Medical Biomaterials
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Lecture – 23
Metallic Biomaterials

Hello everyone. Welcome to the course on Medical Biomaterials. We are going to start a new topic that is the metallic biomaterials. Metals have been used as biomaterials for a very long time. They are being used from historically especially after a fracture, replacement of bones, in dental applications, (Refer Time: 00:36) the jaw sometimes artificial teeth, orthodo notic applications and in cardiovascular region, some high sophisticated metal alloys, shape memory metal alloys are being used in cardiovascular application. So, metals have been therefore, very long time they have several properties which are very advantages. And of course, metals are used a in your bio senses, pacemakers and so on. Especially as lead wires because you need to have metallic ends which can transport current.

So, metals have already have been used for quite some time. So, we are going to spend some time on metallic biomaterials where they have been used what are their properties, their advantages disadvantages and so on actually. As you know they got many advantages of course, they also have disadvantages like number one corrosion. So, corrosion could lead to metals losing their properties, metal erosion could happen because of corrosion that is one thing. Another thing is metals are very strong and when they are used next to bones the most of the load may be taken up by the metals not by the bone, so that is called stress shielding

So, metals have that disadvantage, that because of stress shielding the bones do not take the weight, but all time metals take the weight, that is the another disadvantages metals. So, that is why new metals alloys or being invented. So, that there and the modulus tries to match with that of the bone. So, we look at some of these properties and some advantages in the next few classes these are called the metallic biomaterials.

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So, where there are used like I said bone and joint replacement. Joint surgery lot of metals are used chromium nickel bone, after fracture they use the titanium screws stainless steel implants. Dental implants titanium is widely used especially when they are implanting an artificial tooth because the titanium screw acts as the anchor with the jaw. Maxillo and cranio facial reconstruction after an accident if there is lot of damage to the jaw and rest of the bones in the head metal wires are used quite a lot to tie up all this ends. So, lot of metals with very good properties are tried. Cardiovascular devices things like your artificial heart pacemakers and then left heart assisted devices pumps. So, all these are cardiovascular devices. Titanium is regularly used in pacemakers, defibrillators carrier structure for replacement heart valves intra vascular stents like your cardiovascular stents metals are used external prostheses external joints external support for bones that are broken in side. Surgical instruments as you know all the surgical instruments are made up of only metals.

So, metals have lot of applications the beauty of metals is you can make it, any form unshaped because metals have been there historically for several thousands of years. So, some of the technologies well developed, and we can modify their surfaces we can modify their tensile strength another property. So, they find lot of applications.

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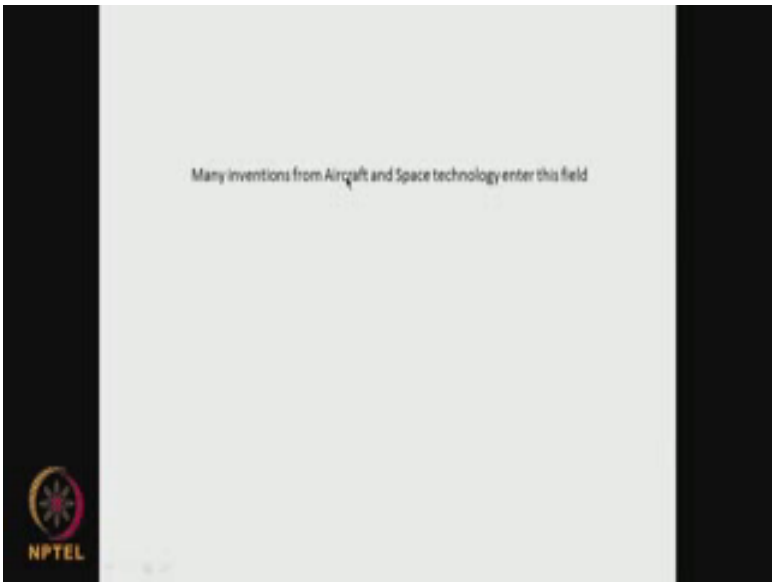

And of course, as you know the air craft industry the space technology has developed tremendously in the past 50 years. And many of the knowledge from those technologies, I have also come to biomaterials. For example, some of the high and alloys with very special properties also find their application and biomaterials light weight metals. Again find applications in biomaterials porous metals find application in biomaterials some of the combinations of metals and polymers metals in ceramics are also used quite a lot in space application they also find application in biomaterials.

