Biomechanics of Joints and Orthopaedic Implants
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Lecture 39
Bone Fracture Healing

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Good morning everybody.

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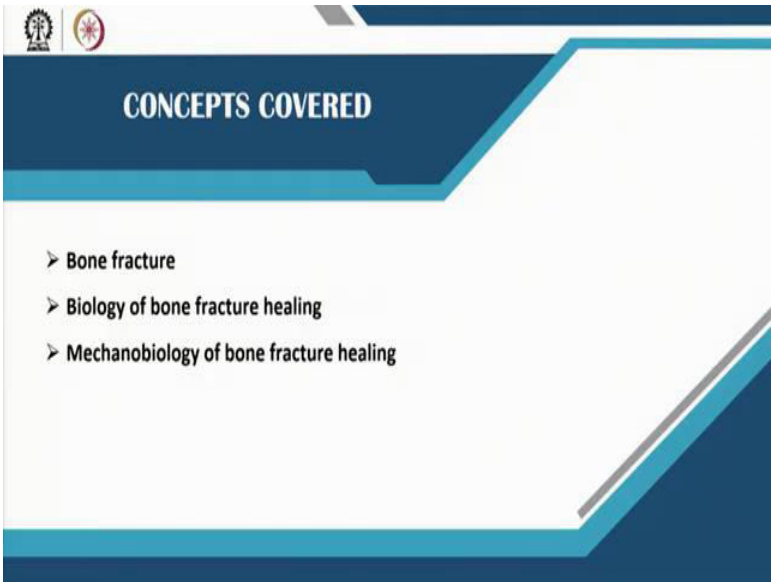

The concepts covered in this lecture are bone fracture, the biology of bone fracture healing, and the mechanobiology of bone fracture healing.

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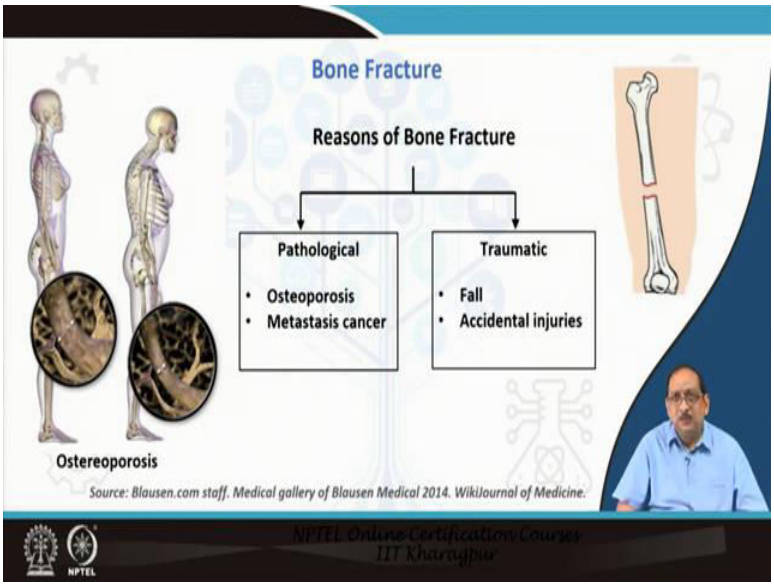

Let us discuss the reasons for bone fracture. Reasons may be pathological as well as traumatic. The pathological reasons may be due to osteoporosis and metastasis and cancer. Traumatic reasons may be due to fall, or accidental injuries.

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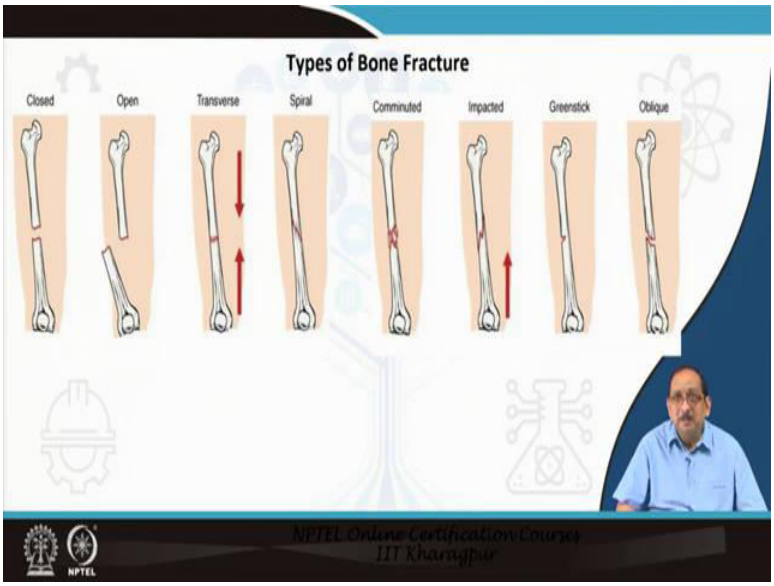

There are several types of bone fracture presented in the slide, which may be closed, open transverse, and spiral. It may also be comminuted, impacted, Greenstick and oblique.

