

# LOAD-BEARING CHARACTERISTICS AND FRACTURE

## 1. Introduction

Bone is a dynamic, composite, load-bearing material designed to support body weight, resist deformation, and maintain structural integrity under various types of physiological loads. Its ability to withstand forces depends on its **material properties (elasticity, strength, anisotropy, viscoelasticity)** and **structural design (cortical vs trabecular architecture)**. Understanding load-bearing characteristics and fracture mechanics is essential in orthopedics and rehabilitation.

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## 2. Load-Bearing Characteristics of Bone

### 2.1 Structural Basis

Bone is a **composite material** of:

**Hydroxyapatite (mineral)** → compressive strength

**Collagen fibers** → tensile strength & toughness

**Water** → contributes to viscoelastic behavior

Two forms:

**Cortical bone** – dense, strong, resists bending & torsion

**Trabecular bone** – porous, shock-absorbing, resists compression

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### 2.2 Stress–Strain Behavior of Bone

Bone demonstrates:

**Linear elastic region** (instant deformation)

**Yield point** (micro-damage occurs)

**Plastic region** (permanent deformation)

**Failure point** (fracture)

**Elastic Modulus (Stiffness)**

Higher in longitudinal direction

Cortical bone: ~17–20 GPa

Trabecular bone: 0.05–0.5 GPa

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## **2.3 Types of Loads & Bone Response**

Bone experiences several loading modes in daily activities:

### **1. Compression**

Most resistant loading mode

Vertebrae, femur primarily resist compression

High mineral content → strong compressive resistance

### **2. Tension**

Resisted by collagen component

Occurs in tendons pulling on bone (avulsion fractures)

### **3. Shear**

Bone weakest in shear

Common in joint surfaces and vertebral slips

### **4. Bending**

Produces tension on one side and compression on the other

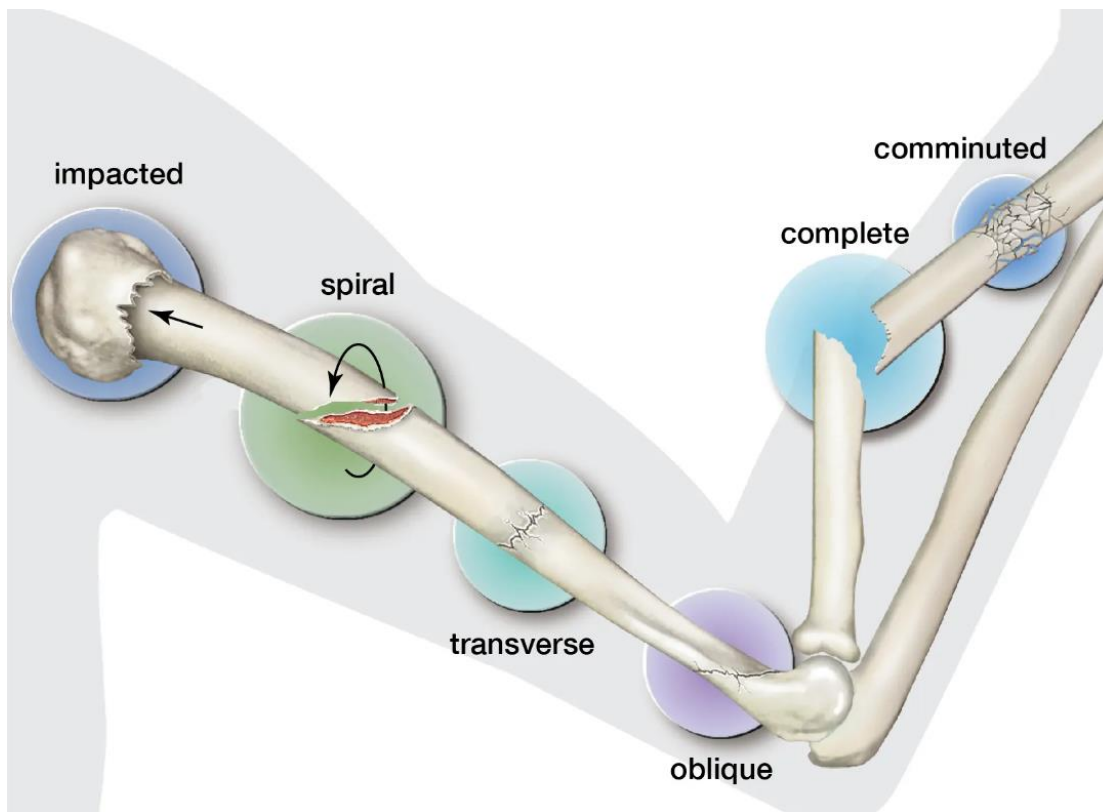
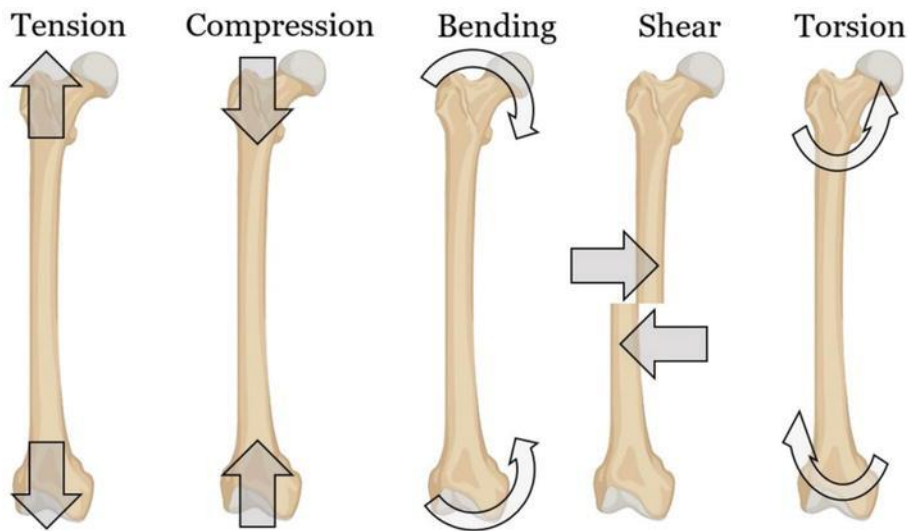
Long bones commonly fail in bending (e.g., forearm fractures)