So, we have to thank the aircraft industry as well as the space technology for new ideas and inventions that are happened there, which get directly transferred into the area of biomaterial.

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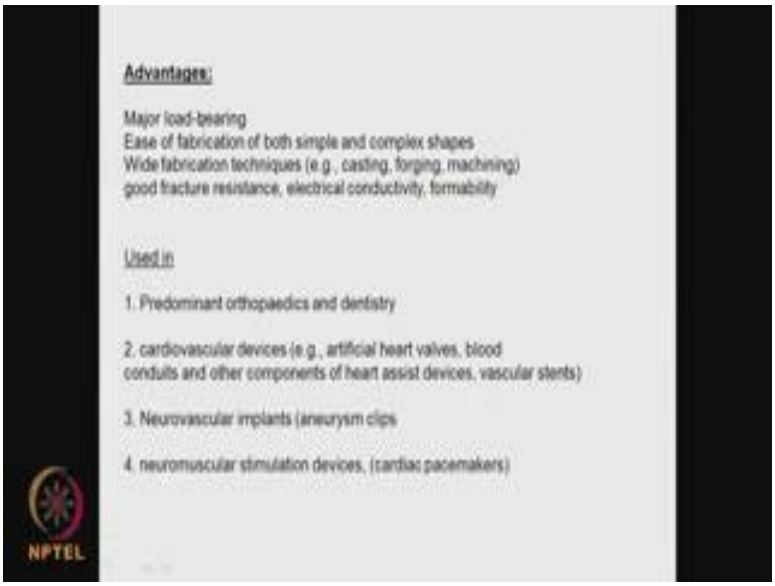

What are the advantages they have very good load bearing especially when you are talking about your foot or and the bones the legs, they have to carry lot of load is a fabrication it is very simple as I said thousands of years evolved in the metal fabrication preparation of alloys? So, they are very simple very simple struck shapes very complex shapes can be easily made, wide fabrication techniques we can do by casting forging machining. So, so many different fabrication techniques are available for metals we do not have such if you take polymers or even nonmetals like ceramics.

Of course, polymers also have some fabrication techniques, but nothing to beat this good fracture resistance. What is this fracture resistance supposing, there is a crack that is developed does not mean it will completely break, but it takes some time for it break where as you if you take a ceramic as soon as crack is developed it may break very fast the fracture resistance is very poor if you take a polymer that also has poor fracture resistance, but if you take a metal even if there are cracks the propagation, of the cracks and the development of the crack into them? So, that the material fails is longer they have very good electrical conductivity. So, of course, we use this in many applications in bio sensors lead wires. So, all this places you are going to have metals only.

Formality we can make any form. So, all these are extremely useful they are used of course, as I said in orthopedics dentistry cardiovascular like artificial heart valves, blood conduit is heart assist device sometimes, some people have there left part of the heart not

functioning properly. This could be as a congenital or it happened because of some deceases. So, the even of amount of blood is not pump to the body. So, what happens? They have some external device connected. So, this is called an assist device. So, the external device actually helps to pump enough blood out of the heart into the body they are called assist devices. And of course, they are made up of pumps and the pumps are made up of metals vascular stents the stents that are used inside after angioplasty that is called titanium.

Now titanium nickel now we have titanium, nickel bare metals or sometimes it is coated with drugs. So, all these are metals neurovascular implants aneurysm clips all these clips, which tries to bring skin and tissues together, neuromuscular stimulation devices cardiac pacemakers. So, all these areas as metals are used.

