**Introduction to Biomaterials**

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**Module No. # 01**

**Lecture No. # 33**

**Biodegradable Polymers**

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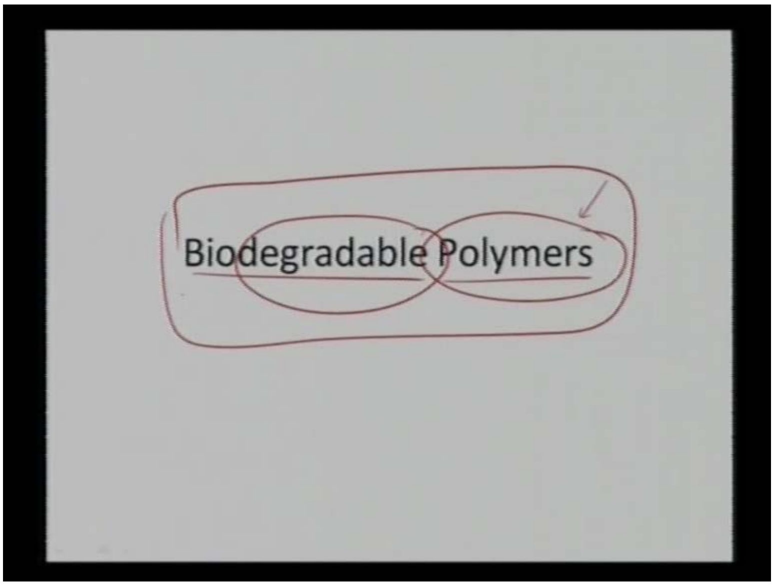


In this lecture, we learn about biodegradable polymers. What is the emphasis on polymers because the metallic alloys or the ceramic alloys. Sometimes they have some certain limitations like metallic alloys. Sometimes they have a much more problems with in terms of their corrosion corrosion products as well ceramics they tend to be highly brittle. So, sometimes the polymer is needed which can suffice the temporary temporary assistance to a certain certain activity and then it can degrade with time. The problem with metals and ceramics is the ceramics they are they tend to be highly stable. They are bioinert in nature and then they tend to be there for longetivity for very high their lives are very very longer.

So, they tend to remain in the body for a very long duration of time and they can't just get degraded. Similarly, for metals metals they pose a high risk of being being able to introduce certain toxins or they can also cause some irritations once they are inside the body. So, and to take a particular temperate as to serving is the scaffold or probably providing a sort of a drug delivery; metals may not really be suitable material because they do not they they have certain reactivity with the blood plasma as well as they can cause certain in undesirable effects in the in the body. So, sometimes it becomes essential to utilize polymers and make them make them serve certain purpose once there inside the body.

And in this particular lecture, we will learn about the biodegradable polymers. Biodegradable it means that the polymers have to degrade within certain biological environment and so, that is the overall key of this particular lecture that we are talking about polymers. So, polymers how they are different in terms of their properties and mechanisms and the processing and all such things and polymers tend to be different form ceramics and metals and they can be easily degraded within the body in the biological conditions. So, that is the reason we are talking about this biodegradable polymers.

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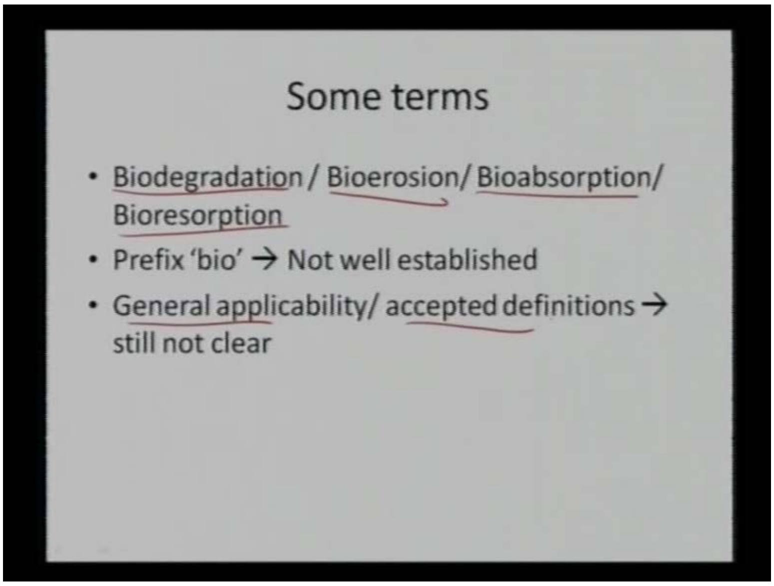


And again there are certain terms which are associate associated with the biodegradable polymers. We use certain terms inter changes changeably such as biodegradation, bioerosion, bioabsorption or bioresorption. The common thing between all those four terms is the term bio and exactly the that term bio itself is not really been established well. Establishment of what it exactly means and again it has some general applicability some accepted definitions. But, still it is not well it is not well accepted by all the people in the this biomedical biomedical of the biological community. So, this bio term is still very, very defined still very vaguely.

