Review of literature

The application of dental implants for prosthodontic reconstruction can be traced back to ancient Egypt, where seashells were hammered into human jaw bone to replace missing teeth although it is unknown whether these substitutes were placed ante mortem or post mortem, it illustrates the desire to create artificial substitutes for natural teeth that could be anchored in bone. Early implants with documented success were fabricated from noble or base metals shaped in either basket or pin designs that attempted to recreate natural roots which could then be connected to transmucosal fixed prostheses.

According to the Academy of Prosthodontic 2005 dental implant is defined as; "A prosthodontic device of alloplastic material, implanted into the oral tissues beneath the mucosal and/or periosteal layers and / or within the bone to provide retention and support for fixed or removable prostheses. **(6)** While the American Dental Association (ADA) Organization defined implants as; "Material inserted or grafted into tissue. "A device specially designed to be placed surgically within or on the mandibular or maxillary bone as a mean for providing a dental replacement; endosteal (endosseous); eposteal (subperiosteal); transosteal (transosseous). **(7)**

According to the dental Glossary, dental implants are used to replace missing teeth. A dental implant is a false root that is permanently secured in the jaw i.e. small titanium rod is fixed into the jawbone, and once the jawbone has adhered to the structure, a false tooth is attached to it. **(8)**

According to Encyclopedia of Surgery, dental implants are surgically fixed substitutes for roots of missing teeth. If embedded in the jawbone, they act as anchors for a replacement tooth, also known as a crown, or a full set of replacement teeth. **(9)**

Evolution of dental Implants

The earliest implant attempts date back in history to the old Pharaonic Egyptian civilization. Their early implantation attempts were probably only in corpses and only limited to the higher class of the society. These attempts were driven by their religious beliefs; that the body has to be buried in the best shape possible, so that it would enjoy full function upon revival. Their writings of implantation of animal and carved ivory teeth are the oldest documentation of primitive implantology. **(10)**

The ancient South American civilization is also credited with evidence of early attempts to replace lost teeth by using artificial teeth carved from stone. **(11)** From the same era a mandible fragment dating back to 600 A.D. (Anno Domini) now present at Harvard University contained three tooth shaped shell pieces placed in the sockets of missing lower incisors presumably placed during the person's life. **(12)**

The era of allotransplantation

Allotransplantation of natural teeth to the upper wealthy class of society was a common procedure during the eighteenth and nineteenth centuries, especially in the western civilization. Natural teeth were extracted from poor individuals who used to sell their teeth for money. **(13)** The transplants were unpredictable, often complicated by infection and rejection, but in some cases, it lasted for a considerable amount of time lasting from a few years up to 25 years. (13)

Allotransplantation of human teeth was faced with some opposition; Philip Pfaff **(14)** in 1756 was the first researcher to point out the possibility of disease transmission through this procedure.

This idea was continued well during the twentieth century and tooth banks were established in the 1970's. They obtained donor teeth usually from

those extracted for orthodontic reasons. The teeth were preserved in refrigerated tissue culture. Upon transplantation, they only had a survival expectancy of five to ten years. The idea began to fall into disuse with the advance in osseointegrated implants and the fear of transmission of the AIDS virus. **(15 16)**

Early attempts in modern implantology

The earliest attempt reported for placement of an endosseous implant is probably by Moggiolo in 1809. He placed a single staged 18 carat gold implant into a fresh extraction socket, just above the gingiva. **(10, 17)** Unfortunately, the placement of these implants was usually followed by gingival inflammation and severe pain that frequently led to their removal. **(17)**

In 1886, Drs. Edmunds and Harris implanted a platinum post and a porcelain crown into an artificially created socket in the alveolar bone. The platinum post was covered by a layer of lead that was melted around it and subsequently roughened for increased retention. It was reported that this implant was still in function after 27 years of its initial placement. **(18)**

Until the turn of the twentieth century, many researchers and innovators continued to come up with novel designs, devices and materials all seeking the same goal. They demonstrated their work and ideas to different dental societies and meetings, but were frequently rejected or harshly criticized. **(19, 20, 21, 22)**

Dr. Greenfield E. S. presented his well known classic paper in Philadelphia 1913. He introduced his work of eight years to the Academy of Stomatology and presented a novel technique and ideas in hope of making implantation a permanent operation. His technique is thought to be the forerunner of the hollow cylinder implant of modern implantology. Greenfield used a trephine mounted on a handpiece to drill a precise trough in the alveolar bone, leaving a solid core of bone in the center of this trough.