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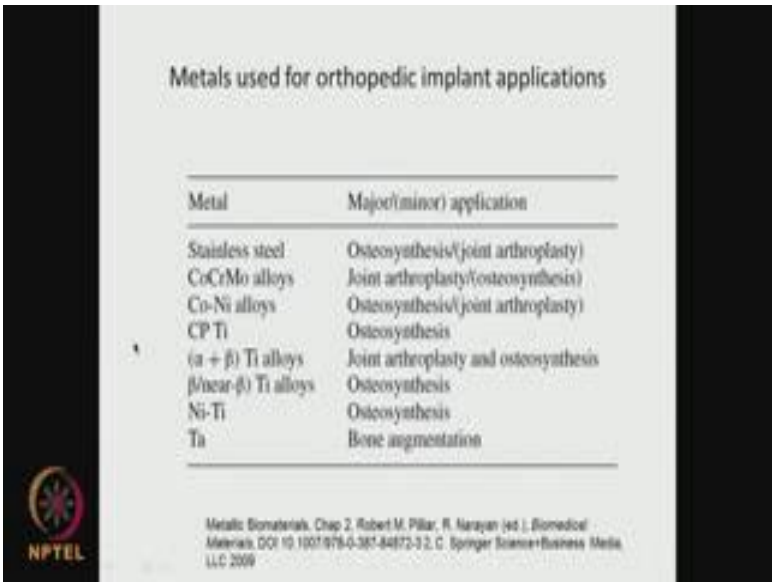

Stainless steel it is very useful it is used in osteos all related to joints stainless steel is used cobalt chromium molybdenum type of alloys again joint arthroplasty osteosynthesis, cobalt nickel alloys osteosynthesis joint commercially pure titanium osteosynthesis different types of titanium alloys joint, arthroplasty and osteosynthesis beta near beta titanium alloys osteosynthesis, nickel titanium osteosynthesis tantalum bone augmentation.

So, stainless steel and several alloys nickel they are all used catalonian orthopedic area this table is adopted from this particular reference.

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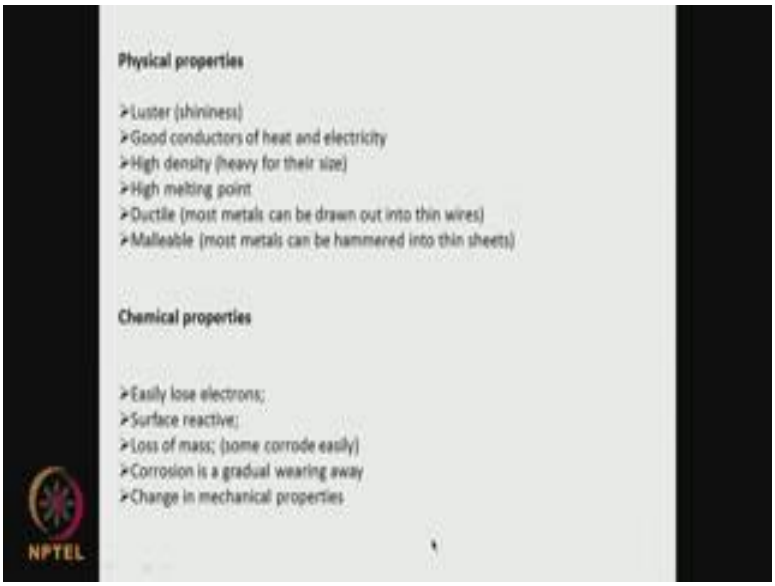

So, what are the physical properties shine shininess, luster that is the not really important if the material is placed inside the body, but it is important if it is outside the body. Good conductor of heat and electricity. So, that is useful. So, it can quickly despite heat unlike polymers which will not despite heat high density. So, there heavy for their size your small size of metal may weigh much more then the similar size of polymer high melting point that is also very useful ductile. So, we can draw into very thin wires. So, especially if you are connecting mini parts, then it as to be metallic wires. Malleable we can hammer it and make it into very thin sheets that is the beauty of metal.

So, we can have very thin material, thickness going ride up to microns. It may be very difficult for you to make it; in nonmetals these are physical properties of metals. Similarly, we have chemical properties they easily loose electrons. So, they can get charged on the surface they are surface reactive. So, if you want to add some surface groups or modify the surfaces these metals are very good. They corrode easily that is disadvantage. Stainless steel they can start corroding that is why stainless steel is good for short duration ideally titanium maybe better for long duration. So, the corrosion is problem. When it starts corroding slowly the metal can wear away.

So, if I am having a joint and slowly apart from the normal mechanical wearing if there is going to be corrosion they can start wearing out and corrosion also can form oxides, these oxides could be having lesser strength when compare to the metal. So, there could

be changes in mechanical properties. So, mechanical properties changes because of corrosion because of wearing because of oxide formation and so on actually. So, that can also happen over a longer period of time.