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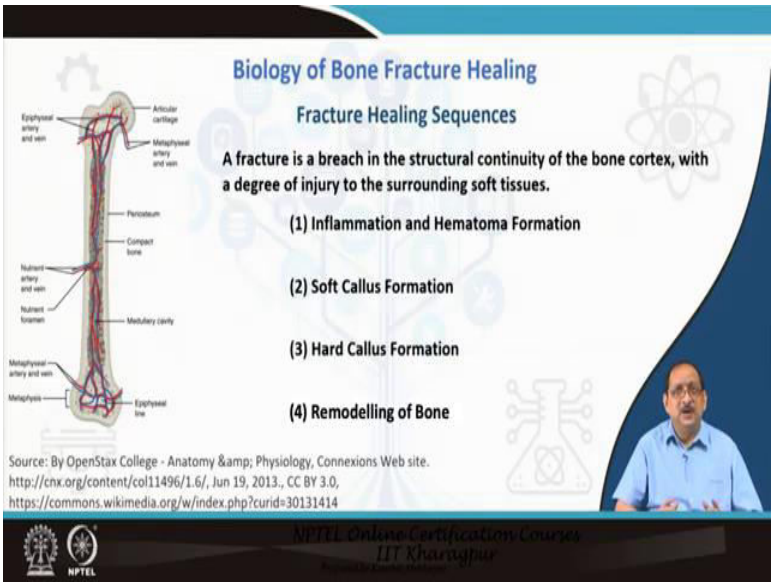

Now, let us discuss the biology of bone fracture healing. First, the sequence of bone fracture healing is discussed. So, a fracture is a breach in the structural continuity of the bone cortex, with a degree of injury to the surrounding soft tissue. The sequences are inflammation and hematoma formation, soft callus formation, hard callus formation, and finally, remodelling of bone.

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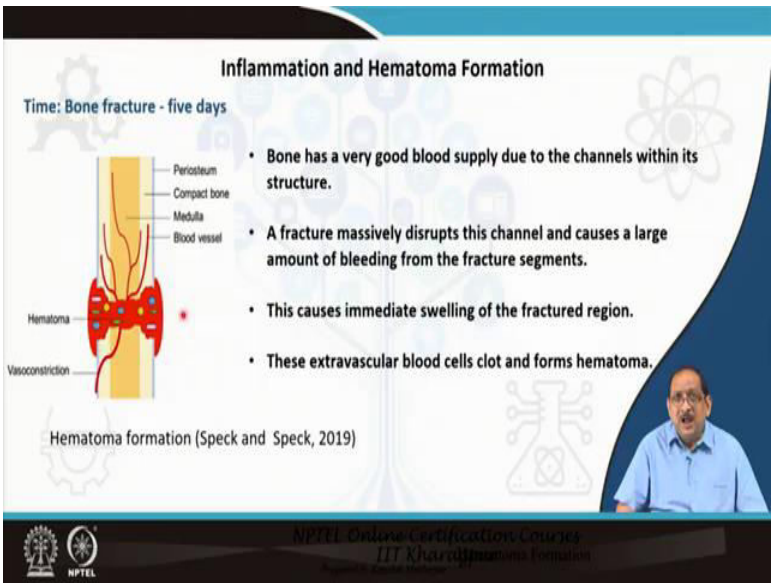

Inflammation and hematoma occur from the point of fracture within five days. Bone has a very good blood supply due to channels within its structure. A fracture massively disrupts this channel and causes a large amount of bleeding from the fracture segments. This causes immediate swelling of the fracture site. So, you can see that there is swelling of the fracture side. These extravascular blood cells clot and forms hematoma.

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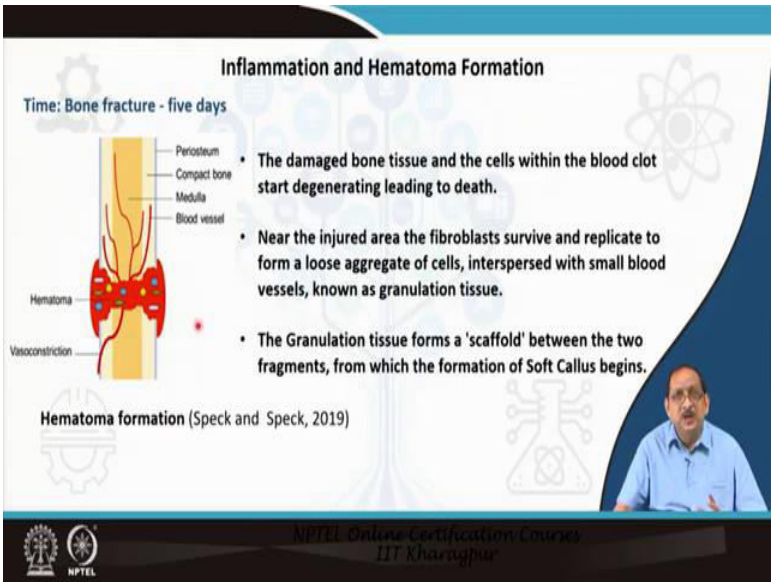

The damaged bone tissue and the cells within this blood clot start to degenerate leading to death. The fibroblasts survive and replicate near the injured area to form a loose aggregate of cells scattered within small blood vessels, together known as granulation tissue. The granulation tissue forms a scaffold between the two fragments, from which the formation of the soft callus begins.

