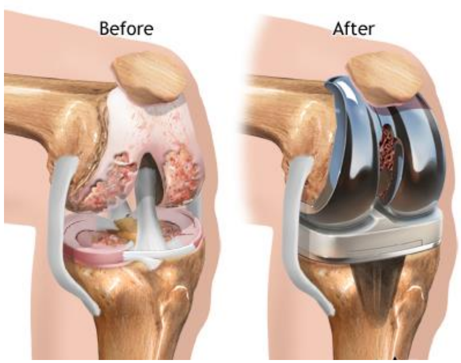
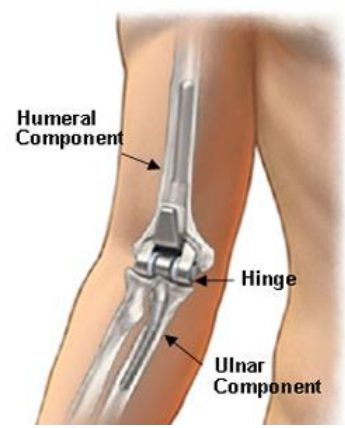
Prostheses

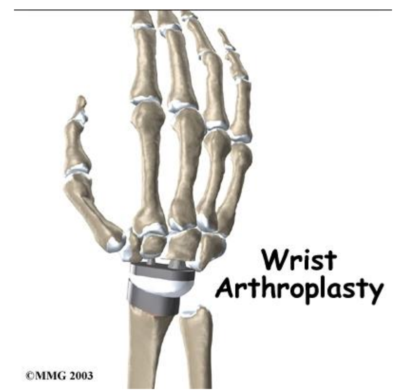
A **prosthesis** is a device designed to replace a missing part of the body, or to make a part of the body work better

Joint(s) prosthesis is the addition to or replacement of a member(s) or of structural elements within a joint to improve and enhance the function of the joint.

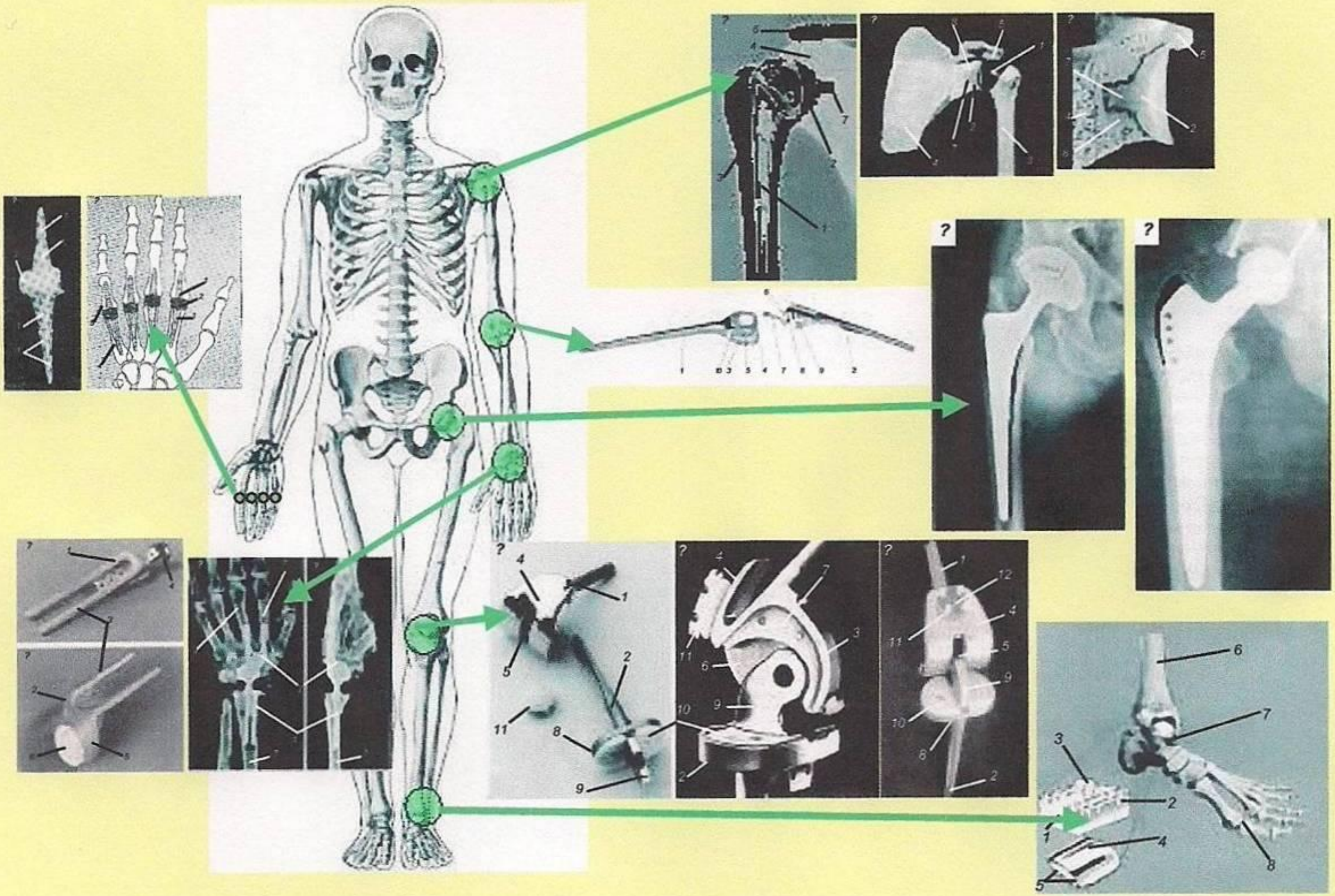
Principal joint prostheses include hip replacement and knee replacement.



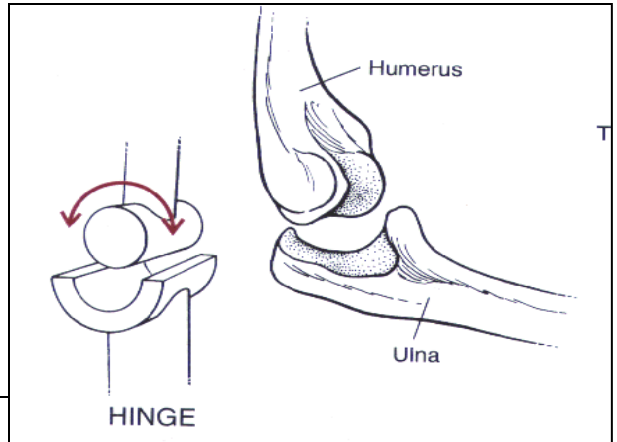


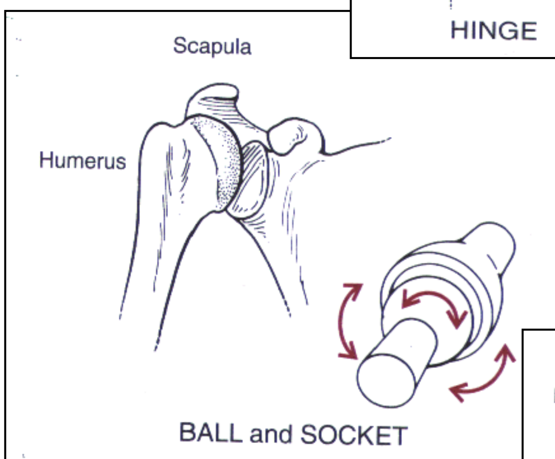


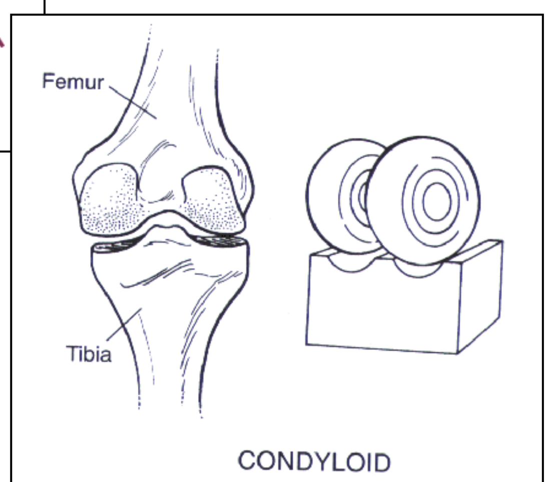
Constructions of different artificial BioJoints



Joint types







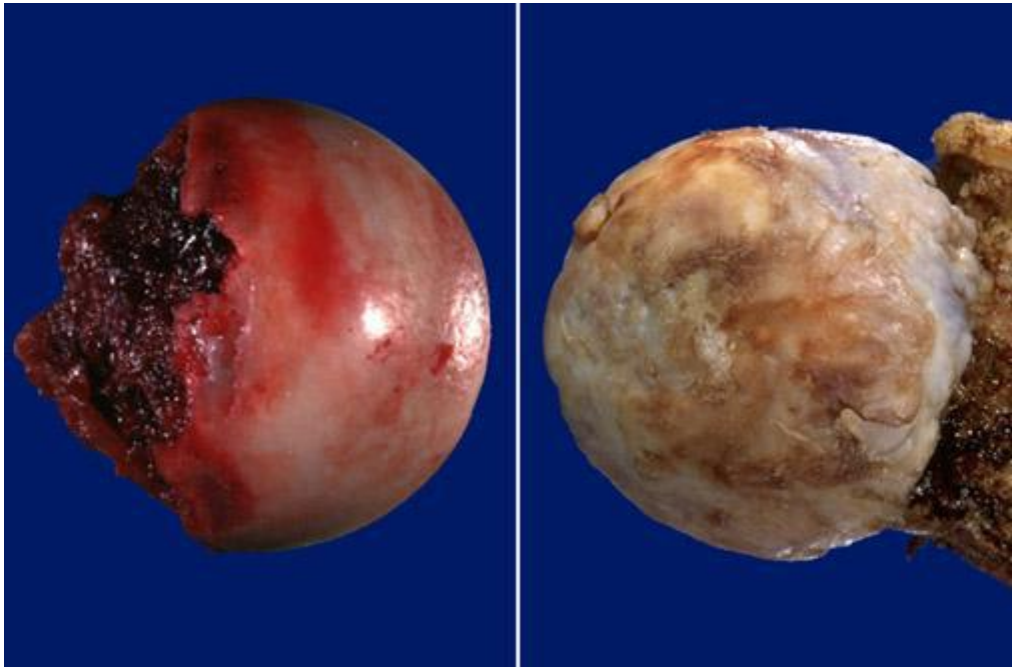
A. Hinge joint
Movement on a single plane (extension, flexion)
Elbow, finger phalanges

B. Ball-and-socket joint
Movement on three planes (extension, flexion - abduction, adduction - rotation)
Hip, shoulder

Γ. Condyloid joint
Movement mainly on a single plane (extension, flexion) with a small rotation
Knee

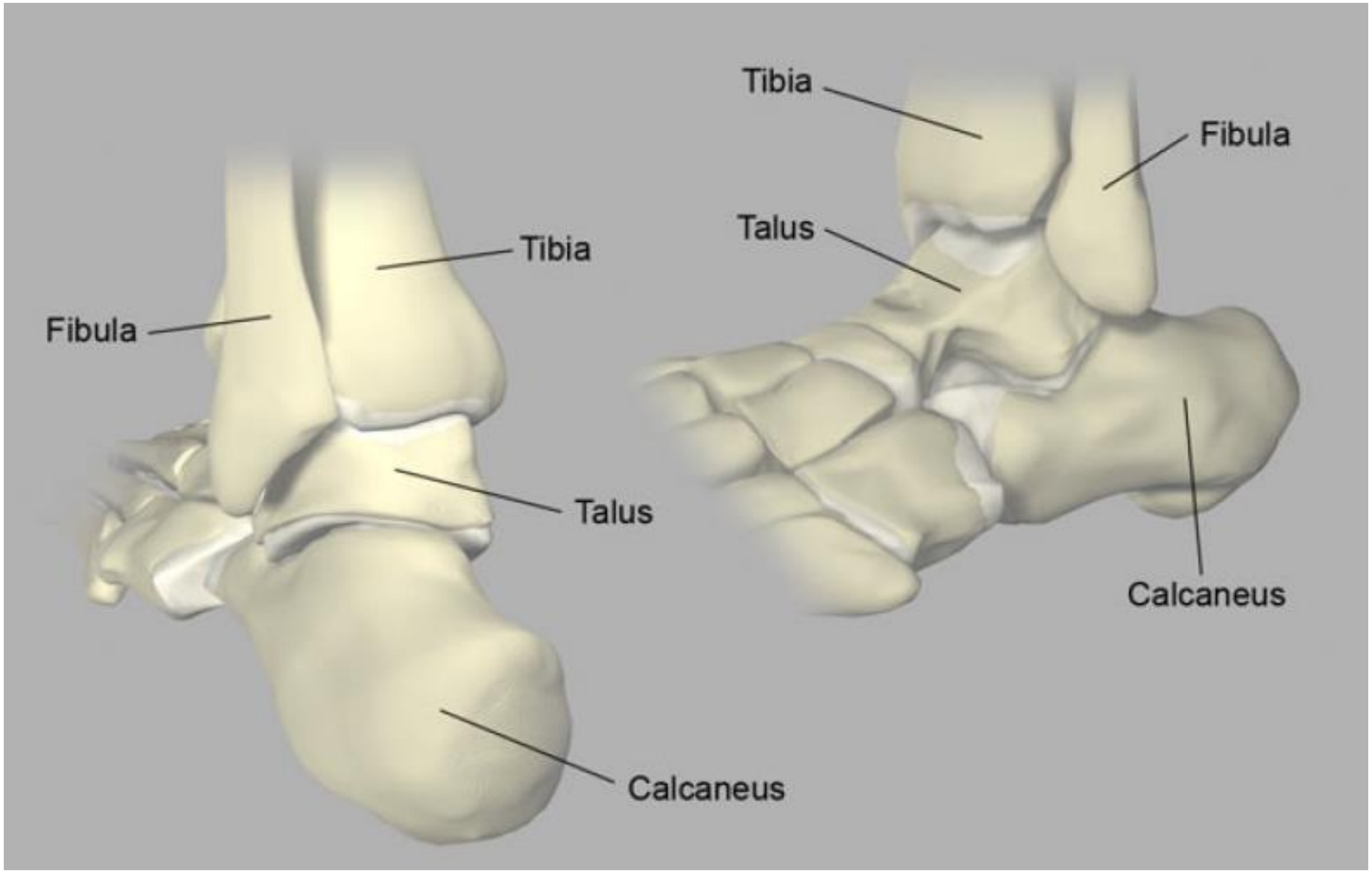
Causes for joint replacement

- Accidents (fracture due to osteoporosis)
- Osteoarthritis, rheumatoid arthritis

