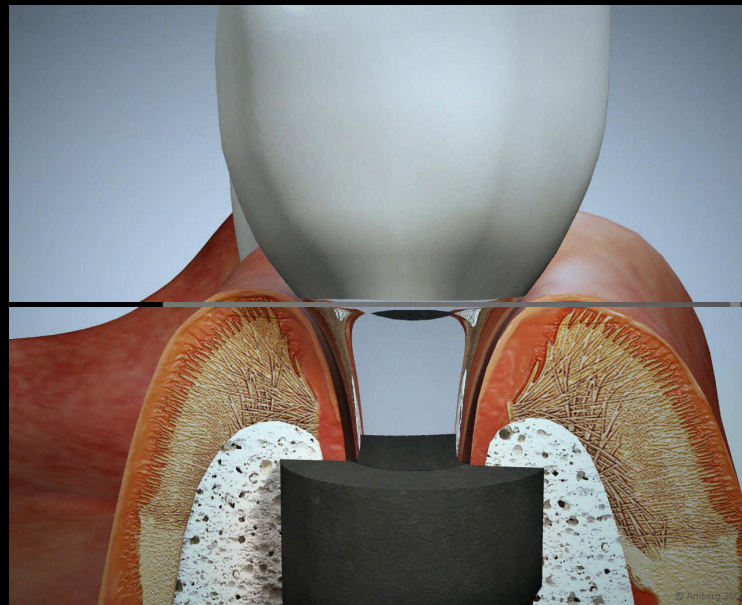


Progressive Bone Loading

Misch, Chapter 26, Pages 511-528



Dr. Mohammed Alshehri

Dental Implant fellowship program

Introduction

At the post healing Stage II surgery, the implant is most at risk for failure or crestal bone loss within the first year.

Failure results primarily from excessive stress or poor bone strength at the interface during early implant loading.

the three most common causes of early prosthetic related implant failure

- non passive superstructures.
- partially unretained restorations.
- loading of the implant support system beyond the strength of the bone-to-implant interface

Literatures

- **Root Laboratory** reported that 5.9% of the implants restored were lost from the final impression to the initial delivery of the prosthesis.
- **Jaffin and Berman, Jemt et al., and Friberg et al.** reported early implant failures as great as 35%, especially in poor bone quality, after successful surgical survival of implants.
- **Zarb and Schmitt** reported early loading failures in 3.3% of primarily completely edentulous mandibular patients with good-quality bone.
- **Naert and Quirynen** observed a 2.5% early loading failure rate in partially edentulous patients.
- **Sullivan et al** reported late failures in 7% of the maxillas and 1.4% of mandibles after reverse torque testing had identified 6.4% maxillary and 3.2% mandibular implant failures at Stage II Recovery.
- **Salonen et al reported** a 3.9% failure rate in a study of 204 implants.

Progressive Bone Loading concept

Misch first proposed the concept of progressive or gradual bone loading during prosthetic reconstruction to decrease crestal bone loss and early implant failure of endosteal implants in 1980 based on empirical information.

Misch et al. reported on 364 consecutive implants in 104 patients with 98.9% survival at Stage II uncoverly followed with a progressive loading format and found no early loading failures during the first year of function.

In a more recent report, no early loading failures were observed in the posterior maxilla over a 5-year period with 453 implants and 131 prostheses using a bone density-based implant design and progressive bone loading. Kline et al reported a 99.5% success rate at 5 years for 495 implants following a similar approach.

Bone Density

Wolff's law states, "Every change in the form and function of bones or of their function alone is followed by certain definite changes in their internal architecture, and equally definite alteration in their external conformation, in accordance with mathematical laws."

This phenomenon occurs throughout the skeletal system as evidenced by a 15% decrease in the cortical plate and extensive trabecular loss to bone immobilized for 3 months. Cortical bone decrease of 40% and trabecular bone decrease of 12% also have been reported in response to disuse.

