Biomechanics of Dental Implants

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Outline

- History of Dental Implants
- Types
- Materials Used
- Procedures for Implantation

Outline

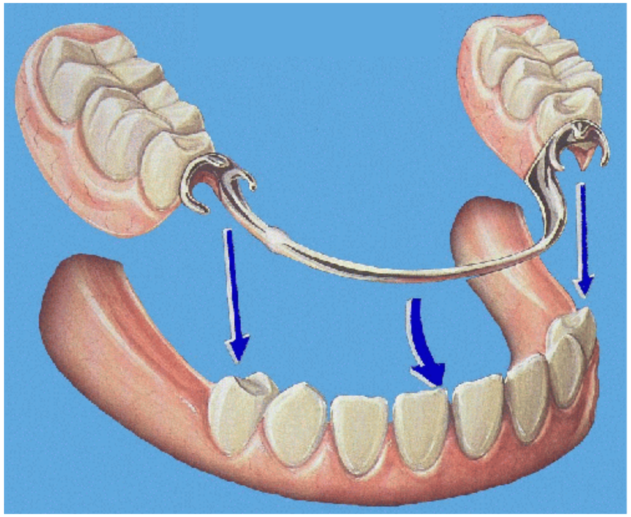
- Osseointegration
- Forces and Loading
- Problems/Disadvantages
- Future Developments

History

- Replace damaged or missing teeth
- Ancient Aztecs and Egyptians
- Dentures; around for 50 years
- Integrated dental implants; around for 25-30 years

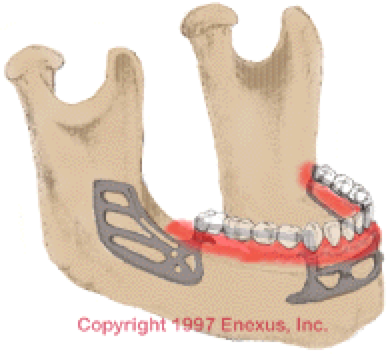
Types of Dental Implants

- Intramucosal Inserts
  - AKA dentures
  - Attached to gum
  - Reduces chewing ability 40-80%
  - Lowest cost



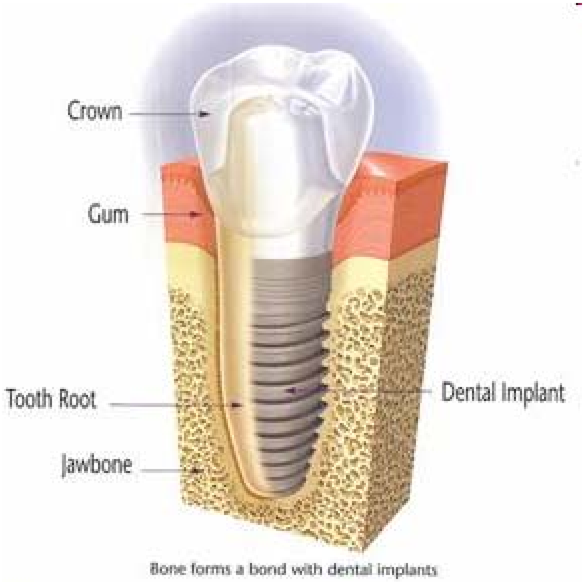
Types of Dental Implants

- Subperiosteal
  - Attached on top of bone
  - Used with limited bone
  - Up to 90% chewing ability
  - High cost



Types of Dental Implants

- Endosteal
  - Attached to bone
  - Up to 100% chewing ability
  - High cost

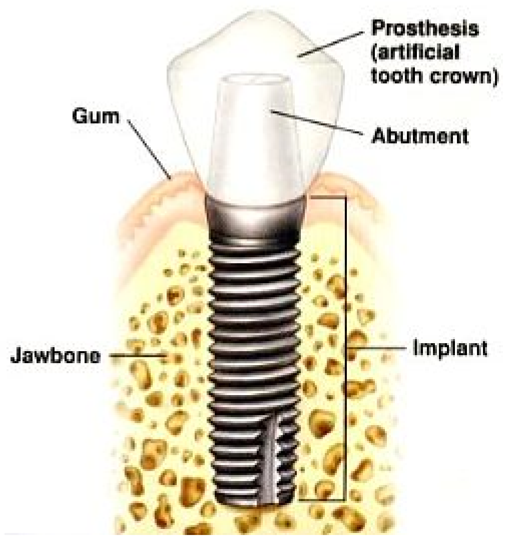


Types of Dental Implants

- Implant-Borne Bridgework
  - Many adjacent missing teeth
  - Bridge between several implants
  - Up to 70% chewing ability
  - Medium cost