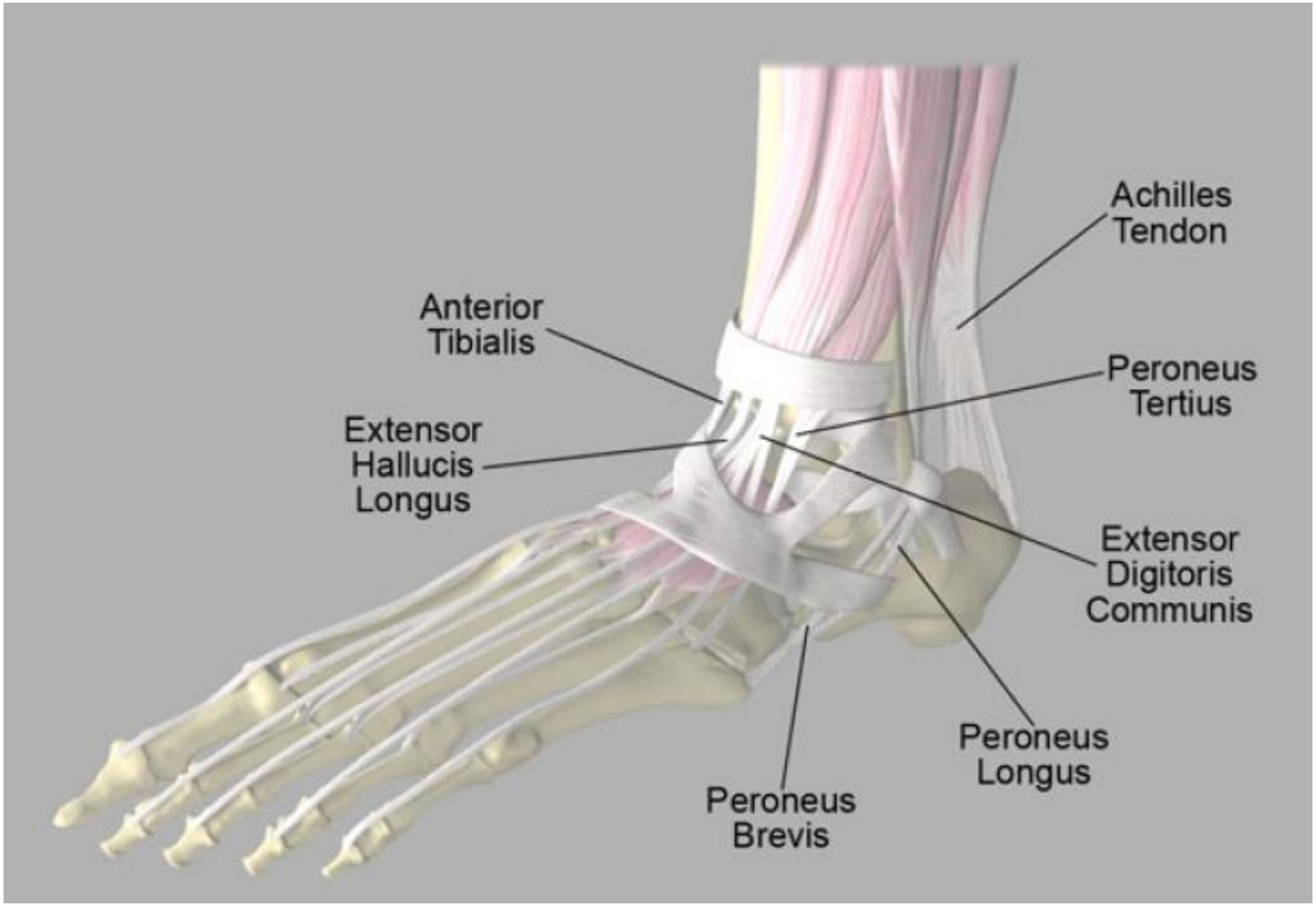


The Ankle

Anatomy-Bones of the ankle

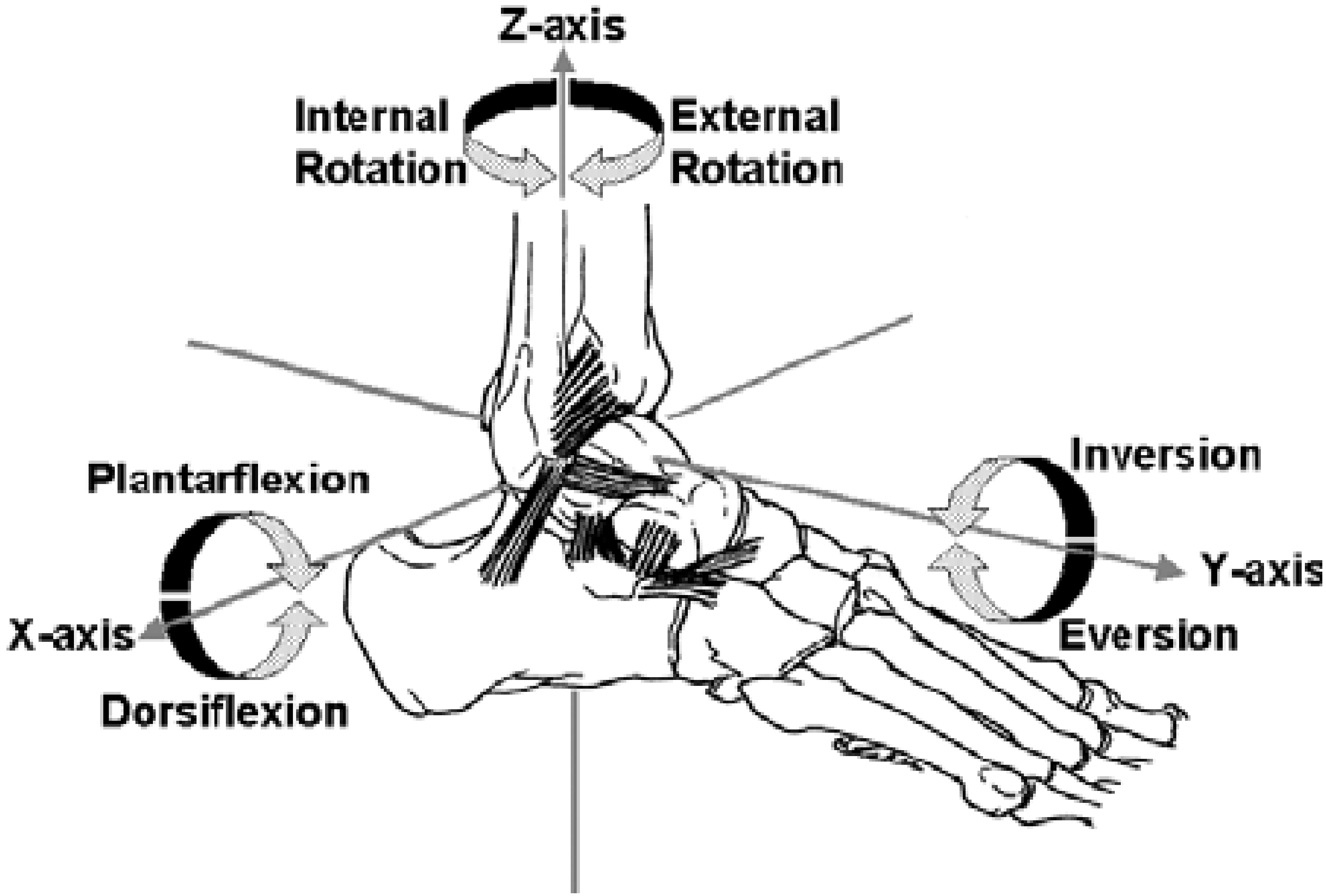


Ankle Tendons

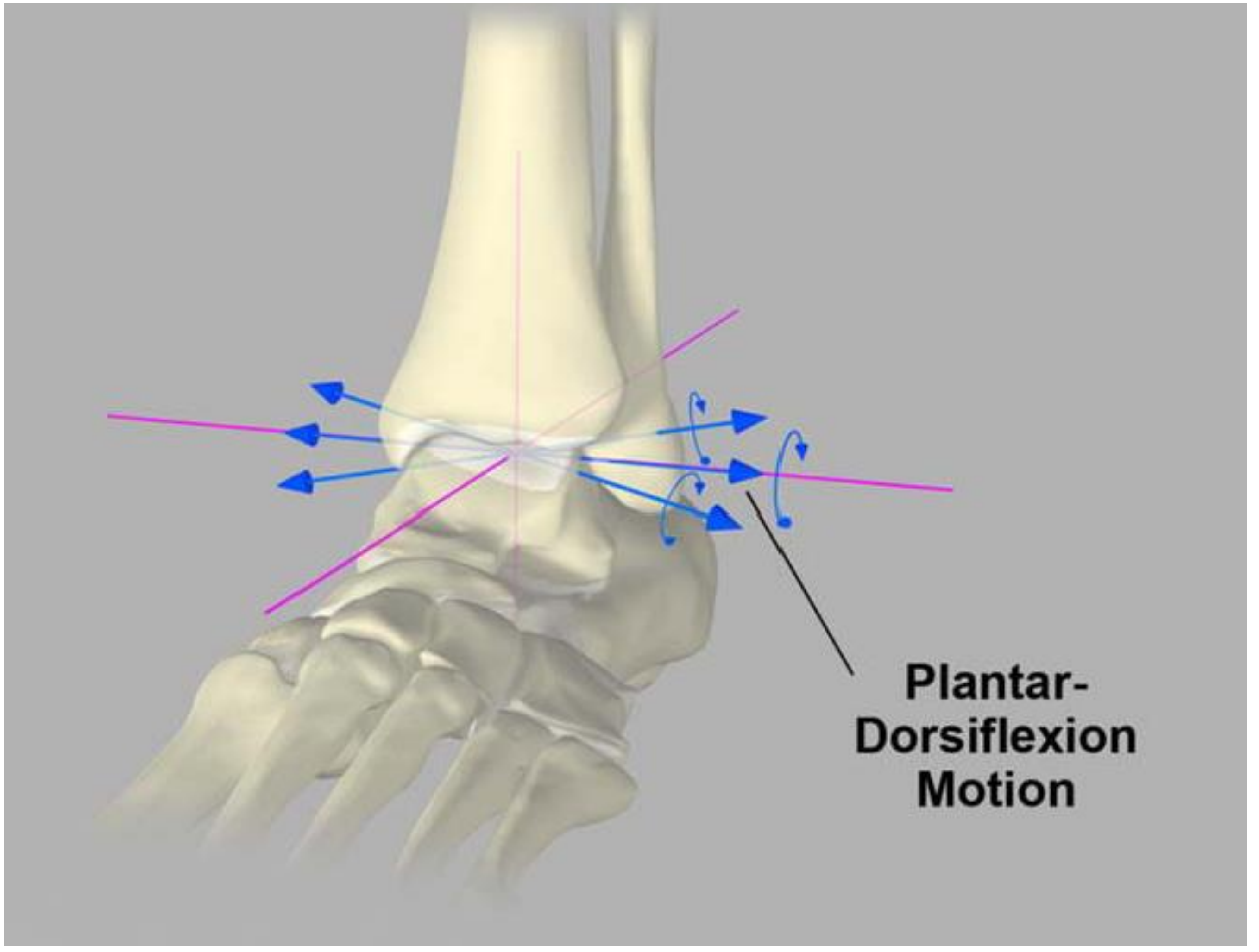


Biomechanics

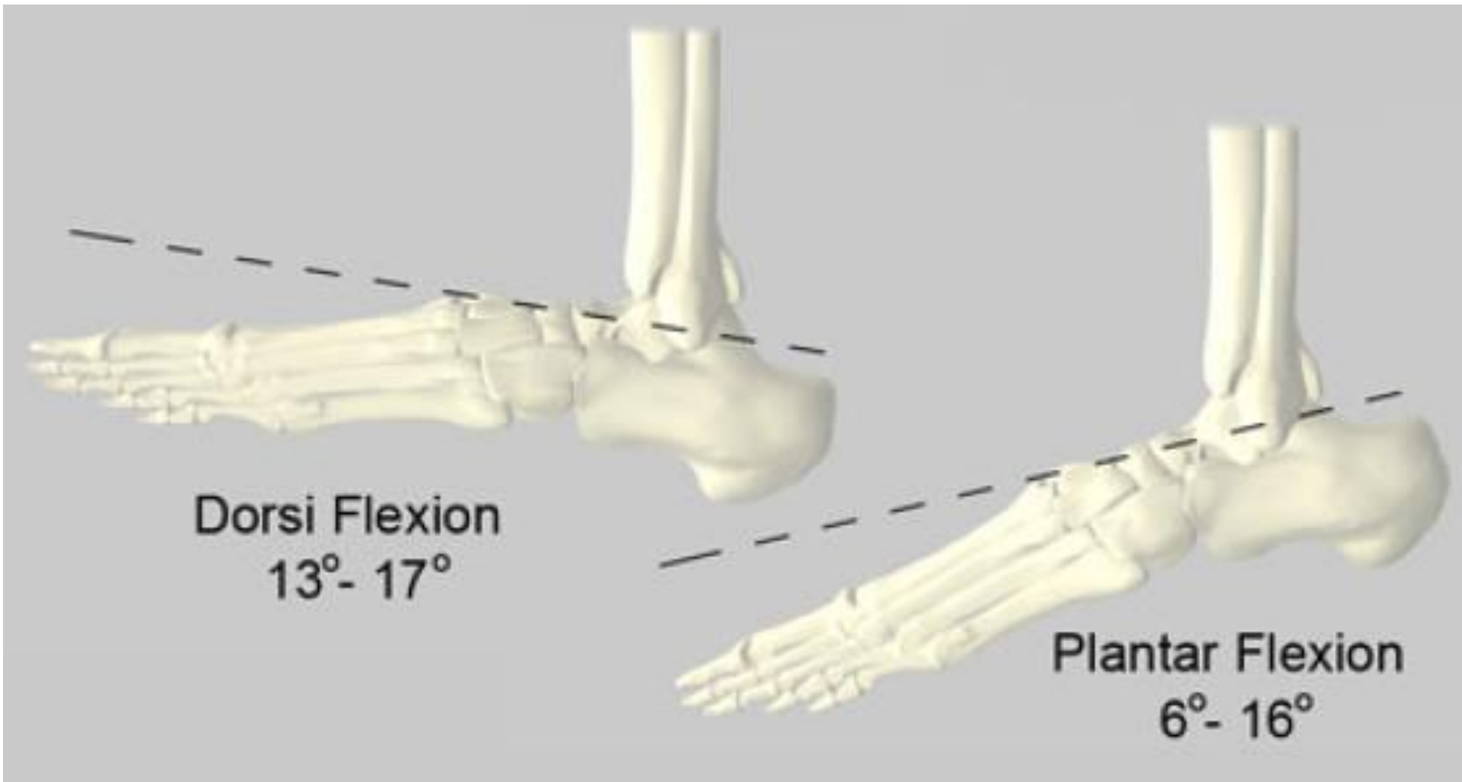
1. Ankle Motion



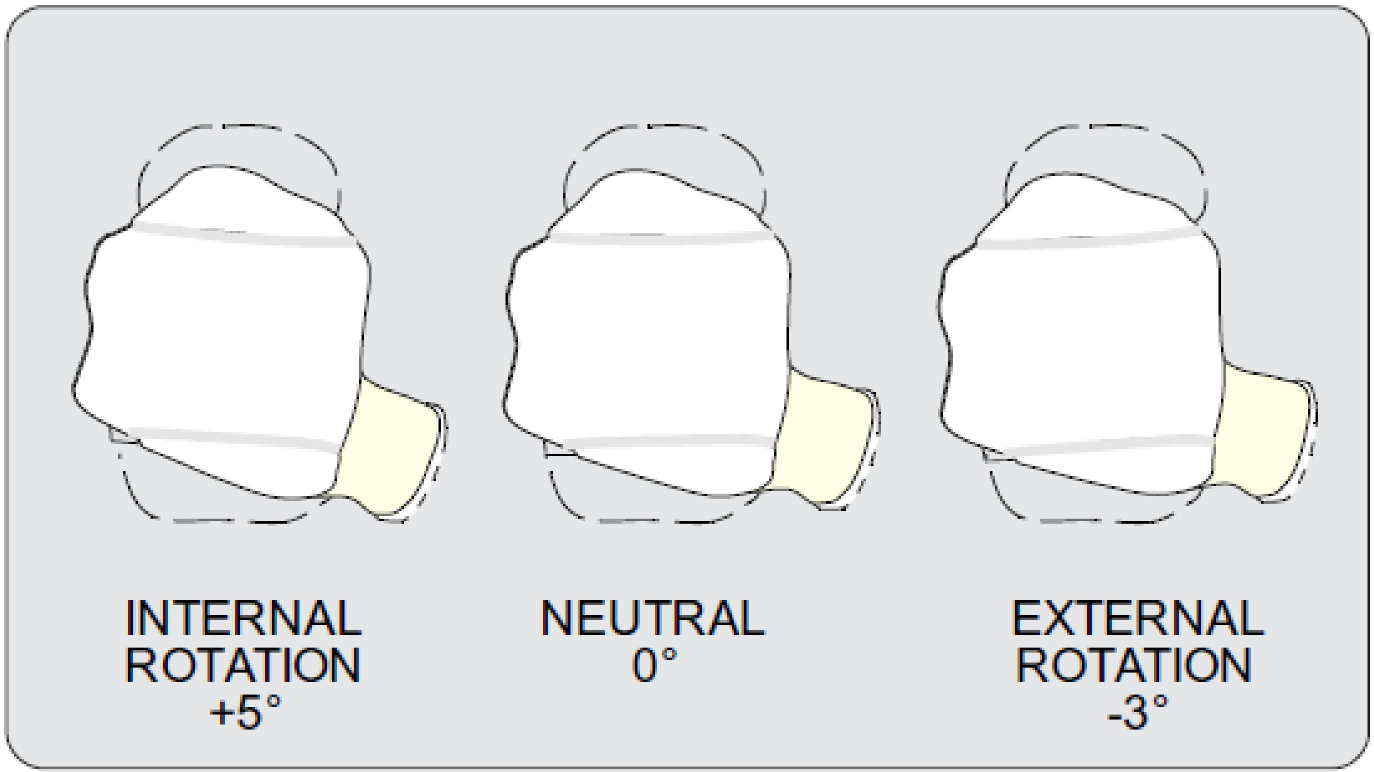
Plantar – dorsiflexion: the principal motion of the joint