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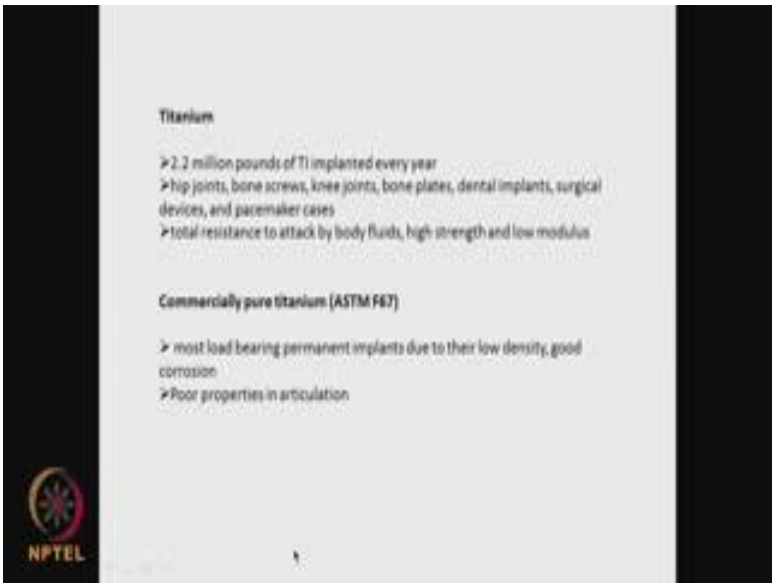

Titanium is used quite a lot 2.2 million pounds of titanium implanted every year that is a big number. So, if even if you this suppose divide by 2.2 then that is 1 million kg of titanium implanted hip joints bones screws.

So, if there are keeping a metal next to a broken bone, they are connected by screws knee joints lot of metals lot of alloys cobalt chromium are used, bone plates stainless steel titanium dental implants surgical devices pacemakers. All these titanium is used. Titanium the beauty of it is resistance to attacked by body fluids. And it is got a very high strength and low modulus unlike stainless steel stainless steel as very high modulus, if you remember almost 200 plus whereas titanium is almost half, but of course, we need to still come down if you want to match the bone which is about 40 or something, titanium of course, straight trying to come down. So, titanium alloys are coming down below hundred there is something called commercially pure titanium CP titanium. So, most load bearing permanent implants due to because they have low density. So, they modulus is slowly closer to the real bone they have good corrosion properties, but they have poor properties in articulation that is the disadvantage of this particular material, but otherwise c p titanium as got lot of advantages.

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Titanium alloys there are many other metals like vanadium aluminum niobium molybdenum iron are mixed with titanium to form alloys. And these alloys have very good properties they reduce the modulus further they also try to give them shape memory property.

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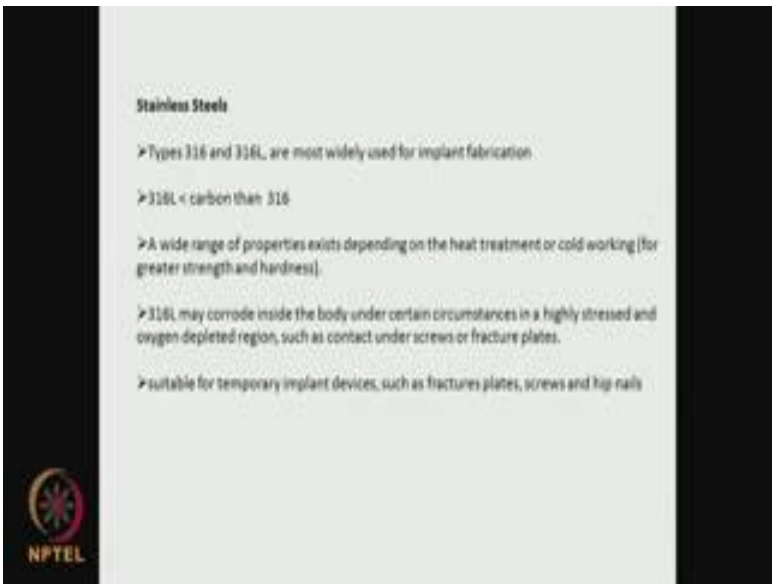

Stainless steel of course, it is very cheap. So, it is widely used 316 and 316L, L means it is got less carbon. So, it is much better than 316. So, 316 l is used many implants, but

stainless steel is widely used because they are cheap they have lot of good properties they give good strength hardness and so on.

