridge. They have decreased ability to withstand mechanical forces.

The implant diameter ranges from 3.5 mm to 6 mm and length ranges from 5.75 mm to 23.5 mm. The taper of the root form implants can vary from 0°to 14°. Increase in implant diameter has been proved to result in a 3.5-fold increase in the strain on bone crest. Increase in the length can cause a 1.65-fold reduction in strain. Taper of the implant body increases the strain, especially in narrow and short implants, where it increased by 1.65- fold. Hence in order to minimize the peri-implant strain on the crestal bone, a wide, relatively long and untapered implant is recommended as the most favorable choice.

Intramucosal implants

Implants that are inserted within the mucosa, the intra-mucosal implants are of two types: the single inserts and tandem inserts. The rationale behind these inserts is to provide a mechanical lock in the keratinized mucosa. However for this to occur, the tissues must be allowed to heal in to a tightly fitting shape around the head of the inserts. External stressing on the healing tissues can cause stretching and enlargement of the receptor sites and loss of mechanical retention. The inserts must also seat fully in to the prepared sites, allowing for proper reinsertion of the denture base against the tissues to establish complete seating of the denture. To avoid mobility of the receptor sites during healing, the original dentures should be fixed in place with surgical wires. To simplify the surgical procedure and to eliminate the surgical fixation, the design of the insert has been modified. The insert neck has been lengthened, head altered and a special receptor site preparation bur has been designed to prepare a receptor site that is slightly narrower than the insert. However movement of the receptor site will result in enlargement of the site. The basic concept of mucosal implants suggests two rows of inserts, one on the crest of the ridge and the other on the palatal inclines to increase the mechanical interlocking.

Mini implants

Mini-implants have been used as anchorage units for moving teeth. They belong to the transitional type of implants. Transitional implants are implants that are placed to serve a purpose for a specific period of time, after which they are removed. Mini-implants are basically of endosseous type, cylindered - titanium implants. Tapered type of endosseous implants has also been used. Mini-implants commonly used have a diameter of 1.0 to 1.2 mm at the apex and 1.4 to 2.4 mm at the body for the tapered type of implants. The thread pitch in the screw varies from 0.5 to 1.5 mm.

Mini-implants can also be used for supporting fixed prostheses in cases where there is compromised interocclusal space. Implants of a diameter of 1.8 mm are available and these can be used in multiples to retain complete dentures in both maxilla and mandible. When these implants are given in sites with inadequate bone for conventional implants, they provide adequate support and also maintain the available blood supply in the peri-implant tissues in a better way than in comparison with the conventional implants. Sites accepting the small diameter implants should be of denser bone types I and II.

Surgical phase

Based on the surgical stages and placements, two basic forms of implants are in use currently. The first category of implants was introduced and developed by Branemark and colleagues.[6] These implants are referred to as two-piece implants. They constitute an implant body and a separate abutment. The implant is placed during the first stage of surgical procedure. The tip of the implant is placed at the level the crest of the bone or slightly apical to crest. The gingival tissues are re-approximated for primary closure over the top of the implant, which is then left undisturbed for a healing period of 3 to 6 months for osseointegration. This surgical placement technique is known as the 'submerged placement'. After successful integration of the implant in the bone, a second stage surgery is performed and a restorative abutment is connected to the implant. The gingival tissues are re-approximated around the abutment as they would be around a natural tooth. A second healing period is allowed for the tissues before the restorative procedures are continued.

The second category of implants is referred to as one-piece implants. This was introduced and developed by Schroeder.[7] This comprises of an implant body and a healing abutment manufactured as one piece. The implant is placed surgically with its top positioned coronal to the crest of the ridge. Gingival tissues are approximated around the, now transgingival implant, rather than over the top of the implant at the time of the surgery. This is known as 'non-submerged placement'. This is also known as the single stage placement system as no second stage surgery is needed. Restorative procedures are carried out after the healing is completed.