But the overall, it means certain some biological system to be comprising of plasma or certain cells or certain enzymes. That can incorporate this particular biological environment. But, this term terminology is also very very important because that is what will define whether it is degradation whether it is a bioerosion, bioabsorption or a bioresorption.

So, how these terminologies are different from each other, we will discuss at a little bit and as we go along. But, these are again concentrate and over around the polymers polymers only because in this particular lecture we are talking about the biodegradation of polymers. And this bio degradation polymers help us because once a person was gone undergone certain injury or some weakening of a part then, it temporary support is required for some certain duration of time. So, to support that, we have to implant a particular polymer. And why we are stressing more on the biodegradation part is because if the polymer is biodegradable we do not require another surgery for removal of this particular polymer.

So, that is the key feature of the biodegradation part and because if we if we trend to implant a ceramic or tend to implant a metal; metal might serve as the strengthening or basically the work house, particularly support as a support as a support material, but, polymer can also provide a temporary support and at the temporary support can degrade as soon as the weakening part is strengthening with time.

So, there is a degradation of polymer in conjunction with, in harmony with the surrounding material or the surrounding tissue which is now growing up and taking taking the takings its own functionality. So, for the certain duration of time when the functionality of the part is lost, that part is now being supplemented by the polymeric region which now degrades with time. So, in this particular process we do not require another surgery. So, that we do not require the removal of particular implant, biological implant which is again a polymer based. Other than that we can also have some sort of dual functionality or multifunctional system and that can also be made using polymers. How do we do it? I will talk about in the upcoming slides.

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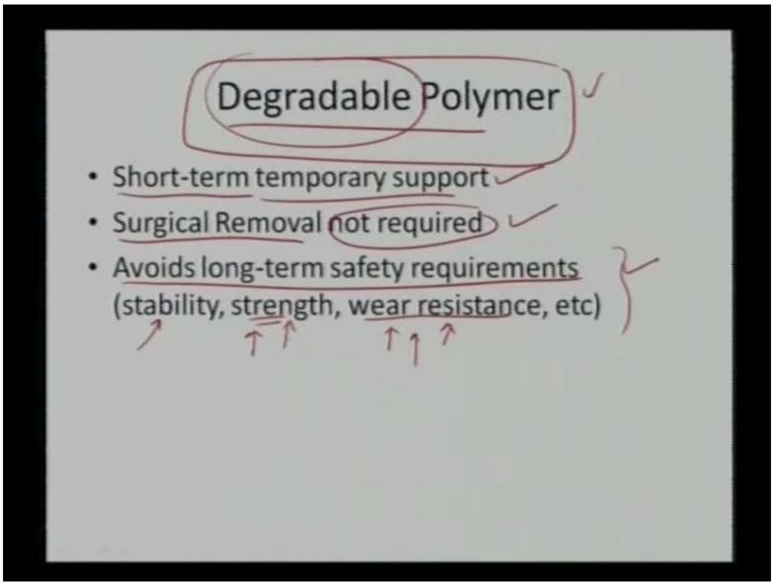


So, first thing is the degradable polymer. Degradable polymers it means the polymer is getting degraded and this degradation is not really biodegradation in this particular term and degradation means on this short term temporary support because after it has served its purpose it can just degrade. And again so, because of that we do not require its surgical removal. So, we do not require the removal of it of the particular polymer using surgery, but, the importance of these degradable polymers is that it avoids the long term safety requirement.

Because if an implant is to sustain inside the body for a certain duration, it was it has to conform to certain biological requirements such as stability, the parts should be stable enough that it can support its function for a for a stipulated duration of time. It has instead of should have enough strength again to give a function to serve the functionality without getting itself collapsed. So, it needs some particular strength in terms of be able to support the load. So, that that that is the term in terms of strength. Stability also comes in terms of being stable it means it should not get oxidized it should not corrodic. So, it remains in its own pristine condition even while it is induced or implanted into the body.

At the same time, it should also get corroded or walled so easily because there are some certain moving parts inside the body. So, if we make them as a acetabular cup lining then, this particular undergo certain erosion or corrosion or certain wear with the adjoining material and in the process of it start getting upgraded. So, we need the, particular material also need to be wear resistant. So, it. So, all those particular criteria in terms of stability, mechanical stability, chemical stability, compositional stability, in terms of strength again it can be fatigue strength, it can be yield strength. So, again it can be mechanical strength. So, to support particular yielding yielding behavior.