Or of course, it can corrode inside the body, especially when they are stressed when you have oxygen depletion and when they are in contact screws or fracture plates. So, they are good for temporary implant purposes fracture, plates idea is once the fracture is yield they can be removed screws hip nails. So, we call this more of a temporary implant hydroxyapatite coating. This is a inorganic material hydroxyapatite.

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So, what it does it improves the surface property. It helps for osteointegration for example, if I use stainless steel which very inert. So, the bone and the cells do not integrate whereas, when I coated with hydroxyapatite, it helps in the osteointegration for example, there is an example biointegration with hydroxyapatite coating ninety percent of the implant gets biointegrated with the bone in 10 months' contact where as if it is pure titanium without any coating of (Refer Time: 16:38) in 10 weeks 50 percent of the in 10 months 50 percent of the implant only contact in 10 months. So, it is of course, not very good and as you can see hydroxyapatite is much better of course, hydroxyapatite is not stable because it is an inorganic material number, one number 2 there it is susceptible to bacterial infection and hydroxyapatite is a calcium phosphate.

Nothing, but calcium phosphate so, but there is lot of interest in hydroxyapatite they are being used in dental applications they are used in bones filling and so on we will talk

more about, it later it is an inorganic material it comes under family of ceramic because they have this osteo osseointegration properties; that means, they can easily integrate with the bone much easier and compare to bear titanium.

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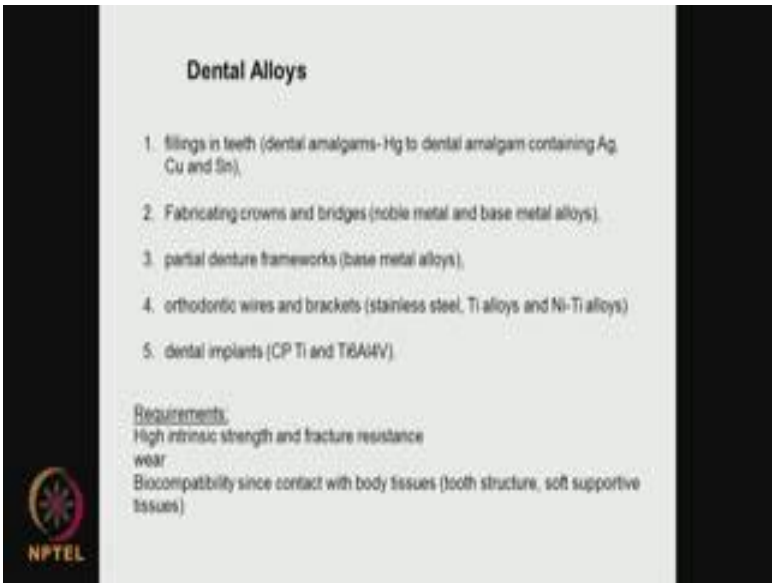

Dental alloys, this is another big area where metals are used filling in teeth dental amalgams I think dental amalgams are being used like mercury based for hundreds and hundreds of years even thousands of years, I would say when dentistry became popular almost thousands years back where they used silver mercury copper and mercury (Refer Time: 18:13) mercury and so on. Because the beauty of mercury is it can easily have adapted to the shape and gap and fills up and quickly solidifies. That is why amalgam is being still used quite popular.

There was there is some worry that mercury may be leaching out and create Poisson poisons effect to the user, but it has still not been proved and the beauty of mercury as I said is they can easily solidify into any form, which is used in filling up of carries gaps and so on actually. So, dental amalgams are very widely used. Crowns bridges fabricating crowns and bridges that is the top of the t noble metals and base metals alloys, they are being used partial denture frame works. So, again base metal alloys are used that is partial denture non top of that, you may even put in pmma based front end, because pmma that is poly methyl methacrylate is of same color as your teeth.

