Without History, There would be no Future

History of Bone Grafting

17th century: “Age of the Scientific Revolution”, interest in anatomy and physiology of human being:

- 1659-1657: Zacharias Janssen (Dutch spectacle-maker) and Antonie van Leeuwenhoek (Dutch businessman and scientist) construction of first microscope & discovery of microorganisms, “Father of Microbiology”.

- 1615, William Harvey (English physician): Discovery of systemic blood circulation, heart pumping function.

- 1632, Rembrandt’s masterpiece “The Anatomy Lesson of Dr. Nicolaas Tulp” (Dr. Tulp- Dutch surgeon and mayor of Amsterdam, yearly public dissection taught to Amsterdam Guild of Surgeons).

- 1668, Dutch surgeon Job van Meekeren (pupil of Dr. Tulp): first bone grafting procedure: dog bone was harvested and placed into soldier’s skull to heal a war wound. Bone fragment was fully incorporated.

- 1742, Henri-Louis Duhamel, France: growth of long bone at their ends, periosteum had a deep osteogenic layer, which he termed the “cambium layer”, and pivotal role of periosteum in osteogenesis.

- In 1858, Dr. Rudolf Virchow, Germany, physician and biologist: cell theory - tissue regeneration dependent on cell proliferation (cells arise from pre-existing cells).

- 1867, Dr. Louis Ollier, France: manuscript-for the first time used term “bone graft”: “implanted bone fragments are viable if they include the periosteum, which is the most important viability factor of the graft”.

Bone Augmentation Modalities in Implant Dentistry

Part I

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International Bone Symposium in Implant Dentistry

San Francisco

Thursday, March 30 – Saturday, April 1, 2017

Learn from the leading international bone grafting experts.

San Francisco
Bone Graft(ing)

Bone grafts are implanted materials that promote bone healing response by providing osteogenic, osteoinductive, or osteoconductive activity to a local site.

Tissue Engineering and Regenerative Medicine (TERM) for Alveolar Ridge Augmentation

1. **Matrix** (scaffold)- graft material and its stabilization; role of space maintenance.
2. **Cells**- capable of bone regeneration, having osteogenic potential (from MSCs to osteoblasts).
3. **Signal** (molecular mediators or cytokines)- for cell proliferation and differentiation: growth factors-BMP, PDGF, FGF, others- PRP, PRF.

Healthy HOST bone response & adequate Vascularization

Biologic Mechanisms that provide rationale for Bone Grafting: 3 Os of Bone Graft Healing

- **Osteoconduction**
  - is a bone formation initiated from the surrounding viable bone cells while the bone graft serves as a scaffold (framework) through the mechanism of creeping substitution. Osteoblasts from the margin of the bone defect generate new bone. This process occurs with autogenous, xenogeneic, allogeneic, and synthetic grafts.
  - In the very least, bone graft material should be osteoconductive.

- **Osteoinduction**
  - is a bone formation from the bone graft that has a potential to induce bone growth from MSCs (pluripotent) through the process of differentiation and proliferation. This stimulation of osteoprogenitor cells process occurs with autogenous grafts, some allogeneic & rhBMPs. Signal- proteins (peptide growth factors or cytokines).
  - Many of these growth factors are present in normal human bone.
  - BG with 2 Os- provide scaffold for existing osteoblasts & trigger formation of new osteoblasts.

- **Osteogenesis**
  - is a bone formation from the host living bone cells (osteoblasts and osteocytes) in addition to other 2 Os. This process occurs mostly with autogenous grafts or tissue engineering.

Bone Loss after Tooth Extraction

- Post-extraction bone resorption is always 3D, with the greatest loss of bone:
  - **Bucco-palatal or horizontal direction (bone width)**, occurring mainly on the buccal side of the alveolar ridge. Schropp reported that 2/3 of the horizontal bone loss occurs within 3 months and 1/3 takes place within the remaining 9 months of the first year postextraction (up to 4-5 mm).
  - A mean reduction of the width of the ridge has been reported to be 5 to 7 mm within a 6-month period or 50% during the 12 months following tooth extraction.
  - The loss of bone height is smaller, reported to be about 1-2 mm within the first 6 months postextraction.