Prefabricated hollow cylinder implants of irido-platinum wire were inserted to fit exactly in these troughs and later were fitted with an artificial crown that was attached to the cylinder through a slot at the top of the implant. **(18, 19)**

In 1937, Adams presented the first submergible threaded cylindrical implant, His design even included a smooth gingival collar and a healing cap. The implant was cemented to an overdenture and allowed some vertical and lateral movements. **(23)**

Strock placed the first successful oral implants in 1937 at Harvard University using a vitallium implant in bone immediately after tooth extraction and it showed successful results. **(24)**

In the mid 1930 several implant concepts evolved as subperiosteal implant, first placed by Gustav Dahl **(25)** in 1948 , Endosteal Blade Implant introduced by Leonard Linkow and Ralph and Harold Roberts in 1967.**(26, 27)**

It was till 1952 that dental implant produced a major leap when Branemark, an orthopedic surgeon in the University of Lund, Sweden, experimented the fusion of titanium cylinder into the thigh bone of a rabbit. Several researches followed and it was not until 1981, when data to Branemark and his team was available to publish landmark paper for the doubts of scientific community. **(28)**

Classification of dental implants

Branemark et al. **(28)**, Weiss **(29)** and Worthington **(30)** classified dental implants according to their anatomical relation to the bone into the following categories:

I- Intramucosal or mucosal insert

This type of implants involves cutting small intramucosal, retentive areas in which buttons can be attached to the denture. These buttons fit directly

into soft tissue folds and were of value for patients with medical risks because of the non invasive nature of the procedure. [31]

II- Subperiosteal implant

It is a tailored cast metallic framework with posts. The metallic framework is placed beneath the periosteum and overlying the bone cortex. The posts project above the mucosa to retain the final prosthesis. Subperiosteal dental implant is indicated mainly in severely atrophied ridge where the mylohyoid, genial tubercles and/or the mental foramen lie at the crest of the ridge. [32]

Ill- Transosseous or mandibular implant

Transosteal dental implant is that one which penetrates both cortical plates and passes through the full thickness of the alveolar bone. It is composed of a metal plate with retentive pins to hold it against the inferior border of the mandible. It can be only applied in the symphseal area of the lower jaws. It is also called staple bone implant, mandibular staple implant or transmandibular implant. [33, 34]

IV-Endosteal or endosseous implant

It is a device which is primarily supported in the bone of the mandible and/or maxilla from which an extension or a post extrudes through the gingiva into the mouth where it supports fixed or removable prosthesis. [35, 36]

Recently, alveolar ridge distraction have been introduced for augmentation of atrophied mandible and maxilla by the help of distraction implant that contains two mobile endosteal parts which enable heightening of the alveolar ridge up to 6mm. The prosthetic superstructure is loaded 4 to 6 months after distraction. [37]

Classification of endosseous implants

- ***Ramus blade and ramus frame implant*:** The philosophy leading to the development of this design is insufficient width and height of the mandible, where the implant is attached in part to the ramus of the mandible. (38)
- ***Blade shaped implant:*** This implant type has the form of a flat wedge-shaped blade, with vents through which tissue may grow resisting lateral, occlusal and torquing forces. It is created to fit into knife edge and shallow ridges, where it can act as an abutment for full arch fixed prosthesis with some natural teeth remaining, it is also used as a distal abutment in free end cases to carry fixed partial denture and as overdenture abutments with a minimum of four implants. Retention of blade-vent implant is obtained primarily by bone growing through the vents; therefore retention is lost in blades having an open-end design like a fork. **(38, 39)**
- ***Root form implant:*** Given sufficient width and height of available bone, root form implant has become the first choice in selection of an implant because of its better healing, more retention, less fracture and wider stress distribution over a greater surface. **(40)**