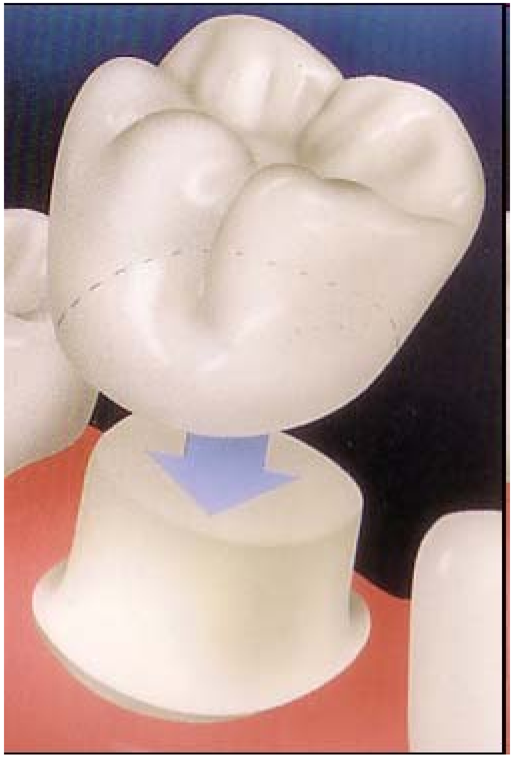
Materials

- 3 Main Components:
  - Crown
  - Abutment
  - Implant



Materials

- Crown
  - Mimic teeth properties
  - Porcelain (ceramic)
  - Porcelain-fused-to-metal
  - Gold



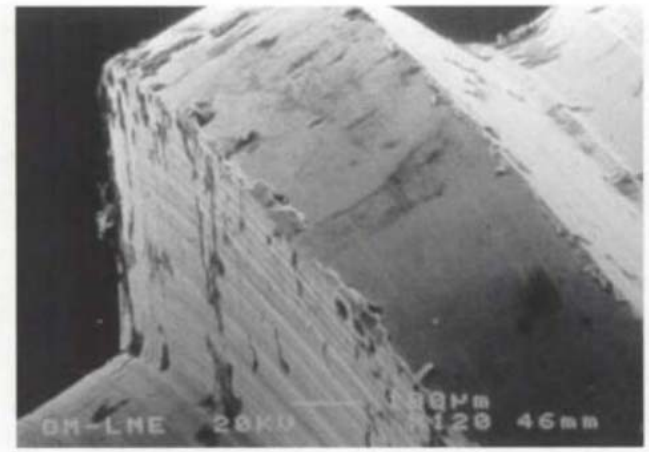
Materials

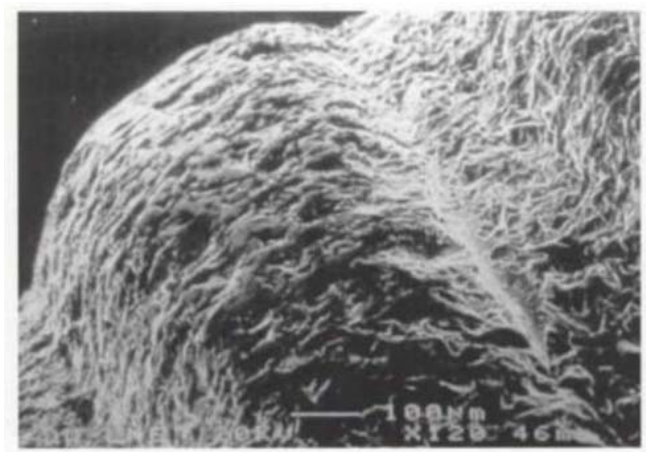
- Implant root
  - Titanium or titanium alloy
  - Corrosion resistant
  - Highly biocompatible

Figure 7.1 Different types of threaded implants.

Materials

- Implant root
  - Ideal length: 10mm
  - Ideal width: 3-5mm
  - Porous surface
    - Shot blasting
    - Hydroxyapatite coating