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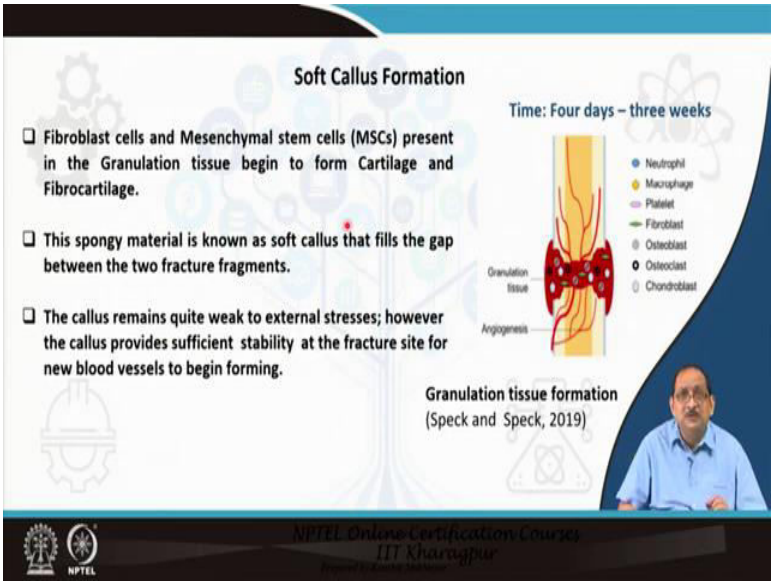

Now, the fibroblast cells, there are many specialized cells that are taking part in this whole process, as you can see on the right. The fibroblast cells and the Mesenchymal stem cells present in the granulation tissue begin to form cartilage and fibrocartilage. this spongy material, known as soft callus, fills the gap between the two fragmented, fractured bony parts.

The callus remains relatively weak to external stresses. However, the callus provides sufficient stability at the fracture site for new blood vessels to begin forming.

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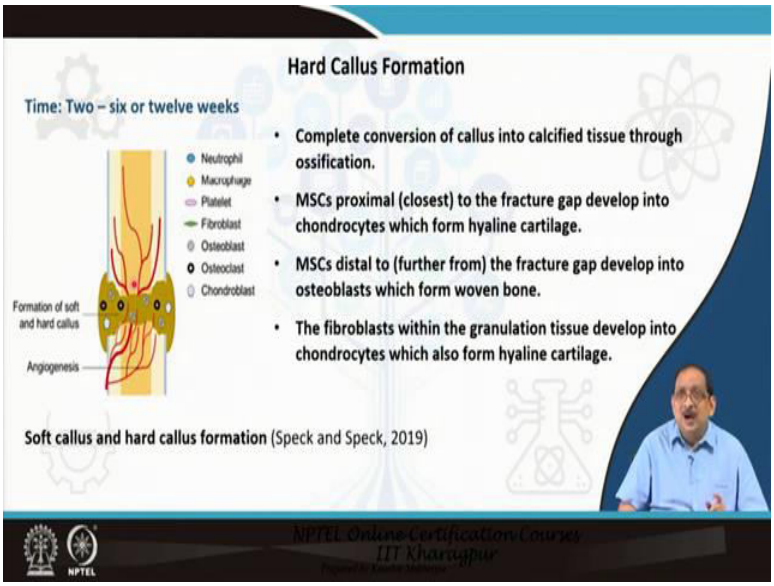

Now, the hard callus is formed due to the complete conversion of the soft callus into calcified tissue through ossification. And this occurs between 2 to 6, 12 weeks after fracture. The MSCs closest to the fracture site develop into chondrocyte, which forms hyaline cartilage. MSCs is distal to the fracture gap develop into osteoblasts, which form woven bone.

The fibroblasts within the granulation tissue develop into chondrocyte, which also forms hyaline cartilage.

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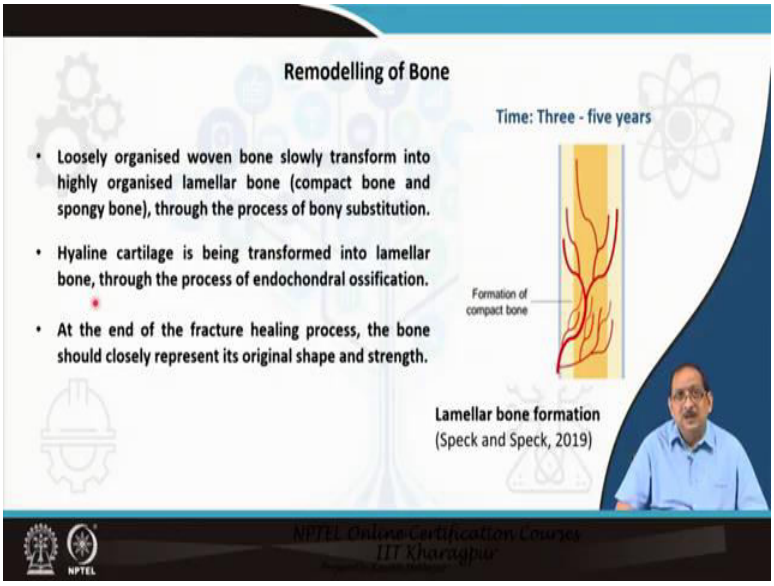

The final phase is the remodelling of bone. Here in the closely woven sorry, here in the loosely organized woven bone slowly transforms into highly organized lamellar bone, it may be compact bone and spongy trabecular bone, through the process of bone substitution. The hyaline cartilage is being transformed into the lamellar bone through the process of endochondral ossification. The bone should closely represent its original shape and strength at the end of the fracture healing process.