Orthodo notic wires and brackets, as like I mentioned if there is an accident and facial reconstruction as to be done or jaw reconstruction as to be done, wires are used brackets are used their called orthodo notic wires and brackets stainless steel titanium alloys nickel titanium alloys are widely used. Dental implants commercially pure titanium different types of titanium bridge are used in dental implants. So, here high intrinsic strength and fracture resistance that is very important intrinsic strength, because teeth there is lot of mechanical activities taking place the jaws up and down and. So, teeth coming contact with each other they have to they come in contact with the food and then lot of body fluids are there enzymes of coming out bacteria are being produced. So, teeth I think it is quite and harsh environment, where there is going to be lot of wear and tear because your teeth moves all the time, and of course, biocompatibility since they come in contact with the body tissues not only your mouth inner part of the mouth the tongue the saliva and other fluids.

So, it is in contact with so many supportive of tissues. So, dental is extremely complicated area, and I would say another area is your urinary track where you have bacteria salts dental is also very complicated area because in dental we also have bacteria both aerobic, anaerobic, bacteria enzymes from your saliva and body fluids soft tissues, then your heart jaw and so on actually. So, it is a challenge designing material which will lost for a long time, and as well as take care of strength and wear and all those things.

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Dental amalgams they are susceptible to corrosion buildup of the corrosion product serves to limit the rate of further corrosion. So, this corrosion products from a seal at the amalgam tooth interface another problem, is if they coefficient of expansion are different with respect to the teeth then during if they are getting heated up or cooled, especially when we take hot liquid or cold there could be gaps created, because the coefficient of thermal expansion between the dentin that is your tooth material and the artificial metals placed may be different we did a problem if you remember long time back advantage of dental amalgams easy in situ formability to a desired shape. If you have seen a doctor the place the mercury amalgam inside a tooth gap where there is a carries and they preset very hard and after sometime it sets and forms.

Of course as I said mercury toxicity is a concern, but there is no proof that mercury leaches out and creates problem to the user still it is not very clear.

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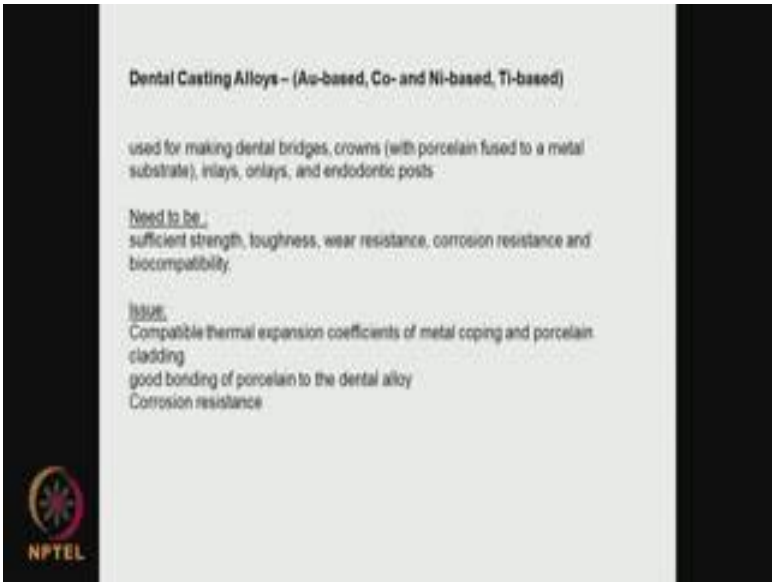

Alloys, dental castings alloys. Gold cobalt and nickel titanium all these are used they are used for making dental bridges. So, if you are connecting one to tooth another top portions crowns making of the top of that. What do they do they make metals then on top they will have a porcelain fused to metal? So, it looks like reality, but inside it will be metals because it is to take care of lot of load corrosion and so on actually. Inlays onlays endodo notic posts all these are metals.

So, they should have sufficient strength toughness they have to be really tough wear resistance because this lots of activities that is going on mechanical activity between teeth and teeth and food, another particle corrosion resistance like I said either is air coming in and there are lot of chemicals produced due to the body fluids. So, they have to be able to resist corrosion and they should be, of course, biocompatible because it is in contact with the soft tissues hard tissues body fluids and so on. So, compactable thermal expansion coefficients of metals and porcelain cladding this is a problem, which we looked at long time back good bonding of porcelain into the dental alloys. So, I am putting porcelain on top of the metal. So, there as to be good bonding corrosion resistance as I said again coming back corrosion has to be completely be nil. So, we should be able to last for very long time.