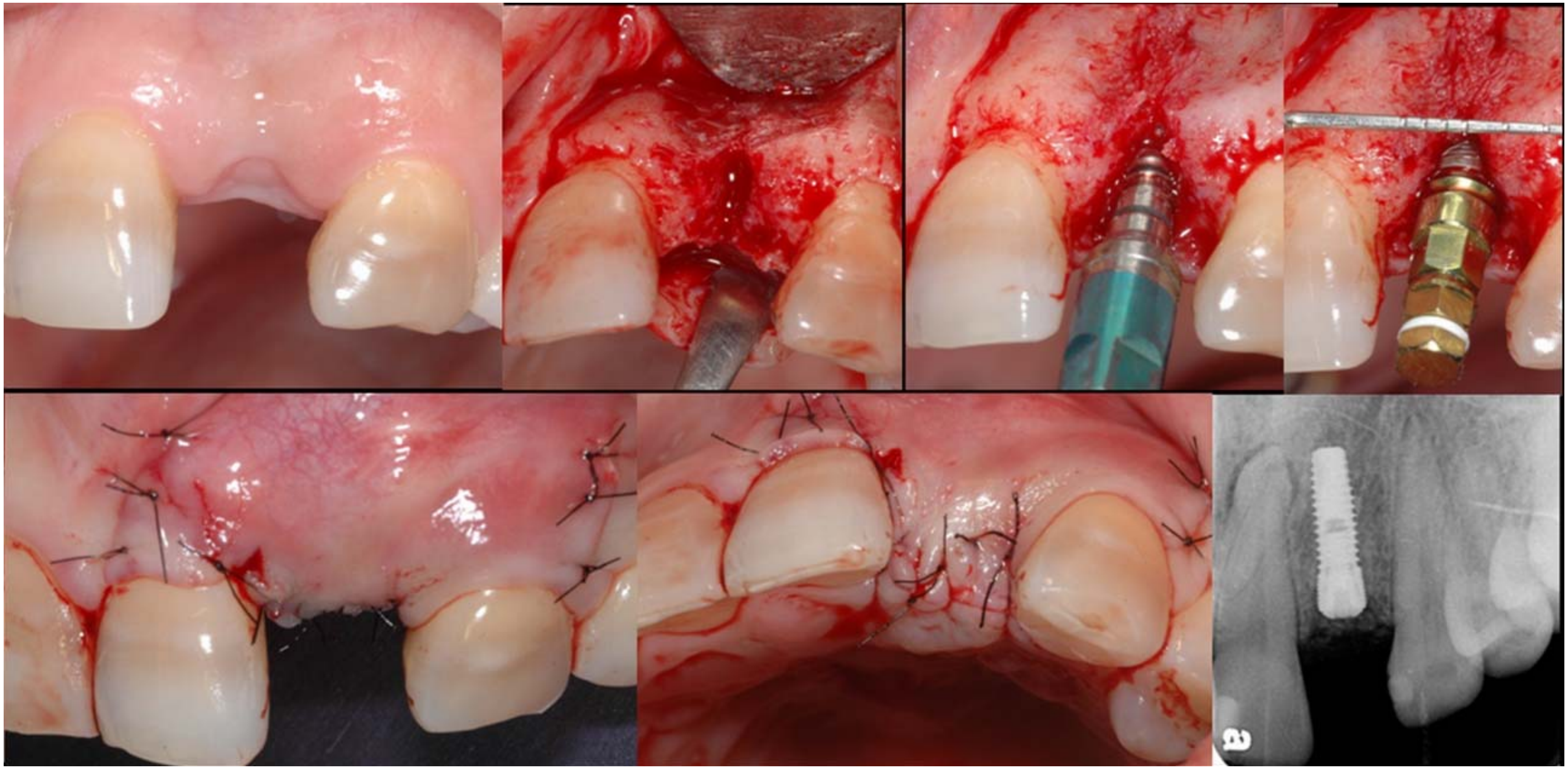




Implantation

- Two stage technique
  - Implant inserted into jawbone
  - Totally recovered by gingival tissue
  - Tissue reopened
  - Desire 40 N of torsion
  - Abutment and crown attached

Two stage technique

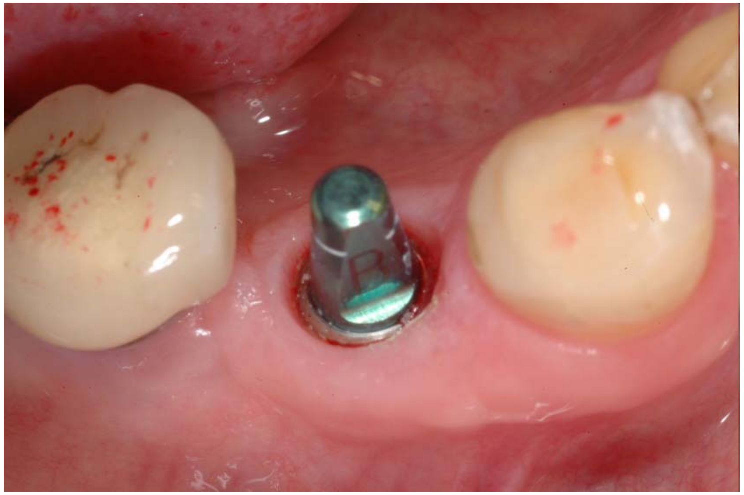


Two stage technique

Implantation

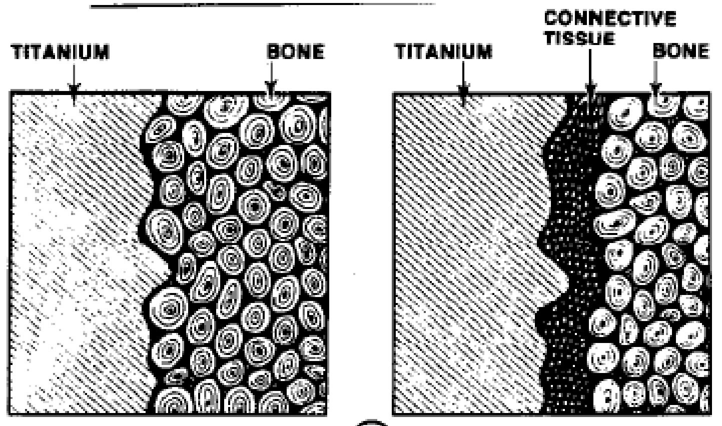
- One stage technique
  - Implant inserted into jawbone
  - Only 1 surgery
  - Protrudes through gums
  - Desire 40 N of torsion

