**Chief Complaint:** 14-year-old girl admitted with a broken left leg.

**History:**  Nicole Michaelson, a 14-year-old girl, was skiing when she fell and broke her left leg. As she fell, her left leg got caught under the body of another skier who ran into her. An X-ray revealed that the fracture was a compound, tibial-fibular fracture just below the knee. The X-ray also revealed a torn meniscal cartilage in the knee above the fracture. The girl remained in the hospital for 14 days because of an infection of the leg in the area of skin breakage. Her immobilized leg was casted after the infection subsided. She remained in a full leg-length cast for 3 months, after which the upper portion of the cast was removed and she was allowed to start bearing weight on the leg. The bones ultimately healed, but the girl continued to have left knee swelling ("water on the knee") and pain made worse by walking. Arthroscopic examination of the knee revealed a meniscus that was still torn 6 months after her injury.

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**Questions**:

1. **What does the term "tibial-fibular fracture" mean?**

*A tibial-fibular fracture is a fracture of both the tibia and fibula in the lower leg*.

2. **What is a compound fracture?**

*A compound fracture is one in which the broken bone is protruding through the skin.*

**3. Why was her injury more likely to become infected than a routine fracture of the leg?**

*Nicole's compound fracture wound is more likely to become infected than a simple fracture because the bone is protruding through the skin. The skin is normally colonized with bacteria that could infect underlying tissues when the skin is broken down. Nicole's wound should be watched very carefully for infection because infections of osseous (i.e. bone) tissue are particularly difficult to treat*

4**. Describe the microscopic features of osseous tissue that help long bones withstand lateral stress without breaking.**

A lateral stress placed on a bone (e.g. on Nicole's left tibia and fibula) actually causes (A) compression of the bone on the side of impact and (B) stretching (tearing) on the side opposite of the impact. d-way through the bone, these "compressive" and "tearing" forces cancel each other out, and thus tough compact bone is not needed in the middle. Instead, this middle area (or "medullary cavity") is filled with yellow and red bone marrow.

The outer rim (or "bony collar") is what experiences the greatest stress on lateral impact. It withstands this stress in the following ways:

(A) On the side of impact, the bony collar withstands compressive crushing by virtue of the tough hydroxyapatite crystals in its extracellular matrix. Arranged in concentric layers within the osteons (Haversian systems) of compact bone, these hydroxyapatite crystals serve as weight-bearing pillars for the bone.

(B) On the side opposite of the impact, the bony collar withstands tearing apart by virtue of the vertically arranged bundles of tough collagen in the extracellular matrix of bone. This collagen is oriented in a spiraling vertical pattern in which the fibers in each concentric lamella are roughly perpendicular to those in adjacent lamellae (i.e. a "plywood-like" design).

5. **Describe the microscopic features of the osseous tissue that help long bones withstand compressive forces without breaking.**

*The bony collar of long bones helps them withstand compressive stress by the mechanism described in #4A above (i.e. hydroxyapatite, weight-bearing pillars). In addition, long bones also withstand compressive forces by virtue of the spongy ("cancellous") bone in the epiphyses. The interlocking network of bony plates (called "trabeculae") found in spongy bone help to distribute the weight of the body out to the tough bony collar of the diaphysis. In this way, bony plates act much like the trusses or struts in old-time railroad bridges which distribute the weight of the train evenly over the entire bridge.*

**6. What features of the knee joint structure help minimize friction between the thigh bone and the leg bone?**

*The knee joint is a synovial joint. Its capsule is filled with a lubricating synovial fluid which helps reduce friction between the femur and the tibia during flexion and extension of the knee. The articular surfaces (i.e. joint surfaces) of the femur and tibia are covered with smooth hyaline cartilage, which also helps to reduce friction between these two bones. Finally, there are two half-moon shaped pieces of fibrocartilage, called the medial and lateral menisci, which lay on top of the tibial surface. The shapes of these menisci match the shape of the medial and lateral condyles on the distal surface of the femur, allowing for some stabilization of the knee joint as well as a shock absorbing function during weight-bearing.*

**7. Describe the changes a broken bone undergoes as it is healing**.

*Steps in repair:*

*A. fracture hematoma (i.e. blood clot) forms*

*B. soft tissue callus*

*• fibroblasts and osteoblasts migrate in from the periosteum and (1st 3 to 4 weeks) endosteum*

*• fibroblasts lay down a collagen matrix - some of the fibroblasts differentiate into chondroblasts (i.e. cartilage-forming cells) and lay down a fibrocartilage splint (i.e. soft tissue callus)*

*C. bony callus - osteoblasts begin to replace the fibrocartilage splint with spongy bone, forming a bulge that is initially wider than the after the injury.*

*D. bone remodeling - as the patient starts to use (or bear weight on) the bone, the bone starts to remodel along lines of maximal stress (this remodeling process requires the activity of both osteoblasts and osteoclasts)*bony callus remodeled bone (the bulged area shows up on an X-ray and should not be confused with bone cancerTop of Form

8*. How does weight-bearing influence the bone repair process you described above? (i.e. what effect does weight-bearing have on the orientation of the Haversian systems?)*

*The most popular hypothesis regarding the effect of weight-bearing on bone remodeling is called Wolff's law. Wolff's law states that bone grows and remodels in response to the mechanical stresses placed upon it (e.g. from muscle pull or gravitational pull). Thus, bone is laid down along lines of maximal stress.*

*This is presumably why:*

*A. long bones are the thickest midway down the diaphysis, where the stresses are the greatest.*

*B. curved bones are the thickest where they are most likely to buckle*

*C. the bony plates in spongy bone are oriented like weight-bearing trusses.*

*D. large bony processes are located where muscles attach to (and pull on) bone.*

*At the microscopic level, the Haversian systems in bones tend to be laid down along the lines of maximal stress. As one's exercise activities change, the microscopic architecture of bones change. For example, a woman who wears flat shoes for several years will undergo significant bone remodelling if she starts to wear high-heeled shoes. And individuals who are exposed to gravity-free environments for prolonged periods of time (e.g. astronauts) experience slow, microscopic disorganization of the Haversian systems.*

*The ability of a bone to develop the most efficient mechanical structure to suit its needs is truly remarkable, as illustrated by the use of fibular grafts. In this procedure, patients who have had the mid-portion of their tibia removed (e.g. to remove a cancer) can have it replaced with a fibular graft. The fibula, which has very little weight-bearing function, is removed, and a portion of it is placed in the area of the missing portion of the tibia. Over time, as the individual begins to bear weight on the graft, the grafted fibula comes to look just like the former tibia. Fibular grafts can also be used to replace lost arm bones, and a similar remodelling process occurs here* too.

**9. Why did Nicole's bones heal much more quickly than her cartilage?**

*Despite their seemingly dead appearance, bones are very much alive and have a good blood supply. Cartilage, on the other hand, has a relatively poor blood supply, often receiving its nutrients indirectly through diffusion from neighboring tissues and synovial fluid. Because of its good blood supply, bone heals relatively quickly. Cartilage, on the other hand, is very slow to heal, and sometimes never heals. Tendons and ligaments, whose blood supply is intermediate between bone and cartilage, is correspondingly slower to heal than bone but faster to heal than cartilage*.

*Nicole's meniscus was still damaged six months after her injury. Sometimes, torn meniscal cartilage must be removed via arthroscopic surgery. In the elderly with osteoarthritis, the entire knee joint is sometimes surgically replaced with a prosthetic joint.*

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