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RESEARCH ARTICLE

GRAFTS AND GRAFTING TECHNIQUES IN IMPLANTS - A Review

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Abstract

Bone graft is the gold standard materials used for repairing bony defects. There are various bone graft materials/biomaterials and methods available for bone augmentation. The present article explains in detail about bone grafts and the recent advancements in bone graft materials as well as bone augmentation in implant dentistry.The literature search was performed for relevant articles on bone grafts for dental implants in PubMed/Medline, Scopus, Google Scholar, and Science Direct published in English literature published between January 2005 and March 2023. Relevant studies on bone grafts for dental implants were also included and critically analyzed in this review. Various biomaterials can be used to augment bone for implant placement. Each graft procedure has its own advantages and disadvantages in each clinical application and should choose the graft material carefully to attain a high success rate and less morbidity.

Introduction:-

Repairing and restoring bone defects has a long history. The surgeons of the pre-Incan period used gold and silver plates and shells as grafting materials to repair trephine holes in the skull 3000 years BC. Trephination – the removal of a circular section of bone from the skull – is the oldest known surgical intervention. **Dr Philip Von Walter** is credited in 1821 as being the first surgeon to use bone autografts for reconstruction of the remaining defect after a trephination in the skull[1]. The term '**autograft**' implies transplantation of bone tissue from one site to another, within the same individual. Bone transplantation has been a common surgical procedure since the early 1920s[1].

Causes of ridge defects:

1. Surgery
2. Trauma
3. Infection or
4. Congenital malformations.

Goals of osseous replacement :

1. Maintenance of contour,
2. Elimination of dead space,
3. Reduce postoperative infection
4. Enhance bony and soft tissue healing.

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5. The insufficient quantity of bone is due to tooth loss which results in rapid resorption of alveolar bone due to lack of intraosseous stimulation by periodontal ligament (PDL) fibers, for example, pneumatization of maxillary sinus following tooth loss.

Definition

Bone Graft is defined as the augmentation or replacement of the portion of the maxillary or mandibular bone with an osteogenic material - GPT 9.

Bone grafting is a surgical procedure that replaces missing bone with material from patient's own body, an artificial, synthetic, or natural substitute. Bone grafting is possible because bone tissue has the ability to regenerate completely if provided the space into which it has to grow. As natural bone grows, it generally replaces the graft material completely, resulting in a fully integrated region of new bone[2].Therefore, for managing thin ridges to ridges with insufficient height and dealing with soft tissue malformation to produce brilliant pink aesthetics,grafting play a major role in the prognosis and outcome of dental implant therapy.

Classifications

Classification 2

Grafts are classified based on:

1. Structure
2. Activity of the graft
3. Type or source of the graft material

Based on the Structures

They can be classified as:

1. Particulate graft
2. Block graft
3. Bone putty

Based on the activity

1. Osseoconductive
2. Oseeoinductive
3. Osteogenic

Based on the source

- Natural source:
- Autogenous graft
  - Extraoral:
    - Iliac crest
    - Tibula
    - Fibula
    - Ribs
  - Intraoral
    - Symphysis
    - Ramus
    - Maxillary tuberosity
    - Exostosis
- Isograft
- Allograft
  - DFDBA
  - FDBA
  - Frozen graft
- Xenograft
  - Bovine-derived
  - Porcine-derived
  - Coralline calcium carbonate

- Synthetic sources:
- Alloplasts:
  - Hydroxyapatite
  - Calcium phosphate cements
  - Beta-tricalcium phosphate
  - Biphasic alloplastic materials
  - Bioactive glasses
  - Synthetic polymer
- Ceramic and bioactive molecules

Classification 2:
Classification of bone grafts based on material groups:

1. Allograft‐based bone graft involves allograft bone, used alone or in combination with other materials (e.g., Grafton, Orthoblast).
2. Factor‐based bone graft are natural and recombinant growth factors, used alone or in combination with other materials such as transforming growth factor‐beta (TGF‐beta), platelet‐derived growth factor (PDGF), fibroblast growth factors (FGF), and bone morphogenic protein (BMP).
3. Cell‐based bone grafts use cells to generate new tissue alone or are added onto a support matrix, for example, mesenchymal stem cells.
4. Ceramic‐based bone graft substitutes include calcium phosphate, calcium sulphate, and bioglass used alone or in combination; for example, OsteoGraf, ProOsteon, OsteoSet.
5. Polymer‐based bone graft uses degradable and nondegradable polymers alone or in combination with other materials, for example, open porosity polylactic acid polymer.

Discussion:-

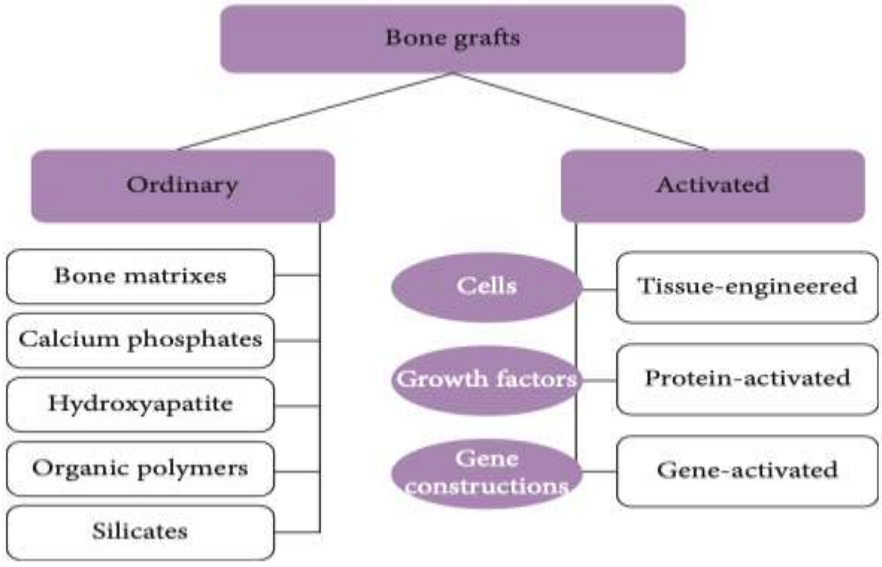

Figure 1:- Types of Ordinary or activated bone grafts.

Based on the structure:
Particulate graft
Small particles of autogenous grafts or synthetic graft material.

They can either be harvested as small particles or as a block and then be ground to smaller particles.
The particles are mixed with blood or blood components to improve the uptake and nutrient supply or graft[3].

Indications
Minor fenestrations and dehiscence.

3-walled and 2-walled defects.
Indirect and direct sinus lift.

Contraindications
Large horizontal defects
Large defects

Block grafts
Block grafts are chunks of graft material that can be used to increase the height and width of the available bone.

The block can be stabilized with stainless steel or titanium screws.

Autogenous block can be harvested from:

Intraoral sites:
Symphysis, ramus of the mandible.

Extraoral sites:
Iliac crest, fibula, tibia and ribs.

Indications
Vertical height augmentation
Increasing width of bone area

Contraindication
Sinus lift surgeries

Bone putty
Clay like graft material comprising of multiple combinations of their synthetic or natural bone grafts in a resorbable matrix.

Basically composed of demineralized bone, sodium hyaluronate along with beta tricalcium phosphate and hydroxyapatite.

Advantages
The material being pliable can be molded into any desired shape.
It can be packed into spaces without leaching.

Disadvantages
Price of the material is expensive
Being a new material, long-term clinical trials are not available.

Based on the activity of the graft
The biologic mechanisms that provide a rationale for bone grafting are osteoconduction, osteoinduction, and osteogenesis.

Osteoconduction
Occurs when bone graft material serves as a scaffold for new bone growth, which is perpetuated by the native bone. Osteoblasts from the margin of defect that is being grafted, utilize the bone graft material as a framework upon which to spread and generate new bone. In the very least, a bone graft material should be osteoconductive.

Osteoinduction
Involves stimulation of osteoprogenitor cells to differentiate into osteoblasts and then begins formation of new bone. The most widely studied type of osteoinductive cell mediators are BMPs. A bone graft material that is osteoconductive and osteoinductive will not only serve as a scaffold for currently existing osteoblasts but will also trigger formation of new osteoblasts, promoting faster integration of the graft[4].

Osteopromotion
Involves enhancement of osteoinduction without possession of osteoinductive properties. For example, enamel matrix derivative enhances the osteoinductive effect of demineralized freeze‑dried bone allograft (DFDBA), but will not stimulate bone growth alone.

Osteogenesis
It occurs when vital osteoblasts originating from bone graft material contributes to the growth of new bone along with bone formation.

Based on the source
Natural source
Autograft
Autologous or autogenous bone grafting involves utilizing bone obtained from same individual receiving the graft. Bone can be harvested from nonessential bones, such as from iliac crest, mandibular symphysis (chin area), and anterior mandibular ramus (coronoid process). When a block graft will be performed, autogenous bone is the most preferred because there is less risk of graft rejection as the graft is originated from the patient's body. It would be osteoinductive and osteogenic, as well as osteoconductive.

Disadvantage of autologous grafts is that additional surgical site is required, another potential location for postoperative pain and complications[5].