One stage technique



Osseointegration

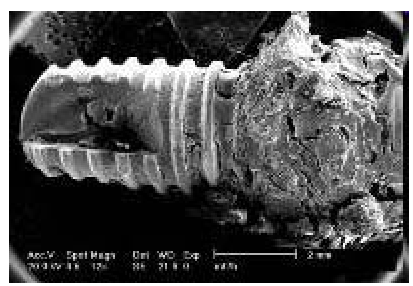
- Occurs when an implant is inserted into living bone
- Connection/bond forms between living bone and implant
- Key for long-term implant stability



C OSSEOINTEGRATED D NON-INTEGRATED

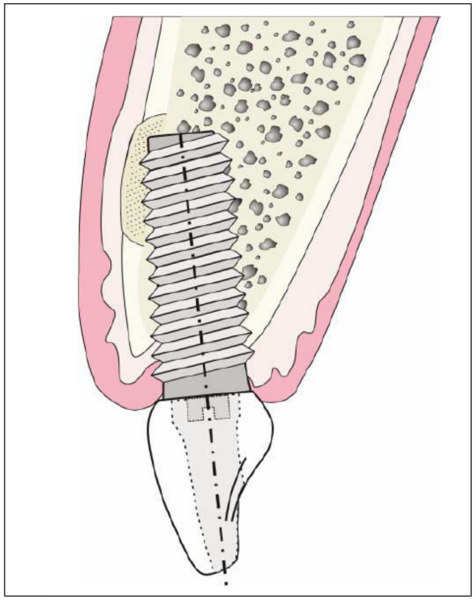
Osseointegration

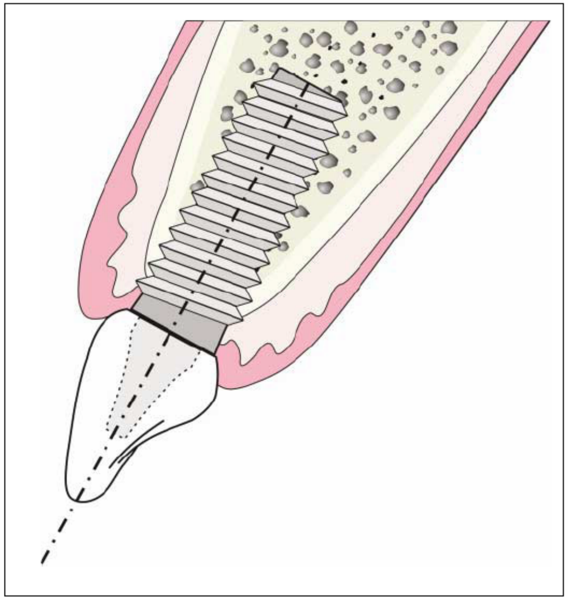
- Factors affecting osseointegration
  - Material
  - Surface composition and structure
  - Heat
  - Initial stability
  - Bone quality



Forces

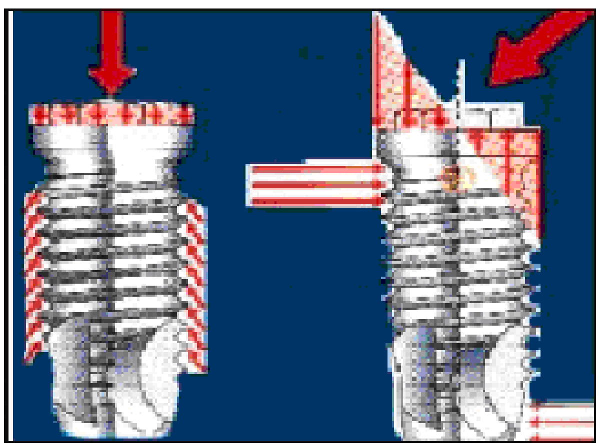
- Mainly vertical and transversal
- Compression, tension, shear, and bending moments
- Mastication and bruxism