### **5. Torsion**

Rotational stress

Causes spiral fractures

Trabecular orientation influences torsional resistance



## 2.4 Anisotropy in Load-Bearing

Bone is **anisotropic**:

Strongest **longitudinally**

Weaker **radially and circumferentially**

Explains why sideways falls cause hip fractures

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## 2.5 Viscoelasticity in Load-Bearing

Bone's load response depends on **time and rate**:

**High loading rate** → bone becomes stiffer but more brittle

**Low loading rate** → bone absorbs more deformation (ductile)

Explains fracture differences in slow vs high-impact trauma

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## 3. Fracture Mechanics in Bone

### 3.1 Definition

A **fracture** occurs when applied stress exceeds the bone's **ultimate strength**. Bone fracture behavior depends on:

Loading type

Loading rate

Bone geometry

Age & pathology

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### 3.2 Mechanisms of Fracture

#### 1. Fatigue Fracture (Stress Fracture)

Repeated low-magnitude loads

Accumulation of micro-damage

Seen in athletes, military recruits (metatarsals, tibia)

#### 2. Traumatic Fracture

High-magnitude, short-duration load

Caused by falls, accidents

#### 3. Pathological Fracture

Occurs in weakened bone (osteoporosis, tumor)

Very low loads can cause fracture

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### 3.3 Types of Fractures Based on Loading Mode

#### Compression Fracture

Common in vertebrae

Bone collapses under axial load

#### Tensile Fracture

Avulsion injuries at tendon/ligament attachments

Transverse fractures often caused by tension

#### Shear Fracture

Intra-articular injuries

Vertebral spondylolisthesis

#### Bending Fracture

Produces a **transverse fracture** at tensile surface

Children: greenstick fractures

#### Torsional Fracture

Spiral fracture caused by rotational force

Seen in sports injuries

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### 3.4 Fracture Patterns and Biomechanical Correlation

Loading Mode	Fracture Type	Example
Compression	Vertebral compression	Osteoporotic spine
Tension	Avulsion or transverse	Patella tendon, tibial tuberosity
Bending	Transverse/greenstick	Falls on outstretched hand
Torsion	Spiral	Skiing injuries
Shear	Oblique fractures	Distal radius, ankle injuries

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## 4. Factors Affecting Fracture Resistance

### 1. Age

Elderly bone = brittle + low mineral → higher fracture risk

Children = more ductile → greenstick fractures

### 2. Bone Geometry

Long bones stronger in compression + bending

Shape influences load distribution

### 3. Bone Pathology

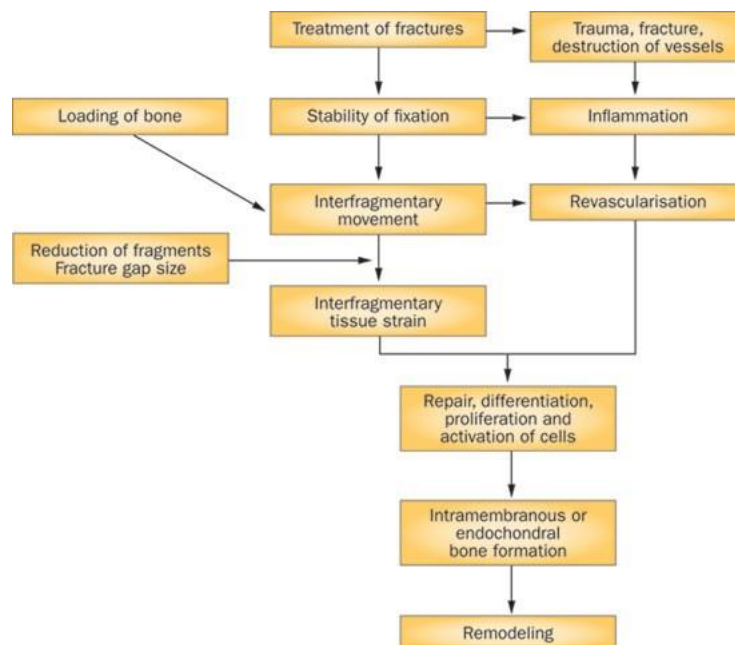
Osteoporosis reduces trabecular thickness

Cancer weakens cortical structure

### 4. Muscle Forces

Muscles reduce or increase mechanical load

Sudden strong contractions → avulsion injuries



## **5. Clinical Significance**

Guides orthopedic implant design (plates, screws, prosthetics)

Helps predict fracture risk in osteoporosis

Important for sports biomechanics and fall-prevention programs

Explains why certain fractures occur in specific activities

Crucial for designing physiotherapy rehabilitation protocols

## **6. Conclusion**

Bone is a uniquely designed load-bearing material that can withstand complex mechanical environments. Fracture occurs when the applied stress exceeds bone strength, which depends on loading direction, magnitude, rate, and structural integrity. Understanding these biomechanical principles is essential for diagnostics, rehabilitation, injury prevention, and orthopedic treatment.