In some cases the two piece implant and abutment components can be placed simultaneously in one surgical procedure, during which the gingival tissues are re-approximated around the abutment. This is referred to as 'semi-submerged placement'. Also in a few cases, such as in those associated with bone grafting procedures, the one piece implant can be placed, completely submerged at the time of surgery. When a submerged implant design is used, second implant components that are added to the implant body during the second stage surgery leads to connections that are flat and maintained by screws. Researches have proven that such connections can become contaminated with microorganisms, thereby leading to inflammation reactions in the host tissues. This host response can lead to soft tissue changes like recession, bone loss, enlarged biological width, etc. With non-submerged implants, no such interfaces are created as they are of one piece in nature. Hence, the undesired host tissue responses can be negated and soft tissue changes minimized. The restoration of both the types of implants can be achieved with either screw retained or cemented restorations.

Implant surfaces

Dynamic implant surfaces have been developed with an aim of enhancing the interface between the implant and the bone. The term osseocoalescence has been proposed to refer specially to chemical integration of implants in bone tissue.[8] The term applies to surface reactive materials, such as calcium phosphates and bioactive glasses which undergo reactions that lead to chemical bonding reactions between bone and biomaterial. With these materials it is believed that the tissues coalesce with the implant.

Two categories of the surface of implants are cited as being important for determining tissue responses. One category includes the topographic or morphologic characteristics. The other type includes the chemical properties. The surface topographic of implants can be varied from smooth to rough. Several quantitative parameters have been reported, the most common being R(a), the arithmetic mean of deviations in the roughness profile from the mean. R(q) refers to the mean square root of deviations from smoothness and R(max) or R(y) refers to the maximum peak to valley height contoured during a regular microscopic scan.

The surface chemistry can also be varied between the implants. The commercially pure titanium is the most commonly used material because of its clinically proven bio-compatibility. Ti.6A1.4V is also a widely used alloy for implants. The biocompatibility of Titanium is mainly attributed to the stable oxide layer formed on its surface. Coating of the implant surface with materials such as calcium phosphate, hydroxyapatite, etc. has been studied. The most common problem with such surface coatings is the separation of the coatings from the metallic substrates, a phenomenon known as 'delamination'.[8]

Based on their surface characteristics the implant systems can be either of the following:

1. Implants with smooth surface
2. Machine finished surface

The methods of altering the surface texture of the implants are: Ablative and additive.

Ablative methods remove materials from the surface of the implant to roughen it. Some common ablative methods include grit blasting, acid-etching and grit blasting followed by acid etching.

Additive methods add material to the surface of the implant to roughen it. The most commonly used additive method is plasma spraying. The plasma gun is a high intensity electric arc burning in a gas stream. Titanium is introduced as a powder into this gas stream where it melts and then it is sprayed over the surface of implant to obtain the roughness over the surface.

Immediate, Early and Delayed loading

Based on the loading, implants can be classified into immediately loaded, early loaded and delayed loaded. The immediate loading protocol consists of an implant supported temporary or definitive restoration placed occlusal contact within two weeks of implant placement. The immediate loading procedure includes a non-submerged stage 1 surgery followed by loading of the implant with a provisional restoration at the same appointment or shortly thereafter.

Early loading refers to implant supported restoration in occlusion between two weeks and three months and is done by two stage surgical technique.

Immediate loading of the implants is indicated in patients who are intolerable to removable provisional prosthesis and in case of patients requiring immediate results and who are unable to wait for the healing period. It is contraindicated in patients with inadequate bone volume, inadequate bone density, patients with parafunctional habits and systemic disorders. In spite of the advantages of the immediate loaded implants, several authors have studied and reported that the delayed loading of implants has a more predictable outcome of osseointegration.