Data from: Devlin, Pietrokovski, Evian, Schropp, Johnson, Sal Panicano, Busa
Alveolar Ridge Enhancement

- **Ridge Preservation (RP)**
  - Hard and soft tissue grafting procedures that preserve the ridge volume performed at the time of tooth extraction.
  - **Goal:** minimize bone loss after tooth loss for immediate or delayed implant placement ("can't prevent but can minimize")

- **Ridge Augmentation (RA)**
  - Hard and soft tissue grafting procedures that increase the ridge volume beyond the skeletal envelope that existed at the time of tooth extraction, performed at the time of extraction or later (mo., yrs.) in edentulous condition.
  - **Goal:** enlarge alveolar ridge volume for immediate or delayed implant placement.

Surgical Options for Alveolar Ridge Augmentation

- **Horizontal**
  - Less challenging,
  - More predictable,
  - Techniques:
    - GBR/GTR,
    - Ridge-split,
    - Block graft,
    - DO,
    - Others

- **Vertical**
  - More challenging,
  - Less predictable,
  - Techniques:
    - DO,
    - Block graft,
    - Sandwich osteotomy,
    - Ti mesh/particulate graft (GBR),
    - Others

Horizontal Augmentation of the Alveolar Ridge (4 techniques)

- GBR (particulate) graft
- Ridge-split
- Block Graft
- DO

Vertical Augmentation of the Alveolar Ridge (4 techniques)

- Sandwich osteotomy (Ridge-Split)
- Block Graft
- DO
- Particulate bone graft with Ti-mesh/PTFE+/-rhBMP-2

Alveolar Ridge Augmentation Procedures (conceptually)

1. Inlay (interpositional) bone graft:
   - 1) Particulate,
   - 2) Block,
2. Onlay (juxtaposed) bone graft:
   - 1) Particulate,
   - 2) Block,
3. Alveolar Distraction Osteogenesis,
4. Free bone flap transfer (microvascular anastomosis)

Dynamic bone augmentation options:
- Distraction osteogenesis,
- Orthodontic tooth movement (forced eruption)

Inlay (Interpositional) Bone Graft

- **Inlay (Interpositional) Particulate (GBR):**
  - 3-4 wall tooth socket:
    - Ridge preservation,
  - 1-2-wall bone defect:
    - RSP- horizontal or sandwich osteotomy-vertical,
    - Sinus lift (subantral augmentation),
    - Some Tent-pole procedures (implants, tenting screws, block graft)
Onlay Bone Grafting

- Onlay Particulate (GBR):
  - GTR/GBR procedure,
  - Subperiosteal tunnel,
  - Tent-pole technique with Ti-mesh, Screws or Implants,

- Onlay Block Graft:
  - Introral donor site,
  - Extraoral (distant)

Onlay Bone Grafting

Kao, Fagan, Conto, Hamrick, Schwartz-Arad

PASS Principle
of Successful Alveolar Ridge Augmentation

- Primary Wound Closure,
- Angiogenesis,
- Stability,
- Space Maintenance.

International Bone Symposium 2017

- Autogenous Block Bone Grafting (Misch),
- Particulate Bone Grafting (GBR) with Ti mesh for vertical and horizontal bone augmentation (Malmquist, Hamrick),
- Vertical ridge augmentation using Bone (GBR) & Soft Tissue grafting (Jovanovic),
- Sandwich Osteotomy (ridge-split expansion) for vertical and horizontal ridge augmentation (Ewers, Jensen, Tolstunov),

International Bone Symposium 2017

- Subantral and subnasal vertical bone augmentation in maxilla (Mazor, Choi),
- Soft tissue management of the alveolar ridge atrophy (Jovanovic, Mazor, Palacci),
- Bone growth enhancement, tissue engineering, stem cell technology, and use of blood products (Choukroun, Mazor, Malmquist, Misch),
- Anterior Esthetics in Implant Dentistry (Palacci).
Bone Augmentation Modalities in Implant Dentistry

Part II

Bone Augmentation Modalities

- Onlay
- Distraction
- Inlay

Bone Augmentation

- Transverse Correction Width
- Vertical Correction Height

Bone Augmentation Modalities

- Onlay
- Distraction
- Inlay

2D vs. 3D Bone Augmentation

Two-dimensional (2-D) bone augmentation for vertically preserved but width-deficient alveolar ridges: Block Vs. RSP

Three-dimensional (3-D) bone grafting procedures both horizontally and vertically deficient alveolar ridges: DO

2D

GBR (Onlay) with particulate graft

Ridge Preservation

2D

Block Grafting (Onlay) with or without particulate graft

2D

Ridge-Split Expansion (Inlay) with particulate graft

Transverse Correction

Height
Healing by secondary intention:

- Maintain its proper soft tissue architecture (vestibule and keratinized tissue) and the labial soft tissue has to be undisturbed.
- A resorbable or non-resorbable membrane is used to retain graft material, isolate the wound from the oral environment, and guide the soft tissue healing over the graft.