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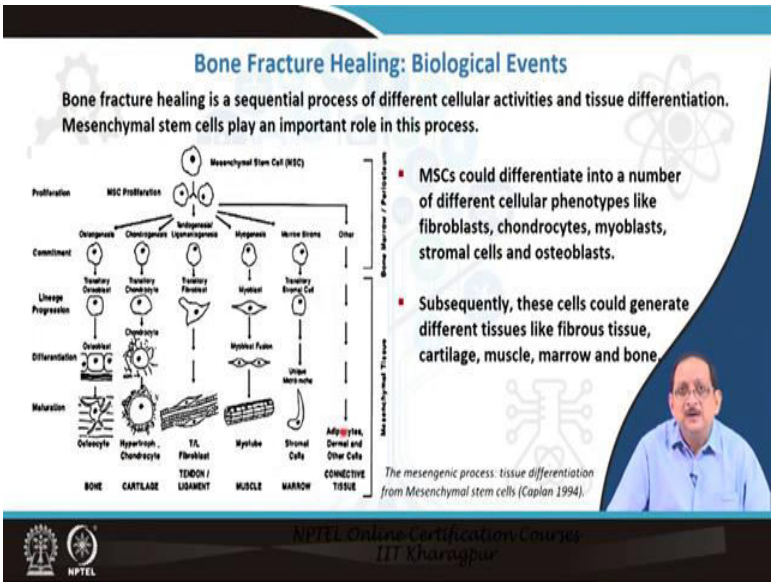

Let us discuss the biological events of bone fracture healing. Bone fracture healing is a sequential process of different cellular activities and tissue differentiation, wherein the mesenchymal stem cells play an essential role in the process. The MSCs could differentiate into several different cellular phenotypes, like fibroblasts, chondrocyte myoblast, stromal cells, and osteoblasts.

Subsequently, these cells could generate different tissue types like fibrous tissue, cartilage, muscle, marrow, and bone. This is presented in the form of a figure on the left.

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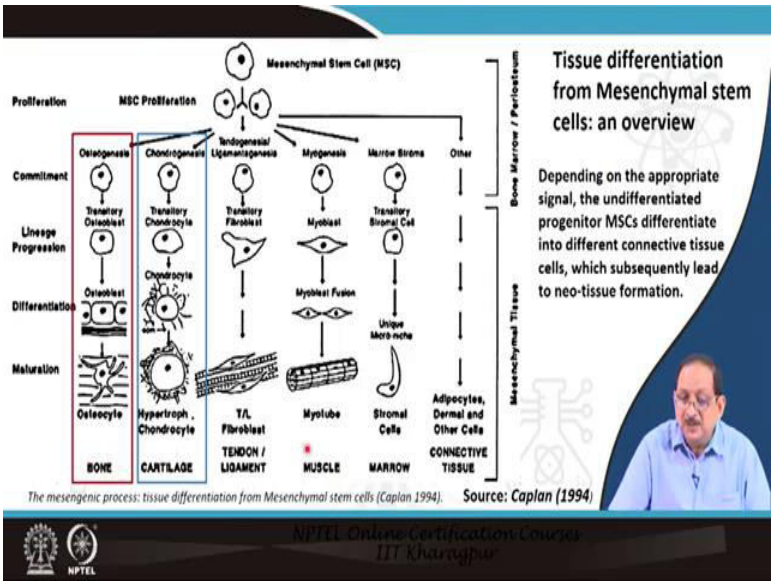

Now, let us look more inside this figure, wherein tissue differentiation from mesenchymal cells has been discussed. Depending on the appropriate signal, the undifferentiated MSCs differentiate into different connective tissue cells, like osteoblasts, chondrocyte, fibroblast, myoblast, as discussed earlier, leading to neo-tissue formation.

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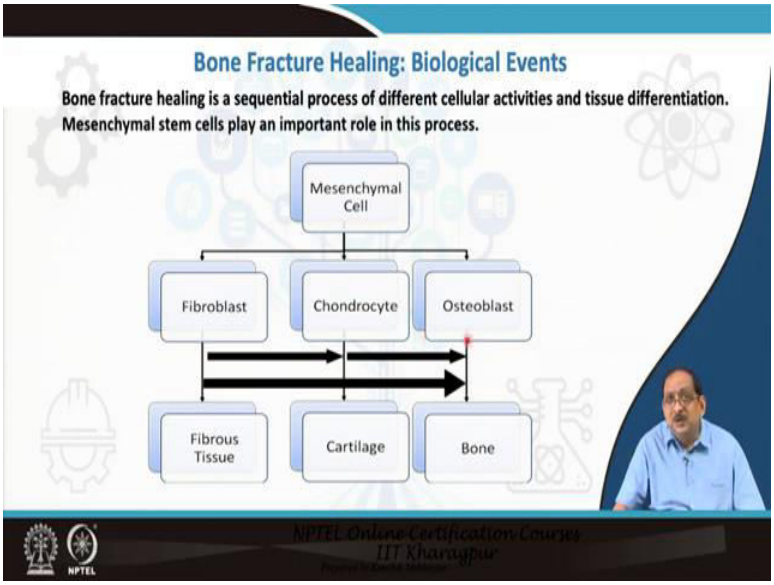

Now, let us discuss in detail the biological events of the fracture healing process. Bone fracture healing is a sequential process of different cellular activities and tissue differentiation. The mesenchymal stem cells play an important role in this process. So, you can see the mesenchymal stem cells can differentiate into several cell phenotypes, like fibroblast, chondrocyte, and osteoblasts.

It can also form myoblast and stomal cells. Individual fibroblasts could generate fibrous tissue; chondrocytes could generate cartilage, osteoblast would generate bone tissue. However, the fibroblast can also differentiate into chondrocytes, it can also differentiate into osteoblasts whereas, chondrocytes can differentiate into osteoblasts.