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Then wrought stainless steel cobalt chromium nickel, beta titanium, nitinol alloys are used for making these orthodo notic wires high yield strength, low elastic modulus. So, low elastic modulus we need to have because, we want to match with your bone modulus of the bone that is very important. So, lot of novel materials combinations nitinol and so on being (Refer Time: 24:02).

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More dental alloys they have a gold silver alloys as you can see different types of gold silver alloys, silver copper alloys different types of silver and copper silver tin alloys all these are dental alloys used, in quite lot in bridges inner cladding outer cladding, and so on and then other alloys cobalt chromium alloys cobalt chromium, nickel alloys, nickel titanium alloys such as nitinol. They are called super elastic wires mostly they are used in wires orthodo notic wires holding the jaw with rest of the, and then cranial wires, which keeps the various broken parts of the cranium together. So, lot of metals are used in this particular area. So, lot of metals and alloys as you can see chromium nickel titanium and then of course, the metals amalgam all are used in dental applications.

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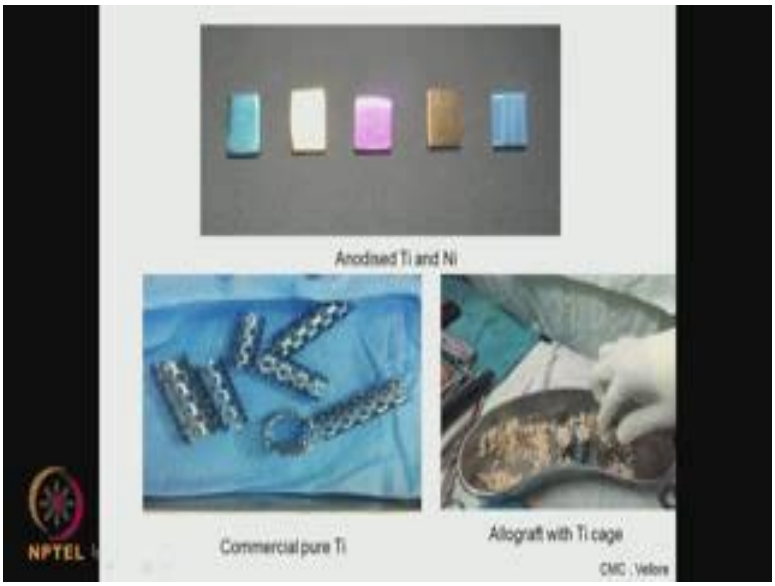

So, let me show some pictures look at this this is commercial pure titanium. So, these are called titanium cages, they are used in bone segments there is a breakage and the bone there is a gap between bones, they put in titanium cages. How do they may be fill up sometimes they fill with allograft; that means, they will take some parts the bone from the patient powderate, they may fill it up sometimes they may be put in calcium sulphate hydroxyaptite, and then I put this material back and fill up the gap commercially pure titanium. These are cages these are titanium nickel and anodized titanium, nickel as you can see different types of anodized titanium nickel combinations here used here.

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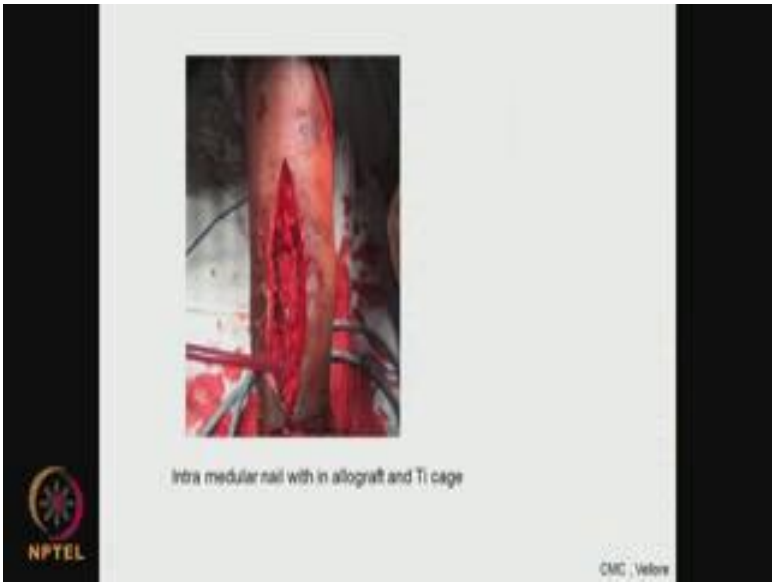

So, we can see the titanium cages here, the one which I showed in the previous picture. So, they may have a allograft or calcium sulphate field which is put here as you can see and there is a nail, which may go like this is called the intra medular nail with titanium allograft cages here. So, this is a defect where you have the bones and there is a big gap that is created, that is called the long bone long bone segment defect. So, they keep the titanium allograft, and there is a medular nail which goes runs through again that nail which called a intra medular nail again that is made up of metal.

