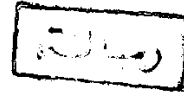


Ain Shams University  
Faculty of Medicine

# BIOMECHANICS OF BONE

An Essay



Submitted for Partial Fulfilment of Master Degree in Orthopaedic Surgery

By

Mohamed Saad El-Din Abdel Fatah El-Mohammedy  
M.B.B.ch (Cairo)

617.471  
M. S

Under Supervision of

**Prof. Dr. M. Nabil Khalifa**

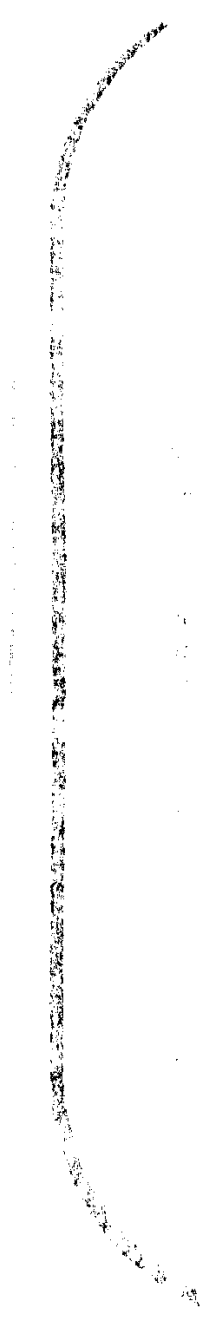
Professor of Orthopaedic Surgery  
Faculty of Medicine  
Ain Shams University

**Dr. Atef M. El- Beltagy**

Lecturer of Orthopaedic Surgery  
Faculty of Medicine  
Ain Shams University

1996







# Acknowledgement

Foremost, I feel always indebted to God, the most kind and the most merciful.

I like to express my deepest gratitude and thanks to Prof. Dr. Mohammed Nabil Khalifa, professor of Orthopædic surgery, Faculty of Medicine , Ain Shams University who helped me a lot with his true guidance, at most concern and great encouragement.

Also I would like to thank Dr. Atef Mohammed El Beltagy lecturer in Orthopædic Faculty of Medicine, Ain Shams University for his help and concern and giving a lot of time to help me in revision and preparing the essay.

I also thank all the staff of Orthopædics in El Demerdash for their great help in discussions.

I also thank my health ensurance hospital that gives help to me.

I also thank my family members, my wife, my mother, my sisters and my children who save time to prepare the essay.



## CONTENTS

	Page
List of figures	3
<b>Introduction</b>	5
<b>Anatomy and physiology of bone</b>	
Anatomy	7
Physiology	19
<b>Basis of biomechanics</b>	
Statics and dynamics	22
Elasticity	31
Energy and work	39
Viscoelasticity	41
Kinematics	44
<b>Biomechanics of bone</b>	
Properties of bone	49
Biomechanics of cortical bone	60
Biomechanics of cancellous bone	70
<b>Applied biomechanics</b>	
Fracture of bone	85
Malalignment and realignment	90
Design	93
<b>Conclusion and summary</b>	99
<b>References</b>	102
<b>Arabic summary</b>	110

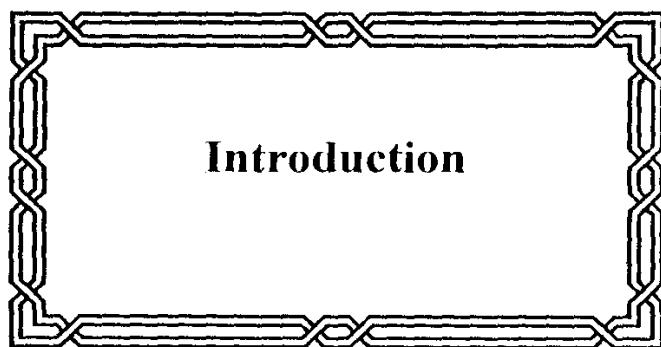


## LIST OF FIGURES

Fig. No.	Title	Page
1	Cancellous and cortical bone	8
2	Bone cells and ossification	11
3, 3.1	Vascular supply of bone	14
4	Lacunar-canalicular organization of bone	15
5	Characteristics of the force	23
6	Parallogram law of vector	23
7	Examples of force and moment	29
9	Force and moment balance	29
10	Basic types of stress	32
11	Stress-strain curve of ductile material	34
12	Load-deformation curve of ductile material	34
13	Area moment of inertia of I beam nail and flange nail	37
14	Tibia under torsional loading	38
15	Load-deformation curve of tibia loaded in torsion	40
16	Viscoelastic models	43
16.A	Hysteresis loop	43
17	Instant center in rolling	47
18	Strain rate and modulus and tensile strength of cortical bone	62
19	Stress-strain plot of cortical bone	62
20	Stress-strain plot of cortical bone for tensile and compressive loading	63
21	Strain rate dependence of cortical bone	63
22	Strain-time curves illustrating viscoplastic behavior	65



<b>Fig. No.</b>	<b>Title</b>	<b>Page</b>
23	Age-related effects on modulus and tensile strength of cortical bone	66
24	Temperature dependence of fatigue life for cortical bone	68
25	Fatigue life curve for cortical bone	68
26	Compressive stress-strain behavior	72
27	Compressive modulus as a function of apparent density and loading direction for trabecular bone	73
28	Ultimate compressive strength as a function of apparent density for trabecular bone	73
29	Compressive modulus as a function for apparent density for trabecular bone	74
30	Age-related diaphyseal expansions increase the strength of the diaphysis	81
31	Beam in four-point bending	82
32	Classification of fractures	86
33	Definitions of the horizontal angles for lower extremity	91
34	Axial alignment parameter of the lower extremity	91





## **Introduction**

Biomechanics is a branch of science that deals with the effects of energy and forces on biologic systems. The study of biomechanics involves the application of Newton's laws of mechanics to models of biologic objects in order to describe their behavior and their functions.

Biomechanics of bone is the study of mechanics of bone as a biomaterial and application of engineering principles to the locomotor system.

Orthopaedic biomechanics has focused on the effects, motion deformation of forces and moments acting on tissues such as bone, cartilage, growth plate, ligaments, meniscus, synovial fluid and tendon.

The study of biomechanics has been important in the development and design of many of the joint replacement and fracture fixation devices commonly used in Orthopaedic surgery today. Kinetics describes motions within musculoskeletal system, such as those of diarthrodial joints (hip, knee, shoulder, etc.) as well as the locomotion and gait.

In addition to describing normal structure and function, clinical Orthopaedic biomechanics seeks to examine specific pathologic conditions through the study of joint instability, gait pathologies and fracture healing.

Furthermore, surgical procedures designed to restore normal mechanics may be critically evaluated, using techniques such as force analysis of tendon transfer, kinematics studies of ligament repair and line analysis of joint replacement (Mow et al, 1994).

In his daily practice the Orthopaedic surgeon deals with the effects of forces. He may alter force systems by transferring a tendon, by an arthrodesis of a spine, by designing an arch support or by performing osteotomy. He deals with a consequence of internal effects of externally

applied forces and moments when a fracture is plated or a dislocation is reduced.

The analysis and correction of disorder of the musculoskeletal system are based on an understanding of the working and properties of the members involved. This includes a knowledge of statics, dynamics and strength and behavior of materials (Frænkel et al, 1971)