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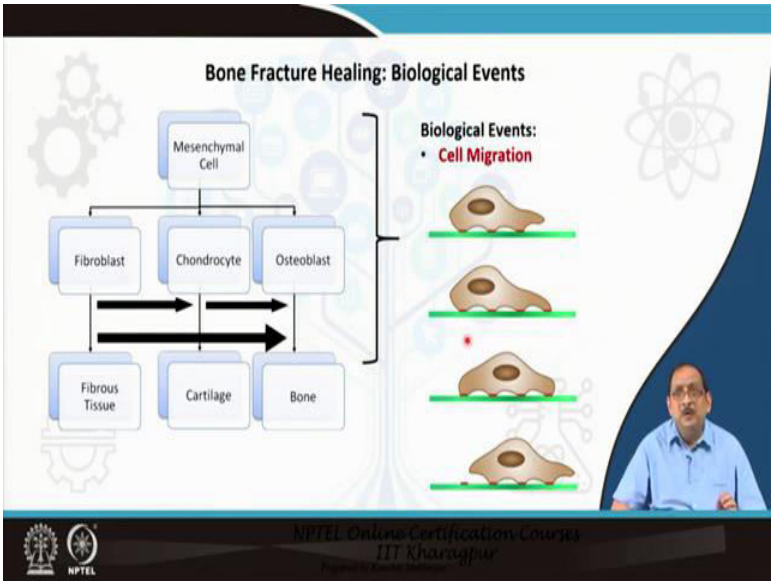

Now, the individual process of these biological events are discussed. The first is cell migration; cell migration is the directed movement of a single cell or a group of cells in response to chemical or mechanical signals.

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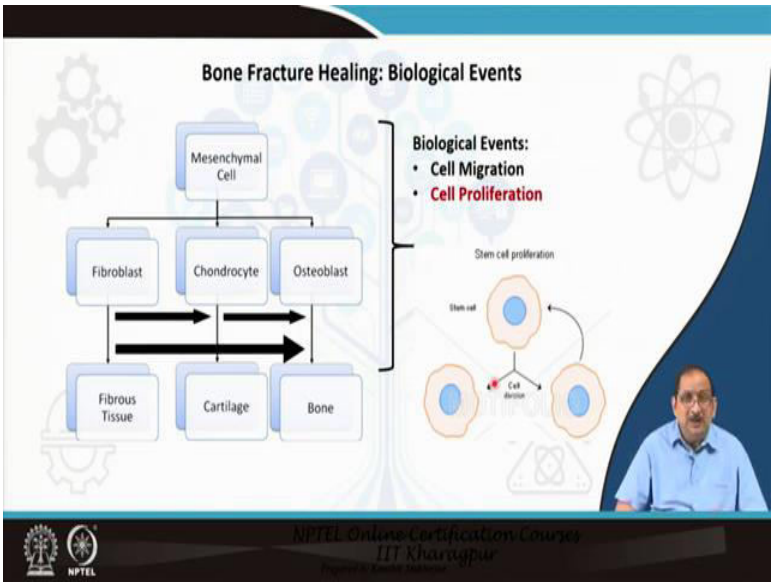

Cell proliferation is how a cell grows and divides into the same type of daughter cells. This leads to an exponential increase in cell number of the same type, eventually leading to a rapid mechanism of tissue ingrowth.

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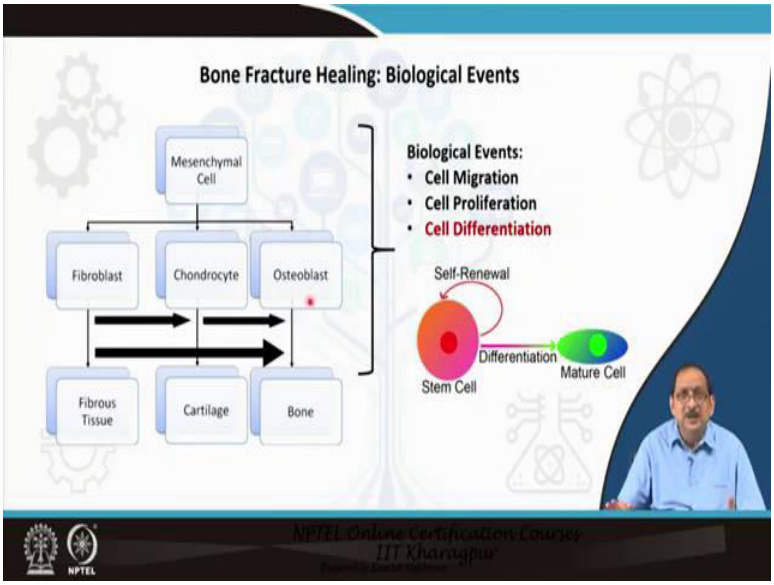

Finally, cell differentiation is the process by which a cell changes from one cell type to another. So, it is from one kind of cell to a different kind of cell, say from fibroblast to chondrocyte, and osteoblast, or chondrocyte to osteoblast, can be the activity the event can be summarized as cell differentiation.

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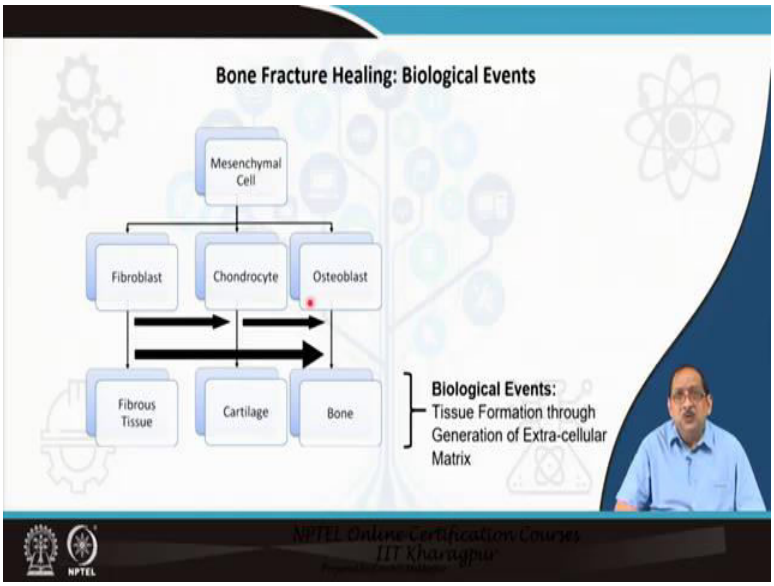

Finally, the tissue is formed through the generation of an extracellular matrix.