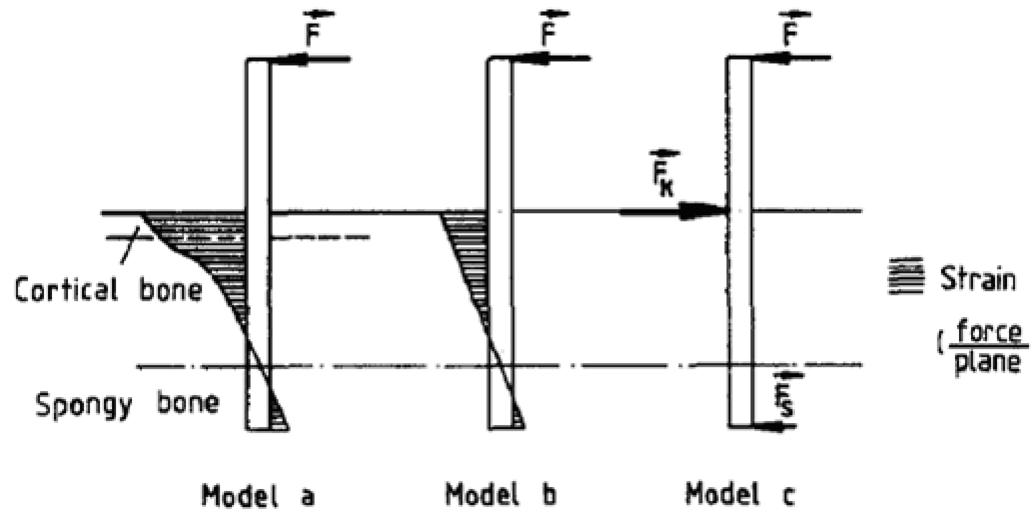




Forces

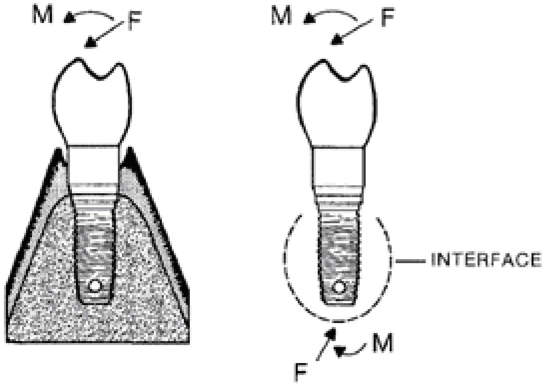
- Inclined surface of crown → angled force
- Axial and lateral components





Forces

- Human bite force: 250-1200N (molars), 80-400N (frontal)
- Lateral components of bite force: 20N
- Maximum contact stress on teeth: 20 MPa
- Bending moments: 10-50N·cm



Material Stiffness

Material	Young's Modulus (GPa)	Poisson's Ratio
Cortical bone	13.7	0.30
Cancellous bone	7.93	0.30
Titanium	120	0.35
Type III dental gold alloy	96.6	0.35
Feldspathic procelain	82.8	0.35
Enamel	48	0.33
Dentin	13	0.31

Material Strength

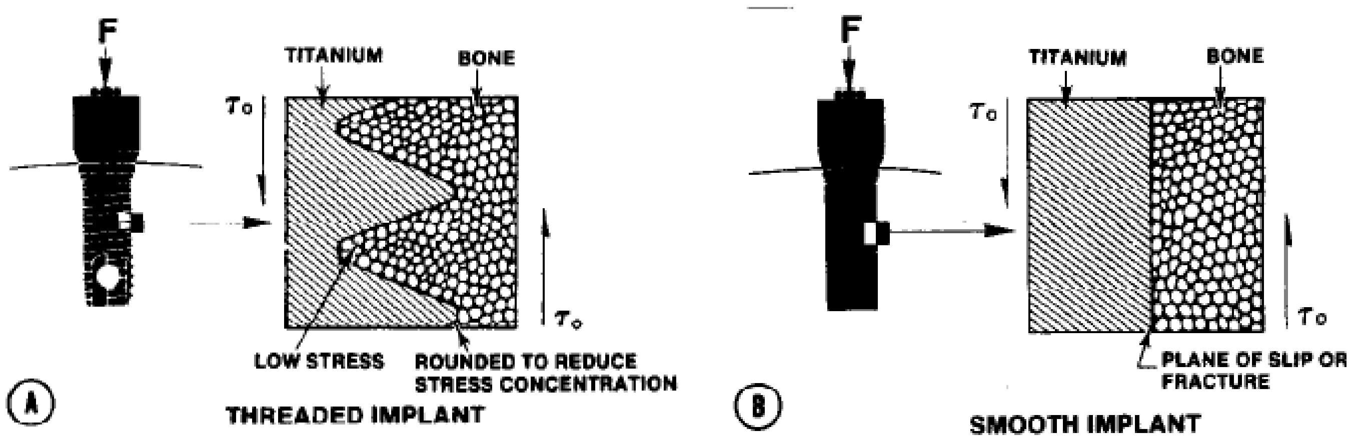
- Titanium yield stress: 225 MPa
- Cortical bone yield stress: 130 MPa
- Cancellous bone: even lower elastic modulus and strength
- Bone or bone-titanium bond will fail before the titanium

Osseointegrated Implant

- Bone heals around implant in the absence of loading
- Interlocking/in growth of bone into asperities of titanium implant
- Transmit shear stress directly into bone
- Misalignment results in internal stresses and reduces loading capacity