Also in terms of wear strength, fatigue strength also those criteria can be just negated. Why because the material has to degrade. So, obviously, the material is getting degraded it can basically be replaced by by the tissues or the on growing tissues which are healthy. So, in those terms it can avoid the long term safety requirements once we have degradable polymers. So, degradable in this particular terminology it is just degradation the bio term is not really just induced into it right now. And it can provide short term temporary support some other scaffold and temporary scaffold and then it can basically degrade as soon as the hallow tissues start growing and above that the surgical removal does not becomes necessary.

Because again the polymer will degrade inside the body and it will be basically excreted throughout certain phenomenon. And again it avoids the long terms safety requirements. So, it can avoid the stability strength wear wear resistance, corrosion resistance, oxidation resistance. All those terms can be basically negated once you have a degradable biopolymer.

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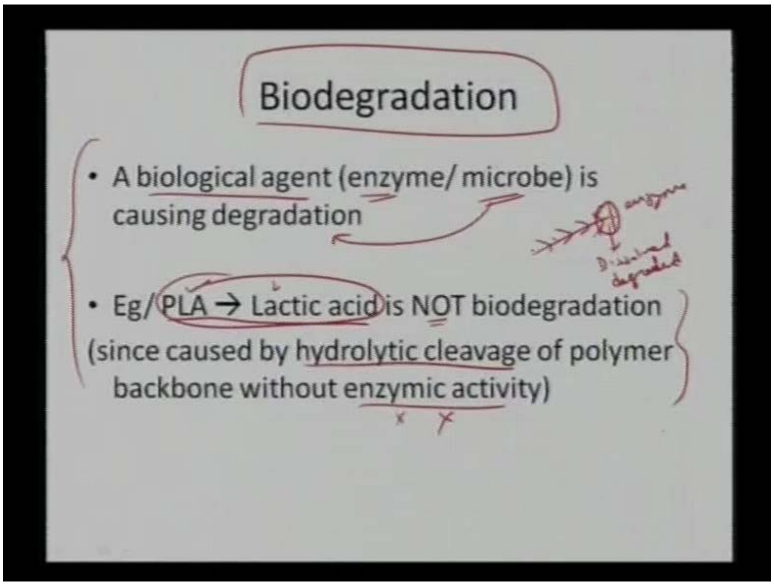


Now, coming to the specific terms of what we talked about the such as biodegradation, bioerosion, bioabsorption, bioresorption. So, first coming to the biodegradation part. In this case we just certain biological agent which can be an enzyme or which can be a microbe and that particular microbe or enzyme is responsible for the degradation. So, in this case we have a long polymer chain and that thing is now being broken into small pieces by certain enzyme. So, that now this particular short short chain of polymer it can now get dissolved or degraded.

So, it is dissolved or degraded it can basically go out in smaller chains and then it is nothing, but, the degradation on the polymer. So, by biodegradation we are involving certain microbes or enzymes that those basically break down the backbone or the long chain polymer and then fragments into smaller regimes. And now these smaller regimes become much more easier to get dissolved or deposited or get deposited or degraded into the body. And again in certain conversions such as polylactic acid to lactic acid is not biodegradation because that is caused by the hydrolytic cleavage of the polymer. And this all is occurring without any enzymic activity. So, this sudden conversion though they appear to be degradation; those are not biodegradation. So, in this particular case we have polylactic acid, that is converting to lactic acid by the hydrolytic cleavage.

So, in this particular process; the polymer backbone is now getting fragmented, but, all this is happening without enzymic activity from this hydrolytic cleavage is occurring in this particular case. So, from that we are getting this particular degradation and that is how the dissolution of this particular PLA occurs into lactic acid that gets degraded and that is not a biodegradation. That is only degradation, polymer degradation.

So, we require the presence of an enzyme or microbe which is causing a degradation to call it the biodegradation. So, that is the overall process of biodegradation that in the particular biological environment, we have presence of either microbes or enzymes to cause a particular fragmentation of a of a backbone polymer chain into smaller fragments which are now, which can now get dissolved or degraded. That is called the biodegradation.