Plantar and Dorsiflexion in the Normal Ankle During Walking



Axial Rotation in the Normal Ankle During Walking

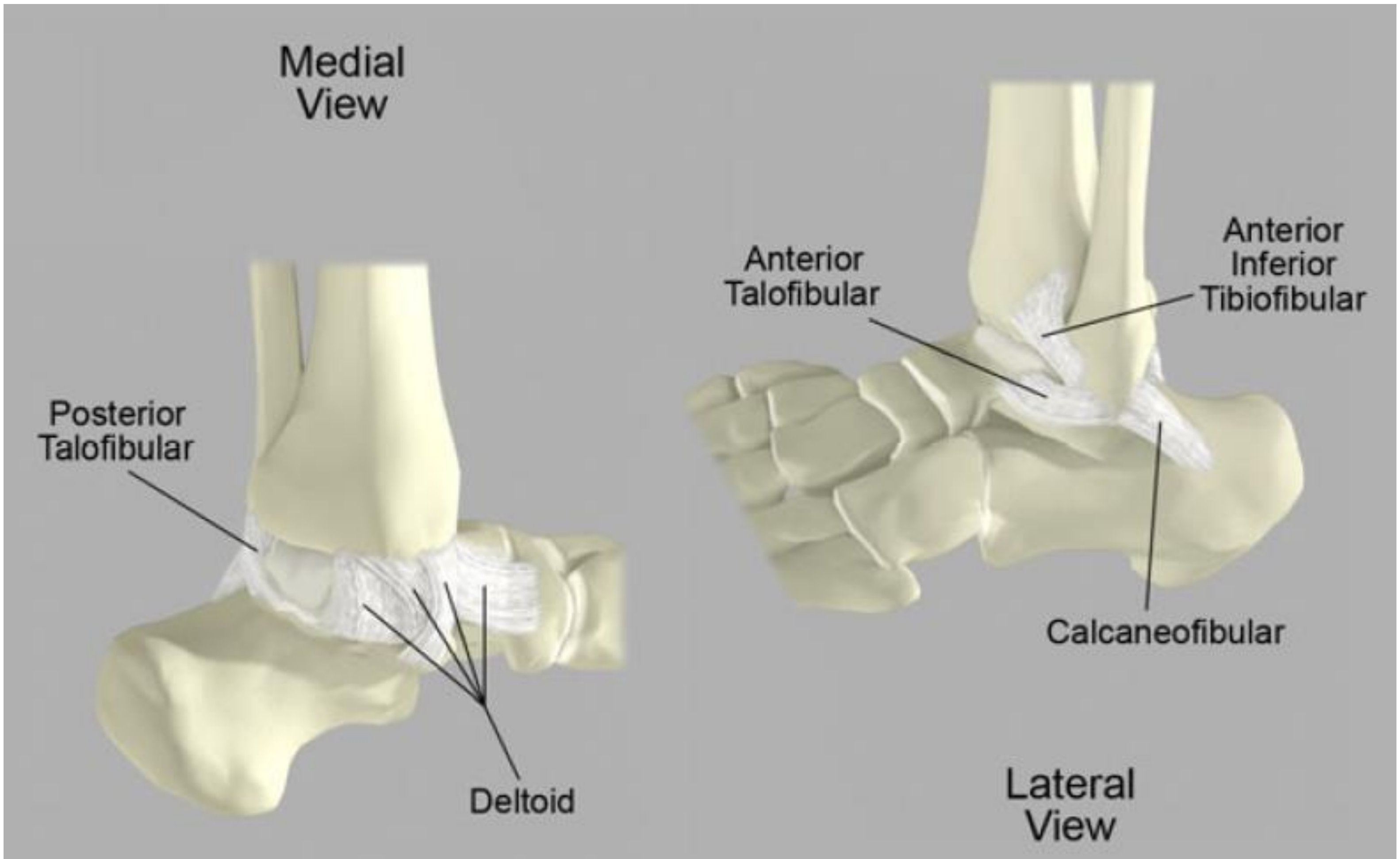


Inversion and eversion

2. Stability of the joint

External stability *(Ligamentous Structures)*

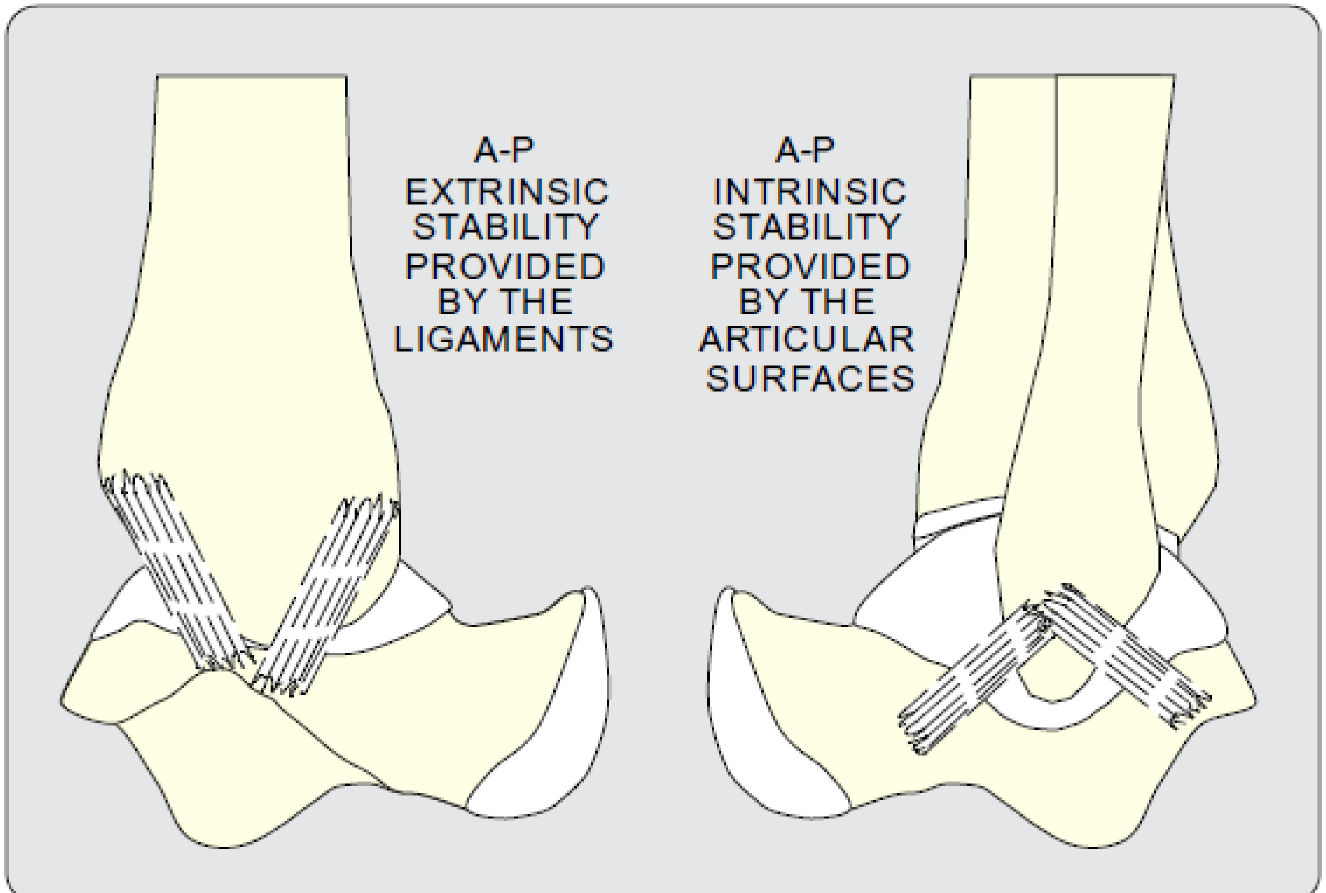
Intrinsic stability (*Shape of articulating surfaces*)