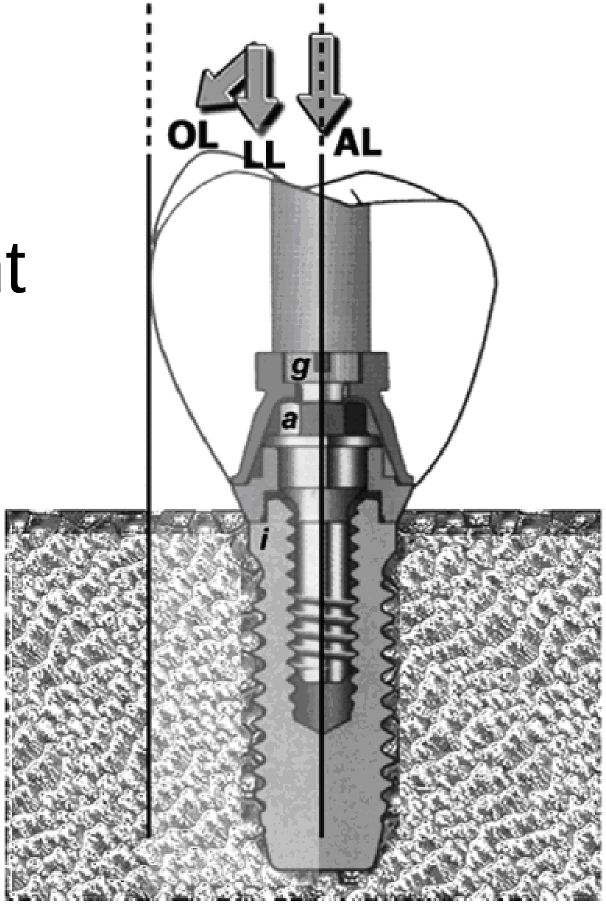
Loading

- Bone-titanium interface moves as unit; no relative motion of titanium in bone
- Inclined faces of screw thread transmit load to surrounding bone



Loading

- Factors affecting load bearing capacity of implants:
  - Type of loading
  - Shape and dimension of implant
  - Implant surface
  - Implant structure/material
  - Quality of bond to bone



Finite Element Method

- Study stress and strain in teeth
- Complex physical system divided into large number of discrete elements
- Individual elements are easy to analyze

FEM Models

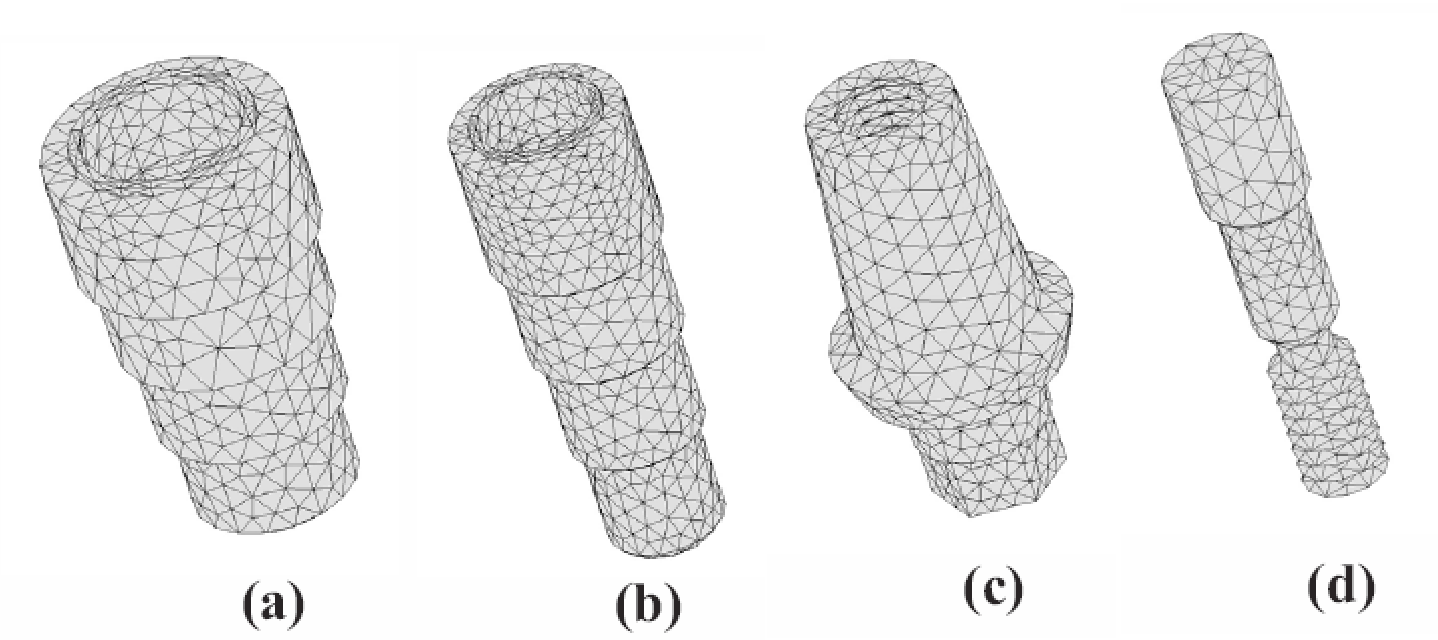
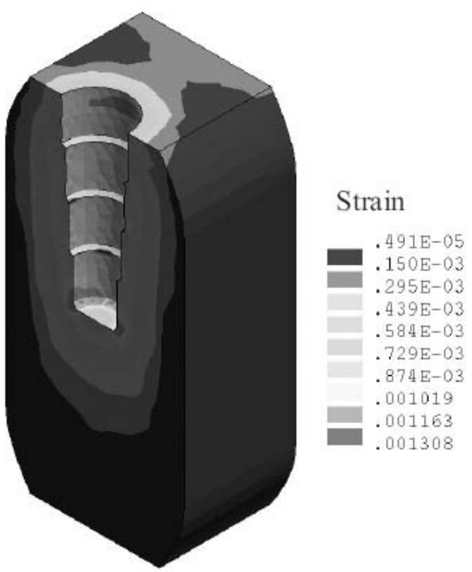
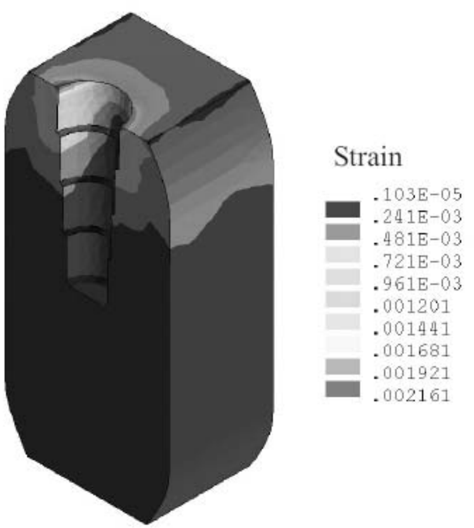