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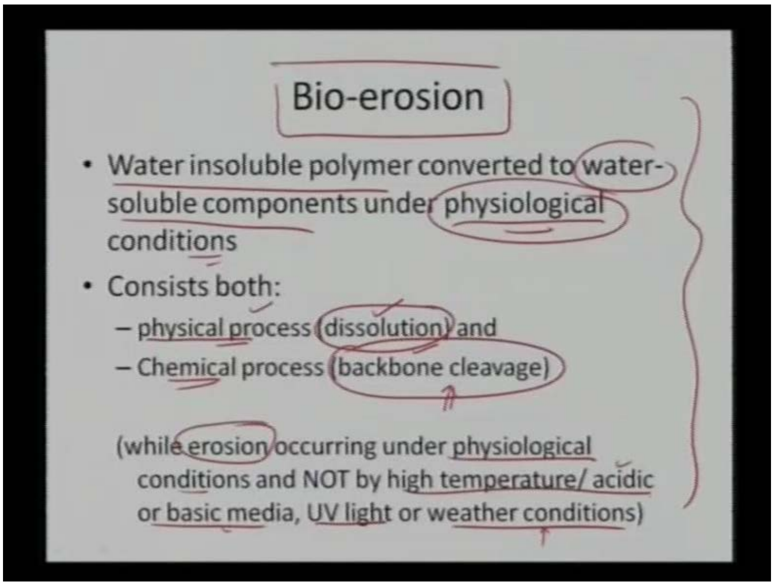


The second term called bioerosion. So, in this particular case we have waters insoluble polymers and now they are converted to the water soluble components and this all is happening again under certain physiological conditions. So, bioerosion means we have degradation of polymer occurring within certain physiological condition. So, that is that is what is happening that we incur both physical process which cause a dissolution and again the chemical process which cause the cleavage of the backbone chain of the polymer.

So, we are making water insoluble polymers, a longer chain of polymers which was earlier insoluble in water that gets fragmented into smaller chain particles which is which is again water soluble in nature. So, we have two flavors which are occurring; physical process which causes the dissolution and chemical process which causes the cleavage of the backbone chain of the polymer.

So, this all phenomenon is occurring under physiological conditions. And this is not by the high temperature acidic or basic medium or even UV light or weather conditions. So, this erosion is occurring under certain physiological condition. There is certain physiological forces which are acting and that is causing a degradation and not by temperature or UV light or certain chemicals which are acidic or basic media or even the weather condition. So, bioerosion is certainly basically physical physiomechanical phenomenon.

So, it is called physiological phenomenon, physiological conditions assessed by certain chemical process which cause the backbone cleavage. So, that is what is happening and not because of either temperature or acidic and basic media or even by fragmentation from the UV light or the ultra violet light or even the weather condition which can degrade the polymer and not cause the bioerosion. So, the bioerosion we have physiological conditions which are dominating and that causes the insoluble polymer, water insoluble molecules get converted into the water soluble molecule and that erosion under physiological conditions is called bioerosion process. That is again the terminology what we have learned. So, we can we did see that; however, biodegradation is different from the bioerosion.

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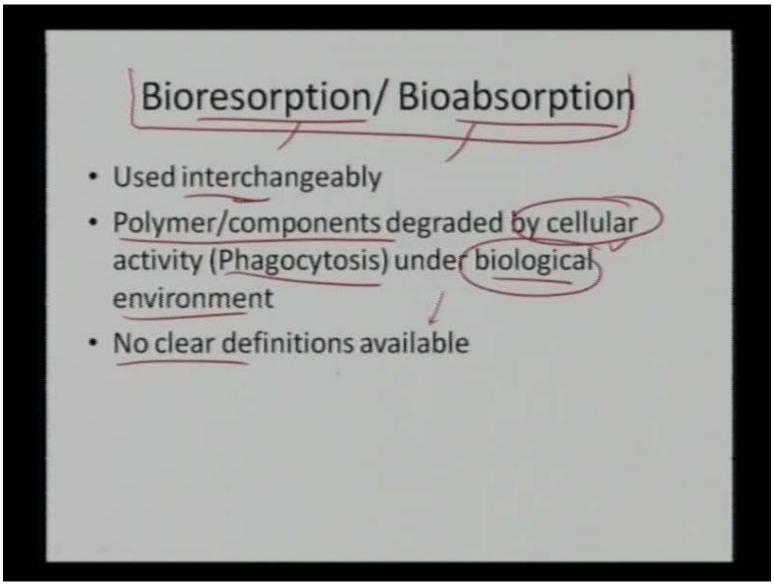

And now we come onto the part of bioresorption. So, we do see that with our how these particular terminologies are different. So, in the bioresorption or bioabsorption they can be used interchangeably. So, there is not much difference in the biological community to distinguish these two terms bio bioresorption and bioabsorption. They are basically interchangeable. In this case we have polymer or components which are degraded by cellular activity.