Constraint against significant anterior - posterior, medial - lateral and inversion - eversion motion:

Anterior-Posterior

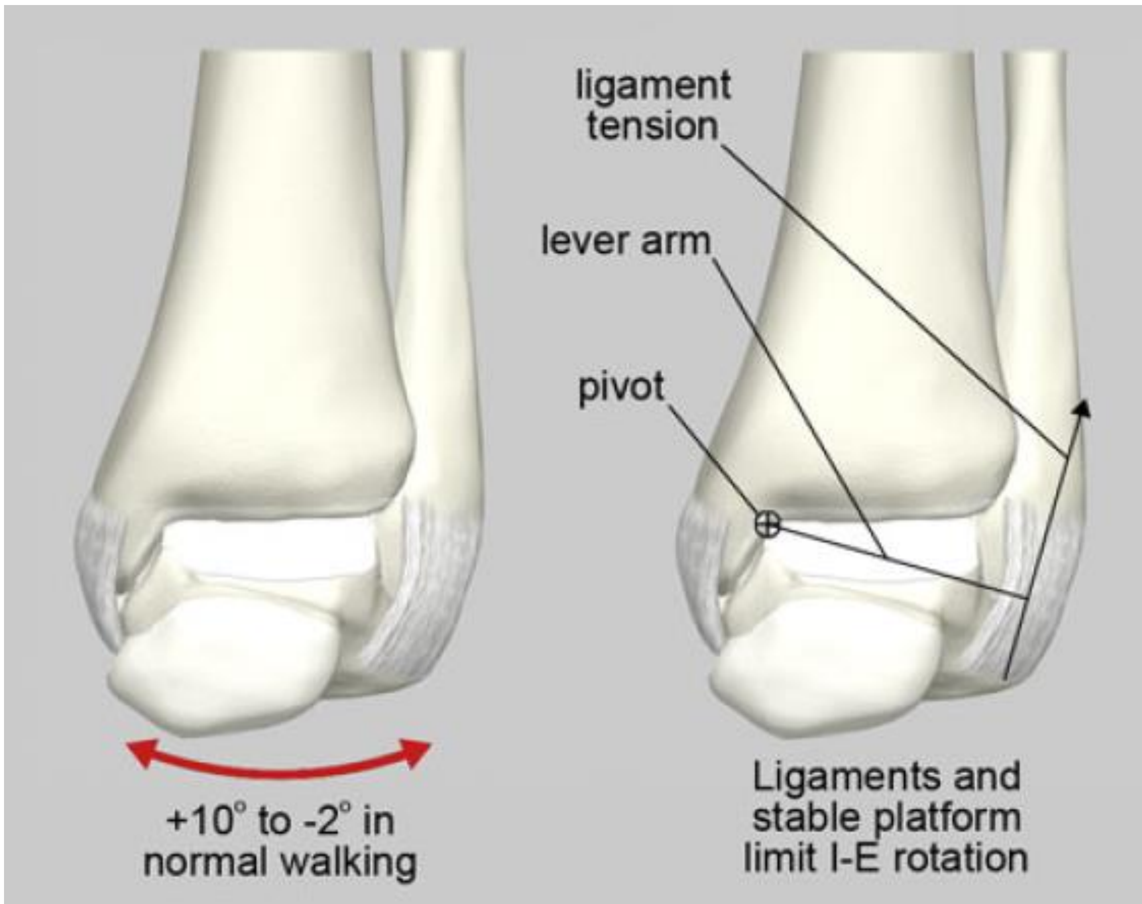
Anterior - posterior stability is primarily extrinsic and is provided by the ankle ligaments. Some intrinsic stability is also present.



A-P Stability of the Tibiotalar Joint

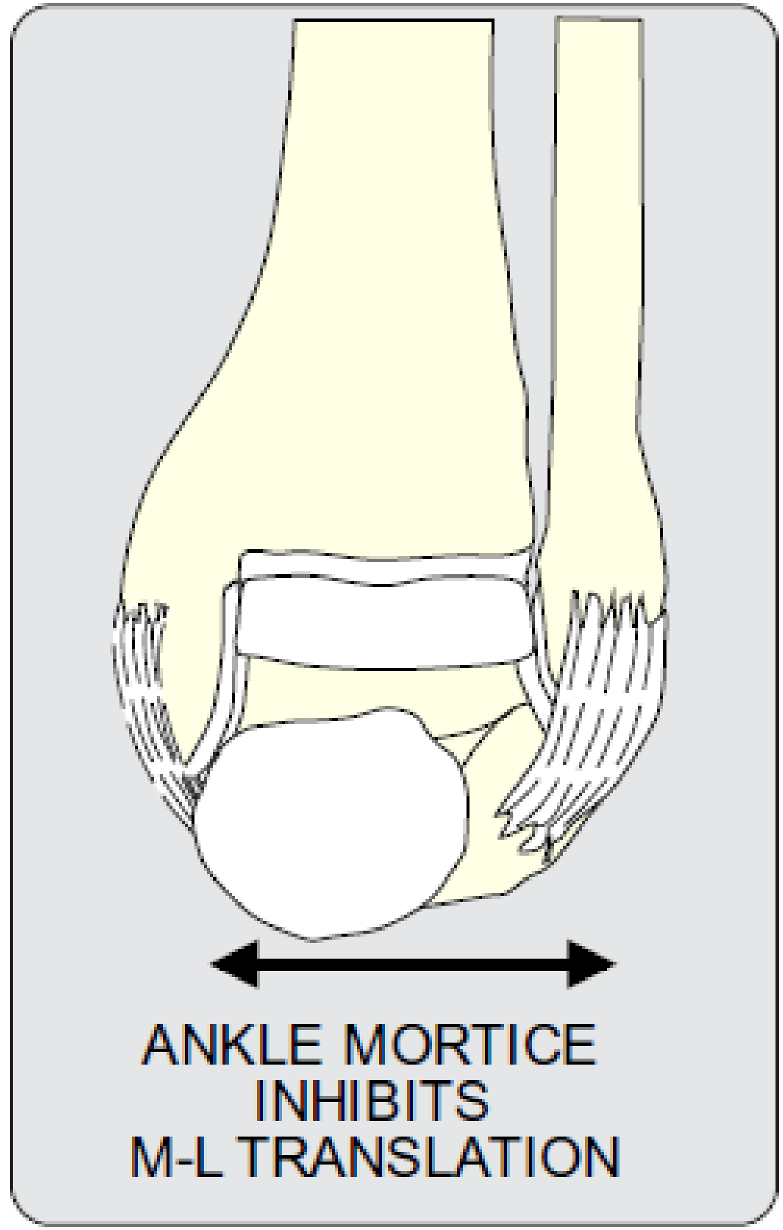
Inversion-Eversion

Inversion - eversion stability is provided by the tibiotalar ligaments and the width of the tibiotalar articulating surface



Medial – Lateral

Medial - lateral stability is almost entirely intrinsic and is provided by the ankle mortise as shown in Fig.



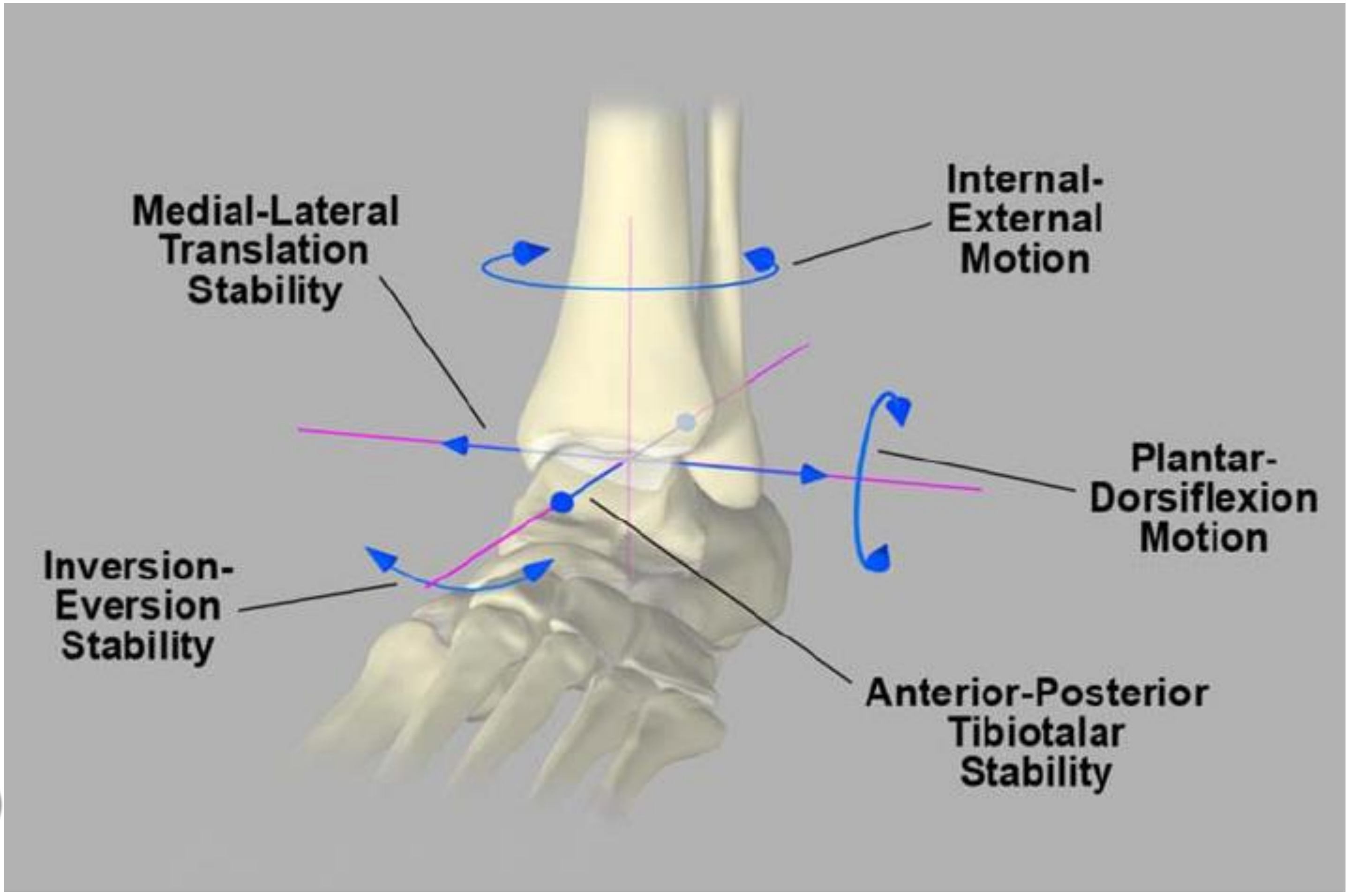
Movement and Stability

Axial rotation; motion is limited primarily by the mortice and ligaments of the ankle.

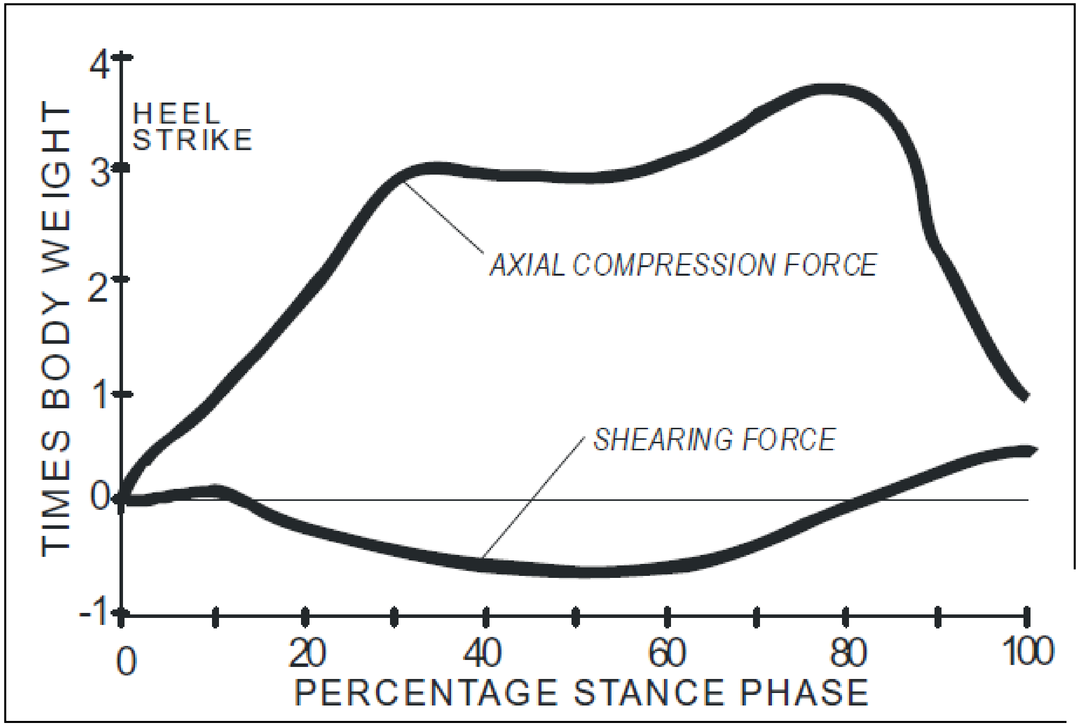
Inversion - Eversion (I-E); which motion is limited by the ligaments and the tibiotalar articulating surfaces.