The root form implants have been classified as follows

According to implant material:

Non metallic implants:

Non metallic materials are used for their improved esthetic properties, lack of thermal conductivity and extreme inertness. Efforts are undertaken to improve their inferior physical properties and develop tooth colored materials with improved masticatory forces. **(41)** The most common types are:

- ***Ceramic*:** The gray color of a titanium implant might hamper the esthetic appearance in cases of thin peri-implant soft tissue or tissue retraction and exposed crown margins. Zirconia ceramic material with its superior esthetics, excellent biocompatibility and high mechanical properties is suitable for the fabrication of dental implants. [(42)]
- ***Polymers*:** Composite implant has been recently used because it is very strong in the fiber form and as a result, advanced form of composite can be as strong as metal. Hydroxyapatite-based composite dental implant and polysulfone composite material exhibited favorable osteogenesis with excellent biocompatibility to bone and high mechanical properties.[(43)]
- ***Carbon*:** Vitreous carbon implants which are made of glassy carbon layer on a stainless steel core are indicated for single tooth replacements, either as a single free standing unit or splinted to adjacent teeth, but it is easily fractured or chipped if not properly handled. [(44,45)] Pyrolytic carbon which is less brittle and has strength and ability to absorb energy on impact four times greater than that of glassy vitreous carbon is more suitable as a dental implant material. [(46)]

Metallic implants

Historical development of metallic implants may be summarized as follows:

- ***Vitallium*:** Vitallium implants were developed from castable cobalt-chromium molybdenum, which is an inert biocompatible material. Subperiosteal implants were fabricated from that alloy. [(47)]
- ***Stainless steel and tantalum*:** Although this alloy is strong, cheap and easy to machine, its corrosion properties disapproved its use as a dental implant material.[(47)]

- ***Tantalum and Niobium*:** This alloy is difficult to be casted because of its high melting point which is 2996°C and 2468°C respectively. Therefore, it must be processed with powder metallurgical techniques and high vacuum centering. Tantalum was considered to be mechanically inferior to titanium and more susceptible to corrosion.[(48)]
- ***Pure Titanium:*** Implants of pure titanium are commonly used as bone anchorage elements in oral and craniofacial reconstructive surgery. Its mechanism of biocompatibility and corrosion resistance based on high reactivity of Ti towards O2 forming tenacious oxide layer of TiO2 is the most attractive feature for its usage in dentistry. Poor wear resistance and poor tensile and shear strength are disadvantages of pure titanium implants. [(47)]
- ***Titanium Alloys:*** The most commonly used alloy for dental implants is Titanium Aluminum Vanadium (Ti-6Al-4V), it has 60% greater strength than pure titanium. Although it is stiffer than bone, its modulus of elasticity is closer to bone than any other metal, this property leads to more even stress distribution at the critical bone implant interface because the bone and implant will flex in a similar manner. Titanium-tantalum and Titanium-niobium alloys are also used as dental implants.[(49)]

According to surgical stages;

- ***One stage surgery:*** The implant body is inserted into the bone where its abutment portion penetrates the oral mucosa into the oral cavity. This technique does not include the reopening of the surgical site at the prosthetic stage. Dental implants used are non-submerged dental implants. [(50)]

- ***Two stage surgery:*** The implant body is completely embedded in bone in the first stage surgery, once totally integrated, it is exposed and an abutment is added. [50]

It was first introduced by Branemark at the years of the early sixties of the last century and includes the complete submerging of the dental implant for a proper healing period of three to four months in the mandible and up to six months in the maxilla.

The second stage of the surgery was to uncover the imbedded implant and to start the prosthetic procedure. In the original protocol, studies have advocated a two-stage surgical protocol for load-free and submerged healing to ensure predictable osseointegration. The most commonly used technique in clinical practice and its success rate is up to 98 %.[51]

According to time of installation:

- ***Immediate placement*:** Lazzara [52] described the protocol for immediate placement following extraction. This author advocates the use of grafting materials and/or membranes. The implant must be as long as possible according to the residual bone volume in order to ensure adequate primary stability and enhance osseointegration.