Fig. 1. A 3D FE model of an implant/bone system constructed for analysis in this study. (a) 8mm fixture, (b) 13mm fixture, (c) abutment, (d) abutment screw

Forces

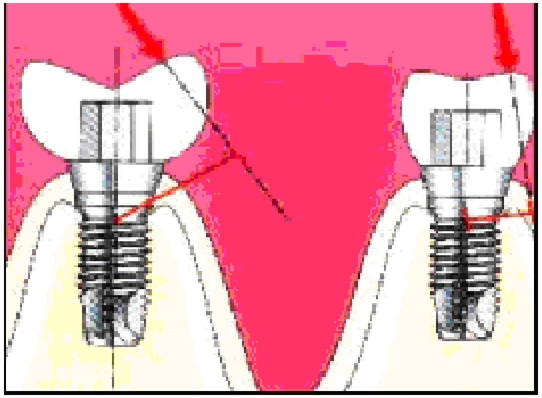
- Axial loading; maximum strain around implant base
- Lateral loading; maximum strain around implant neck

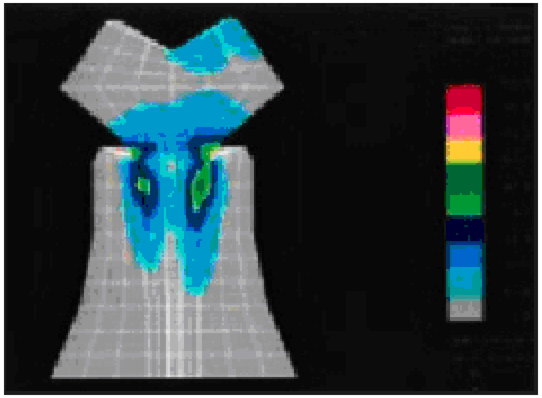




Moments

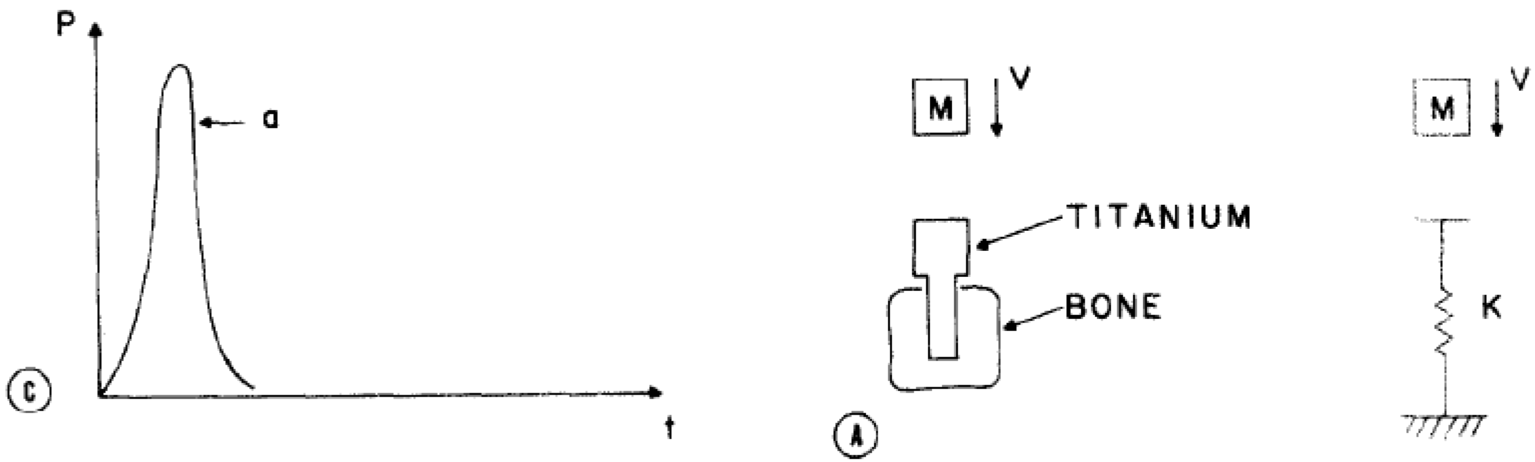
- Crown larger than diameter of implant
- Larger crown and higher cuspal inclinations lead to higher moments
- FEM study: narrow crown stress of 64 MPa; wide crown, 84 MPa