Anterior - posterior (A-P) **translation**; which motion is limited by the ligaments and the tibiotalar articulating surfaces.

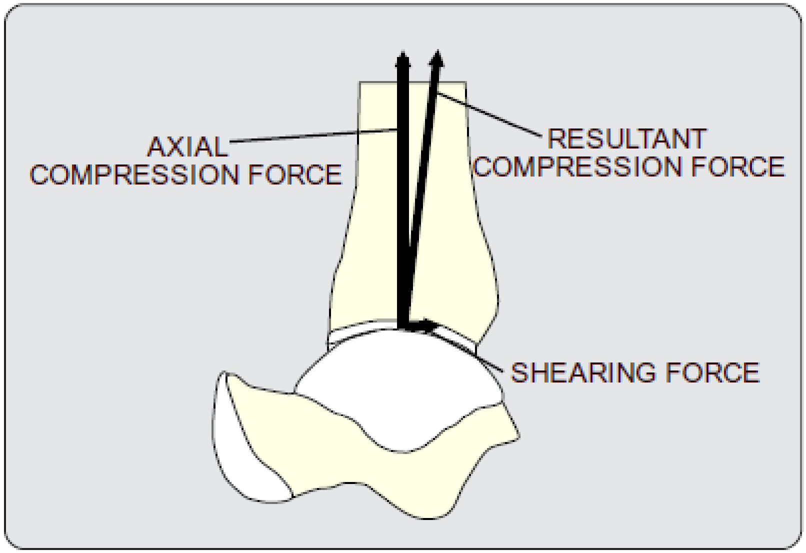
Medial - Lateral (M-L) translation; which motion is limited by the mortice



3. Forces



TIMES BODY WEIGHT
4
3
2
1
0
-1
HEEL STRIKE
AXIAL COMPRESSION FORCE
SHEARING FORCE
0
20
40
60
80
100
PERCENTAGE STANCE PHASE



AXIAL COMPRESSION FORCE
RESULTANT COMPRESSION FORCE
SHEARING FORCE

Pathology

Disease processes involving the ankle joint are usually classified into:

- Congenital: Incomplete or poor embryonic development of the ankle can result from congenital anomalies.
- Metabolic: Bone disorders involving deficiencies in calcium metabolism secondary to hormonal, genetic or nutritional imbalance can affect the integrity of the bones and ligaments of the ankle.
- Neuro-muscular: Diseases affecting the nerves and muscles of the leg and foot generally cause significant joint disturbances.
- Infectious: Sepsis of the ankle from any gram positive or gram negative bacteria can result in destruction of the ankle joint, known as septic arthritis,
- Autoimmune: Arthritis of the ankle can be a result of autoimmune disorders such as rheumatoid or psoriatic arthritis which can completely destroy the articular cartilage.
- Post-traumatic: Fractures, dislocations or severe ligament injuries can compromise ankle joint function

Total Ankle Replacement

Design Evolution

First Generation Designs

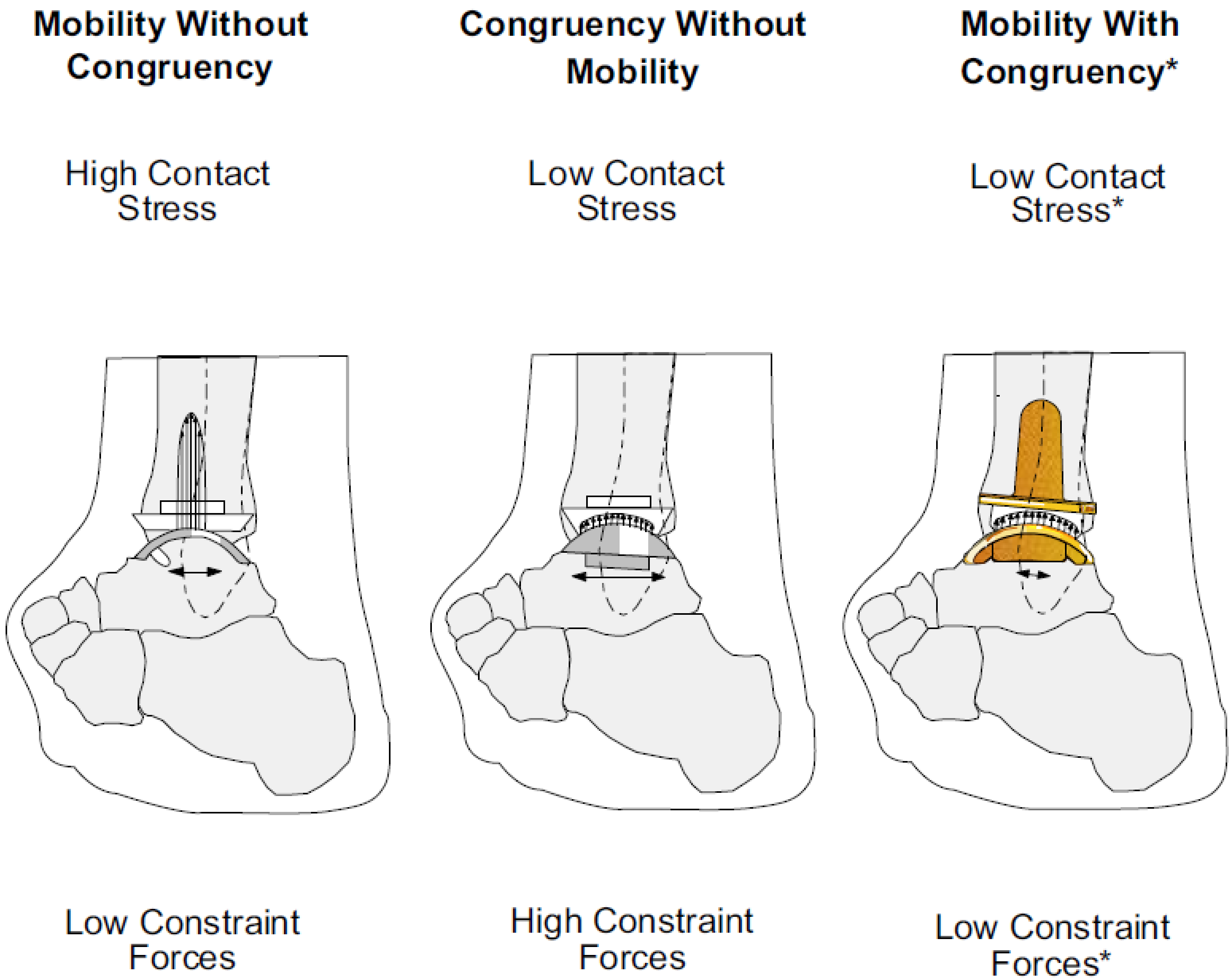
A. The Smith Ankle, Duke University in the early 1970's, cemented device with a stainless steel tibial component and an UHMWPe talar component.

B. The Mayo Clinic Ankle, developed in 1974. It is a two part, fixed bearing, highly constrained, cemented design with a stainless steel talar and UHMWPe tibial component.

C. ***The NJ Fixed Bearing Ankle,*** 1974, a cylindrical design with congruent articulating surfaces. It is a two piece device with a Co-Cr tibial component and an UHMWPe talar component

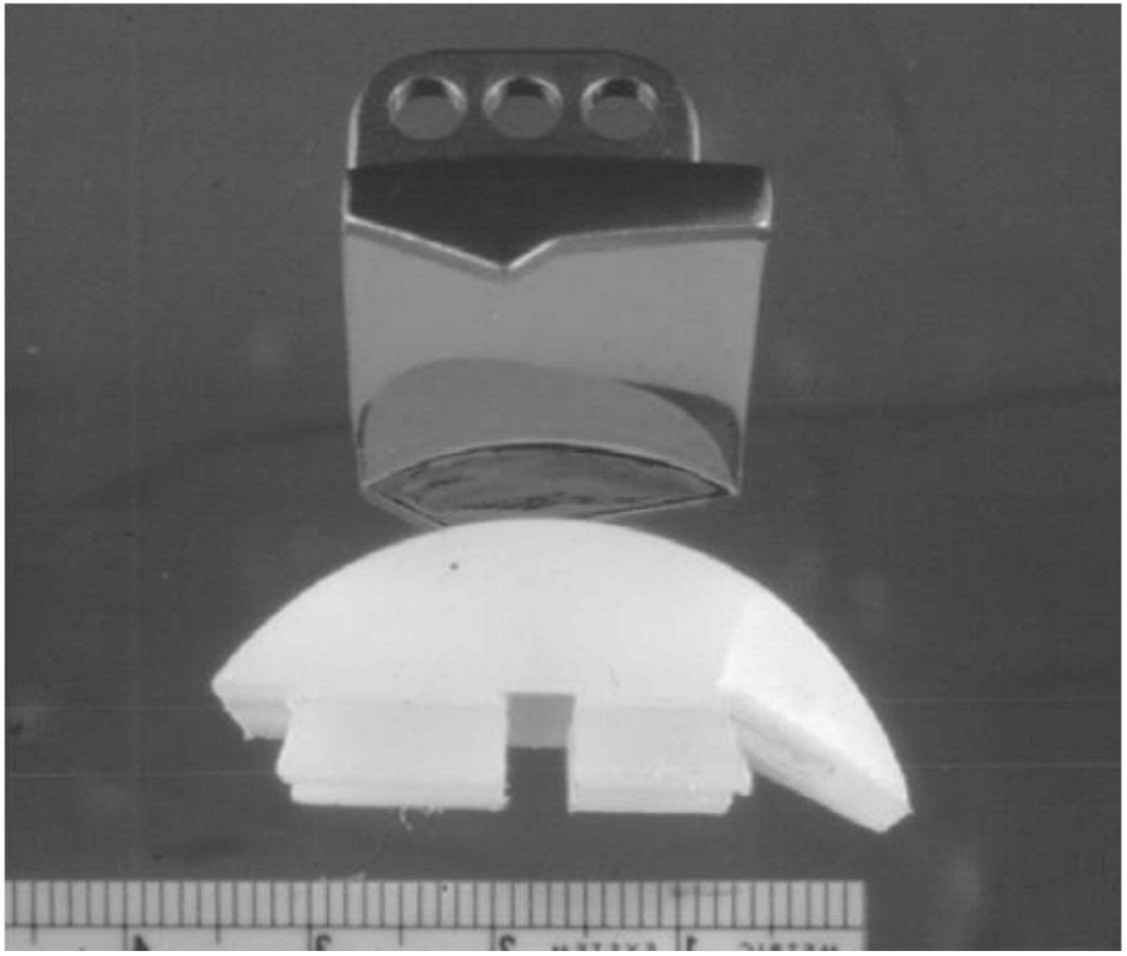
In order for total ankle replacement to gain general acceptance as a viable surgical option, several criteria must be met:

- Prosthetic design must permit optimal contact stress at the articulating surfaces and optimal fixation (preferably biological);
- Stability must be enhanced without compromising mobility;
- Strict criteria for surgical indications must be established;
- Arthrodesis must be a reasonable option as a salvage procedure (e.g. minimal bone resection)."