So, there are certain cells which can basically degrade the material under certain biological environment. So, in this particular case we can give an example of phagocytosis that can occur under the presence of certain cellular cellular activity and under biological environment and that is caused in a degradation of polymers. So, we have certain cellular activity is degrading a polymer to cause bioresorption or bioabsorption. And since these are all fragmented they can again get adsorbed by the body they can also get dissolved into into the body and that basically is causing the absorption or the bioresorption of a particular polymer. And there is no clear definition as yet available what really exactly it means. It just means that under certain biological environment, certain cells, certain cellular activity such as phagocytosis might might occur that is degrading the polymer and that what is cause causing the bioresorption.

So, we do see that there are total biodegradation again that bioerosion and bioresorption or the bioabsorption. And we do see that how different how differently they are being cited.

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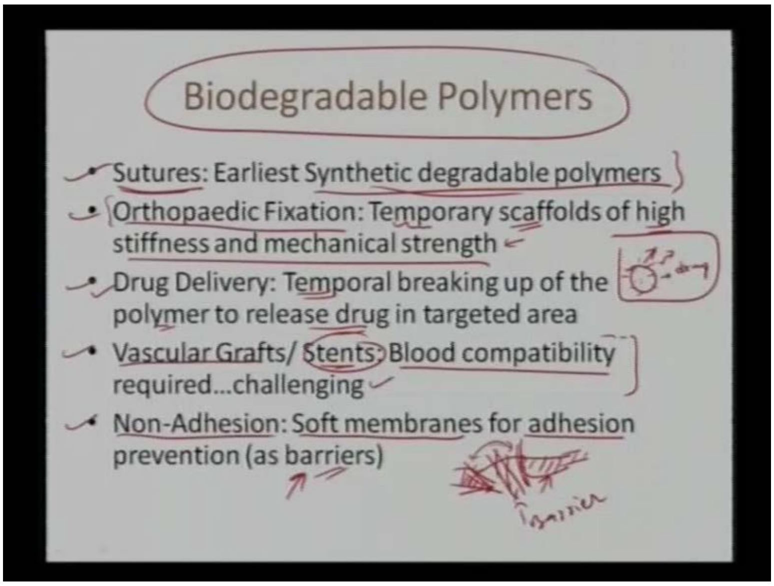


So, that is what is happening in terms of all the four examples. And now coming on to the bio, once we have to learnt about the degradation of a polymer, how this biodegradable polymers, how they are useful and what are the applications? We can see them and again. We can also stress that there is the biodegradable polymers again very very essential because it eliminates the long term safety requirements which might be essential for a long term implant which is implanted to the body and also it can avoid the surgery part. Like once we have inserted the implant into the body we do not require one more surgery just to remove the particular implant. That that is what might be required for a implanted ceramic or a implanted metal.

In case any injuries happening such as; it might happened that a metallic implant must broken up on the body. So, it might require one more surgery to remove the particular metallic implant and then perform the overall overall repair and then do a repair surgery.

But again in this particular case we are using the polymer only as a support support entity as a temporary barrier. So, that is why in this particular case we can eliminate the surgery part because any way even then the polymers left into the body automatically the healthy the healthy tissues will start taking its place and will start maintaining the degradation of polymer and in the long run, we do not even require the surgery to remove the polymer. It will automatically get dissolved into the body.

And coming back to certain examples of it; Sutures, they are the earliest synthetic degradable polymers. So, those have been utilized to very, very long even in the medieval days when we had certain when we had all the fights and wars and all the cuts basically were sutured. So, we we did had sutures quite long back and in initially the straws the straws were used to utilized for for the sutures, but, right now we have a certain synthetic degradable polymers which are available to us just. So, those are basically utilized in this particular case and we can also utilize them for orthopedic fixation.

So, we sometimes require some certain temporary scaffolds of which should possess very high stiffness and good mechanical strength. So, we require certain temporary scaffolds those those can be provided by the degradable polymers. So, we have sutures which can be synthetic degradable polymers. We can also utilize them in orthopedic fixation for serving as a temporary scaffold as well providing high strength, high stiffness and mechanical strength. So, that they can basically temporarily hold a particular structure and provide and without (( )) functionality of a particular part.

They can also be utilized for the drug delivery and for the drug delivery, the polymer need to get needs to get degraded. So, it can temporarily, it can provide breaking of the polymer and release the drug. So, we have particular polymer, it can start degrading and the polymer and the polymer can have certain absorb drug in it and once the drug is absorbed and the polymer is degrading, automatically there is a realize of drug into the body and into the particular targeted area and that can also provided by the biodegradable polymers as well certain vascular grafts and stents. And in certain cases bio blood compatibility is also very required because the blood is continuously flowing in this particular areas. In muscular grafts, you have the plugging or the clotting of the blood might happen. So, to avoid the clotting in the undesirable part in into adjoining part we want to avoid the clotting of the blood.

