

11017/1

# HEALING OF ARTICULAR CARTILAGE

## A THESIS

Submitted in Partial Fulfilment  
For The Degree of M. S.  
(Orthopaedic Surgery)

By

**AMR EL SAYED WAHB**

M. B., B. Ch.

Supervised by

**Prof. Dr. HASSAN EL ZAHER HASSAN**

Prof. of Orthopaedic Surgery, Ain Shams University

**Prof. Dr. HUSSEIN EL KHATEEB**

Assis. Prof. of Orthopaedic Surgery, Ain Shams University

Faculty of Medicine  
Ain Shams University

**1987**

9/

## ACKNOWLEDGEMENT

I am extremely grateful to my dear Prof. Dr. HASSAN EL ZAHER, Professor of Orthopaedics , Faculty of Medicine , Ain Shams University , for his patience , guidance during all the period of this work . His careful reading , valuable comments and encouragement were all extremely valuable .

I wish to express my deepest thanks and gratitude to Dr. HUSSEIN EL KHATEEB , Assistant Professor of Orthopaedics , Faculty of Medicine , Ain Shams University , for his careful guidance and constructive assistance .

Many thanks to the staff members of Orthopaedic Department , Ain Shams University .

I would like to express my sincere appreciation to my wife for her great support in presenting the whole work on the computer.

=====



## CONTENTS

	Page ====
I MORPHOLOGY OF ARTICULAR CARTILAGE	1
* HISTOLOGY.....	1
- Zonal Classification Of Articular Cartilage .....	3
- The Cell:Morphology , Ultrastructural Characteristics..	4
Nutrition And Metabolism .	
- The Matrix:Collagen , Ground Substance , Histochemical	10
Identification And Measurements Of Proteoglycans	
* BIOCHEMICAL PROPERTIES.....	19
- Collagen:Structure , Biosynthesis , Degradation And Bio-	
Mechanical Function .	
- Proteoglycans:Structure , Synthesis , Degradation.....	24
Metabolic Control Mechanism And Biomechanical	
Function .	
- Interaction Of Proteoglycan And Collagen.....	34
- Water.....	35
* AGING OF NORMAL ARTICULAR CARTILAGE.....	38
II MECHANICAL PROPERTIES OF ARTICULAR CARTILAGE	42
* ENGINEERING TERMINOLOGY.....	42
Force , Stress , Strain , Stress Versus Strain Curve,	
Creep , Viscoelastic Materials , Relaxation , Fatigue.	
* MECHANICAL PROPERTIES OF CARTILAGE IN COMPRESSION.....	46
* MECHANICAL PROPERTIES OF ARTICULAR CARTILAGE IN TENSION....	49

	Page =====
* LOAD CARRIAGE.....	53
Response Of Articular Cartilage To Single Load	
Application For Short Duration , Long Duration And To	
Cyclical Loading .	
* MECHANICAL FAILURE IN ARTICULAR CARTILAGE.....	58
* STRUCTURE-FUNCTION RELATIONSHIP.....	60
- Significance Of Collagen Distribution .	
- Functional Reserve Of Cartilage .	
* LUBRICATION.....	62
- Principles.....	62
- Types.....	63
 III TYPES OF ARTICULAR CARTILAGE INJURY AND REPAIR	 67
* FACTORS AFFECTING ARTICULAR CARTILAGE.....	67
Continuous Compression , Immobilisation , Trauma And	
Inflammation , Lacerative Injury , Biochemical Agents.	
* TYPES OF INJURY AND REPAIR MECHANISMS.....	81
- Aetiological Classification .....	81
- Classification According To The Extent Of Lesion.....	82
- Intrinsic And Extrinsic Repair Mechanisms.....	82
- Pathophysiology Of Trauma.....	84
- Healing Potential Of Articular Cartilage.....	86
- Chondrocyte Multiplication.....	88
- Matrix Synthesis.....	89
- Repair After Traumatic Lacerative Injury .....	91

0 /

	Page =====
1.Repair Of Partial-Thickness Defects.....	92
2.Repair Of Full-Thickness Defects.....	96
* REPAIR IN IMMATURE CARTILAGE.....	102
- Reactions Associated With Incomplete And Complete Defects.	
- Clinical Application.....	111
* FACTORS PROMOTING HEALING OF ARTICULAR CARTILAGE.....	112
- Continuous Passive Motion.....	113
- Role Of Surgery.....	116
- Electro-Chemical Enhancement.....	119
- Biochemical Agents.....	121
- Transplantation Of Articular Cartilage.....	124

#### IV SUMMARY

135

#### V REFERENCES

#### VI ARABIC SUMMARY

2/

MORPHOLOGY  
OF  
ARTICULAR CARTILAGE

12

# THE MORPHOLOGY OF THE ADULT ARTICULAR CARTILAGE

## HISTOLOGY OF THE ARTICULAR CARTILAGE

The articular cartilage is formed of hyaline cartilage that covers the articular ends of long bones . The word hyaline cartilage is derived from [Hyalos (in Greek)] , means glass , which [cartilage (in Latin)] means gristle . (Bullough P.G., 1980).