All bones require blood supply in the transplanted site. Depending on where the transplant site is and size of the graft, an additional blood supply may be required. For these types of grafts, extraction of the part of the periosteum and accompanying blood vessels along with the donor bone is required. This kind of graft is known as a **free flap graft.**

Isograft
Isografts are grafts harvested from an individual of the same species with the same genotype but different phenotype; for example, an identical twin. Isografts have a good success rate.

Allografts
Allograft is derived from humans. The difference is that allograft is harvested from an individual other than the one receiving the graft. Allograft bone is taken from cadavers that have donated their bone so that it can be used for living people who are in need of it; it is typically sourced from a bone bank.

There are three types of bone allograft available: (Figure 2)
1. Fresh or fresh‑frozen bone
2. FDBA
3. DFDBA

The use of allografts for bone repair often requires sterilization and deactivation of proteins normally found in healthy bone. Contained in the extracellular matrix of bone tissue are the full cocktail of bone growth factors, proteins, and other bioactive materials necessary for osteoinduction (Table 1) and successful bone healing; the desired factors and proteins are removed from the mineralized tissue by using a demineralizing agent such as hydrochloric acid. The mineral content of the bone is degraded, and the osteoinductive agents remain in a demineralized bone matrix (DBM)[6].

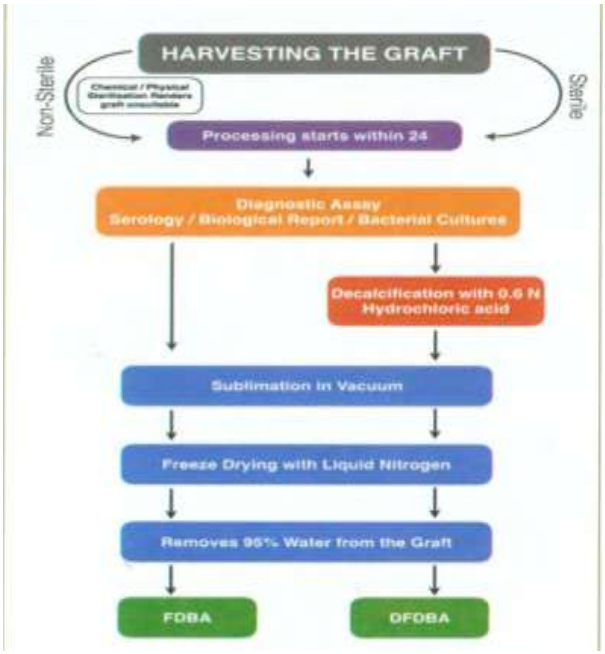

Figure 2:- Manufacturing of FDBA and DFDBA.

Table 1:- Based on the activity of the graft.

Type	Osseoconductive	Osseoinductive	Osseogenic
Alloplast	✔	x	X
Xenograft	✔	✔/ X	X
Allograft	✔	✔	X
Autograft	✔	✔	✔

Synthetic variants

Flexible hydrogel‑hydroxyapatite (HA) composite which has a mineral to organic matrix ratio, approximating that of human bone.Artificial bone can be created from ceramics such as calcium phosphates (e.g., HA and tricalcium phosphate), bioglass and calcium sulphate are biologically active depending on solubility in physiological environment.[5] These materials combine with growth factors, ions such as strontium or mixed with bone marrow aspirate to increase biological activity. The presence of elements such as strontium can result in higher bone mineral density (BMD) and enhanced osteoblast proliferation.

Xenograft

1. Xenografts are sourced from animals.
2. The sources of the graft can be:
3. Bovine- derived
4. Porcine – derived
5. Coralline calcium carbonate (non- resorbable)
6. Calcifying marine algae: Corallina officinalis (Flourohydroxyapatite)

Alloplastic grafts

Alloplastic grafts may be made from hydroxyapatite, a naturally occurring mineral (main mineral component of bone), made from bioactive glass. Hydroxyapatite is a synthetic bone graft, which is the most used now due to its osteoconduction, hardness, and acceptability by bone. Some synthetic bone grafts are made of calcium carbonate, which start to decrease in usage because it is completely resorbable in short time and makes breaking of the bone easier. Finally used is the tricalcium phosphate in combination with hydroxyapatite and thus giving effect of both, osteoconduction and resorbability[7].

Growth factors

Growth factors enhanced grafts are produced using recombinant DNA technology. They consist of either human growth factors or morphogens (BMPs in conjunction with a carrier medium, such as collagen).The factors and proteins that exist in bone are responsible for regulating cellular activity. Growth factors bind to receptors on cell surfaces and stimulate intracellular environment to act. Generally, this activity translates to a protein kinase that induces a series of events resulting in transcription of messenger ribonucleic acid (mRNA) and ultimately into the formation of a protein to be used intracellularly or extracellularly. Some of Growth factors are TGF-beta, insulin like growth factors I and II, PDGF, FGF, and BMPs. Cell-based bone graft substitutes: Stem cells are cultured in the presence of various additives such as dexamethasone, ascorbic acid, and glycerophosphate to direct the undifferentiated cell towards osteoblast lineage.The addition of TGF-beta and BMP-2, BMP-4, and BMP-7 to the culture media can also influence the stem cells towards osteogenic lineage. Mesenchymal stem cells have also been seeded onto bioactive ceramics conditioned to induce differentiation to osteoblasts[8].

Ceramic-based bone graft substitutes

Majority of bone grafts available involve ceramics, either alone or in combination with another material (e.g., calcium sulfate, bioactive glass, and calcium phosphate). The use of ceramics, like calcium phosphates is calcium hydroxyapatite which is osteoconductive and osteointegrative; and in some cases, osteoinductive. They require high temperatures for scaffold formation and have brittle properties.

1. Calcium sulfate is also known as Plaster of Paris. It is biocompatible, bioactive, and resorbable after 30-60 days. Significant loss of its mechanical properties occurs upon its degradation; therefore, it is a questionable choice for load-bearing applications:
2. **OsteoSet** is a tablet used for defect packing. It is degraded in approximately 60 days.
3. Allomatrix is Osteoset combined with DBM, forms a putty or injectable paste. OsteoSet is a calcium sulfate tablet used for bone defect sites, whereas allomatrix is a combination of calcium sulfate and DBM that forms an injectable paste or fable putty.

Bioactive glass(bioglass)

It is a biologically active silicate-based glass, having high modulus and brittle nature; it has been used in combination with polymethylmethacrylate to form bioactive bone cement and with metal implants as a coating to form a calcium-deficient carbonated calcium phosphate layer which facilitates the chemical bonding of implants to the surrounding bone. Different types of calcium phosphates are tricalcium phosphate, synthetic hydroxyapatite, and coralline hydroxyapatite; available in pastes, putties, solid matrices, and granules[8].Such calcium phosphates products include Bio-Oss and OsteoGraft. Both products use hydroxyapatite, either as a particulate (Bio-Oss) or as blocks and particulates (OsteoGraft). Pro-Osteon is a unique product based on sea coral, which is converted from calcium carbonate to calcium hydroxyapatite. The advantage of this material is that the structure of coral, which is similar to that of trabecular bone.

Polymer-based bone graft substitutes

This can be divided into natural polymers and synthetic polymers. Subclassified into degradable and nondegradable types. Polymer-based bone graft substitutes include the following:

Healos is a natural polymer-based product, a polymer-ceramic composite consisting of collagen fibers coated with hydroxyapatite and indicated for spinal fusions.

Cortoss is an injectable resin-based product with applications for load-bearing sites[9].

Biphasic alloplastic materials

1. These materials are referred to as biphasic because they are made of two different microstructural phases. For example, biphasic calcium phosphate consists of Hydroxyapatite (HA) and Beta- Tricalcium Phosphate (TCP) in different ratios.
2. Biphasic calcium phosphate also has a negative surface charge (Zeta potential) that has been found to have favourable bone formation characteristics. The negative charge accelerates bone growth.

Degradable synthetic polymers, like natural polymers are resorbed by the body. The benefit of having the implant resorbed by the body is that, the body is able to heal itself completely without remaining foreign bodies. (Figure 3).

