A TERM PAPER ON SOFT TISSUE MECHANICS

WRITTEN AND SUBMITTED

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# ABSTRACT

What is a soft tissue? In anatomy, a soft tissue includes the tissues that connect, support, or surround other structures and organs of the body. Soft tissue includes tendons, ligaments, fascia, skin, fibrous tissue, fat and synovial membranes. In contrary to other tissues, it is a wide-ranging biological material in which the cells are separated by extracellular material. Connective or soft tissues may be distinguished from hard tissues such as bones for their high flexibility and their soft mechanical properties.

Soft tissues are complex fiber reinforced composite structures. Their mechanical behavior is strongly influenced by the concentration and structural arrangement of constituents such as collagen and elastin, the hydrated matrix of proteoglycans, and the topographical site and function in the organism.

In this paper, we’ll discuss soft tissue mechanics based on:

* Soft tissue in human body (STM)
* Collagen as a fibrous protein and basic structural elements of STM
* Stress-strain relationship in collagen biomaterials
* Cartilage and its applications in articulating joints such as hip, knee ankle and shoulder
* Mechanical testing procedures for soft tissues.

# SOFT TISSUE IN THE HUMAN BODY

Soft tissues are found throughout the body. There are many types of soft tissue, including fat, blood vessels and muscle. Soft tissue surround, support and connect organs and other tissues in the body. The functions of soft tissues include:

* Surround, support and connect organs and other parts
* Give shape and structure to the body
* Protect organs
* Move fluids, such as blood, from one part of the body to another
* Store energy

The soft tissues of the body include:

* Lymph vessel: lymph vessels are small tubes like blood vessels that run throughout the body. They contain lymph fluid to collect and carry waste products, germs and damaged cells away from the body’s tissues.
* Muscle: there are 3 types of muscle – smooth muscle, skeletal muscle and cardiac muscle.

Smooth muscle works automatically without you thinking about it. It is found in the walls of the body’s hollow organs such as the stomach and blood vessels, smooth muscles allow organs to relax and get bigger or tighten and get smaller.

Skeletal muscle is a type of muscle that you control to move your body. It is mainly found in the muscles attached to the bones. skeletal muscle keeps the skeleton together and helps you stand upright. It also allows you to move different parts of your body.

Cardiac muscle forms the wall of the heart and allows the heart to pump blood. Cardiac muscles are involuntary muscles.

* Blood vessel: blood vessels are long, elastic hollow tubes that are found throughout the body. Arteries, veins and capillaries are types of blood vessels. Blood travels through blood vessels and carries oxygen, nutrients, hormones, waste and other products around the body.
* Synovial tissue: synovial tissue is a thin and loose connective tissue that lines joints, such as elbows and knees. It is also found around tendons and fluid-filled sacs between bones and tendons. Synovial tissue makes synovial fluid, which is a thick liquid that allows areas to move easily.
* Nerve: nerves are soft tissues that control all of the body’s functions and movements. Nerve tissue is made of 2 main types of cells – nerve cells (neurons) and glial cells (neuroglial cells). Nerve cells send messages as electrical impulses from one part of the body to another.
* Fat: fat is a soft tissue made up of fat cells (adipocytes) that are packed tightly together.  Fat is commonly found under the skin of the hips, waist and abdomen. It also surrounds organs, such as the kidneys. Fat cushions the body, provides padding between organs and helps keep the body warm. The body also stores fat and uses it for energy when you need it.
* Fibrous tissue: fibrous tissue is a connective tissue made up of rope-like parts called fibers. These fibers help move body parts and keep them strong and stable. Tendons and ligaments are made up of fibrous tissue. Fibrous tissue is also found in the walls of blood vessels and surrounds many organs.

# COLLAGEN AS A FIBROUS PROTEIN AND BASIC STRUCTURAL ELEMENTS OF STM

Soft connective tissues of our body are complex fiber-reinforced composite structures. Their mechanical behavior is strongly influenced by the concentration and structural arrangement of constituents such as collagen and elastin, the hydrated matrix of proteoglycans, and the topographical site and respective function in the organism. [1].

Collagen is a protein which is a major constituent of the extracellular matrix of connective tissue. It is the main load carrying element in a wide variety of soft tissues and is very important to human physiology. Collagen is a macromolecule with length of about 280 nm. Collagen molecules are linked to each other by covalent bonds building collagen fibrils. Depending on the primary function and the requirement of strength of the tissue the diameter of collagen fibrils varies. In the structure of tendons and ligaments, for example, collagen appears as parallel oriented fibers, while many other tissues have an intricate disordered network of collagen fibers embedded in a gelatinous matrix of proteoglycans. [1]

# STRESS-STRAIN RELATIONSHIP IN COLLAGEN BIOMATERIALS

For the connective tissue parts of the skin the three-dimensional network of fibers appears to have preferred directions parallel to the surface. However, in order to prevent out-of-plane shearing, some fiber orientations also have components out-of-plane. Figure 1 shows a schematic diagram of a typical J-shaped (tensile) stress-strain curve for skin.



# CARTILAGE AND ITS APPLICATIONS IN ARTICULATING JOINTS

Cartilage is a specialized connective in which the chondrocytes occupy only 5% of the volume. Chondrocytes have cell processes that extend a short distance into the matrix, but do not touch other cells. Thus, in cartilage, cell–matrix interactions are essential for the maintenance of the extracellular matrix. [2]

Cartilage is a supporting connective tissue that, together with the bone, forms the framework supporting the body as a whole. There are many distinct types of cartilage, which exhibit numerous similarities as well as differences. Among them, articular cartilage is the best known and the most studied type. Articular cartilage is the thin layer of connective tissue that covers the articulating ends of bones in synovial (diarthrodial) joints. It provides a smooth surface for joint movement and acts as a load-bearing medium that protects the bone and distributes stress.

# MECHANICAL TESTING PROCEDURES FOR SOFT TISSUES

Mechanical properties of very soft tissues, such as brain, liver, kidney and prostate have recently joined the mainstream research topics in biomechanics. This has happened in spite of the fact that these tissues do not bear mechanical loads. The interest in the biomechanics of very soft tissues has been motivated by the developments in computer-integrated and robot-aided surgery—in particular, the emergence of automatic surgical tools and robots—as well as advances in virtual reality techniques. Very soft tissues are usually tested in compression using an unconfined compression set-up, which requires ascertaining that friction between sample faces and stress–strain machine platens are close to zero. Top and bottom faces of a cylindrical specimen with low aspect ratio are rigidly attached to the platens of the stress–strain machine (e.g. using surgical glue). This arrangement allows using a [no-slip boundary condition](https://www.sciencedirect.com/topics/engineering/no-slip-boundary-condition) in the analysis of the results. Even though the state of deformation in the sample cannot be treated as orthogonal the relationships between total change of height (measured) and strain are obtained. Two important results are derived:

* [deformed shape](https://www.sciencedirect.com/topics/engineering/deformed-shape) of a cylindrical sample subjected to uniaxial compression is independent on the form of constitutive law,
* vertical extension in the plane of symmetry *λz* is proportional to the total change of height for strains as large as 30%. The importance and relevance of these results to testing procedures in biomechanics are highlighted. [3]

# REFERENCES

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