So it is a bloodless tissue which in young people is translucent and bluish white , while in older individuals it becomes more opaque and slightly yellowish in colour .

Articular cartilage is devoid of nerves and is generally considered to be avascular , although a few blood vessels may be found in its deepest parts adjacent to the bone (Freeman , 1973). The articulating cartilages are most happily contrived to all purposes of motion in those parts . Therefore , the articulating cartilages have soft , smooth slippery surfaces so that they move upon one another with ease and mutual abrasion is prevented .

Also due to their elasticity , the violence of any shock , which may happen in running , jumping , etc. , is broken and gradually spent , which must be extremely damaging if the hard surfaces of bones had been immediately contiguous . (Hunter W., 1743).



Also the articulating cartilages are flexible and therefore the contiguous surfaces are constantly adapted to each other and the friction diffuses equally over the whole .

The surfaces of the articular cartilage is smooth , however recent electron microscopic studies have revealed a gentle surface undulation . (Gardner and Woodward ,1969) . This undulation entraps synovial fluid like pools in the valleys , facilitating the lubrication of the articular surfaces . (Walker et al , 1969).

The average thickness of the articular cartilage in the larger joints is 2-4 mm . The thickness varies over an articular surface and in general is greater at the joint periphery of concave surfaces and at the centers of convex surfaces . It also varies from joint to joint , being thickest on the patella (5mm or more) and thinnest on the interphalangeal joint . (Bullough & Goodfellow , 1968) . The thickness of the articular cartilage remains unchanged during the adult life , provided that its surface remains healthy . (Meachim , 1971) . It is formed of a relatively small number of cells embedded in abundant extracellular matrix .

Chondrocyte activity is necessary for the synthesis and probably the physiologic degradation and removal of the matrix . (Turek , 1984).

### \* ZONAL CLASSIFICATION OF ARTICULAR CARTILAGE

This classification was suggested by COLLINS (1949) .  
For descriptive purposes , the articular cartilage is divided into zones aligned parallel to the articular surface .(Fig. 1) .

#### Zone 1 , Superficial Or Tangential:

At the surface , fibres are arranged tangential to the surface , the cells are ovoid or elongated and are disposed parallel to the surface . Lamina splendens is the most superficial part of this zone .

#### Zone 2 , Intermediate Or Transitional:

Collagen fibres form a coiled interlacing network , cells are more numerous , spheroidal , and dispersed but equally spaced.

#### Zone 3 , Deep Or Radial:

Spheroidal cells are larger and are arranged in columnar fashion , often in groups of two to eight cells . The collagen fibres are thick and form a more tight meshwork and are arranged somewhat radial to the articular surface .

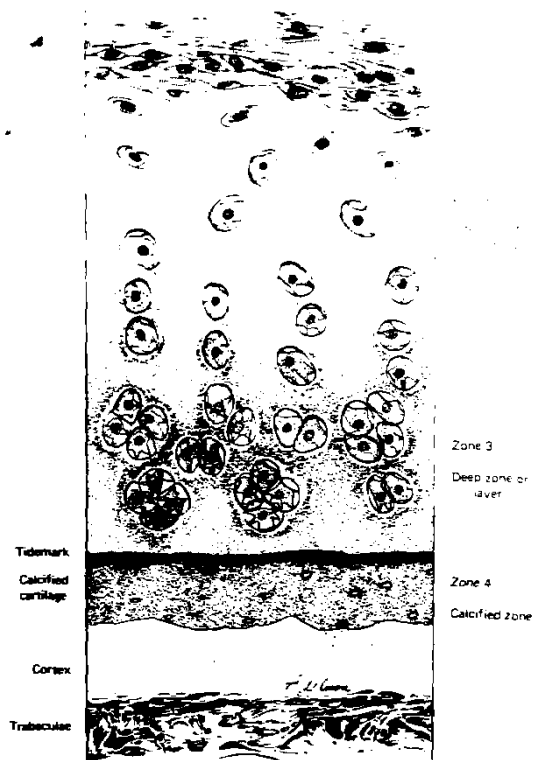


Fig. 1 : Zones of adult articular cartilage .

#### Zone 4 , Calcified:

This zone is adjacent to the subchondral bone . The cells are sparse and smaller and the matrix is heavily impregnated with calcium salts .

The junction between the non calcified cartilage and calcified cartilage (zones 3 & 4) appears as a basophilic line known as "Tide-mark" . (Fawns & Landells , 1953) .