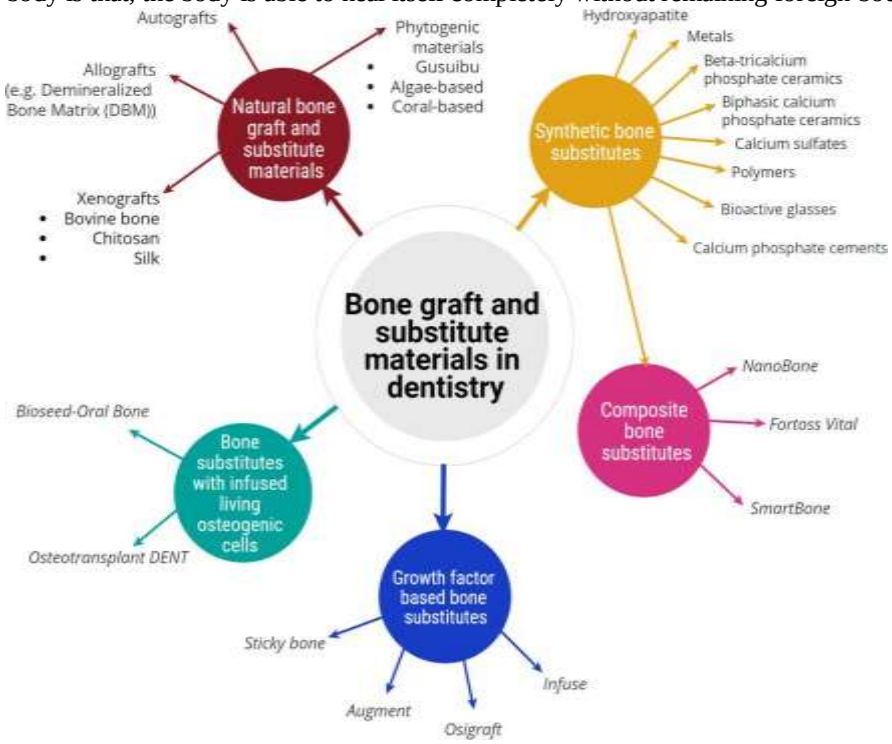

Figure 3:- Bone grafts and its substitute materials in Dentistry.

Barrier Membranes

A barrier membrane is used primarily in implant, oral and periodontal surgery to prevent the epithelium from growing into an area where bone growth is desired. This method of preventing epithelial migration into a specific area is known as guided tissue regeneration (GTR). Membranes are classified into non-resorbable and resorbable products[10].

Non-resorbable Membranes

Non-resorbable membranes, as the name suggests, do not resorb on their own and require a second surgical procedure for removal.

Polytetrafluoroethylene(PTFE)

• This was the first non-resorbable membrane to event to be used clinically (1984). Polytetrafluoroethylene (PTFE) is an inert, biocompatible membrane that prevents tissue ingrowth. There are different types of PTFE membranes that have been developed for use in grafting. They are:

1. Expanded PTFE (E-PTFE)
2. High- density PTFE (D-PTFE)
3. Titanium-reinforced PTFE

Expanded PTFE (E-PTFE)

1. It is manufactured by heating PTFE and then applying a force which causes an expansion of the microstructure. This creates pores in its structure.
2. E-PTFE membranes have two microstructures:

a. Coronal portion and
b. Occlusive portion

Coronal portion:

Coronal portion is fixed which has an internodal distance of 25 pm that facilitates early clot formation and collagen fiber attachment that, in turn, stabilizes the membrane until it becomes fixed.

Occlusive portion:
Here the internodal distance is less than 8 pm to allow nutrient inflow. It also prevents the infiltration of other tissue cell types. These pores can harbour bacteria and limit the amount of bone regrowth that can occur. It is currently not being used for dental surgeries. However, it is being used extensively for digestive, cerebral and cardiovascular surgeries[11].

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2. It is currently not being used for dental surgeries. However,
3. It is being used extensively for digestive, cerebral and cardiovascular surgeries.

High-density PTFE (D-PTFE)
D- PTFE was developed in 1993, and is made of high density PTFE, with a submicron (0.2) μ
It also facilitates easy removal of the membrane without damaging the underlying structures.

Titanium- reinforced PTFE
- Titanium reinforcement of PTFE allows shaping of these membranes and can be used for socket preservation procedures

Titanium mesh
Titanium meshes were introduced in 1969 by Boyne and were mainly used to treat continuity defects in the maxilla and mandible. The rigidity of titanium aids in space maintenance and prevents collapse of the contour.Titanium meshes also: Prevent graft displacement, permit bending, contouring, andadaptation to anybony defect.Some of the drawbacks of using titanium are: Increased stiffness of titanium sometimes leads to mucosal irritation (Figure 4)

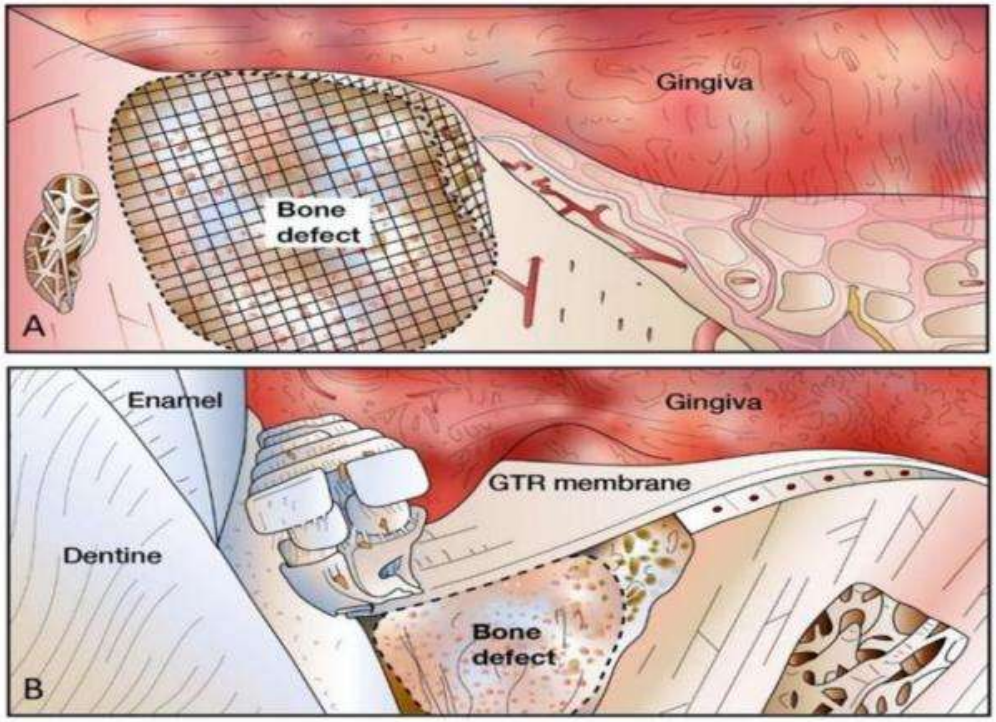

Figure 4:- (**A**) Use of a titanium mesh as a structural scaffold and physical barrier in GBR for prevention of soft tissue cell migration and promotion of bone regeneration. (**B**) Use of a barrier membrane in GBR.

Nylonmembranes
They are non-resorbable membranes which are made of knitted nylon fabric, that is mechanically bonded onto a semipermeable silicone membrane and coated with collagen peptides. density PTFE, with a submicron (0.2 pm) pore size.This combination of high density and small pore size entirely eliminates bacterial infiltration and also reduces the amount of fiber attachment to the membrane[12].

Natural	Synthetic
Collagen of porcine origin (Bioguide)	Poly-DL-lactide (Guidor, Resolute, Atrisorb)

Collagen from bovine achilles tendon (Biomend, Periogen)	Polyglactin 910 (Vicryl mesh)
Collagen from bovine corium (Avitene)	Polylactic acid (Epiguide)
Collagen from bovine peritoneum (Cargium membranes)	Polydiaxonon (Mempol)
Collagen of fish origins (Periocol)	Carbonate (Inion)
Oxidized cellulose membrane (Surgicel)	-
Alloderm (Allogenic skin matrix)	
Duramater	
Amniotic membrane	

Table 2:- Differences between Natural and Synthetic grafts.

Harvesting Autogenous Grafts

Intraoral

1. Cortical bone chips
2. Osseous coagulum
3. Bone blend
4. Symphysis
5. Ramus
6. Tuberosity

Extraoral

1. Calvarium
2. Rib
3. Fibula
4. Iliac

Intraoral

1. harvesting autologous bone graft include the mandibular symphysis, mandibular ramus and the maxillary tuberosity.
2. Graft can be acquired from:

a. Cortical bone chips
b. Osseous Coagulum
c. Bone blend

Cortical Bone Chips

1. Shavings of bone removed by osteotomy and osteoplasty
2. Larger shavings of bone are vulnerable to sequestration

Osseous coagulum

Bone particles harvested with a bur and mixed with blood

Difficult to collect graft in a quantifiable manner and difficult to aspirate completely.

Bone blend

Collection of bone using rongeurs and trephines followed by trituration in an amalgam capsule to achieve a slushy osseous mass.

Symphysis

Primary source of quality cortical bone and is mostly used to augment vertical defects

Advantages:

1. Conventional surgical access
2. Proximity of donor and recipient sites
3. Reduced operative and anesthesia time, making it ideal for outpatient implant surgery.
4. Absence of scarring, no extraoral donor site morbidity.

Disadvantages:
1. Bleeding
2. Mental nerve injury
3. Soft tissue injury of cheeks, lips and tongue
4. Block graft fracture and infection.