Implant position and angulation may require different abutments to allow optimum esthetics. Lack of inter-maxillary space may preclude traditional abutments and require special or custom abutments. The number and variety of abutments available have been the direct result of the need to better orient the implant to the occlusal plane to facilitate prosthetic therapy. Therefore depending on the need several abutment systems are available. As described earlier the abutments can be classified in different ways. (Table 5 and 6)

TABLE 1: BASED ON MORPHOLOGY AND AREA OF PLACEMENT.

i) Endosseous/Intraosseous/In-bone implants

Root form implants

- Unthreaded
- Threaded
- Mini implants

Blade implants

Spiral implants

ii) Transosseous / Through bone implants

iii) Sub-periosteal / On-bone implants

iv) Submucosal implants / Intra mucosal inserts

v) Endodontic stabilizers

TABLE 2: BASED ON THE SURFACE.

Implants with smooth surface

Implants with altered surface topography (machine finished surface)

- Additive treated surface (eg. Plasma sprayed)
- Ablative treated surface (eg. Grit blasted, acid etched)

Implants with altered surface chemistry

(eg. Hydroxyapatite coated, Fluoride coated etc.)

TABLE 3: BASED ON THE MATERIAL USED

1. Metallic

1. Titanium
2. Titanium alloys
   - Titanium-Tantalum
   - Titanium-Nickel
3. Cobalt chromium
4. Molybdenum
5. Stainless Steel
6. Gold alloys

2. Non metallic

1. Ceramics
2. Vitreous carbon
3. Porous aluminum silicate
4. Polymers and composites (under evaluation)

TABLE 4: BASED ON THE BIO-ACTIVITY

- Bio active
- Bio inert
- Bio glass
- Bio-resorbable

TABLE 5: BASED ON RETAINING PROSTHESIS OR SUPERSTRUCTURE

1. An abutment for screw retention uses a screw to retain the prosthesis or superstructure;
2. An abutment for cement retention uses dental cement to retain the prosthesis or superstructure.
3. An abutment for attachment uses an attachment device to retain a removable prosthesis.

TABLE 6: THE ABUTMENT CONNECTION CAN BE CLASSIFIED INTO:

1. One and 2 piece flat top
2. One and 2 piece conical shouldered
3. UCLA type plastic castable
4. UCLA machined/plastic cast to cylinders
5. ULCA gold sleeve castable
6. One piece fixed post
7. Two piece fixed shoulder
8. Pre angled fixed
9. Telescopic millable post
10. Ceramic
11. Single tooth direct connection
12. One and two piece over denture abutment

Prosthetic union

The endosseous implant and abutment support the final prosthesis or superstructure which is attached to the implant by any of the three following methods.

1. Screwing the restoration to the implant directly
2. Screwing the abutment to the implant and attaching the restoration to the abutment with either additional screws or cement
3. Cementing the abutment to the implant before attaching the crown.

The first two options are more frequently followed methods while the third method is not usually recommended. Retrievability is the major advantage of either type of the screw retained types. Implant screw loosening, however continues to be a frequently cited disadvantage of these techniques. The retrievability facilitates individual implant evaluation, soft tissue inspection, calculus debridement and any necessary modifications. Future treatment procedures can also be made easily and less expensively.

Screw loosening is the problem associated with this type of restorations. The understanding of the screw mechanics is essential to avoid the tribulations. The screw loosening occurs only when the outside forces that try to separate the parts are greater than the force keeping it together. Forces that try to disengage the parts are known as 'joint separating forces' and those that keep the parts together are known as 'clamping forces'. The implant screws can be kept tight by two means: Maximizing the clamping forces or minimizing the separating forces.

The joint separating forces in implants normally includes

- Excursive contacts
- Off-axis centric contacts
- Angled abutments
- Wide occlusal table
  - Inter-proximal contacts
  - Cantilever contacts
  - Non-passive framework

Minimizing these forces can prevent implant abutment screw loosening. The clamping forces for resistance of implant screws to separating forces can be maximized by the following methods

1. Placing implants parallel to the forces of occlusion
2. Minimizing cantilever lengths
3. Anti-rotational features engaged for single tooth restorations
4. Passively fitting frameworks
5. Occlusion adjusted to direct the forces along long axis

- Eliminating posterior working/balancing contacts
- 'Centralized' Centric contacts
- Share anterior guidance with natural teeth

A few authors have studied the micro gaps that exist between the abutment and implant. They concluded that for screw-retained abutments, the micro gap is 60 um and for cement retained its 40 um which is invariably closed by the cement. In the screw retained abutments, the gap can be colonized by microorganisms but this is not the case with cement retained abutments as the cement fills the gap. But despite of this critical factor of microbial colonization in the micro gaps of the screw retained abutments, no significant difference in the soft tissue changes have been reported between the screw and cement retained types.