Inlay Grafting: Ridge Preservation and Ridge-Split Bone Augmentation Technique

Split Osteotomy (Ridge Augmentation) similar to Socket Grafting (Ridge Preservation)

Inlay Grafting: Ridge Preservation and Ridge-Split Bone Augmentation Technique

- Ridge Split Expansion Procedure
- Ridge Split Expansion Procedure - MAXILLA (single stage)

Ridge Split Expansion in Maxilla: single stage approach

Ridge Split Expansion in Mandible: staged approach
Ridge Split Expansion in Mandible: staged approach

- The Osteoperiosteal Flap (Ole Jensen, 2008, 2010)
  - "Book" flap: bone rotating about its base (binder) in a green-stick (hinged) manner (still connected to its base).
  - "Island" flap: bone is being fully separated from its base (free-floating).

Ridge Split Expansion Procedure - The Osteoperiosteal Flap (Jensen)

Comparison of RSP with Block Graft

- Onlay Block Graft (Autogenous)
  1. 2D + bone augmentation,
  2. Donor site morbidity:
     - pain, swelling, nerve injury,
  3. Free graft (degree of loss of cellularity and vascularity),
  4. Graft type: External (Onlay): adding cortical graft to the existing (collapsed) cortical bone,
  5. Vascularization: interrupted from the donor site, plasmatic imbition from the host,
  6. Soft tissue are detached & stretched for primary closure (mandatory),
  7. Dimensional stability: resorption,
  8. Implants- always placed in 4-6 mo.

- Inlay Ridge-Split Expansion
  1. 2D + bone augmentation,
  2. No donor site morbidity,
  3. Vascular Bone flap (Osteoperiosteal flap),
  4. Graft type: Internal (Inlay or Interpositional): particulate graft is placed between cortical plates,
  5. Vascularization: preserved - muco-osteoperiosteal vascular flap,
  6. Simultaneous expansion of the soft tissue; secondary healing,
  7. High degree of dimensional stability (lasting),
  8. Simultaneous implants- possible

Modes of 3D Bone Augmentation

- 3D (H + V):
  - Distraction osteogenesis,
  - 3D block grafting,
  - Forced eruption.

4D Bone Augmentation = Aging (Time)

In both sexes, the resorption pattern in the sagittal plane of the maxilla results in facial (buccal) bone loss. In a female patient, the anterior maxilla exhibits downward growth with a lingual vector. This may cause earlier implant thread exposure. In the male patient, on the other hand, the anterior maxilla exhibits only vertical downward growth.
Aging and Bone Changes (Loss): Case Report:
April: 37 healthy y.o., thin gingival biotype, thin buccal cortical bone
Immediate implantation

Incidence of buccal plate fenestration in the esthetic zone: CBCT study, Chen, et al. LOMI, 2014: Conclusion: occurrence of fenestration is common (approximately 20%)
Analysis of the dimensions of the labial bone wall in the anterior maxilla: a CBCT study, El-Nahass & Naim, Clin Oral Implant Res, 2015: Conclusion: 75% showed thin labial wall (less than 1 mm).

What would I do different now (case of young female with a high smile line, thin gingival biotype and thin buccal cortical plate):
1. No immediate implant placement: atraumatic extraction and ridge preservation,
2. Implant placement (4 mo):
   a) Computer-guided surgery,
   b) Position: more palatal and subcrestal,
   c) For the 7-8 mm ridge: I would place 3.5 mm diameter implants,
   d) Additional particulate graft (xenograft) on the facial,
   e) Simultaneous CTG,
   f) Blood products as a membrane- PRF,
   g) Staged approach with stage 2 at 6 months.
3. Restorative stage: 9 mo-1 yr from implant Sx,
4. Maintenance and follow-up !!