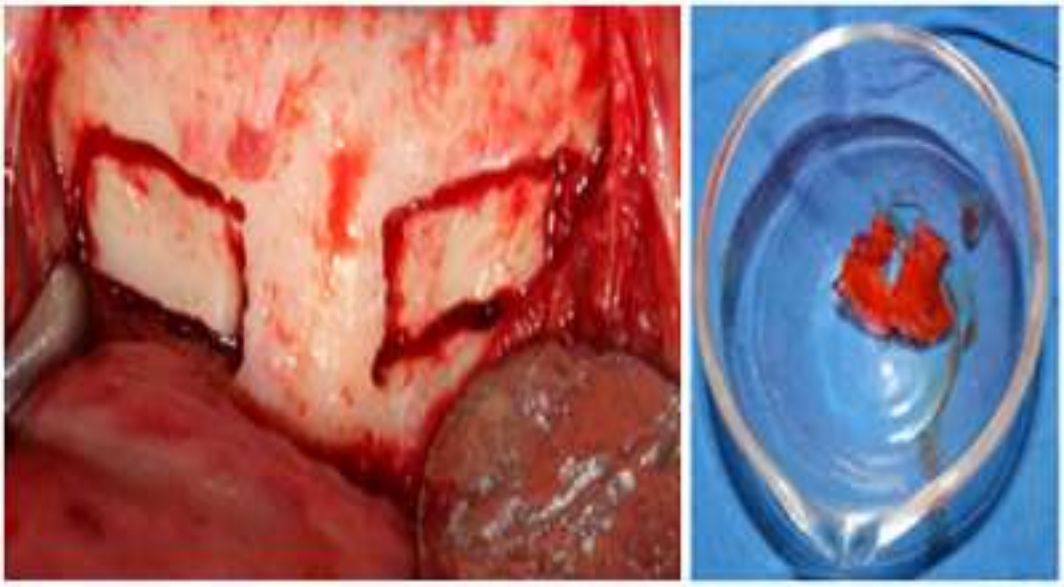

Figure 5:- Block bone graft harvested from the mandibular symphysis.

Ramus

The harvested bone may be placed in an extraction site, an implant site defect, a buccal alveolar defect. It may be used as vertical onlay graft of the ridge or as an inlay graft[13].

Advantages:

It can be used either as a block or particulate graft.

Disadvantages:
1. Chances of damaging the neurovascular bundle of the inferior alveolar nerve which can cause temporary or permanent paresthesia.
2. Injury to the lingual nerve
3. Mandibular fracture.

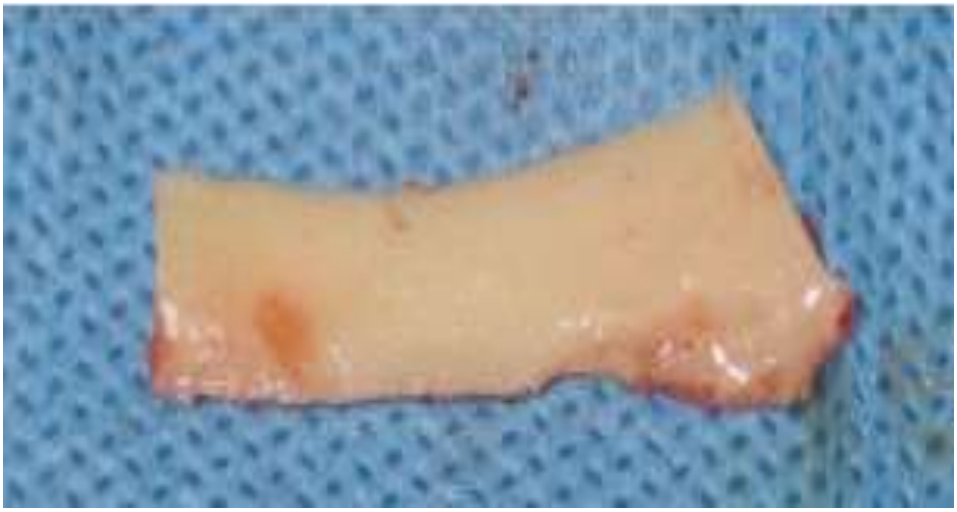

Figure 6:- Block bone graft harvested from mandibular lateral ramus area.

Tuberosity

It is a rich source of medullary bone. Depending on the anatomy, it may serve as a source of autograft for small to medium sized defect.They are mostly used in sinus lift procedures and to cover up fenestrations.Since the bone is mostly cancellous, it is advisable to use it only as a particulate graft.

Advantage:

Since the boss is porous, it aids in vascular ingrowth.

Disadvantages:

1. Exposure of the maxillary sinus cavity
2. Possible buccosinususal fistula
3. Injury to the remaining teeth.

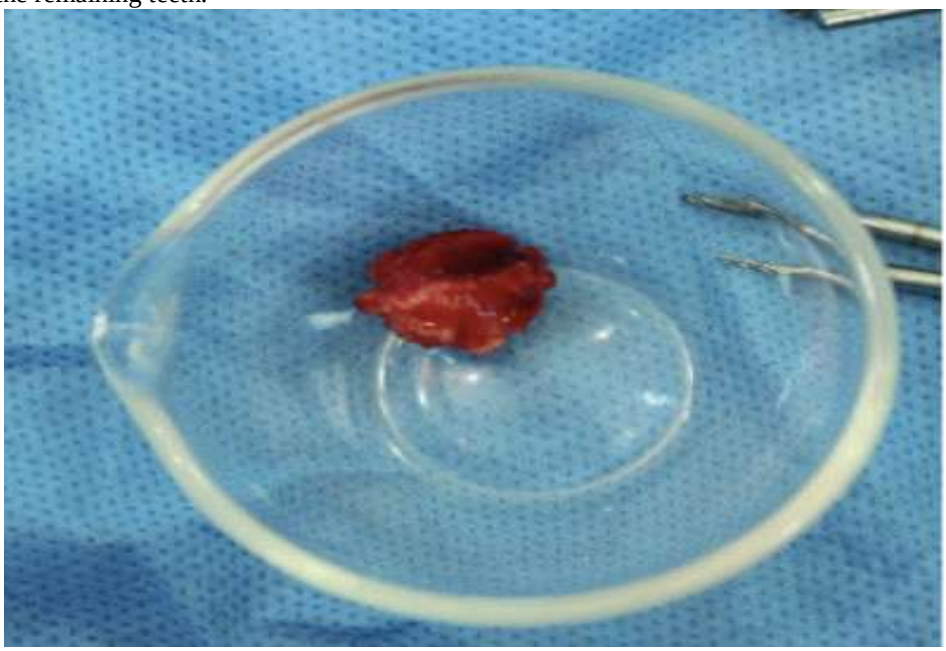

Figure 7:- Block bone graft harvested from the maxillary tuberosity.

Extraoral Donor Sites

Iliac crest

The iliac crest graft provides medullary and cortico-medullary bone in large quantities, enough for large maxillary reconstructions in width, height and bilateral elevation of the maxillary sinus floor.

Advantages:

1. Large amount of bone
2. Corticocancellous bone

Disadvantages:

1. Postoperative morbidity
2. Temporary difficulty in walking
3. Due to its endochondral origin, this type of bone graft resorbs more rapidly than theintramembranous grafts.

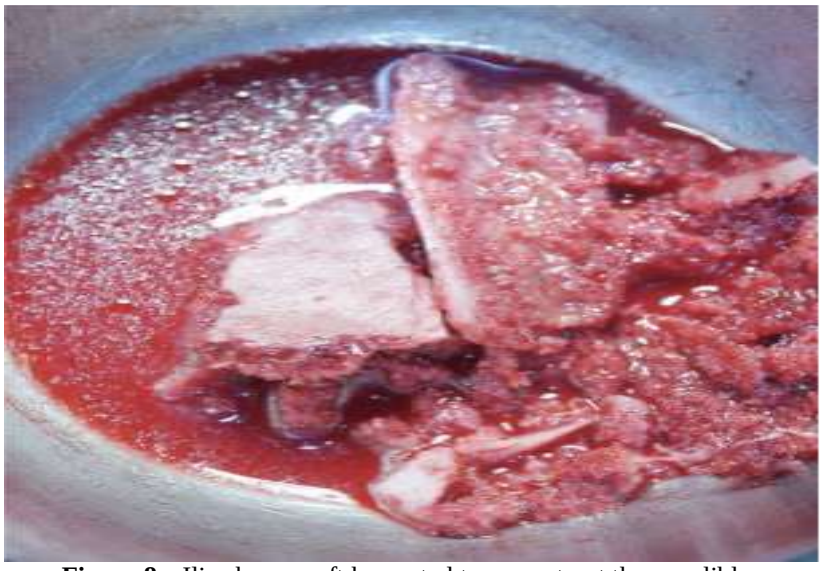

Figure 8:- Iliac bone graft harvested to reconstruct the mandible.

Cranial vault

The bone graft taken from the cranial vault provides large amount of cortical bone and small amount of medullary bone.

Advantages:

1. By having intramembranous origin, it displays lower rates of resorption due to embryological resemblance to the jaw.
2. Ease of access to large amount of cortical bone.

Disadvantages:

1. Damage to the parietal branch of the superficial temporal artery.
2. Penetration of cranial cavity during removal of the graft, leading to irreparable damage.

Ribs

Used for the mandibular reconstruction ofisolated mandibular defects and in rare cases, reconstruction of atrophic maxilla.

Advantages:

1. Favourable shape
2. Shorter postoperative hospitalization time
3. Lesser donor site sequelae

Disadvantages:

1. Pneumothorax
2. Thin bone is liable to fracture

Fibula

In patients who undergo large ablative surgeries of the jaws, reconstruction of the maxilla or mandible should be done using vascularized bone containing free flaps[14].

