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Bone and its Considerations in Implantology: A Review

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Abstract

Bone is an organ that is able to change in relation to a number of factors and has its implications in Implantology especially when dealing with the edentulous arches. This review will elaborate on various aspects of bone and its clinical implication

Keywords: Bone, implantology, resorption, remodelling.

Introduction

Bone is an organ that is able to change in relation to a number of factors, including hormones, vitamins, and mechanical influences. Wolff, in 1892, elaborated on these concepts and published, "Every change in the form and function of bone or of its function alone is followed by certain definite changes in the internal architecture, and equally definite alteration in its external conformation, in accordance with mathematical laws.The maxilla and mandible have different biomechanical functions. The mandible, as an independent structure, is designed as a force-absorption unit. The maxilla is a force distribution unit. Any strain to the maxilla is transferred by the zygomatic arch and palate away from the brain and orbit. As a consequence, the maxilla has a thin cortical plate and fine trabecular bone supporting the teeth.

Consequences of tooth loss:

Bone density in the jaws decreases after tooth loss. This loss is primarily related to the length of time the region has been edentulous and not loaded appropriately, the initial density of the bone, flexure and torsion in the mandible, and parafunction before and after tooth loss.

Bone Remodelling and Density:

Remodeling is a process of resorption and formation at the same site that replaces previously existing bone and primarily affects the internal turnover of bone, including that region where teeth are lost or the bone next to an endosteal implant. Frost proposed a model of four histologic patterns for compact bone as it relates to mechanical adaptation to strain.[1]

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Acute Disuse Window

The bone in the acute disuse window loses mineral density, and disuse atrophy occurs. The microstrain of bone for trivial loading is reported to be 0 to 50 microstrain. A cortical bone density decrease of 40% and a trabecular bone density decrease of 12% also have been reported with disuse of bone.

Adapted Window

The adapted window (50 to 1500 microstrain) represents an equilibrium of modeling and remodeling, and bone conditions are maintained at this level. Bone in this strain environment remains in a steady state, and in homeostatic window of health. This is the range of strain ideally desired around an endosteal implant.

Mild Overload Zone

The mild overload zone (1500 to 3000 microstrain) causes a greater rate of fatigue microfracture. As a result, the bone strength and density may eventually decrease. The histologic description of bone in this range is usually woven or repair bone.

Pathological Overload Zone

Pathologic overload zones are reached when microstrains are greater than 3000 units. Cortical bone fractures occur at 10,000 to 20,000 microstrain (1% to 2% deformation). Therefore pathologic overload may begin at microstrain levels of only 20% to 40% of the ultimate strength or physical fracture of cortical bone. The bone may resorb and form fibrous tissue.

Classifications related to bone density:

Linkow[2] classified bone density into three categories:

Class I bone structure: This ideal bone type consists of evenly spaced trabeculae with small cancellated spaces.

Class II bone structure: The bone has slightly larger cancellated spaces with less uniformity of the osseous pattern.

Class III bone structure: Large marrow-filled spaces exist between bone trabeculae.

Lekholm and Zarb listed four bone qualities found in the anterior regions of the jawbone.

Quality 1 is composed of homogenous compact bone

Quality 2 has a thick layer of cortical bone surrounding dense trabecular bone

Quality 3 has a thin layer of cortical bone surrounded by dense trabecular bone of favorable strength.

Quality 4 has a thin layer of cortical bone surrounding a core of low-density trabecular bone.

Misch[3,4] proposed four bone density groups independent of the regions of the jaws, based on macroscopic cortical and trabecular bone characteristics. In combination, these four increasing macroscopic densities constitute four bone categories described by Misch (D1, D2, D3, and D4) located in the edentulous areas of the maxilla and mandible. The regional locations of the different densities of cortical bone are more consistent than the highly variable trabecular bone. A very soft bone, with incomplete mineralization and large intertrabecular spaces, may be addressed as D5 bone.

Bone Density based Treatment Planning –

Bone density is directly related to the strength of bone before microfracture. A tenfold difference in bone strength may be observed from D1 to D4 bone. D2 bone exhibited a 47% to 68% greater ultimate compressive strength, compared with D3 bone . In other words, on a scale of 1 to 10, D1 bone is a 9 to 10 relative to strength. D2 bone is a 7 to 8 on this scale. D3 bone is 50% weaker than D2 bone and is a 3 or 4 on the strength scale. D4 bone is a 1 to 2 and up to 10 times weaker than D1 bone.

Influence on bone-to-implant contact

The bone implant contact (BIC) percentage is significantly greater in cortical bone than in trabecular bone. The very dense D1 bone of a C–h resorbed anterior mandible or of the lingual cortical plate of a Division A anterior or posterior mandible provides the highest percentage of bone in contact with an endosteal implant and may approximate more than 85% BIC.

Treatment Planning

Bone density is an implant treatment plan modifier in several ways—prosthetic factors, implant

size, implant design, implant surface condition, implant number, and the need or method of progressive loading. To decrease the incidence of microfracture of bone, the strain to the bone should be reduced.