#### \* THE CELL (Fig. 2)

The cartilage cells "chondrocytes" vary considerably in size, shape and number of cells per unit volume of tissue . It has been suggested that the latter is inversely proportional to cartilage thickness .

Generally , the cells at the surface of the cartilage are flatter , smaller and more closely packed than the cells , deeper in the matrix and are arranged to the surface . The chondrocytes may appear single or in pairs two or four forming cell nests and the cells are situated in well defined spaces called lacunae . Freshly isolated living chondrocytes exhibit amoeboid movement . They are constantly changing their shape by putting on and withdrawing their pseudopodia . (Chestrman and Smith , 1968).

Superficial cells are less active than those in the deeper layers . But as we go deeper from the surface , the cells become more rounded , larger and metabolically more active as indicated

by the prominent well defined organelles , and by the increased concentration of matrix components in the pericellular area . The largest cells might be as six times active than the smallest cells . (Stephen et al , 1980).

Cells are most numerous near the articular surface and the number of cells per unit volume decreases with increasing distance from the surface to a depth of 0.5 mm or more , beyond which the number remains relatively unchanged . In the normal human articular cartilage , cell density remains unchanged with advancing age . (Turek , 1984).

Mitotic division can be observed in immature rapidly growing cartilage , but not in mature adult articular cartilage. Actual mitosis is almost impossible to observe except under certain circumstances such as damage to the articular cartilage . This fact can be demonstrated by the increased uptake of tritiated thymidine which is incorporated into DNA , just prior to mitotic division which explains the reactive attempts at repair . This appears within the nucleus after the administration of the tritiated thymidine (H<sup>3</sup>-thymidine) . (Turek , 1984).

Occasionally , the chondrocytes in damaged cartilage exhibit phagocytic activity , but phagocytosis is not seen in intact cartilage . (Bullough P.G. , 1980).

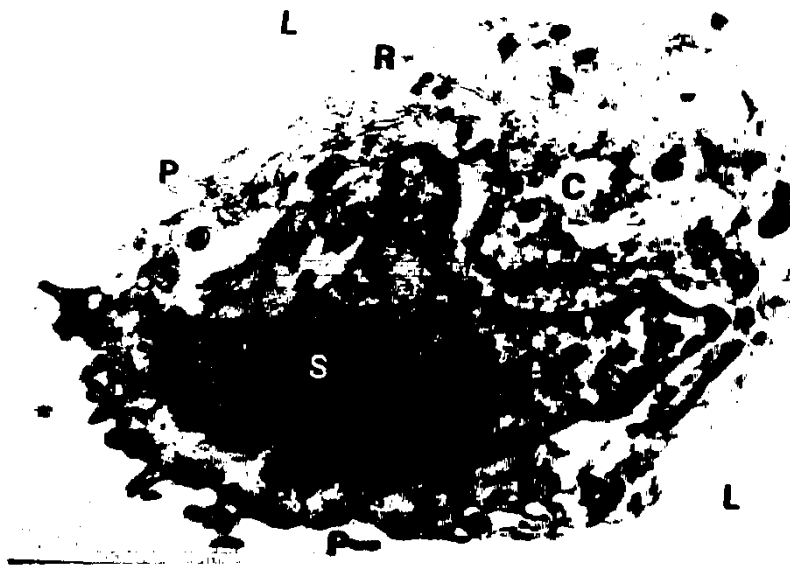


Fig. 2 : Transmission electron micrograph showing a chondrocyte with nucleus (N) with nucleolus (S) , cytoplasm (C) , limiting cell membrane (R), and cell processes (P) . Pericellular (L) and intercellular (T) matrix .

## Ultra Structural Characteristics Of Cartilage Cells

Under the electron microscope , the cartilage cells appear to have all the known cell organelles (Fig. 3) . Mitochondria are sparse in cartilage cells due to their comparatively low rates of oxygen consumption . (Bullough P.G. , 1980).

The rough endoplasmic reticulum studded with ribosomes are responsible for protein synthesis of the cartilage matrix .

The function of the golgi apparatus in the cartilage cells is to complete the addition of the carbohydrate side chains to the glycoproteins arriving from the rough endoplasmic reticulum . (Turek , 1984).

Most of the matrix synthesis takes place in the deeper uncalcified zone of the articular cartilage . That is why , the cells in such a zone have the most prominent endoplasmic reticulum and golgi apparatus . (Bullough P.G. , 1980).

Lysosomes are vesicles budding off from the golgi apparatus and contain digestive enzymes called hydrolases that break down macromolecules originating either intracellularly or extracellularly . So , to some extent, they play a role in the breakdown of cartilage matrix . (Mankin and Lippiello , 1969).

The nucleus is either oval or elongated and its outline is smooth or indented and is surrounded by two membranes forming the