Advantages:

1. The donor site has enough bone length available (25cm) to reconstruct any length of the mandible.
2. Low donor site morbidity and abundant periosteal blood supply that permits multiple osteotomies[15].

Disadvantages:

1. Risk of developing a deep vein thrombosis of the lower leg due to immobilization.

2. High cost.[16]

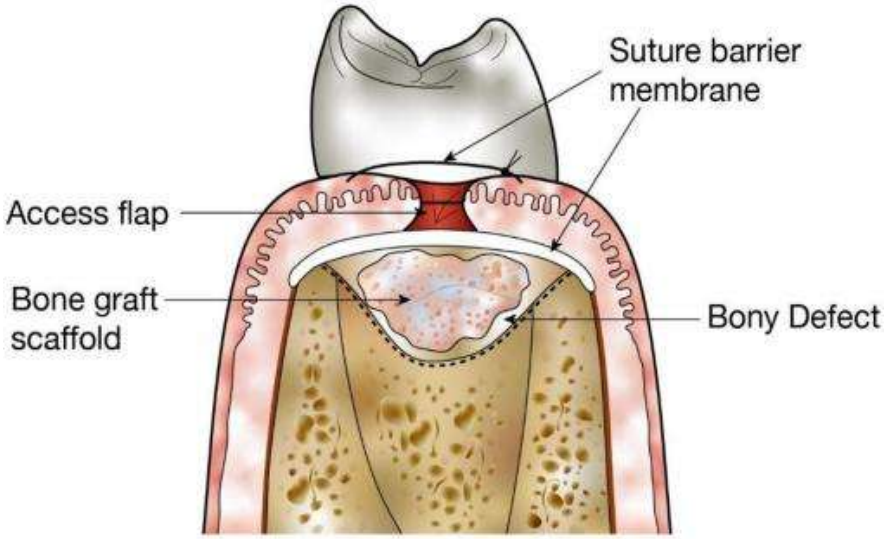

Figure 9:- Showing the anatomical structures of the tooth.

Indications

(i) replace missing bone; (ii) enhance bone formation, in order to restore form and function. Many types of materials have been used and tested to replace missing bone during the last century, for example, banked bone (allograft; bone from individuals within the same species), xenografts (bone derived from other species), ceramics such as hydroxyapatite, metals, corals and plastics[17].

Bone sources

The most frequently used site for bone harvest is the iliac crest. In general, this site can supply enough volume of both cortical and cancellous bone for different reconstructive purposes in the maxillofacial region. Other sites also used, although less commonly, are the tibia, fibula and the ribs. When only a small amount of bone is needed, it can be harvested from the chin or at the anterior aspect of the mandibular ramus. The last two sites can, however, only contribute compact bone[18]. A bone graft may be of two types: free vascularized (i.e. a graft with vessels to be connected with vessels at the recipient bed), or free non-vascularized. The vascularized bone graft may have higher chances of survival but, on the other hand, this type of grafting is more time- consuming and more expensive.(Table 3)

Anatomy of the skeleton

The fundamental bony skeleton of the jaws consist of a mandible and two maxillary bones. Because of the functional aspect of these structures and their atrophic changes during aging, anatomical features have specific importance to distinguish defects and determine the proper treatment plan. The quantity and quality of bone in the alveolar process and adjacent structures are the key elements of this issue. The anatomical knowledge of these structures is also a determinant factor when using them as donor sites for reconstruction.

The alveolar bone of mandible and maxilla is a functional bony process which harbors teeth in a dentate human. After tooth loss, this bony structure loses its dimensions both vertically and horizontally. After atrophic sequences, the maxillary alveolar arch diameter decreases, despite the fact that the mandibular alveolar arch enlarges in diameter and a pseudo-class III relation may appear in severe atrophic alveolar ridges (Figure 10).

D1 demonstrates the thickest cortical bone and the most dense trabecular part and is usually located in anterior mandible;

D4 demonstrates a large volume of low density trabecular bone and thin cortices and is located mainly in posterior maxilla.

D2 and D3 with intermediate characteristics are located in posterior mandible and anterior maxilla respectively.

The maxillary tuberosity is located in the posterior maxillary bone on each side and contains low density D4 bone and attached to the pterygoid plates at the pterygomaxillary junction. It is located next to important anatomical structures- the pterygomaxillary fissure and pterygo- palatine fossa.

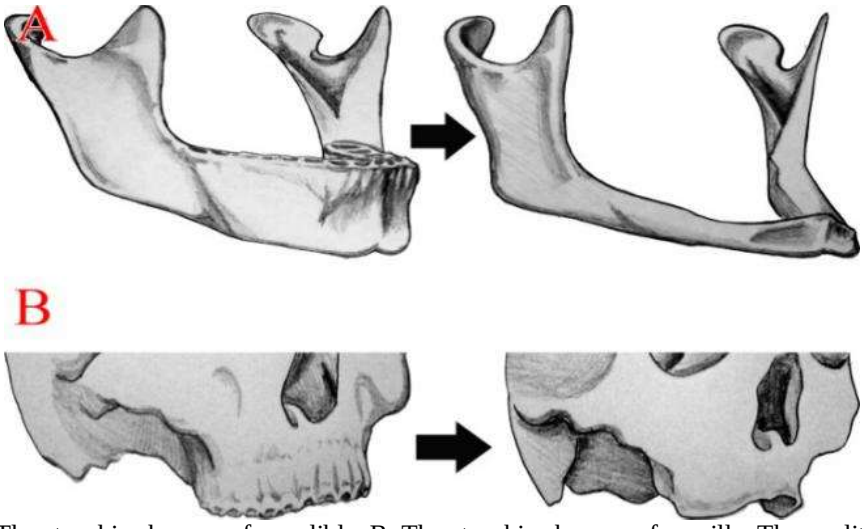

Figure 10:- A, The atrophic changes of mandible. B, The atrophic changes of maxilla. The quality of edentulous alveolar bone is classified to D1, D2, D3 and D4 based on cortical bone thickness and density of trabecular bone respectively.

The maxillary sinus is a pyramidal cavity in each maxilla with a broad base medially and an apex laterally. Its size varies depending on the patient's age and presence of teeth. During the lifetime the sinus enlarges continuously and at the age about 12, the floor of the sinus is almost at the level of the nasal floor. Maxillary posterior teeth loss and sinus pneumatization are responsible for decreasing bone volume in this area.

The mandible is the largest bone of the face and generally consists of thicker cortical bone compared to the maxilla. The anterior border of ramus as runs toward the mandibular body creates external oblique ridges bilaterally. The mandibular canal begins from the mandibular foramen at the middle medial surface of ramus horizontally and vertically and ends at the mental foramen on the buccal surface of the mandibular body near the apices of the premolar teeth on both sides. The least distance from the mandibular canal to the buccal cortex is in the distal part of the mandibular first molars. The canal course through the mandible usually makes a loop near the mental foramen with about a 3 mm diameter. The neurovascular bundle travels through this canal to supply sensation and blood to the mandibular teeth and some part of the chin.

The buccal fat pads or Bichat's fat are located lateral to the buccinator muscles bilaterally and consist of four parts; body, temporal, buccal, and pterygoid extensions. Buccal fat pads are supplied by the temporal and transverse facial arteries. The buccal fat pads are very useful structures in reconstruction of oral defects.

Autogenous Bone Graft techniques

Our bone grafting considerations include sinus augmentation procedures, anatomy, materials, techniques, and complications.

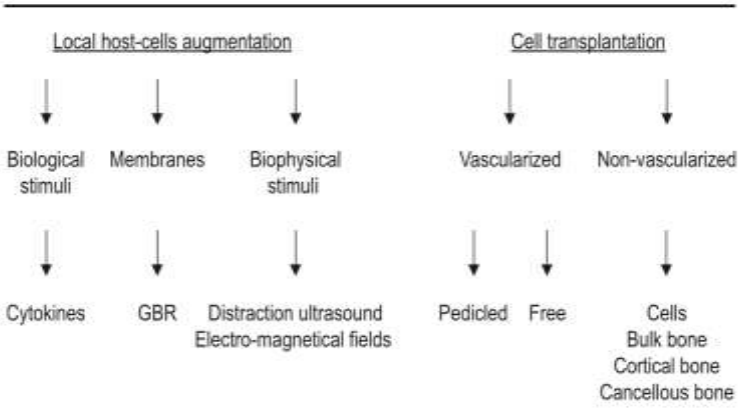

Figure 11:- Showing Bone repair by autologous cells.

Sinus augmentation procedures

Dental implant placement in patients who are edentulous in the posterior maxilla can be difficult for many reasons, including inadequate posterior alveolar height and increased pneumatization of the maxillary sinus, and therefore close approximation of the maxillary sinus to crestal bone. The size of the maxillary sinus correlates with the degree of pneumatization.[18]If appropriate graft materials are being used (i.e., at least 50% autogenous bone with good cellular density) and principles to maximize bone are followed, bone grafting and implant placement can be performed at the same time (i.e., in a one-step method) in ridges with as little as 1 to 5 mm residual crestal bone density when compared with premaxillary or mandibular bone. Adjacent cortices consist of compact bone[19].