Where possible, implants should be placed 1 to 2mm apical to the tooth socket to engage the inferior cortex. [53] Recently, wide diameter implants have been recommended to fill the extraction site more adequately and to allow primary stability. [54, 55]

Immediate placement procedure is indicated with traumatic tooth loss, tooth loss due to decay or with severe periodontal disease. This procedure allows fewer surgical sessions, elimination of the waiting period for socket

healing, shortening the period of edentulism, reducing overall cost as well as preservation of bone height and width. [54, 55]

- ***Immediate-delayed placement:*** It was found that osteoclastic activity increases six to eight weeks after extraction which might lead to auto exposure of implants, therefore placing the implants six to twelve weeks after loss of teeth will not be followed by osteoclastic activity as the osteoblastic activity is very high at that time. [56, 57, 58]
- ***Delayed placement*:** Implants are placed within six to twelve months after tooth extraction to permit complete healing of epithelium and connective tissue and allow bone regeneration to fill the bony socket. Delayed method of implantation showed less fibrous encapsulation, earlier and wider bone formation which established better osseointegration. [56, 57, 58]

According to time of loading:

- ***Early loading*:** It is the loading of the implant within maximum three weeks after implant placement in the mandible.[59]
- ***Delayed loading*:** It is the loading of the implant after its placement by three months in the mandible and six months in the maxilla. [54] Prospective clinical studies showed that the success rate of immediately loaded implants is similar to that obtained in the case of delayed loading once osseointegration has taken place. Yet, some implants that have failed to remain stable after immediate loading became stable and osseointegrated after their load was removed. [56, 57, 58, 59]

According to Implant design:

- ***The prosthetic interface*:** It is defined as the level at which the suprastructure or the abutment connects to the infrastructure or the abutment connects to the implant body. It can be either external or internal. [60]

Chun and Shin [61] found that the internal-hex implant system generated the lowest maximum Von Mieses stresses for all loading conditions because of reduction of the bending effect by sliding in the tapered joints between the implant and abutment.

Implant forms:

- The implant macrostructure:

Dental implant has different forms, they are supplied either: [62, 63]

a. **Uniform smooth (non threaded) cylindrical**

b. **Tapered smooth (non threaded) cylindrical**, so that the surrounding bone is compressed with insertion of the implant due to the "press fit concept" compression.

***c*. Threaded**

Thakur [62] mentioned the advantages of threads as they maximize initial contact, improves initial stability and favor dissipation of interfacial stress.

O'Sullivan [63] advocated the use of double and triple-threaded implants for the type (IV) bone which is totally cancellous with weak trabecular pattern; these type of threads are supposed to have the additional advantage of being; faster to thread into the osteotomy site, generate less heat upon placement, better initial stability & need more torque for placement which means tighter contact with bone.

According to diameter, length, and taper:

Winkler *et al;* compared different implant length and diameter of various implant; Lengths (7 mm, 8 mm. 10 mm, 13 mm, and 16 mm) and diameters (3 ,4 ,5 and 6 mm) And they concluded that ; shorter implants had statistically lower survival rates as compared with longer implants; 3+ mm diameter implants had a lower survival rate as compared with 4+ mm implants; 3+ mm diameter implants are less stable since they have more positive periotest values (PTVs) than 4+ mm implants. [(64)]

A relatively low Cumulative Survival Rate (CSR) over 5 years when endosseous tapered dental implants are placed either immediately after tooth removal or according to a delayed-placement protocol. [(65)]

The lowest CSR (85%) was seen in the 3.4mm wide implants, while the 3.8mm wide implants had the highest CSR (93.16%). [(66)]

Finite element analysis studies about each of these factors taken separately were found to be contradictory; hence Cynthia and Petrie [(67)] made a special finite element study and demonstrated that the effects of the three investigated factors (diameter, length, and taper) on the crestal strains are likely to be interrelated.

Classification of Jaw Bone for Implant Planning

Lekholm and Zarb [(68)] proposed a differentiation of jaw bone quantity or shape, and jaw bone quality.