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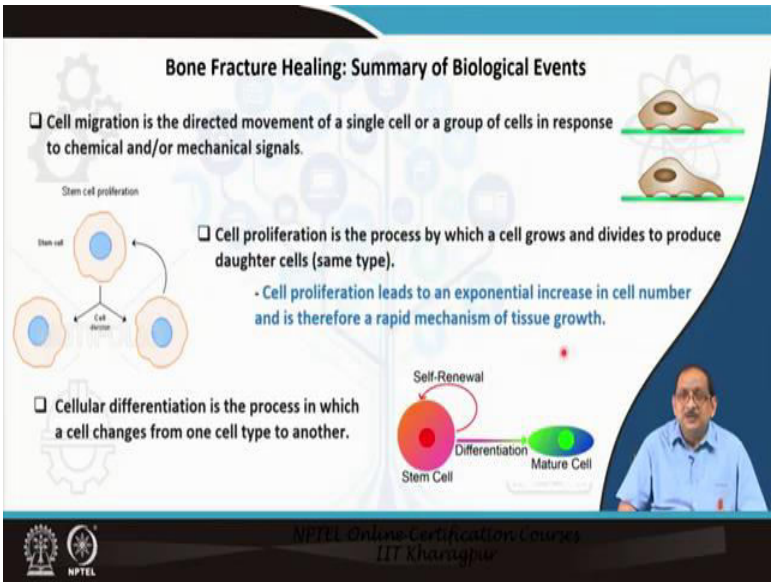

Now, let us summarize the biological events of this complex process. Cell migration is the directed movement of a single cell, or a group of cells, in response to chemical and or mechanical signals. Cell proliferation is a process by which a cell grows and divides into the same type of daughter cells.

Cell proliferation leads to an exponential increase in cell number and is, therefore, a rapid mechanism of tissue growth. Cell differentiation is a process by which a cell changes from one type to the other, as I discussed earlier, from fibroblast to chondrocyte and osteoblasts.

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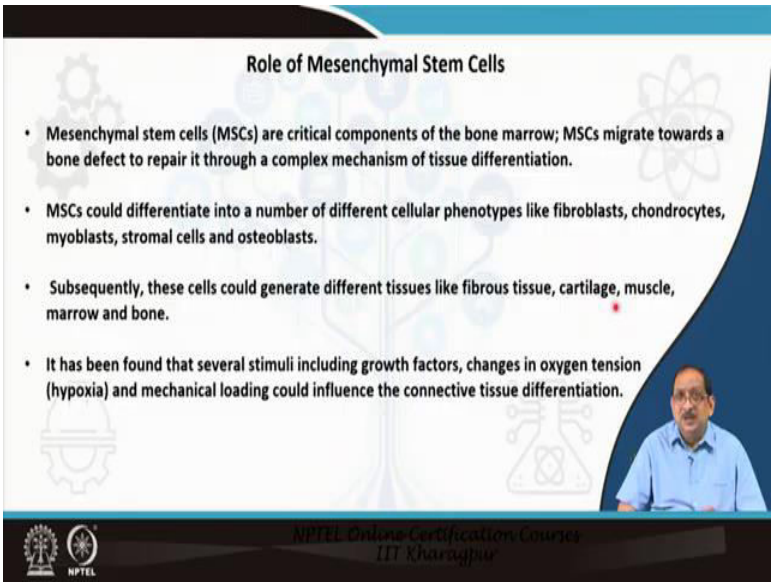

Let us summarize now the role of the mesenchymal stem cells. The mesenchymal stem cells are a critical component of the bone marrow; they migrate towards a bone defect to repair it through a complex mechanism of tissue differentiation. MSCs could differentiate into a number of different cellular phenotypes, like fibroblasts, chondrocytes, myoblast, stromal cells, and osteoblasts.

Subsequently, these cells could generate different tissue types, like fibrous tissue, cartilage, muscle, marrow, and bone, respectively. It has been found that several stimuli, including growth factors, changes in oxygen tension and mechanical loading, could influence connective tissue differentiation.