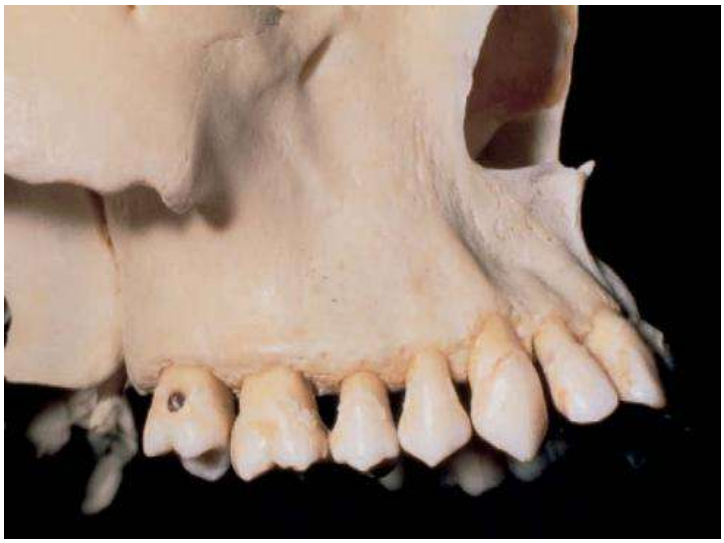

Figure 12:- Showing normal anatomy of the structures in a cadaver.

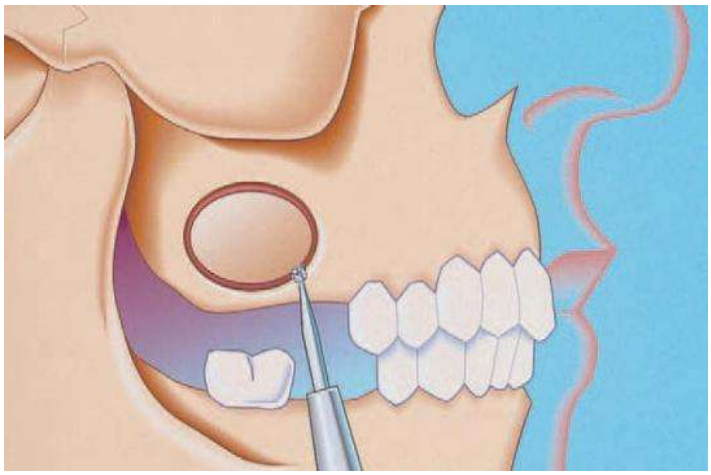

Figure 13:- Showing the procedure of grafting.

Grafting materials that are being used currently for antral floor augmentation include autogenous bone, bone allografts, and alloplasts such as tricalcium phosphate (TCP), bioactive glass, and resorbable and non-resorbable artery), supplies the superomedial sinus area.[20]

Grafting procedure

Autogenous bone is harvested from the predetermined site and is mixed with reconstituted freeze-dried bone in a 1 : 2 ratio. This mixture then is packed into 1-cc tuberculin syringes and is set aside. The mixture is used to densely fill the sinus. After completely filling the maxillary sinus with the desired level of bone mixture, as above, the clinician repositions the mucoperiosteal flap, and the incisions are closed with interrupted non-resorbable sutures[43]. After the bone has matured, it is evaluated to ensure that there is sufficient quantity for implant placement. Implants then can

be placed in the mature graft material according to the surgical protocol for the particular implant system and can be allowed to integrate. Postoperative considerations are similar to those for most oral surgery and sinus manipulation procedures.[21]

Nasal Floor And Block Grafts For Premaxilla Augmentation

Anterior tooth loss usually compromises ideal bone volume. On the day of primary surgical techniques Antibiotics that are effective against both aerobic and anaerobic bacteria should be prescribed preoperatively and postoperatively. The patient's oral-facial area should be prepared and draped. Surgery can be performed with the patient sedated with intravenous medication unless the graft material is procured from the iliac crest, in which case general anaesthesia is used. A local anaesthetic, with a Vaso-constrictor for haemostasis, is infiltrated into the maxillary surgical site and the maxillary or mandibular donor sites (if autogenous bone will be harvested from an intraoral site).[22]

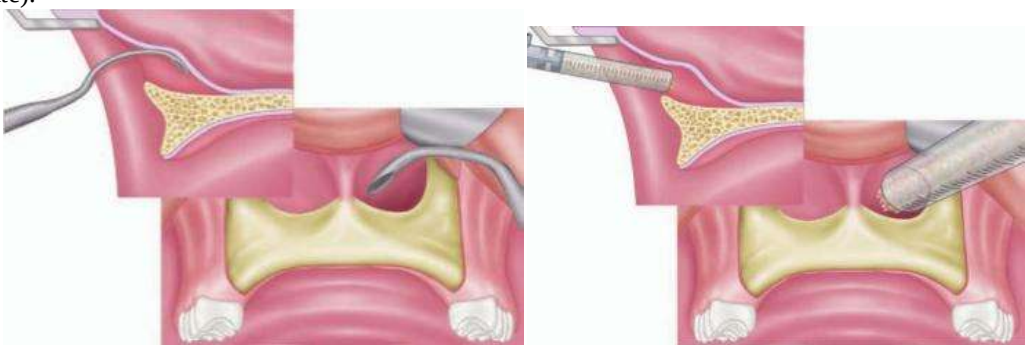

Figure 14,15:- Showing procedure of graft placement.

Bone Grafts For Implant Dentistry

In the present scenario, an Implant procedure is a treatment that replaces missing teeth, improves function, and enhances esthetics. However, cases of bone deficient sites where Implant placement is difficult, bone grafts play their role. In these situations, it is possible to place Implants with bone grafts only.[23]

The Rationale for Bone Grafts

Implant placement requires sufficient volume of bone and bone quality in a biological way. This is achieved by the particular implant design, which requires certain dimensional properties that is long lasting success.[24]

Indications for Bone Grafts in Implant treatment are:

1. In alveolar sockets after extraction
2. Refilling a local bony defect due to trauma or infection
3. Refilling a peri-implant defect due to peri- implantitis
4. Vertical augmentation procedures of the mandible and maxilla
5. Horizontal augmentation in the mandible and maxilla

The commonly used grafting approaches in implant are **Particulate Bone grafting and Block grafting**.

Combination approaches

With reference to the aforementioned GBR techniques, combining one or more of the previously described approaches can be utilized in cases where severe bone defects are present in order to optimize GBR outcomes. In many situations, a membrane may not be required, and the graft material alone can be effective. However, it is found that the use of barrier membranes to cover the grafting material can further improve the quality of regeneration by holding grafting material in proper location which particulate grafts are used, acting as space maintenance and minimizing alveolar bone resorption.[25]

Barrier membranes can be non-resorbable, such as expanded polytetrafluoroethylene (ePTFE) and titanium, or resorbable, such as polypeptides (collagen) and synthetic polymers (polylactide and polyglycolide). These membranes may be used in combination with block grafts and/or particulate graft materials. Membranes required for grafting of severe bony defect has to have a space maintenance property, which make them rigid enough to be shaped to the desired contour, height and width of future bone needed.[26]

This can be achieved by using commercially available non-resorbable titanium based and titanium reinforced membranes or the adjunct use of tenting screws and simultaneous placement of implants to prevent barrier membranes collapse into the space of the bony defects by the overlying soft tissue during healing. In some reports where autografts were utilized for GBR purposes, resorption tended to be higher with when no membrane was used. A clinical study reported a significantly less resorption of the block grafts was found when e-PTFE membranes were used to protect the graft.

Ridge expansion/ ridge splitting techniques

Ridge splitting is an alternative to the various techniques described for horizontal ridge augmentation, such as distraction osteogenesis. It was proven that both pervious mentioned procedures have a similar healing pattern and end results. In an area with a narrow ridge measuring 3 mm in bucco-lingual width or more, splitting of the alveolar bone is started by using either chisels, osteotomes, or piezo surgical devices to increase the horizontal ridge width. Buccal and lingual cortical plates or targeted sites should not be fused and some intervening cancellous bone between those cortical plates should be present to prevent a complete bone fracture and separation.

Minimally Invasive Tunnel Technique

It is considered to be a safe, simple and patient compliance method to augment bone. The subperiosteal tunneling approach is a minimally invasive procedure that allows the surgeon to allocate the graft in a space that is obtained between the soft tissues and the underlying bone through an access represented by a single incision on the mesial limit of the bone defect. This approach is believed to warrant minimal discomfort to the patient in the immediate postoperative phase in addition to ensuring a steady coverage of the graft during the healing time, with minimal risk of exposure, infection, and failure.

Bone manipulation techniques

These techniques are capable of manipulating the bone to alter their density to make it exceedingly durable and strong. These techniques mobilize vital bone with plastic bending, shaping, or condensation of tissue as a bone flap or bone-periosteal flap. This results in contour or dimensional changes, while preserving bone integrity and viability. Current techniques include inlay and onlay grafting, guided bone regeneration (GBR), bone expansion, bone splitting osteotomy, and different fixation devices such as bone screws, pins, titanium mesh, different augmentation materials, and different barrier membranes.