So, that the two interfaces are not join to each other or in the stents where we have continuous blood flow in those certain cases of the blood compatibility can also become a critical issue because that is again very, very challenging because if we have the rupture of a blood vessel and the blood start coming out of it might start clotting and then it can again just cause the joining of the two nearby arteries or and then that might be very, very harmful because this might cause pain for the later surgeries.

So, that might become a critical issue. So, blood compatibility also is a is a challenge which needs to be undertaken by the biodegradable polymers. And in certain cases we also require non adhesion like in some areas to serve as a barrier because and because in certain areas when when the blood clotting starts we need to provide certain barrier which will not allow the adhesion with of the two interfaces. So, we can provide certain soft membranes which will prevent the adhesion.

So, if you have rupture from one one one artery and then we need to provide certain barrier barrier layer and that will that will that will not allow, that will stop the adjoining of these two arteries by this barrier layer. So, we also need to have certain barrier layers and that they those will not allow the joining of the two nearby arteries or two nearby parts. Otherwise if they start joining then it can cause pain later on because these are undesirable parts which should not really get joined together and then later on to separate these parts out from each other, again a surgery might be required and injury surgery might cause even very high pain. So, we need certain barriers as well which which which can again come out from biodegradable polymers.

So, we can see the overall applicability of these biodegradable polymers we can start using them from sutures. So, those have been use since very long and then we have certain degradable polymers available with us.

And then, it can also be from for the orthopedic fixation to provide enough strength as well as stuffiness to take care of the initial temporary temporary task of or the temporary functionality in terms of providing support. It can also drug delivery because certain regimes they apart from the support they also requires some chemicals to be induced in those particular regimes. So, at that can come from the degradation of polymers itself and to the degradation of polymers it can also release certain drugs.

Ah Again certain blood compatibility once we have blood blood compatibility is an issue such as an vascular graft or stents. Again we can supply certain biodegradable polymers as a support as a support layer or which will stop the flow of the blood or the clogging of the blood from that particular regime. it comes to It also serves as a barrier layer to cause non addition between the two surfaces. So, it can be a soft membrane which can basically separate out the two two layers and it can act as a barrier for adhesion prevention.

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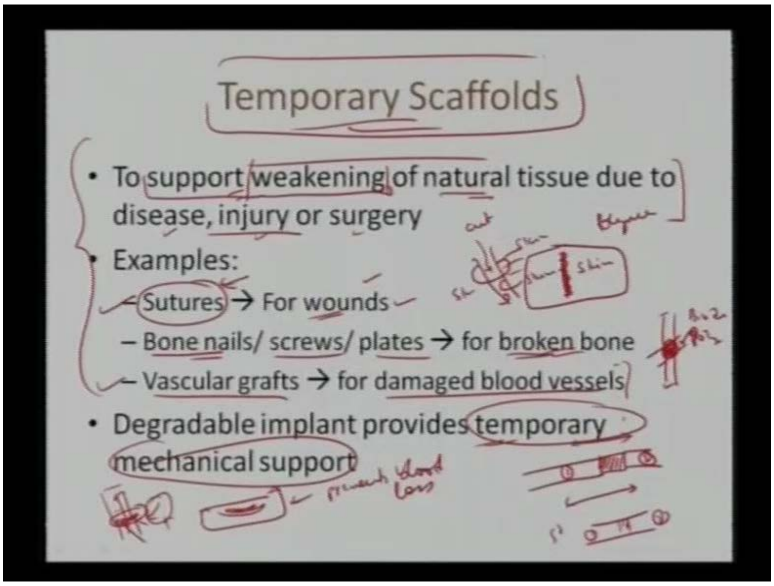


So, these are these are the certain functionalities which can come out of the biodegradable polymers. In certain cases, temporary scaffolds are also require which basically are surfaced by the biodegradable polymers and when a person undergo certain surgery or it a person incur certain injury or during a disease when normal functionality of a particular tissue is basically hampered then, we need its support so that, a normal functionality can restored during the time of injury during time of decease or after after surgery so that, a proper functionality can be restored to a person for a better for a better for a better level of comfort.

So, in that particular cases we require certain polymer polymers for which can be basically degraded with time. So, as we learned that, we require some biodegradable polymers or bioabsorbable polymers or bioerodible erodible polymers that can take that can provide temporary support. So, that thing basically is required when we have a weakening of the natural tissue which can occur because of disease, injury or surgery. So, the primary scaffold which primary scaffold which can be utilized which are temporary in nature it can be sutures and those are basically require for wounds.