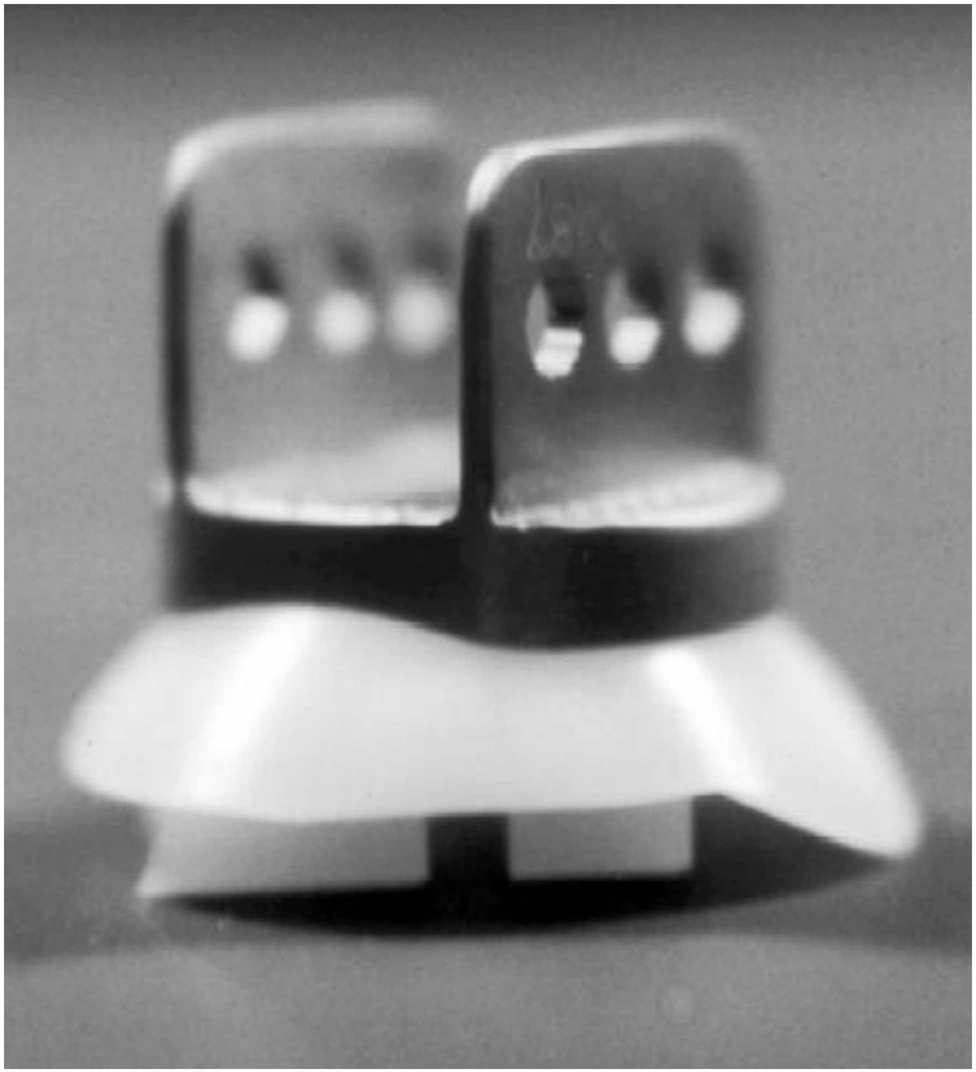
Mobility Without Congruency
High Contact Stress
Low Constraint Forces
Congruency Without Mobility
Low Contact Stress
High Constraint Forces
Mobility With Congruency*
Low Contact Stress*
Low Constraint Forces*

Design of the B-P Ankle System



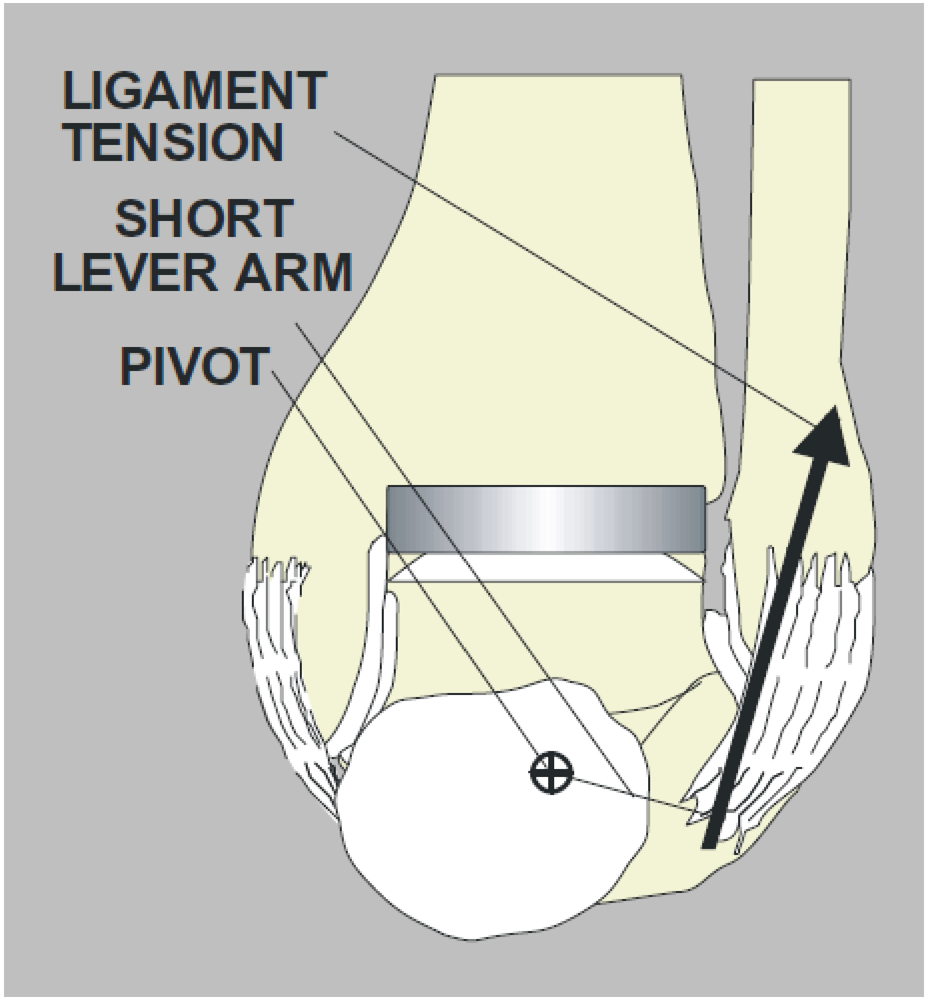
Cylindrical Ankle Replacement, 1974. Failure due to loosening occurred in 5 of 6 devices within the first year, due to lack of axial rotation in the device

B-P Spherical Total Ankle Replacement

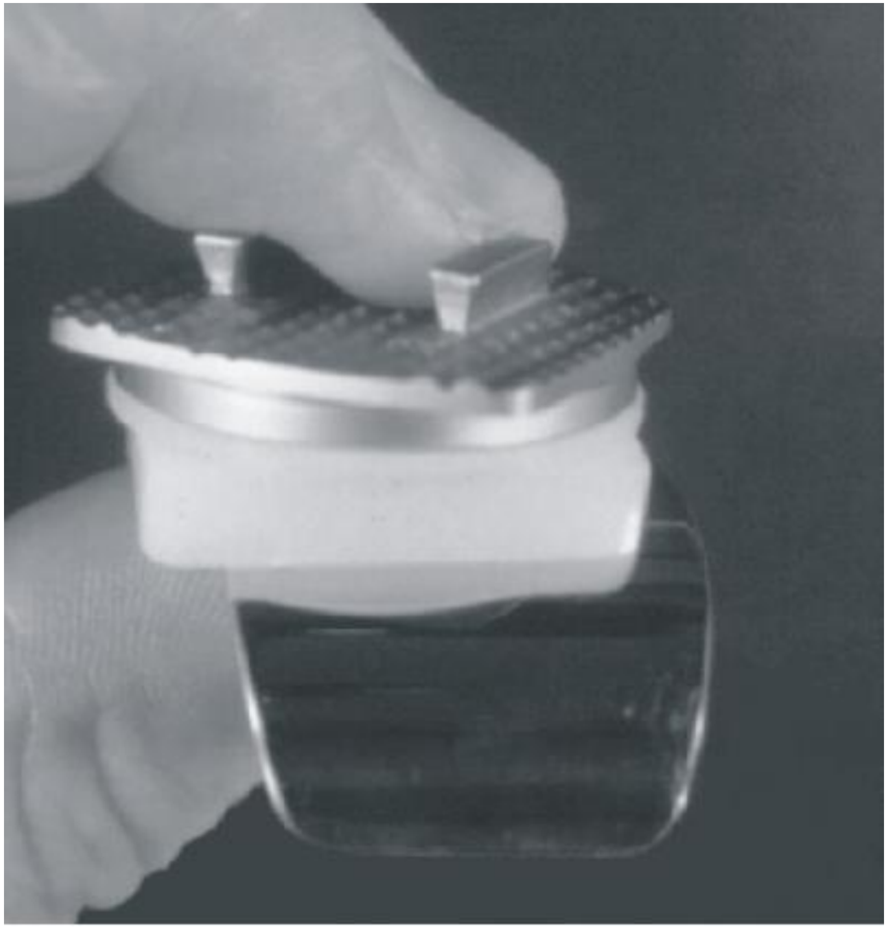


On analysis this design had two serious weaknesses. First, it did not provide essentially total coverage of the resected tibia and talus. Secondly, and most importantly, it did not provide normal I-E stability.

Abnormal I-E Stability



B-P Trunion Total Ankle Replacement



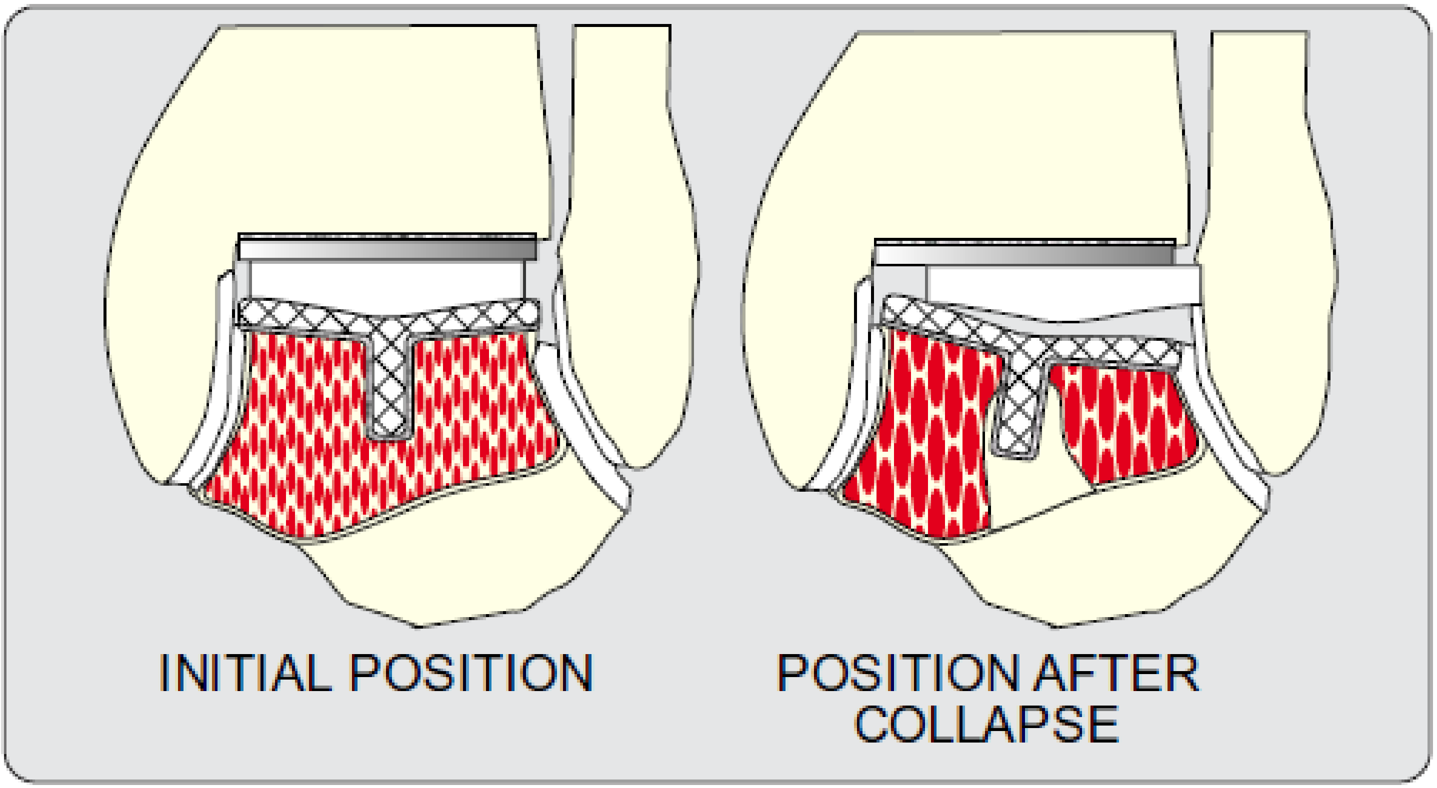
Although the performance of this device was satisfactory, as a result of the authors development of the a knee prosthesis in 1978 , it occurred to them that a meniscal type bearing would eliminate unnecessary ML and AP constraints and thus provide a superior design. This lead to the development of the B-P Mark I, Total Ankle Replacement device

B-P Mark I Meniscal Bearing Ankle

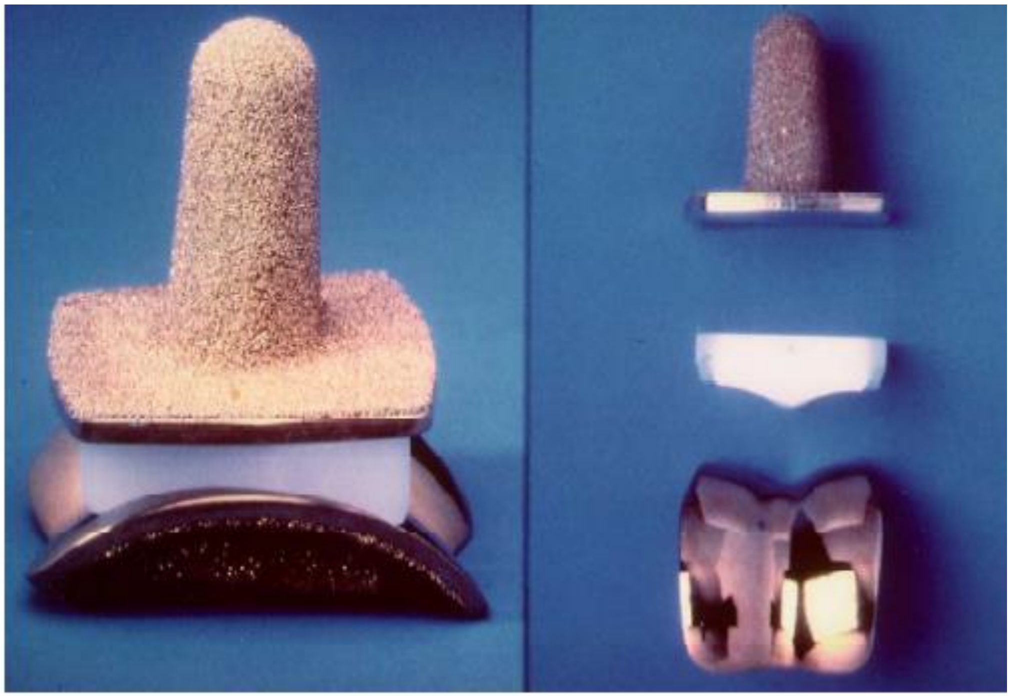
A three part design consisting of Co-Cr talar and tibial components with in interlaying bearing of UHMWPe. It was available in six sizes and intended for cemented fixation