Bone expansion technique

This technique involves the manipulation of the bone to form a receptor site for an implant without the removal of any bone from the patient. The objective is to maintain the existing soft bone by pushing the buccal bony plates of the residual ridge laterally with minimal trauma. This technique takes the advantage of the softer bone quality found in Types III and IV maxillary bone by relocating the alveolar bone rather than losing the precious bone by drilling. The most common anatomic area in which ridge expansion is performed is in the narrow anterior maxilla, followed by posterior maxilla and then the anterior and posterior mandible, respectively.

Alveolar ridge splitting technique

This technique is used to augment the atrophic maxilla and mandible before the implant placement. It is commonly referred as Ridge splitting or Bone spreading technique.This techniques is performed by gaining access to a ridge that is <3 mm wide by splitting the buccal and palatal bone flaps with a scalpel first by separating two cortices through its cancellous bone. This technique is employed in cases where there is an insufficient width to utilize round osteotomes. This procedure provides a quicker method wherein an atrophic ridge can be but it does induce immune rejection.

Alveolar distraction osteogenesis

It is eliminating the need for a second donor site and a second stage surgery. Ideal sites to perform this procedure includeclinical scenarios where there is a knife-edge ridge that widens further apically, and that consists of adequate cortical thickness but with some degree of interpositional lamellar bone. This is particularly true in the anterior region of the maxilla. In this technique, a defect is created when two bone segments are slowly separated under tension. One week after osteotomy and distractor placement (latency period), distraction of segments is advanced at a rate of 0.5-1mm/day until the desired separation is reached. A consolidation period of 5 days/mm of the space created should be maintained before device removal and implant placement. It allows for a vertical bone gain of 3-

20mm without the use of graft material and additional mucosal grafting is not required as the soft tissue follows bone distraction.

Guided bone regeneration

It is also known as "membrane protected bone regeneration." The concept of GBR implies the use of cell-occlusive membranes for space provision over a vertical or horizontal defect, promoting the in-growth of osteogenic cells while preventing migration of undesired cells from the overlying soft tissue. It also effectively stabilizes the blood coagulum and thereby allows for faster healing to occur. This technique can be used before or at the same time as implant placement.

Growth factors

Numerous growth factors have been widely tested in animal models. Amongst these, bone BMPs are considered to be unique as they induce osteogenic precursor cells into osteogenic cells and have shown incredible bone growth in many animals and also human clinical studies. Other growth factors besides BMPs that have been implicated during bone regeneration are also being investigated, including platelet-derived growth factor, transforming growth factor-β, insulin-like-growth factor-1, vascular endothelial growth factor, and fibroblast growth factor, among others.

Autogenous teeth

Autogenous bone is considered an ideal material for the reconstruction of hard tissue defects, due to its ability to promote osteogenesis, osteoinduction, osteoconduction, and enhanced healing.

Biophysical effects

Mechanical loading and electromagnetic signals are important regulators of bone formation. The regenerative capacity of bone depends largely upon its capacity to recognize the functional environment that is required for the emergence and maintenance of structurally intact osseous tissue. Methods such as biophysical stimulation have thus been introduced with success in clinical practice. In addition to distraction osteogenesis, which is dealt with in the next section, exposure to an electromagnetic field and the application of ultrasonic waves are considered to be special forms of mechanical stimulation[50].

Transplantation of cells

Different donor sites require the grafting of different types and amounts of bone-cell-containing materials. Bone-forming tissues can be applied as periosteal flaps, as bulk grafts of cortico-spongiosal or vascularized bone, and as chips of cancellous or cortical bone. Periosteal flaps and chips of cancellous or cortical bone are used to treat small osseous defects if the local conditions are conducive to bone healing. Endochondral bone can be harvested from the ilium, the tibia or the ribs, and membranous bone from the facial skeleton. Animal studies indicate that membranous bone is less prone to resorption than endochondral bone

Local bone grafts

For the repairof alveolar defects local grafts harvested from either the mandibular symphysis or ramus are suitable. The advantages of local grafts harvested from the circum-mandibular wires that were unlikely to maintain rigid fixation grafting of the edentulous mandible in the past. These grafts were secured by donor and recipient sites and an ideal method for out-patient pre-implant surgery.

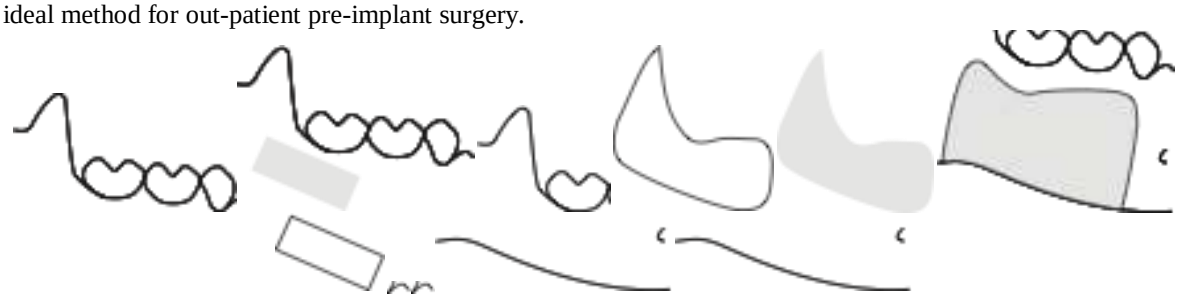

Figure 21:- Showing The location and extent of the corico- cancellous graft taken from the body of the mandible as described by the various authors.

Distant bone grafts
In situations where large amounts of autogenous bone are required for alveolar reconstruction, usually of the edentulous jaws prior to implant placement, distant donor sites are required, usually from the iliac crest.

Maxillary sinus grafting (open technique)
The sinus lift technique is a simple procedure and allows implant rehabilitation in the posterior atrophic maxilla with predictable results. Implant placement is carried out simultaneously to the grafting technique in the case of having enough residual alveolar bone to provide primary stability to the implants. In the case of extreme atrophic bone, not allowing adequate fixation for the implants, primary bone grafting is indicated and secondary placement of the implants after consolidation of the grafting material will be carried out .

Recent Advances
Tissue engineered Bone Grafts
Functional Requirements
Surgical interventions utilizing autografts and allografts have been shown to improve repair of bone defects in various degrees. However, none of currently used grafts has all the ideal characteristics: high osteo-inductive and angiogenic potentials, biological safety, low patient morbidity, no size restrictions, ready access to surgeons, long shelf life, and reasonable cost. The promise of tissue engineering is to combine the advances in the fields of biomaterials and cell biology towards bone grafts matching most or all of these characteristics.

Bone Tissue Engineering
To date, the field of bone tissue engineering has been focused on creating tissue grafts that have capacity to enhance osteogenesis in the site of the bone defect. Constructs have been assembled in vitro by seeding cells with osteogenic potential into biodegradable scaffolds, and either directly transplanted in vivo to assess their bone forming potential, or cultured in vitro to enable development of new tissue and the formation of “mature” bone-like grafts.

Cells
Large numbers of cells capable of producing bone extracellular matrix are needed for the production of clinically-sized engineered tissues. Mesenchymal stem cells, which differentiate and form bone during normal development, have long been the primary cell source for engineering bone grafts. It has long been recognized that adult bone marrow stem cells (BMSC) form multiple mesenchymal tissues in vivo including bone, and have utility for engineering skeletal tissues.

Scaffolds
The scaffold is crucial for the successful engineering of bone tissues as it provides a suitable environment for osteogenic cells to migrate, proliferate, differentiate, and promote new bone formation, and it also provides mechanical competence during the bone regeneration. There are a few requirements to be considered in the design and construction of 3D bone scaffolds. First, the scaffold must be biocompatible and degrade with time into non-toxic products. It should also be highly porous and permeable for cell seeding (in vitro) and infiltration (in vivo), nutrient transport, tissue ingrowth, and vascularization. The scaffold should be mechanically stable, having properties similar to those of the native bone. Finally, an ideal bone scaffold should also be osteoconductive (to recruit bone cells from the recipient), osteoinductive (to differentiate stem cells into bone-forming cells), and osseointegrative (to provide permanent and functional attachment to native bone).