1. cantilever length may be shortened or eliminated,
2. RP-4 restorations, rather than fixed prostheses
3. RP-5 prostheses permit the soft tissue to share the occlusal force and reduce the stress on the implants.
4. Night guards and acrylic occlusal surfaces distribute and dissipate parafunctional forces on an implant system.
5. As the bone density decreases, the occlusal loads should be oriented more axially.
6. Increase the number of implants
7. Increase the width of the implant to provide more surface area to dissipate crestal loads
8. Macro-design of implant – an implant body designed for softer bone should have more and deeper threads than an implant design for hard bone.
9. Surface coatings enhance bioadhesion, rougher surfaces are indicated for soft bone.
10. The softer the bone, higher the need for progressive loading

Available Bone

Available bone describes the amount of bone in the edentulous area considered for implantation. It is measured in width, height, length, angulation, and crown height space. As a general guideline, 1.5 to 2 mm of surgical error is maintained between the implant and any adjacent landmark. This is especially critical when the opposing landmark is the mandibular inferior alveolar nerve. However, the implant may be placed without complication through the cortical plate of the maxillary sinus or inferior border of the mandible. The implant may also be positioned closer to the cribriform plate of a natural tooth. If the implant should become mobile or affected by periimplant disease, the adjacent landmark may be adversely involved. Likewise, if the sinus becomes infected or the adjacent tooth suffers from periodontal disease, the implant may be affected.

Importance of evaluating dimensions of available bone-

Manufacturers describe the root form implant in dimensions of width and length. The implant length corresponds to the height of available bone. The width of a root form implant is most often related to the diameter and mesiodistal length of available bone. Most root form implants have a round cross-sectional design to aid in surgical placement; therefore the diameter of the implant corresponds to the implant width. Many manufacturers propose implants with a crest module wider than the implant body dimension. Yet the often stated dimension of the manufacturer is the smaller body width. The clinician should be knowledgeable of all implant dimensions, especially because the crestal dimension of bone (where the wider crest module dimension is placed) is usually the narrowest region of the available bone and where the implant is closest to an adjacent tooth.

Available Bone Width

The width of available bone is measured between the facial and lingual plates at the crest of the potential implant site. The crest of the edentulous ridge is most often supported by a wider base. In most areas, because of this triangular-shaped cross section, an osteoplasty provides greater width of bone, although of reduced height. Crest reduction affects the location of the opposing landmark, with possible consequences for surgery, implant height selection, appearance, and the design of the final prosthesis. This is particularly important when an FP-1 prosthesis is planned, with the goal of obtaining a normal contour and proper soft tissue drape around a single tooth replacement. The crestal aspect of the residual ridge is often cortical in nature and exhibits greater density than the underlying trabecular bone regions, especially in the mandible. This mechanical advantage permits immediate fixation of the implant, provided this cortical layer has not been removed by osteoplasty.

Available Bone Height

The available bone height is first estimated by radiographic evaluation in the edentulous ideal and optional regions, where implant abutments are required for the intended prosthesis. The height

of available bone is measured from the crest of the edentulous ridge to the opposing landmark.

Anatomical Limitations-

The anterior regions are limited by the maxillary nares or the inferior border of the mandible. The anterior regions of the jaws have the greatest height, because the maxillary sinus and inferior alveolar nerve limit this dimension in the posterior regions. The maxillary canine eminence region often offers the greatest height of available bone in the maxillary anterior.

The mandibular first premolar region is usually anterior to the mental foramen and provides the most vertical column of bone in the posterior mandible. However, on occasion, this premolar site may present a reduced height compared with the anterior region, because of the anterior loop of the mandibular canal (when present) as it passes below the foramen and proceeds superiorly, then distally, before its exit through the mental foramen. The available bone height in an edentulous site is the most important dimension for implant consideration, because it affects both implant length and crown height. Crown height affects force factors and esthetics.

Available Bone Length

The available bone length determines in part the diameter of the implant but most importantly the number of implants that maybe placed in a given edentulous space. The mesiodistal length of available bone in an edentulous area is often limited by adjacent teeth or implants. As a general rule, the implant should be at least 1.5 mm from an adjacent tooth and 3 mm from an adjacent implant. This dimension not only allows surgical error, but also compensates for the width of an implant or tooth crestal defect, which is usually less than 1.4 mm. As a result, if bone loss occurs at the crest module of an implant or from periodontal disease with a tooth, the vertical bone defect will not spread to a horizontal defect and cause bone loss on the adjacent structure.

Available Bone Angulation

Bone angulation is the fourth determinant for available bone. The initial alveolar bone angulation represents the natural tooth root trajectory in relation to the occlusal plane. Ideally, it is perpendicular to the plane of occlusion, which is aligned with the forces of occlusion and is parallel to the long axis of the prosthodontic restoration. The maxillary anterior teeth are the only segment in either arch that does not receive a long axis load to the tooth roots, but instead are usually loaded at a 12-degree angle. As such, their root diameter is greater than the mandibular anterior teeth. In all other regions, the teeth are loaded perpendicular to the curves of Wilson or Spee.