This design also worked reasonably well but due to the failures discussed earlier the Mark I design was changed in order to reduce blood supply disruption and risk of bearing subluxation. The result was a design with a deeper sulcus and shorter, dual fins. This dual fin arrangement also reduces the tendency of a fin to transfer load distally, thus reducing stress protection. Further, finite element analysis of the Mark I indicated that the tibial plate was too thin. Its thickness was, therefore, increased in the Mark II

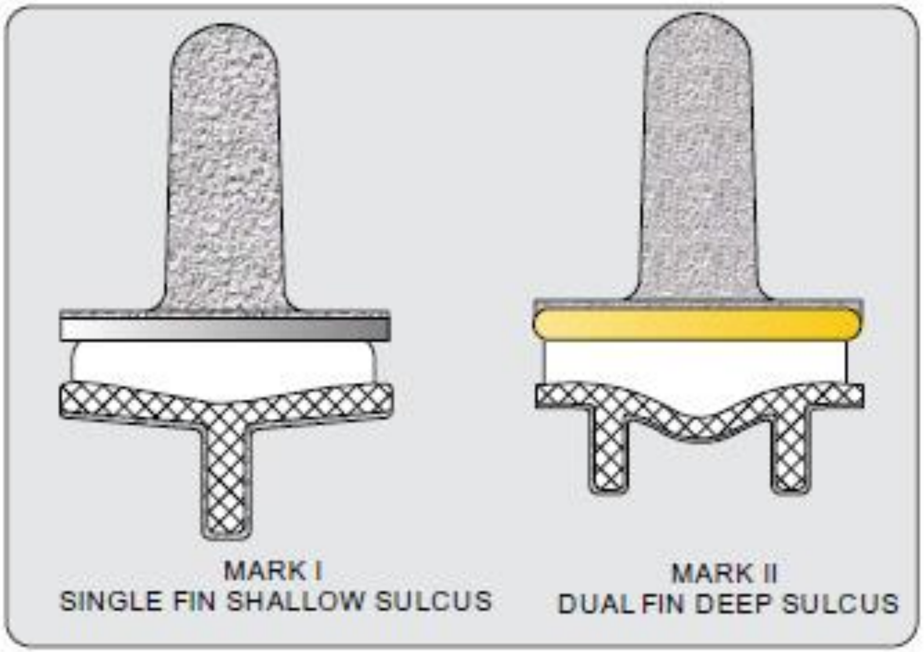
Failure Mode of the Mark I



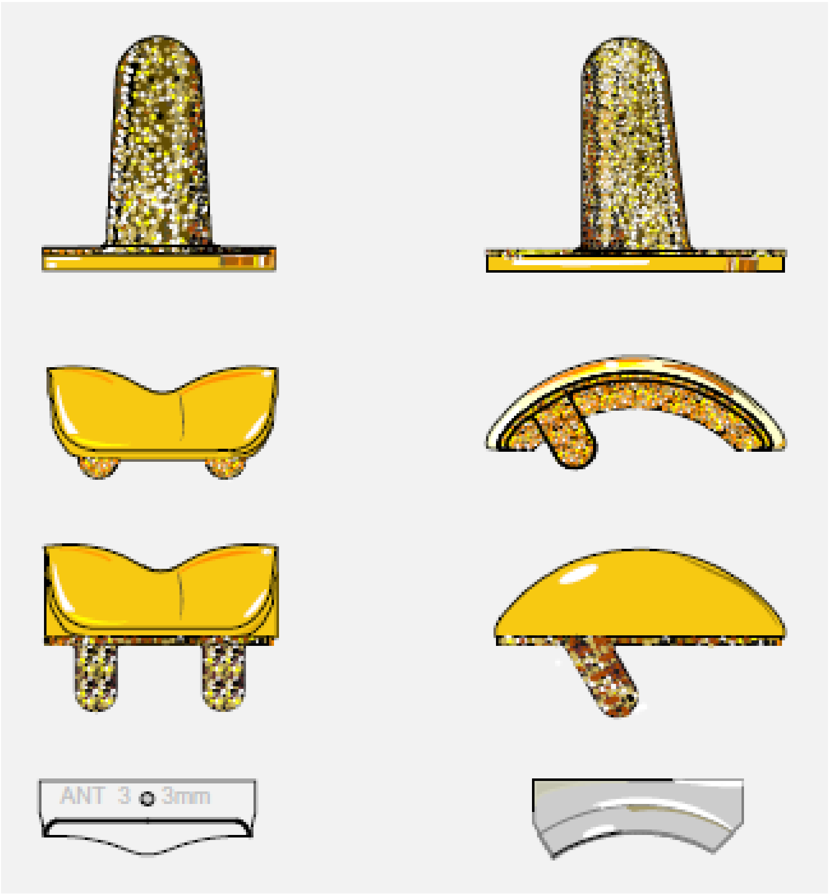
B-P Meniscal Total Ankle Replacement Mark II, 1989

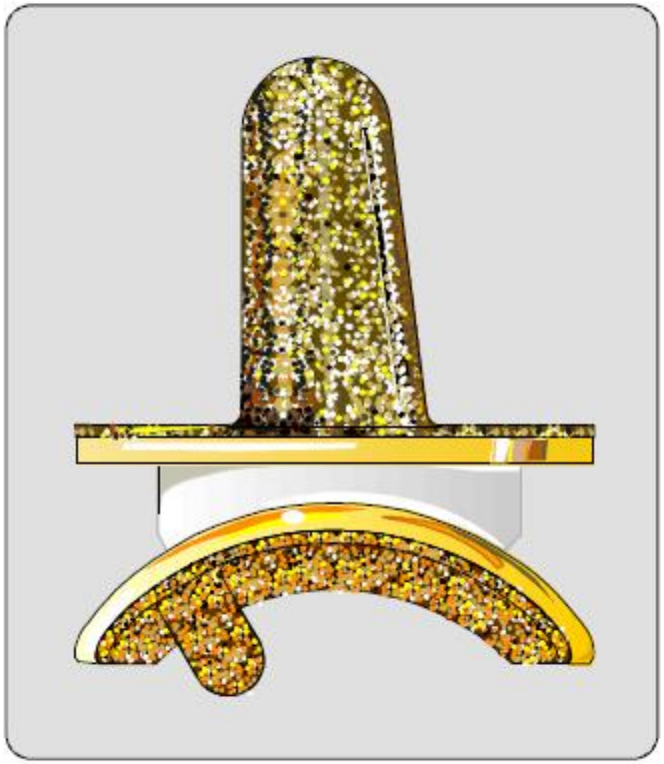


Comparison of the Mark I and Mark II Devices



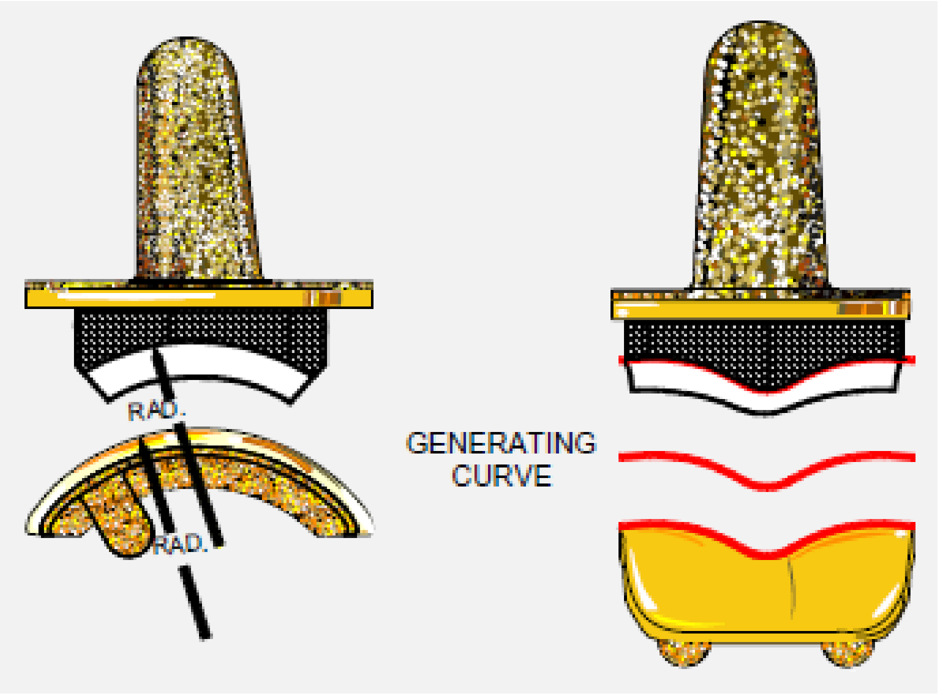
B-P Mark III Total Ankle Replacement System





Properties of the B-P Mark III

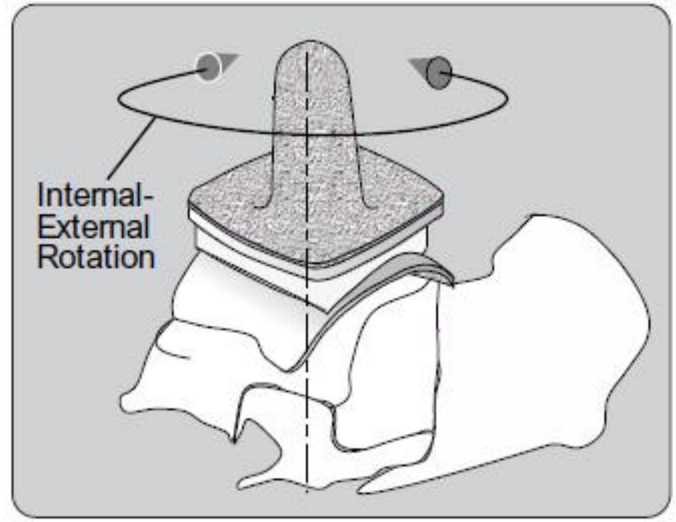
Surfaces

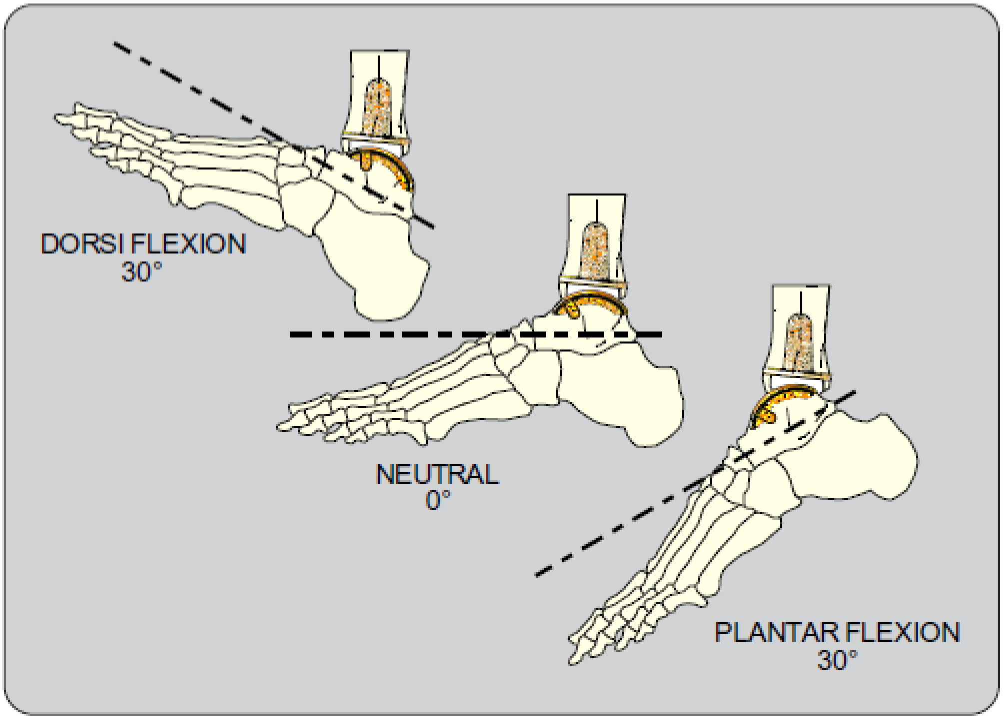


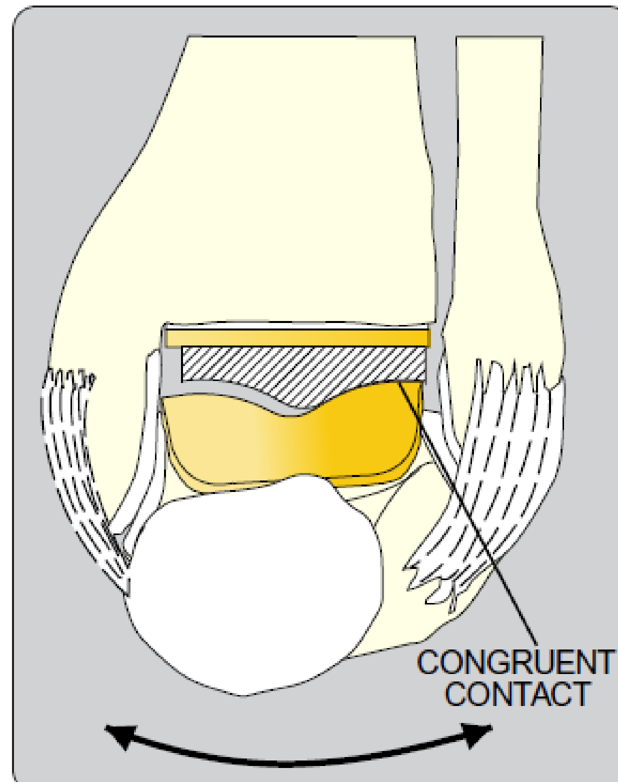
Use of Common Generating Curve for the Talar and Bearing Articulating Surfaces.