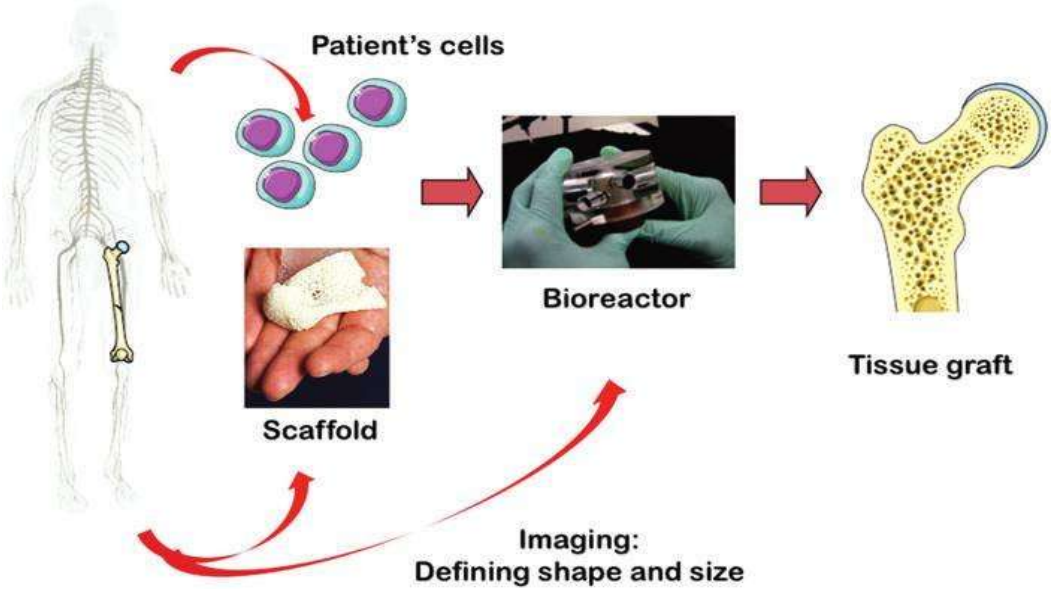

Figure 25:- Bone tissue engineering paradigm.

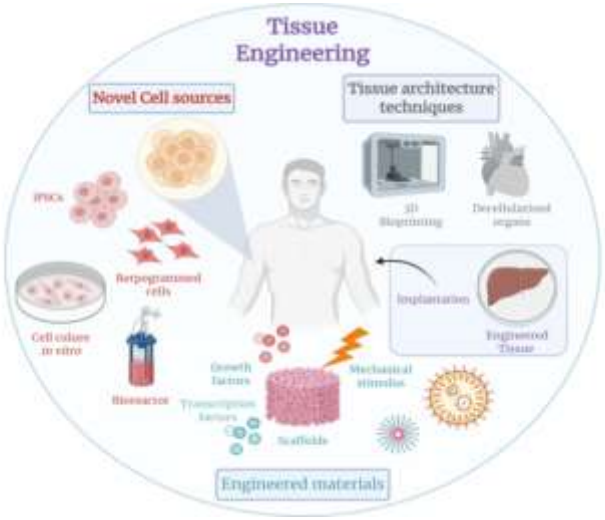

Figure 26:- Tissue engineering procedure.

Protein Based Bone Grafts

Numerous studies of critical-size calvarial, alveolar, and mandibular defectmodels of BMPinduced osteogenesis have demonstrated a successful result in a wide variety of animal models. These have focused on the delivery of BMPs, typically rhBMP-2 and rhBMP-7, with a wide variety of delivery systems including demineralized bone matrix and other alloplastic materials along with the standard commercially available collagen sponge implants .

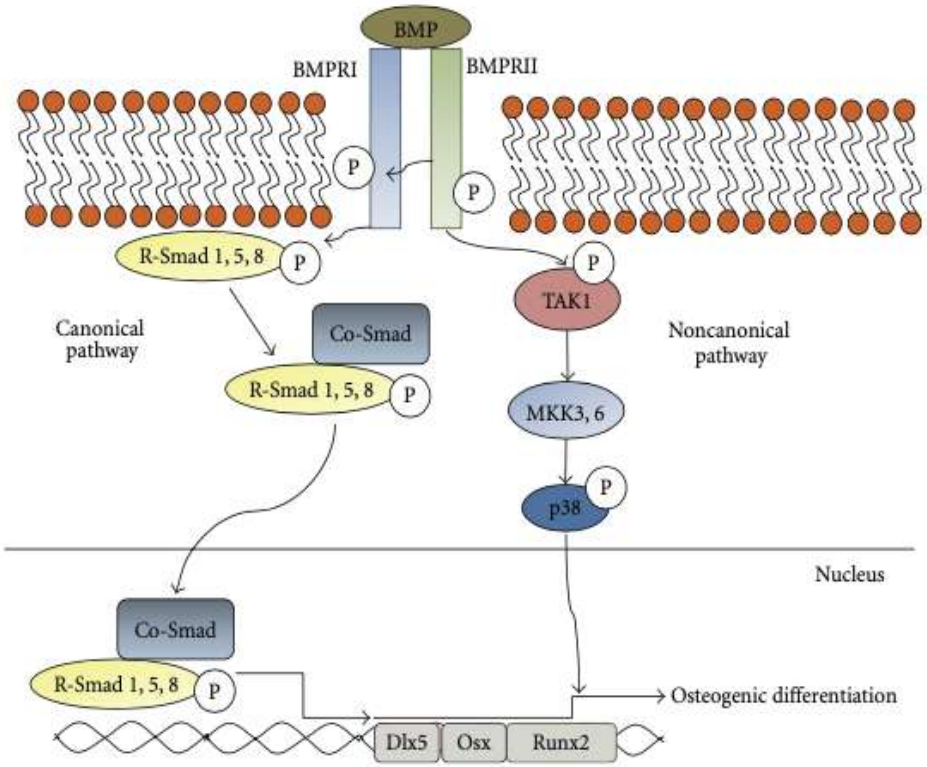

Figure 27:- Showing Mechanism of Bone Morphogenetic Protein Induction of Osteogenesis.

Gene- based Bone Grafts

Bone tissue has significant potential for reparative regeneration. However, with "osteogenic insufficiency," this process can take a long time and often does results in incomplete bone healing, despite the use of current surgical technologies. Osteogenic insufficiency is a pathological condition associated with low activity of systemic or local osteoinductive factors and/or a lack of cambial cells in the bone lesion area; therefore, the natural course of reparative osteogenesis may not provide complete histotypic and organotypic recovery. Therefore, treatment of patients with large bone defects, delayed consolidation, and non-unions remains extremely challenging and is followed by a prolonged loss of working ability, decreased quality of life, and even disability. Successful treatment requires restoration of the lostcambial reserve and/or osteoinductive factors, and classically involves the use of bone autografts, as the "golden standard." However, well-known limitations and disadvantages of this approachpredetermine the development of acceptable alternatives, among which activated bone substitutes are quite promising.

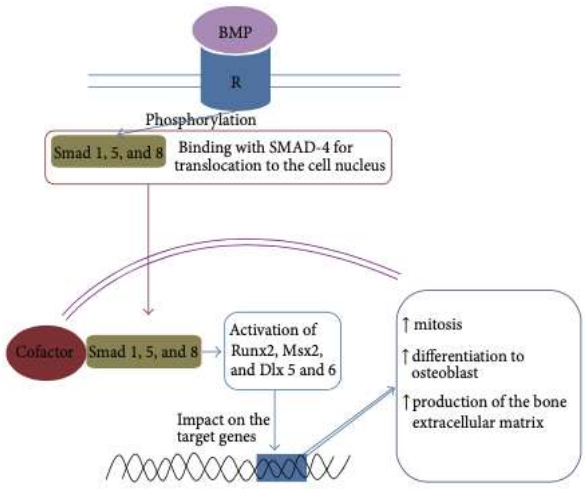

FIGURE 2: Scheme of intracellular Smad-mediated transduction pathway for BMP signals. BMP: bone morphogenetic protein; R: receptor.

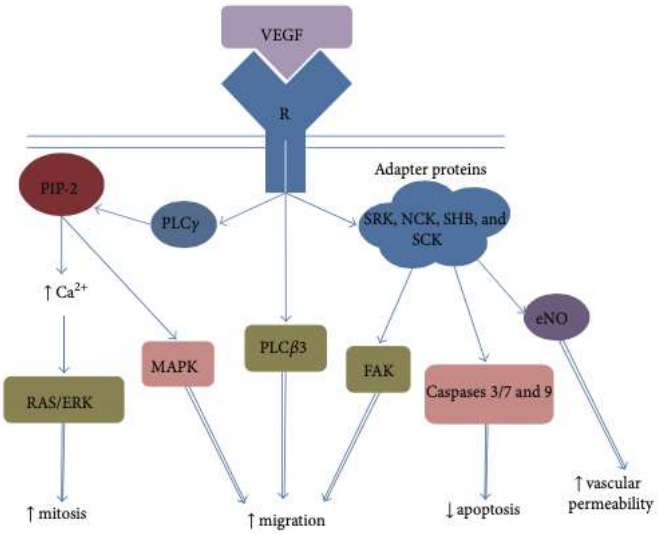

Figure 28:- Scheme of intracellular Smad- mediated transduction pathway for BMP signals.

Conclusion:-

The introduction of endosteal implants, together with better understanding of primary bone healing, has contributed substantially to the successful application of bone grafts in pre-implant surgery.The techniques used to harvest and apply the grafts are not new and found, for a large part, their origin in conventional pre-prosthetic surgery.Sophisticated and the results are far better than in the past, simply because of the favourable loading conditions of the grafted bone by endosteal implants. The resorption as seen in the old days was largely the result of disuse atrophy and compression loading by a conventional, mucosally borne denture. Yet, fundamental rules, learned from the early experiences in pre-prosthetic surgery, are still valid today and the difference between success and failure is very small.A proper understanding of the function and healing of the graft is therefore mandatory when choosing the type of graft for effective pre-implant surgery of the jaws.

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