So, even during time when we get certain cuts or during wars when people when people were basically injured a lot and there is cut or there is some surface open, open surface that next to be stitched together. So, we had we basically have sutures for healing healing of the wounds because there there might be excessive of blood loss once we once the person has certain cuts. So, to avoid that extreme blood loss we need to provide the closing of the top surface that is (( )) the the skin epidermis. So, that we can provide support or we can restrict the blood flow from the from the cut.

So, we have. So, we provide them as threads and those threads are basically sutured over the wound surface to provide a support. So, in that particular case we have the surface which are basically cut so we can provide sutures which can basically come at the stretching which can come as a stretching of the two areas and then we have the stitches stitches stitch regime. So, we have skin on this side, skin on this side and this thing we had skin on hairs, skin on hair and this was the cut portion. Now, after the stitching the two portions are basically been joined together.

So, that is the way we can apply a temporary scaffolds or the temporary support via sutures. The advantage basically out here is the person initially initially when the sutures were non-biodegradable and the person had to go again to the surgeon or to the to the doctor and then get the sutures remove. But in this case, sutures automatically get degraded with time. So, there is there is no necessity for a person to get them removed and go to the doctor again and they automatically heal with time. So, as the healing is occurring these polymers starts dissolving into the body and then these two processes of the dissolution of polymer and the healing of the natural skin it basically is matched so that So, that the temporary support can be provided till the person requires it.

So, till there is a necessity for the for the for the support, suture is suture is enough strength to provide the port and then time is starts getting degraded and that degradation is now being compensated by the healing of the tissues or the cells around it and those take care of the nominal functionality of the skin.

So, that is how though those though those superiors are now being balanced and then that is being provided by the sutures. And in case of bone nails, screws and plates basically when a person undergo certain injury; the bone and if the bone gets broken it requires a temperature support because bone bone may get the bone might get displaced from each other each other interface.

So, to keep the bone in place and to provide enough support, because in this case once there is a huge hug area which is now been broken in the bone. Then to fill the gap certain support is required otherwise there is a gap between the areas of the bone and then it might cause severe pain to the patient. So, to avoid that those particular areas which are now being damaged are basically which are being removed, those areas are not to be filled by polymers, biodegradable polymers which can now provide a continuity of the load transfer or the stress transfer from one another surface to the other surface. So, we had bone which is now fragmented with certain rigid and then bone is like this to provide a continuity in this particular regime in this area, we need to fill it with certain biodegradable polymer. So, now, the bone looks more like this, we have this area and then we have certain polymer area and then again we have the continuity, the bone continuity.

So, the stress can transfer gradually from this this area to this area. From one end to the second end otherwise there will be a discontinuity at the surface. So, we will have a very high stress at the surface and then again, high stress at the surface and that might cause a stress concentration and then that might cause severe pain to the patient.

But since we have this continuity because of this biodegradable polymer, this stresses they go gradually. So, one surface to another surface there is a gradual this is a gradual transfer of the stress from one end to the other end with a polymer interface being there. So, we can see that part that the stress can now become much more we will form across the interface. So, going from one surface to the second surface which is now the broken bone. That part this stress is getting distributed uniformly and that is been caused by the polymer temporary scaffold. Again in certain cases once to avoid extra blood loss; there are certain vascular grafts and those are basically utilized for the damaged blood blood vessels. So, if we have a certain injury and those injuries because of that injury we generally have certain vascular grafts they can be kept near the damage area damage area and that prevents the blood loss blood loss and again this can be again plotted.

So, that the blood vessels again they can start getting restart repairing themselves without excessive blood loss, without letting the blood vessels exposed to the proteins and then get plotted. So, vascular graft can assist that, it can assist restricting the blood loss by serving as the barrier. So, vascular grafts are also very much required and in terms of the temporary scaffolds and they can get degraded with time because they can provide temporary barrier to the damage blood vessels and they they once the blood vessels are repaired themselves the vascular graft can basically degrade itself. So, this is basically what we can see that the degradable implants they can also provide temporary mechanical support. So, those are the things that in case, once we have a certain bone nails. So, to keep the bones in place so, like we have certain displaced bone then we can provide bone nail which can basically keep the bone backend place and then it will allow enough time.

So, that this particular joint gets align properly and then this automatically the bone nail will get dissolve into the body itself. And again similarly, these two end plates they can also serve as a temporary scaffold in the broken bone. So, overall we can see that the temporary scaffolds they serve as the as a support material in the part where we have weakening of the natural tissue. It can arise because of disease it can also arise because of injury or those can also be the post surgery effects. So, those can come from sutures. So, sutures are nothing, but, the, but, the regimes where we have the stitching of the scale because of a cut or because of any injury. So, those particular area they can be now be sutured together or stitch together and it can avoid the, it can help preventing the blood loss and it now once the stitches are out there it has nothing, but, it has joined the two surfaces. So, blood cannot flow freely out from the surface and which time.