Bone Density

- *Functional loading can **compete and maintain** bone mass.*
- ***increase** in cortical bone thickness and overall mineral content under stressful stimuli.*
- *Clinical evaluation confirms an increase in the amount of trabecular bone and cortical plate thickness in patients with natural teeth exhibiting parafunction.*
- ***Cowin and Hegedus** suggested that cell-level strains were almost **10 times** greater than tissue-level strains. The proposed cellular mechanisms include membrane deformation, intracellular action, and extracellular action.*

Bone Density

*A review of the literature of in vivo and in vitro studies has shown that **dynamic or cyclic loading** is **necessary** to cause a significant metabolic change in the bone cell population.*

*The **greater** the rate of change of applied strain in bone, the **more bone formation is increased**.*

*The effect of applied strains on bone is dictated not only by the **rate** of the applied load but also by the **magnitude and duration**.*

*Dental literature review of failures, orthopedic literature of bone remodeling, bone mechanics of the jaws, and finite element analysis suggest the **ability and need to load bone progressively for improved strength**.*

Bone to implant interface

*Computer-aided assessment of fixated implants through digital subtraction radiographic image analysis and an interactive image-analysis system demonstrates an **increase in density of periimplant bone structures** over a 6-month to a 4-year period after the implant was placed. The major changes of bone condensation around the implants occurred after they were **placed the first 2 years**.*

*The histologic type of bone in contact with the implant varies and can affect the amount of stress the bone can sustain within physiologic limits. Continuously loaded implants remain stable within the bone with bone formation in areas under compression and the orientation of **trabeculas corresponding to lines of stress**. The **ideal bone** for implant prosthetic support is **lamellar bone**. Lamellar bone is highly organized but **takes about 1 year** to mineralize completely after the trauma induced by implant placement. **Woven bone is the fastest** and first type of bone to form around the implant interface; however, it is mineralized only partly and demonstrates an unorganized structure less able to withstand **full-scale stresses**. At 16 weeks the surrounding bone is **only 70% mineralized and still exhibits woven bone** as a component.*

Bone to implant interface

*The stress applied to an implant also may lead to implant failure if it **exceeds the physiologic limits of the bone density** present around the implant.*

***Pierazzini et al** has demonstrated the development of denser trabeculas around progressively loaded implants in animals.*

***Piatelli et al** performed the histologic and histomorphometric study of bone reaction to unloaded and loaded nonsubmerged single implants in monkeys. The **softest types of bone lost more** bone than the more dense bone. Therefore increasing the bone-implant interfacedensity may reduce crestal bone loss.*

*The bone interfaces **of six implants**, three loaded and three nonloaded, were evaluated **after 15 months**. Thicker regions of lamellar cortical bone appeared around the **loaded implants compared with unloaded implants**.*

*The **major bone increase in density** and amount was observed in the **crestal region around the loaded implants**. Implants causing a change in the loading environment elicited trabecular growth and realignment within the marrow space.*

Bone to implant interface

- *Most all implants presented a **more negative number** “periostest value” after they had been in function for **more than 1 year**.*
- *The implants in D1 bone, after progressive loading, **did not improve statistically**, although a -7 Periostest value was recorded more often. The implants in D2 bone exhibited a mean decrease of 1 Periostest value. The implants in D3 bone had a slightly greater than 2 Periostest value decrease after progressive loading. The greatest change was seen in D4 bone. After progressive loading, the mean decrease in Periostest value was almost 4 units, with end Periostest values similar to many implants in D2 or D3 bone. Therefore **the poorer the bone density (D3 and D4), the more dramatic the decrease in Periostest values** (which relates to mobility and density of bone around the implant). These reogresssults are similar to those reported in the literature. **NO strict linear relationship exists between load or time, a decrease in Periostest value, and an increase in bone density.***

Bone to implant interface

- *Progressive loading **improved readings** regardless of implant design, coating, or length.*
- *Early results of a pilot study by Appleton et al suggest the loss of crestal **bone is reduced by** progressively loading implants.*
- *In D4 bone about 25% of the implant may be in contact with bone, D3 bone has about 50% bone contact, D2 bone about 70% bone interface, and D1 bone around **80%**. **The** greater bone contact improves the force distribution and decreases the stress transmitted to anyone region on the implant body.*
- *The implementation of progressive loading is more critical for lesser bone densities **because they are several times weaker than those with significant cortical bone.***

Bone to implant interface

- *Parafunction, cantilevers, and other stress magnifiers can increase the forces applied to the prosthesis and their shear components and cause bone microfracture or microstrains in the pathologic zone around the implant. Progressive bone loading aims at increasing the density of bone, decreasing the risk of implant-bone failure, and decreasing crestal bone loss.*

Progressive loading protocol

- *Full-arch prostheses with little or no cantilever and adequate implant number, position, and size rarely require progressive loading, unless the bone density is poor.*
- *The fewer the number of implants and the softer the bone types, the more progressive loading is suggested. Cantilevers, patient force factors, and implant position also may influence the risk factors in implant dentistry. As a general rule, the higher the risk factors, the more progressive loading is recommended.*