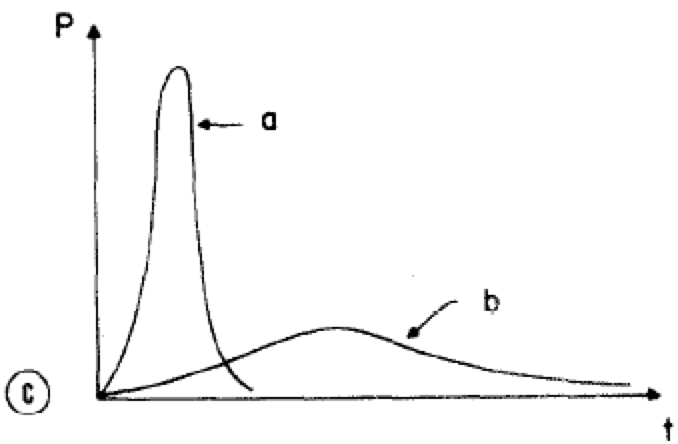
Loading

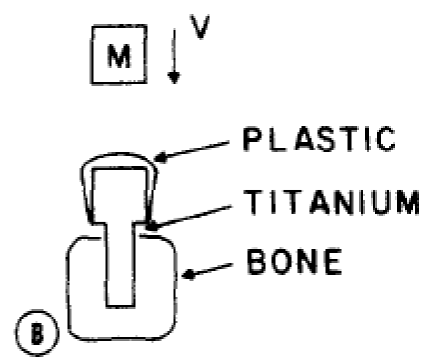
- Bare dental implant modeled as spring K
- Mass (M) with velocity (v) impacts
- High peak force

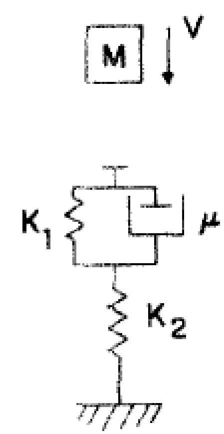


Loading

- Dental implant with abutment and crown modeled by softer spring K_1 and dashpot μ
- Lower modulus of elasticity provides internal damping
- Impulse same, lower peak force

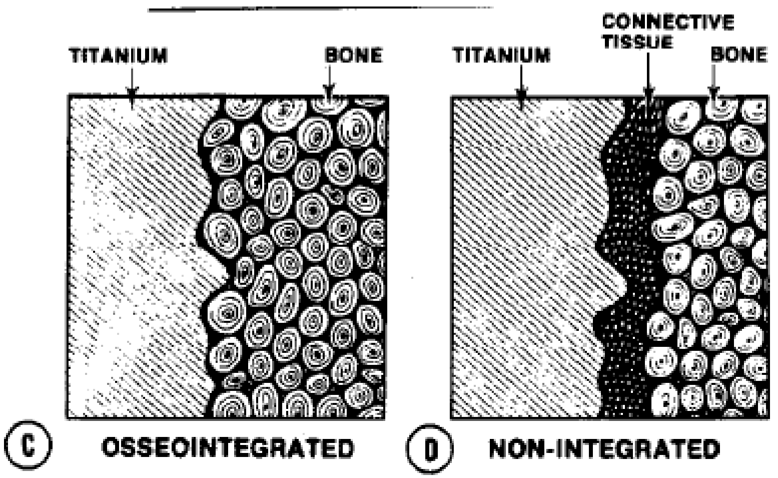






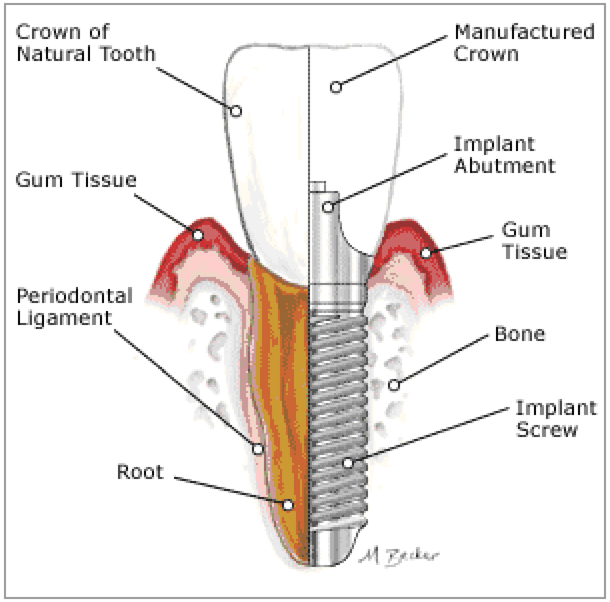
Problems

- Immediate loading may induce implant failure to osseointegrate
- Fibrous layer forms around an implant
- Any motion or abrasion of the implant will lead to degradation of surrounding bone



Disadvantages

- Regular teeth are mobile → roots surrounded by periodontal ligament
- Pressure from ligament dissolves bone, reforms behind → orthodontics
- Dental implants rigid



Future Developments

- Dental implants very advanced (85-100% success)
- Minor research into artificial root membranes
- Major development in computer tomography of jawbone, simulations, stints

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Questions?