Angled abutments

Angled abutments are used to improve the path of insertion of the prosthesis or the final esthetic result. Angled abutments are fabricated in two pieces and are weaker in design than a one-piece post. Implant placed at an angle often requires an angled abutment. The inclinations range from 10 to35 degrees. This change in angulation eliminates prosthetic compromise in most situations. The angulated abutment has 12 facets and 12 positions of angulation in a 360-degree circle.

The angled implant abutment can compensate for the degree of angulation (upto25°) without slicing the abutment and can address the aesthetic problems by eliminating the placement of the screw entrance on the labial side when a labioversion is needed in implant supported prosthesis, especially in the maxillary anterior region. In contrast to the straight implants, the angled implants have a rectangular entry with respect to the surrounding gingiva, which thereby allows better oral hygiene and aesthetics. The angled implant abutments also have disadvantages of difficult operative technique, dependence on operator's ability of judgment regarding the direction and angulations and the inability of altering the position of the implant after its placement.

The indications for angled abutments include single tooth replacements in the maxillary anterior region, fixed prostheses on implants for distal extensions in maxillae, maxillary implant retained fixed dentures, overdentures in maxillae, fixed partial dentures in distal extensions in mandibles over dentures in anterior region of mandible with bar constructions, misjudged direction of preparations, anatomic problems for placement of straight implants.

Internal and External Hex

The connection between the prosthetic component and the implant structure can be classified in to internal helix and external hex. The internal helix type is believed to have a better load transmission along the long axis of the implant body. The Internal hex connection allows a more precise implant to abutment interface and less movement, Permits implant cover screw to be seated level with the top of their implants at stage one surgery and provides greater assurance of primary closure and few opportunities for injury.

Implant over dentures

Overdentures usually involve the incorporation of various attachment systems when they are used with implants. The methods used to provide retention for Overdentures are the bar attachments, ball attachments and magnets. There are two groups of bar attachments: bar units and bar joints. Both types provide retention for an overdenture while splinting the abutments. The bar unit provides rigid fixation while the bar joint provides rotational, resilient, or combined movement to the overdenture. Both types could be used with implants. Some implant systems have their own bar joint components specifically manufactured for use with that particular system.

In bar joint systems the overdenture is supported in part by the mucosal tissues of the ridges. Thus, it is important that the borders of the overdenture be properly extended to provide stability and retention present with conventional dentures in addition to the retention and stability provided by the attachment system. The principle of the bar joint system is to provide retention of the overdenture against vertical dislodging forces. When the overdenture is functionally loaded during occlusion, there is a shared distribution of the occlusal forces between the mucosa and the bar joint.

Rotational movements of the overdenture in the frontal and sagittal planes are permitted by the rotation of the sleeve about the bar. However, these movements are guided by the bar joint system eliminating any excessive, undesirable movements against the mucosal tissues. In most cases, the bar is placed in the anterior region. The bar should be placed directly over or slightly lingual to the crest of the ridge in a straight, horizontal alignment. In the anterior region, the bar should be perpendicular to a line bisecting the angle formed by the posterior alveolar ridges.

There should be at least 2 mm of space existing between the inferior surface of the bar and the gingival tissues of the alveolar ridge. However, it has been stated that there is no disadvantage to having the bar in direct pressure-free contact with the ridge as long as regular oral hygiene is maintained by the patient.