Literature:
- Influence of periodontal tissue thickness, J Clin Perio, 2015: The thickness of the buccal bone was a fundamental factor in buccal bone plate resorption.
  xenograft and PRF, used for ridge preservation, can be considered effective in repairing bone defects before implant placement. The secondary soft tissue healing over the graft preserved the bone defect.
- Etiologic factors:
  1) poor implant spatial positioning; 2) incorrect abutment contour;
  3) excessive implant diameter; 4) horizontal biologic width formation; and
  5) periodontal phenotype.
- Treatment:
  1) Burying the implant and allowing the soft tissues to heal over the implant;
  2) Augmentation of the soft tissues with a connective tissue graft, if needed;
  3) Separate stage 2 of uncovering of the implant, and
  4) Controlling the crown contour with flat or even undercontour to maintain the soft tissues in a stable position long term.

Managing Esthetic Challenges with Anterior Implants
(Chu, Tarnow, Compend., 2013)

Progressive Analysis of Bone Augmentation
4D ➔ 3D ➔ TIME

Alveolar Rehabilitation
Goal:
Bone width correction, Bone height correction, Soft tissue correction

Implant Triangle = Success in Implant Dentistry
1. Good Bone stock,
2. Good quality Soft Tissue,
3. Restoratively-driven implant placement.
Follow-up and Maintenance
Bone Augmentation Modalities in Implant Dentistry

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Dental Implants for Function & Esthetics

Bone is deposited or resorbed in accordance with the stresses placed upon it (remodeling of bone).

Julius Wolff wrote “The Law of Bone Transformation” in 1892, before the advent of radiography.

Brånemark Definition of Osseointegration

- Osseointegration is defined as a direct structural and functional connection between living bone and the surface of a load-carrying implant (P-I Brånemark).

Dental implant coexistence with bone is not a static process but a DYNAMIC one.

Beagle dog research 1985

Gingival Protective Features

Tissue-Integrated Prostheses

Osteointegration in Clinical Dentistry
Soft Tissue Grafting

Prosthetically-driven Implant Dentistry: Computer-aided Implant Technology: CAD/CAM

Success in Implant Dentistry

Distraction Osteogenesis (DO)

- **1-2-wall Horizontal Bone Defects**
- **1-2-wall Vertical Bone Defects**

**DO:**
- Donor side: none,
- Type: dynamic,
- No graft,
- Re- Vascularization: endosteal and periosteal (muco-osteoperiosteal flap),
- Graft consolidation:
  - Callus formation, similar to fracture healing, intramembranous (mostly) ossification followed by bone remodeling,
  - Augmenting tissue: bone and soft tissue (simultaneously expanded)

Advantages of DO

1. Basal bone is moved into the site of primary implant anchorage, so endosseous implants are not in grafted bone, but in a native bone,
2. Soft tissue expands proportionally to “growing” bone in coronal direction, thus improving gingival architecture and implant emergence profile.
Split Osteotomy (Ridge Augmentation) similar to Socket Grafting (Ridge Preservation)

Particulate Vs. Block Graft Face Off

Particulate Graft (inlay and onlay; bone graft substitute: allo-, xenograft; non-vascular):
- Not a “Gold standard” unless biomimetics and growth factors are added,
- Donor site morbidity: No,
- Recipient site morbidity: Rare,
- Immediate implant: possible,
- Re-Vascularization: endosteal (woven-to-lamellar bone formation),
- Graft consolidation: starts with bone formation and proceeds directly to bone mineralization,
- Later-term graft resorption: Minimal (“cancellous grafts more rapidly and completely revascularize than cortical grafts”)

Block Graft (usually, onlay, autogenous; non-vascularized):
- “Gold standard” (ostegenic potential: 3Os),
- Donor site morbidity: Yes,
- Recipient site morbidity: Yes,
- Immediate implant: not recom.,
- Re-Vascularization: endosteal, (plasmatic imbibition),
- Graft consolidation: starts with bone resorption, f/b bone formation and then revascularization,
- Later-term graft resorption: Yes (up to 40%)- detached and devascularized free bone


Aghaloo and Moy (IJOMI, 2007; systematic review): GBR procedure is the only well-documented surgical technique used for localized ridge augmentation.