Ankle Motion

Unlimited axial rotation



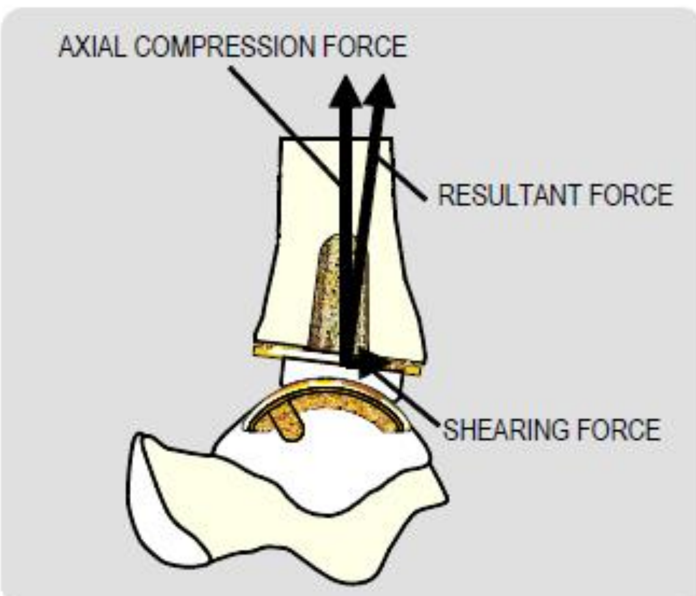


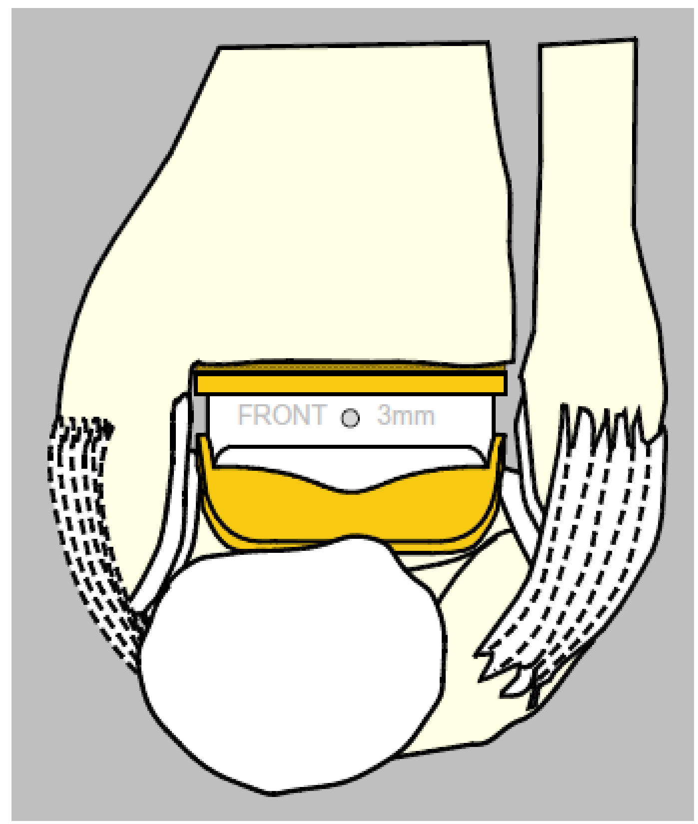


A-P Stability, M-L and I-E Stability

A-P stability of the B-P ankle is primarily extrinsic, as is the natural ankle

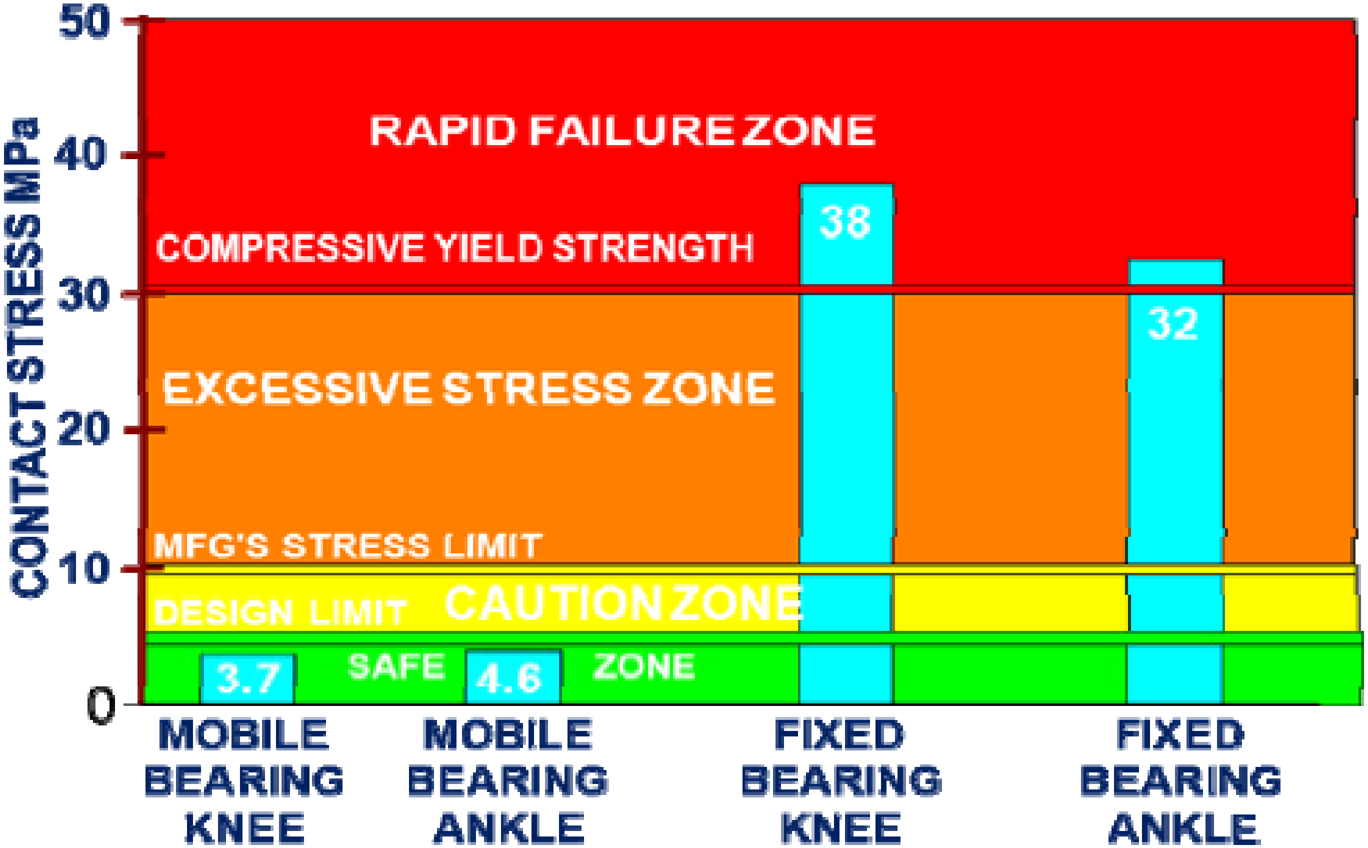
Since the B-P Ankle resurfaces the tibiotalar joint with near natural articulating surfaces it is similar in these stability modes to the normal ankle



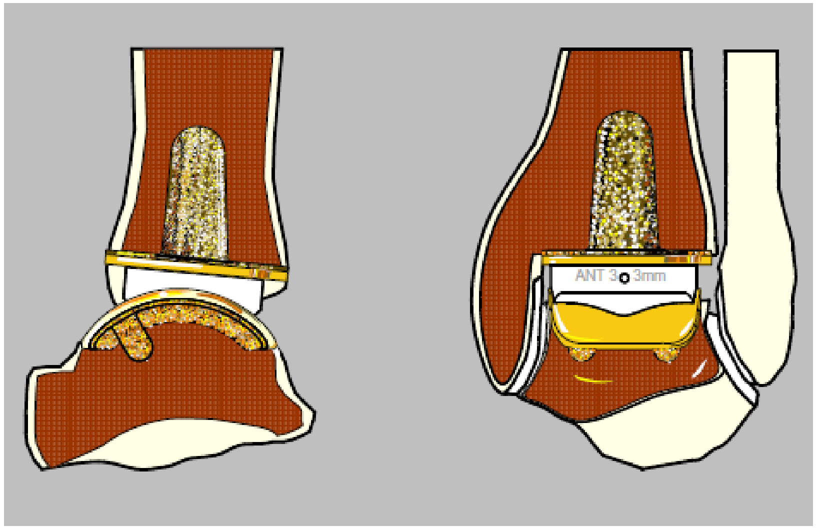


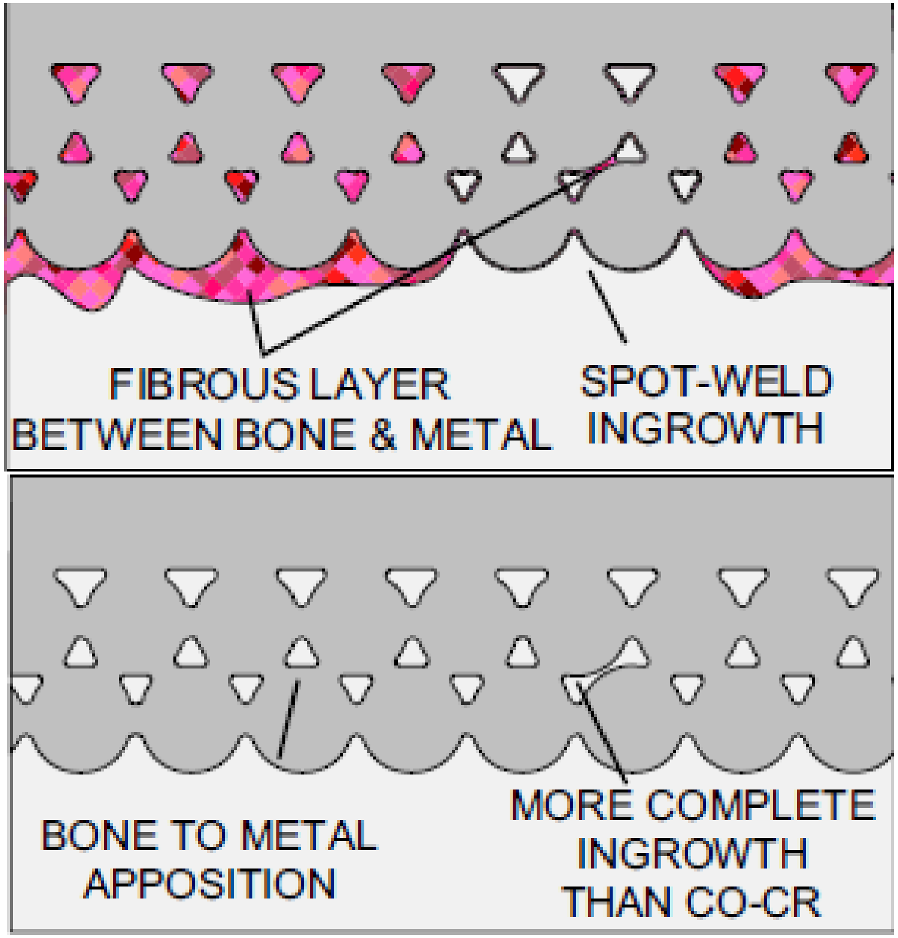
Surface Contact Stress for the B-P Mark III Ankle and Typical Fixed Bearing Prostheses

Force Resistance



Fixation





Biocompatibility

Remaining Problems

- **Cysts, osteolysis**
- **Talar Collapse**

    Avascular Necrosis (AVN)

    Progressive Osteolysis

The Future

Major problem is the adverse reaction to even minor UHMWPe wear

Solutions to this problem appear to be better metallic surface finishing and bearing materials