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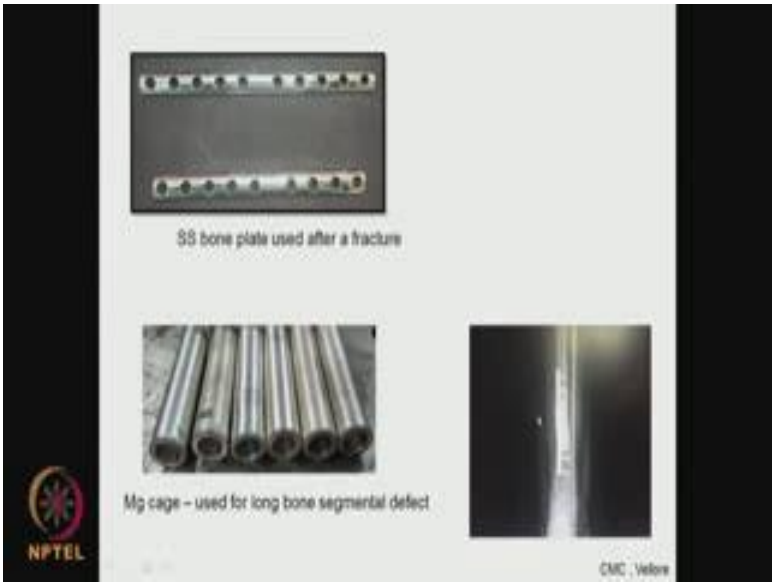

These are stainless steel bone plates used after a fracture as you can see. So, this you have the bone and you have this plate and they are attached with each other using screws here. So, we can have a screws all along as you can see in this picture. So, they keep the bone plate here. This is an x ray picture they keep the bone plate here. And they are screwed up here to the bone depending upon how stiff you want to have the bone plate connected to the bone either we can make it, very flexible and very minimal fixed or we can have maximum fixing by having more screws here, as you can see in this picture magnesium is also used our being looked at as a possible candidate instead of titanium for long bones segmental defects especially, if the gap between bones are very long because magnesium has this biodegradable property unlike titanium.

So, hopefully once the bones have joint with each other, by the time magnesium will slowly start degrading this called a magnesium cage, these are magnesium tubes

whereas, if you are using titanium, it will be remaining there permanently. So, can we have a biodegradable material slowly biodegradable material? So, that once the bone as formed may be it can completely disappear. So, magnesium is being looked at as a possible biodegradable enough material for long bone segmental defect. So, in the titanium cage, as I said they may be filled up with calcium sulphate or hydroxyapatite or even allografts allograft, means the from the patience, himself for herself they may take the powder bone and fill it up and then keep the titanium cage in that gap that is called allograft.

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So, these are some titanium bone plate as you can see in this picture. So, same thing just like stainless steel bone plate you also have the titanium bone plate here. This is used as a fracture and it is as you can see in this fracture picture, they are kept here and you can see the x-ray pictures here. And then you can screw it up all these holds are used for screwing it up with the bone these are 2 different pictures. So, this titanium is able to hold your bone well, in it is place these are some photographs to see of the Christian medical center it is in hospital in Vellore south India, one of the best hospitals for quite lot of orthopedic surgery.

So, we got these pictures from doctor bupalan of CMS Vellore who is an orthopedic surgeon. So, stainless steel bone plates I am sorry stainless steel bone plates titanium bone plates are used quite magnesium is being also looked at for long bone segmental

defect that is filling up of gaps between 2 bones or even titanium cages, filled with some inorganic material as possible filler for curing the long bone segmental defect.

So, we will continue in the next class more on the properties of metals and advantages and disadvantages of various materials.

Thank you very much for your time.