Elements of Progressive Loading

- Time interval
- Diet
- Occlusal material
- Occlusal contacts
- Prosthesis design

Progressive loading protocol (TIME)

- *The macroscopic coarse trabecular bone heals about 50% faster than dense cortical bone.*
- *The healing time between the initial and second-stage surgeries is kept similar for D1 and D2 bone and is 3 to 4 months. A longer time is suggested for the initial healing phase of D3 and D4 bone (5 and 6 months, respectively) because of the lesser bone contact and decreased amount of cortical bone to allow for the maturation of the interface and the development of some lamellar bone.*

Bone Density	Initial Healing (months)	Reconstruction (weeks)	Interval Between Appointment (weeks)	Total Time (months)
D1	3	6	1	5.5
D2	4	10	2	6.5
D3	5	14	3	9.5
D4	6	18	4	12.5

Progressive loading protocol (DIET)

- *The patient is limited to a soft diet such as pasta and fish, from the initial transitional prosthesis delivery until the initial delivery of the final prosthesis.*
- *After the initial delivery of the final prosthesis, the patient may include meat in the diet, which requires about 21 psi in bite force. The final restoration can bear the greater force without risk of fracture or uncementation. After the final evaluation appointment, the patient may include raw vegetables, which require an average 27 psi of force. A normal diet is permitted only after evaluation of the final prosthesis function, occlusion, and proper cementation.*

Progressive loading protocol (OCC. MATERIAL)

- *using acrylic as the occlusal material, with the benefit of a lower impact force than metal or porcelain. Either metal or porcelain can be used as the final occlusal material. If parafunction or cantilever length cause concern relative to the amount of force on the early implant-bone interface, the dentist may extend the softer diet and acrylic restoration phase several months. In this way, the bone has a longer time to mineralize and organize to accommodate the higher forces.*

Progressive loading protocol (OCCLUSION)

No occlusal contacts are permitted during initial healing (step 1). The first transitional prosthesis is left out of occlusion in partially edentulous patients (step 2). The occlusal contacts then are similar to those of the final restoration for areas supported by implants. However, no occlusal contacts are made on cantilevers (step 3). The occlusal contacts of the final restoration follow the implant-protective occlusion concepts.

Progressive loading protocol (PROSTHESIS DESIGN)

Its purpose is to splint the implants together, to reduce stress by the mechanical advantage, and to have implants sustain masticatory forces solely from chewing. In the second acrylic transitional restoration, occlusal contacts are placed on the implants with occlusal tables similar to the final restoration but with no cantilevers in nonesthetic regions. In the final restoration, narrow occlusal tables and cantilevers are designed with occlusal contacts following implant-protective occlusion guidelines.

Progressive loading phases

- *During the surgical Stage II uncover procedure, the surgeon evaluates clinical mobility, bone loss (horizontal and vertical), proper placement in reference to prosthetic design and angulation to load, zones of attached gingiva, and gingival thickness.*
- *If anterior teeth are part of the removable prosthesis, a 7-mm diameter hole is placed completely through the partial denture framework around each permucosal extension. In completely edentulous patients, the tissue surface of the denture is relieved at least 5 mm over and around the implants and replaced by a tissue conditioner.*
- *screw-retained prostheses do not use a progressive loading protocol.*

Progressive loading phases

The procedures for a partially edentulous Kennedy Class I or II patient are presented. The progressive bone-loading appointment sequence for cement-retained prostheses is as follows :

- 1. Initial abutment selection and preliminary impression.*
- 2. Final impression and transitional prosthesis I.*
- 3. Metal superstructure try-in and transitional prosthesis II.*
- 4. Initial insertion of final prosthesis.*
- 5. Final delivery and evaluation.*

Progressive loading phases

Progressive Loading Appointments for a Cement-Retained Prosthesis				
Step	Procedure	Diet	Occlusal Material	Occlusal Contacts
1	Healing abutments Preliminary impression	Soft	0	0
2	Transitional prosthesis I Final impression	Soft	Acrylic	1*; none 2*; no cantilever
3	Transitional prosthesis II Metal try-in; modify transitional prosthesis I	Soft	Acrylic	1 and 2*; contacts only on implant; no contacts on cantilevers/pontics; occlusal table same as final prosthesis
4	Final prosthesis Adjust occlusion	Harder	Metal or porcelain	Occlusion follows implant-protective occlusion guidelines; narrow occlusal table
5	Final prosthesis Final cementation	Normal	Metal or porcelain	Same as above

*1, Partially edentulous; 2, fully edentulous.