UNIT 4 BIOMECHANICS OF JOINTS AND IMPLANTS

The biomechanics of joints and implants focuses on understanding the mechanical properties and movement patterns of human joints, as well as how artificial implants are designed to restore or enhance their function.

4.1 SKELETAL JOINTS

Skeletal joints, also known as articulations, are the points where two or more bones meet. They play a crucial role in providing stability and enabling movement in the skeletal system. Joints are classified based on their structure and function.

Types of Joints (Structural Classification)

1. **Fibrous Joints**
   - Bones are connected by dense connective tissue.
   - Allow little to no movement.
   - Examples:
     - **Sutures** (in the skull).
     - **Syndesmoses** (e.g., between the tibia and fibula).
     - **Gomphoses** (tooth sockets).
2. **Cartilaginous Joints**
   - Bones are connected by cartilage.
   - Allow limited movement.
   - Examples:
     - **Synchondroses** (e.g., epiphyseal plates in growing bones).
     - **Symphyses** (e.g., pubic symphysis, intervertebral discs).
3. **Synovial Joints**
   - Most common and most mobile type of joint.
   - Characterized by a synovial cavity filled with synovial fluid, surrounded by a joint capsule.

- Examples: Shoulder, knee, elbow, and hip joints.

Types of Joints (Functional Classification)

1. **Synarthroses**
   - Immovable joints.
   - Examples: Sutures in the skull.
2. **Amphiarthroses**
   - Slightly movable joints.
   - Examples: Pubic symphysis, intervertebral joints.
3. **Diarthroses**
   - Freely movable joints (all synovial joints).
   - Examples: Knee, hip, and shoulder joints.

Types of Synovial Joints (Based on Movement and Shape)

1. **Hinge Joint** (Uniaxial)
   - Movement: Flexion and extension.
   - Examples: Elbow, knee.
2. **Pivot Joint** (Uniaxial)
   - Movement: Rotation around a central axis.
   - Example: Atlantoaxial joint (neck).
3. **Ball-and-Socket Joint** (Multiaxial)
   - Movement: Flexion, extension, abduction, adduction, rotation.
   - Examples: Shoulder, hip.
4. **Condyloid (Ellipsoidal) Joint** (Biaxial)
   - Movement: Flexion, extension, abduction, adduction, circumduction.
   - Example: Wrist joint.
5. **Saddle Joint** (Biaxial)
   - Movement: Flexion, extension, abduction, adduction, circumduction.
   - Example: Carpometacarpal joint of the thumb.
6. **Gliding (Plane) Joint** (Nonaxial)

- Movement: Sliding or gliding motion.
- Examples: Intercarpal and intertarsal joints.

4.1.1FORCES AND STRESSES IN HUMAN JOINTS

The forces and stresses in human joints are critical to understanding how the body functions under various conditions, such as movement, weight-bearing, and injury.

Forces in Human Joints

Forces in joints are caused by the interaction of muscles, ligaments, tendons, and the skeletal structure. These forces can be broadly classified as:

1. **Compressive Forces**:
   - Occur when bones are pressed together under load.
   - For example, in the knee joint during walking or running, the compressive forces can be several times the body weight.
2. **Tensile Forces**:
   - Act to stretch or elongate tissues, such as ligaments or tendons.
   - Tendons experience tensile forces during muscle contractions.
3. **Shear Forces**:
   - Act parallel to the joint surface, causing sliding between two bone ends.
   - Common in the spine and knee during twisting or lateral movements.
4. **Torsional Forces**:
   - Result from rotational movements, causing a twisting effect on the joint.
   - Present in joints like the knee during pivoting motions.
5. **Joint Reaction Forces**:
   - These are the forces transmitted through the joint in response to external loads and muscle contractions.
   - For example, during stair climbing, hip joints experience high reaction forces.

Stresses in Human Joints

Stress in joints is the force per unit area exerted on joint surfaces or tissues. It depends on factors like the load, contact area, and material properties of the joint structures. Types of stresses include:

1. **Normal Stress**:
   - Acts perpendicular to the surface.
   - Seen in weight-bearing joints like the hip and knee during standing or walking.
2. **Shear Stress**:
   - Acts parallel to the surface.
   - Contributes to joint wear, particularly in cartilaginous surfaces like the knee or shoulder.
3. **Tensile Stress**:
   - Found in stretched ligaments or tendons.
   - Plays a role in stabilizing joints during movement.

Key Joints and Their Unique Stresses

1. **Knee Joint**:
   - Experiences high compressive and shear forces during running or squatting.
   - Commonly subject to stress-induced injuries like ACL tears or meniscus damage.
2. **Hip Joint**:
   - Supports the majority of body weight in activities like walking and running.
   - Subject to compressive forces that are critical in maintaining joint integrity.
3. **Spine**:
   - Intervertebral discs experience compressive, tensile, and shear stresses during bending, twisting, and lifting.
4. **Shoulder Joint**:
   - Experiences tensile and torsional stresses due to the wide range of motion and reliance on soft tissues for stability.
5. **Ankle Joint**:

- Faces compressive and shear forces during walking, running, and jumping.

Impact of Forces and Stresses

- **Cartilage Wear**: Excessive stress on joint cartilage can lead to degeneration, as seen in osteoarthritis.
- **Bone Adaptation**: Bones remodel in response to stress, following Wolff's Law (e.g., increased bone density under high loads).
- **Injuries**: Abnormal stresses can lead to ligament tears, fractures, or joint dislocations.

Understanding these forces and stresses is essential for designing medical interventions like prosthetics, orthotics, and surgical procedures, as well as for developing strategies to prevent injury.