Anatomical Considerations-

Rarely does the bone angulation remain ideal after the loss of teeth, especially in the anterior edentulous arch. In this region, labial undercuts and resorption after tooth loss, often mandate greater angulation of the implants or correction of the site before insertion.

In the posterior mandible, the submandibular fossa mandates implant placement with increasing angulation as it progresses distally. Therefore, in the second premolar region, the angulation may be 10 degrees to a horizontal plane; in the first molar areas, 15 degrees; and in the second molar region, 20 to 25 degrees.

Crown Height Space

The crown height space (CHS) is defined as the vertical distance from the crest of the ridge to the occlusal plane. It affects the appearance of the final prosthesis and the amount of moment force on the implant and surrounding crestal bone during occlusal loading. The CHS may be considered a vertical cantilever.

The greater the CHS, the greater the moment force or lever arm with any lateral force or cantilever.

Therefore, as the CHS increases, a greater number of implants or wider implants should be inserted to counteract the increase in stress.

Available Bone and Treatment Planning

In 1985, Misch and Judy established four basic divisions of available bone for implant dentistry in the edentulous maxilla and mandible, which follow the natural resorption phenomena of each region, and determined a different implant approach to each category.

Division A (Abundant Bone)

Features-

1. Width > 6 mm
2. Height > 12 mm
3. Mesiodistal length > 7 mm
4. Angulation of occlusal load (between occlusal plane and implant body) < 25 degrees
5. Crown height space ≤ 15 mm

Treatment Planning-

The prosthetic options for Division A span the full gamut. An FP-1 restoration requires a Division A ridge. However, an FP-2 prosthesis most often also requires a Division A bone. An FP-2 restoration is the most common posterior restoration supported by multiple adjacent implants in partially edentulous patients, because of either bone loss or osteoplasty before implant placement. An FP-3 prosthesis is most often the option selected in the anterior Division A bone when the maxillary smiling lip position is high or a mandibular low lip line during speech exposes regions beyond the natural anatomical crown position.

Division B (Barely Sufficient Bone)

As the bone resorbs, the width of available bone first decreases at the expense of the facial cortical plate, because the cortical bone is thicker on the lingual aspect of the alveolar bone, especially in the anterior regions of the jaws. There is a 25% decrease in bone width in the first year and a 40% decrease in bone width within the first 1 to 3 years after tooth extraction.

Features-

1. Height > 12 mm
2. Mesiodistal length > 6 mm
3. Angulation < 20 degrees
4. Crown height space < 15 mm

Treatment Planning –

Three treatment options are available for the Division B edentulous ridge:

1. Modify the existing Division B ridge to another division by osteoplasty to permit the placement of root form implants 4 mm or greater in width (Figure4.9). When more than 12 mm of bone height results, the bone converts to Division A. When less than 12 mm of bone height results, the bone converts to Division C–h.
2. Insert a narrow Division B root form implant.
3. Modify the existing Division B bone into Division A by augmentation.

Division C (Compromised Bone)

Features –

1. Width (C–w bone): 0 to 2.5 mm
2. Height (C–h bone) < 12 mm
3. Angulation of occlusal load (C–a bone) > 30 degrees
4. Crown height space (CHS) > 15 mm

There are seven treatment options for the Division C bone:

- Osteoplasty (C–w)
- Root form implants (C–h)
- Subperiosteal implant (C–h, C–a partial, or completely edentulous mandible)
- Augmentation procedures before implant insertion
- Disk design implants (posterior mandible, anterior maxilla)
- Ramus frame implant (C–h completely edentulous mandible)
- Transosteal implant (C–h anterior mandible)

Division D (Deficient bone)

Long-term bone resorption may result in the complete loss of the residual ridge, accompanied by basal bone atrophy.

Features-

1. Severe atrophy
2. Basal bone loss
3. Flat maxilla
4. Pencil-thin mandible
5. >20 mm crown height

It is not infrequent that these patients complain of paresthesia of the lower lip, especially during

mastication. The CHS is greater than 20 mm, which is a significant force multiplier and can rarely be reduced enough to render long-term success.

Treatment Planning-

The partially or completely edentulous patient with a posterior Division D maxilla and healthy anterior teeth or implants may undergo sinus graft procedures with a combination of local autogenous bone, demineralized freeze-dried bone, and calcium phosphate bone substitutes.

It should be the goal of every dentist to educate and treat the patient before a Division D bone condition develops.

Conclusion

The prudent practitioner monitors bone loss in edentulous sites and offers education and treatment before deleterious effects. The bone density, anatomical site and amount of residual bone should become the primary determinants of the multi-faceted treatment plan for an implant supported prosthesis.

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