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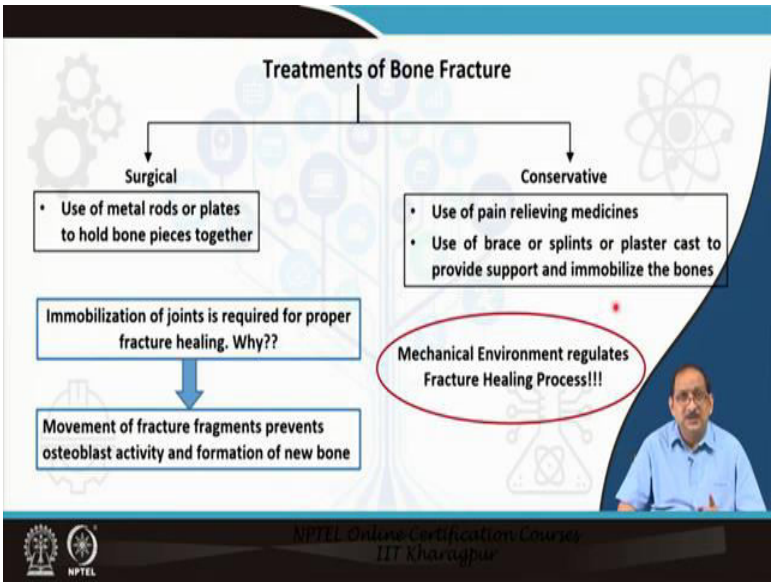

Now, let us move into the treatments of bone fracture. The treatments of bone fracture can be surgical as well as conservative. The surgical treatment involves use of metal rods or plates to hold the bone pieces together. The conservative treatment is based on medicine use of brace, splints, or plaster cast to provide support and immobilize the bone.

Now, immobilization of the joint is required as a primary requirement for proper fracture healing. Why is that? Because the movement of the fragmented pieces of fracture prevents osteoblastic activity and thereby the formation of new bone. It is very important to note that the mechanical environment regulates the process of bone fracture healing.

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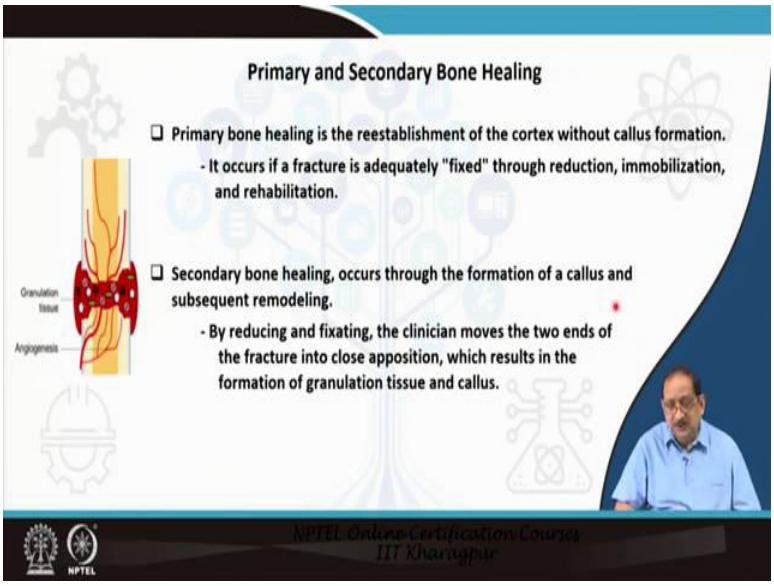

Let us discuss about primary and secondary bone healing. The primary bone healing is the re-establishment of the cortex without callus formation. Please note without callus formation. It occurs if a fracture is adequately fixed through reduction, immobilization, and rehabilitation.

However, secondary bone healing occurs through the process of callus formation and subsequent remodelling as we had discussed earlier. By reducing and fixating, the clinician moves the two ends of the fracture into close apposition, resulting in granulation tissue and callus formation.

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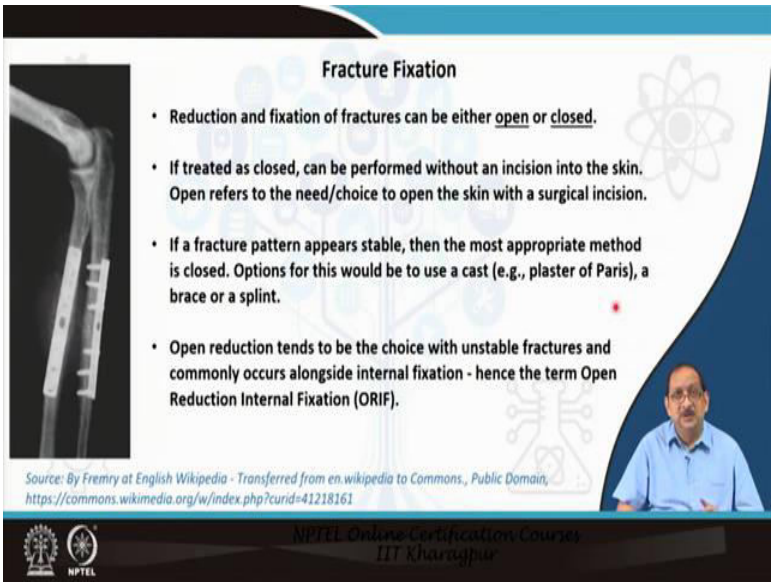

Now, what are the types of fracture fixation? The reduction and fixation of fractures can be either open or closed. If treated as closed,, it can be performed without an incision into the skin. Open refers to the need choice to open the skin with a surgical incision. If fracture patterns appear stable, then the most appropriate method is closed.

Option for this could be plaster clast, plaster cast, a brace, or a splint. Open reduction tends to be the choice with unstable fractures and commonly occurs alongside internal fixation, hence the term open reduction internal fixation ORIF.