The bone quantity is rated from A through E;

A: *Unresorbed alveolar bone.*

B: *Some resorption of alveolar bone.*

C: *Complete resorption of alveolar bone.*

D: *Some resorption of basal bone.*

E: *Extreme resorption of basal bone.*

The bone quality is rated from 1 through 4;

Type I : Almost the entire jaw is comprised of homogenous compact bone.

Type II: A thick layer of compact bone surrounds a core of dense trabecular *bone.*

Type III: A thin layer of cortical bone surrounds a core of dense trabecular bone of favorable strength.

Type IV: A thin layer of cortical bone surrounds a core of low density trabicular bone.

Type II and Type III are considered the most desirable for implant placement. Type II bone occurs most frequently in the anterior mandible, And provides excellent implant interface healing, and successful Osseointegration. [(69)]

Criteria for Implant Success

Albrektsson *et al* [(70)] state the criteria for implant success as follows:

- An individual unattached implant should be immobile when tested clinically.
- An implant radiograph should not demonstrate any evidence of peri-implant radiolucency.
- Vertical bone loss around an implant should not exceed 1.5 mm in the first year of functional loading and 0.2 mm per year following the implants' first year of service.
- An individual implant should be characterized by an absence of persistent signs or symptoms of altered function or sensation.
- At the end of a 10 year period, 80% of individually placed implants should be successful in the context of these criteria.

Superstructure components

Endosteal dental abutment, according to the Academy of Prosthodontics is defined as;"that part of structure that serves to support and/or retain prosthesis and directly receives pressure". "It is that portion of dental implant which passes through the oral mucosa and provides connection between the endosteal dental implant body and the prosthesis". [(71)]

Threaded abutments

- ***Straight abutments:*** They are the most common abutments; they are manufactured from titanium or titanium alloy and used when favorable axial inclination and parallelism of implants are achieved. A collar may be present to compensate for gingival thickness. [(72)]
- ***Prefabricated (angulated abutments)***: They are either 15 to 30 degrees one-piece angled prefabricated abutments or 15 to 25 degrees two piece angled abutments. This type is used to compensate for some anatomic limitations including the dimension of the residual ridge, the location of the mandibular canal, nasal and maxillary sinuses and unfavorable maxillomandibular relationships. It is also used when implant position is in less favorable position due to incompetent surgery. [(73, 74)]
- ***Custom abutments (angled-straight)*:** This type is indicated when the implant system doesn't include angled abutments or when the implants are in a less favorable position and the present angled abutment will not satisfy the needs for proper orientation. A custom abutment is fabricated either by impression making or by preparing direct resin pattern as done for post and core prosthesis. When such castings are made, the internal threads of the implant become unusable necessitating the cementation of the abutment.
- ***Cemented abutments (non threaded)*:** Abutments of this type use cement to retain the abutment to the implants. They are either straight

or 15 to 25 degrees angled abutments. A syringe is used to insert the cement into the implant. Cementation of the abutment should be completed prior to the impression of the final prosthesis. If the final prosthesis is completed before cementation the superstructure will not be seated properly. [(72)]

- ***Abutments with attachments***: This type uses an attachment device to retain a removable prosthesis. Abutment collars are either 1, 2 or 3mm in height so that marginal placement can be varied to give the best esthetic results. The interocclusal space must be sufficient to accommodate the height of the abutment and the attachment. An example of this type is the steri-oss abutment that is made of titanium alloy and available in 2, 3, 4, 5 and 6 mm lengths. This type is capable of as much as 40 degrees misalignment correction between the implants. This versatility makes it useful for fixed-removable restorations and overdentures supported by four to six implants connected by a bar.[(75)]
- ***Healing abutments*:** This is a temporary abutment type, connected to the implant at the second step of implantation after it is surgically exposed to the oral cavity. It is a solid titanium cylinder with slightly wider diameter than the original abutment. A healing abutment longer than the mucosal thickness is selected, connected to the implant and left in place for two weeks while the wound heals. This allows for resolution of post operative tissue swelling before inserting the final abutment. [(50)]

Understanding and using biomechanical theories that affect endosseous implant design may improve the success of these implants in various load conditions and may allow the clinician to better apply these guidelines, with an improvement in success rates.