The majority of the bar joint systems presently available have plastic bar forms. They can be easily adjusted to fulfill the desired form and can be waxed to the copings. The entire assembly can then be cast as a single unit with a metal alloy designated by the manufacturer as being compatible with the copings. Metal or nylon sleeves can be used with these bar joint systems. The flanges of the sleeve flex over the bar when the overdenture is seated to provide the retention for the system. The metal sleeves are adjustable to allow for flexibility in controlling the degree of retention. However, they can be difficult to replace or repair. The nylon sleeves are not adjustable but can be replaced easily. The O-ring abutments on the other hand have the advantages of ease of use, hygiene maintenance and elimination of a superstructure bar. Ball/0-ring attachment could also be advantageous for implant-supported overdentures with regard to optimizing stress and minimizing denture movement. Hence they are more commonly used. But wear of the O-rings will lead to a gradual loss of retention and so they need periodic replacement.

Magnetically retained overdentures have become very popular with the various implant systems. Magnets can be used with virtually any implant system. The system basically consists of a magnet and a keeper.

As explained in the classification of implant abutments (table 5 and 6), several types of abutment-implant connections can be used depending on the available conditions. The types of connections that can be provided are:

One and two piece flat top:

They are used when the focus is to restore the completely edentulous mouth. The restorations resemble pier-like structures that are highly functional but limited in esthetic appeal.

One and two piece conical shouldered

The transition from the completely edentulous arch to fixed partial denture application of the implants resulted in the introduction of this modality. In this type of connection, the coronal area is closer to the implant interface and hence it permits changes in the angulations.

UCLA type plastic castable

This connection eliminates the intermediate transmucosal connection completely and improves esthetics. This connection was later modified as UCLA machined/plastic cast to cylinder. This type is available with and without anti-rotational engagements and problem of screw access channel can be thus eliminated.

UCLA Gold sleeve castable

The direct connection concept was extended to include a machined hexagonal body with low profile shoulder (eg.noble biocare). This thereby eliminated the esthetically compromising abutment screw access channel and the vulnerable porcelain to metal occlusal interface.

One piece fixed post and two piece fixed shoulder

The indications for this connection are simplicity and esthetics. They were rather crude with respect to cervical collar size and flare. The two piece cementable straight or angled abutment permits axial correction and shoulder modification.

Summary

The wide clinical applicability of implants and increasing patient demands has lead to the development of several different systems as seen so far. As the variations in implant design, dimension and topography have critical bearing on the implant-bone interface, the selection of the suitable implant system is the first step towards a successful long term Prosthodontic rehabilitation with implants. In order to make this first step in implant therapy, adequate knowledge of the current implant systems is required. It should be always remembered that clinical knowledge of the operator and scientific documentation of a particular system of implant is more important than the manufacturers' claims.

Although different implant types have been tried, endosseous implants root form implants are the most widely used form now and they often have success rates of 90% to 100%. The success and survival rates of root form implants continue to improve as the surface topography, design and clinical experiences evolve. Considering the bio-mechanical perspective, whenever ideal bone quantity quality are available, it is always advisable to opt for a wide, long, threaded implant which provides more bone-implant contact area and also reduces the crestal bone stress.

There are many desired characteristics of implants, the most important among them is the one that ensures that the tissue-implant interface will be established quickly and then will be firmly maintained for a long duration of time. The current literature and research doesn't support any particular type of implant to exhibit the above mentioned desired qualities. This lack of an 'ideal implant' will continue to act as a driving force for the numerous researchers and Implantologists across the globe in a quest to design an implant that exhibits all the desired qualities.

The continuing search for 'osseo-attractive' implants is leading to modifications in the design and biological molecules on the implant surface. Bio-stimulation has become possible now by attracting or releasing powerful cytokines and growth factors and thereby attaining the desired tissue responses. It has also been proved that the introduction of bone morphogenic protein at the tissue-implant interface can enhance the rate of peri-implant bone formation. Let these approaches lead us towards the development of an osseo-attractive implant in the near future.

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