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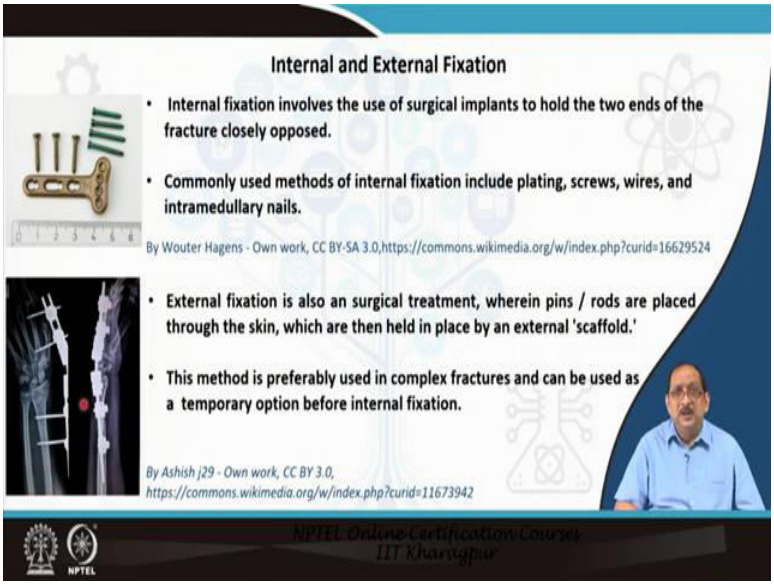

Now, let us discuss some methods of internal fixation. The internal fixation involves the use of surgical implants to hold the two ends of the fracture closely opposed. Commonly used methods of inter fixation include plates, screws, wires, and intramedullary nails.

The external fixation in contrast, is also a surgical treatment, wherein pins and rods are placed through the skin, then held in place by an external scaffold, as shown in the figure. This method is preferably used in complex fractures and can be used as a temporary option before internal fixation.

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Now, let us discuss the factors that affect the bone fracture healing process. There are multiple factors known to affect the process, some of which I am discussing here in this lecture. The local factors are the fracture characteristics, excessive movement, misalignment, extensive damage, and soft tissues caught within the fracture ends can lead to delayed healing or non-union.

Infection is another major factor that threatens the healing process; it can lead to poor or delayed healing or absolute non-union. Blood supply is another major factor in the process of bone fracture healing; reduced blood supply to the fracture site can lead to delayed healing or non-union.

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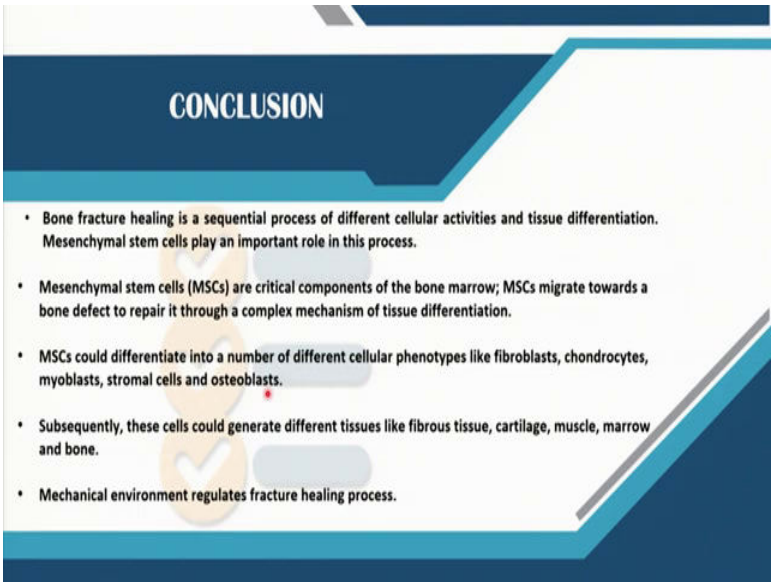

Let me summarize the conclusions of this study. Bone fracture healing is a sequential process of different cellular activities and tissue differentiation. Mesenchymal stem cells play a very

important role in this process. The mesenchymal stem cells are critical components of the bone marrow; these cells migrate towards the bone defect to repair it, through a complex mechanism of tissue differentiation.

MSCs could differentiate into several cell phenotypes, like fibroblast, chondrocyte, myoblast, stromal cells, and osteoblasts. Subsequently, these cells could generate different types of fibrous tissue, cartilage, muscle, marrow, and bone. The mechanical environment regulates the process of bone fracture healing.

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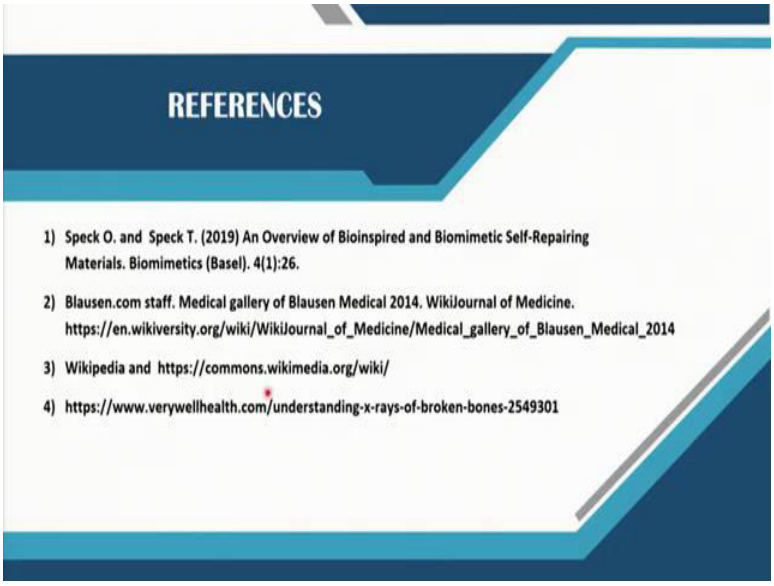

The references of this lecture are listed here.