As soon as the wound is basically healing or the two interfaces are getting join together the suture will start losing its strength and with time it will start degrading and with time it is degrading, it is now being replaced by a healthy tissue. So, in entire process we have some sort of a balance between the degradation of polymer and the growth of the healthy tissue. So, that is what is happening in the suture and again in the bone nail it can also be utilized for the alignment of the bones providing temporary support are also filling up the areas where the bone has been lost or fragmented. And now with time what is happening? That support area is now getting degraded..

So, if you have a certain injury in the particular bone where the bone area is being lost; and that area is now basically there is a smooth transfer of the stress from one regime to another regime because we have certain solid degradable polymer which is sitting in that particular area. And with time what happens? As soon as a polymer is starting it starts to degrade that area is now being filled up by the surrounding bone cells.

And once bone cells start taking up its place is nothing, but, the healing of the wound and again the entire area the entire damage area is now being replaced by the bone. Either it can be the bone nail it can be the bone screw it can also be the bone palte and it is been utilized for the broken bones and then entire polymer can get degraded and that this is now being replaced by the bone cells. So, we get the entirely entirely supporting entirely supporting areas or the scaffold which basically is assisting as in terms of smoothening the stress flow along the particular bone surface as well as well serving as, at the same time it is also serving in terms of providing a smooth painless duration for the patient. So, that is what is happening. And again in the vascular grafts it prevents the excessive blood loss and it basically covers of the damage blood vessels in terms of supporting or avoiding the excessive blood loss.

So, these temporary scaffolds serve as the temporary mechanical devices or temporary mechanical support materials to help the patient recover during the time of injury or disease or during the post surgery effects. So, that is what the overall functionality of this temporary scaffolds in terms of sutures, in terms of bone nails, plates or screws or as well as the vascular grafts.

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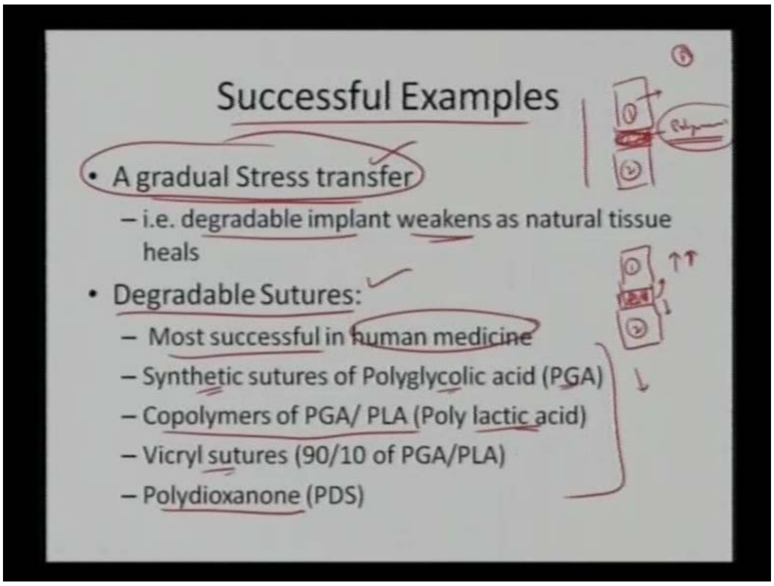


So, we can see that the successful examples they include gradual stress transfer. So, basically what happens is that, degradable implant it starts to weaken itself and so, in the process what happens? Initially we had the support the polymer support between the two bones. So, initially we are seeing a smooth stress transfer between region one to region two and this is nothing, but, the polymeric support. In time what happens? This particular polymer it starts to degrade. So, overall the area which is now being supported, it starts to reduce.

So, now from a higher area from a higher processing area it goes on to a lower cross sectional area. So, in the process the bone has to take little higher stress. Then, what was taking here? In this case one ,in the case a we have more load which was being taken care by the polymeric material because of its higher cross sectional area as soon as it starts degrading now, there is a more more newer fresher bone which is now getting inserted here. So, in the process now bone has start taking more and more load with time because polymer is now degrading. And entirely there is a gradual stress transfer, it is not an immediate stress transfer, it is a gradual stress transfer because in the process polymer with start degrading at a certain rate it would not degrade at once. So, in the process polymer is degrading slowly with time. So, slowly with time as soon as there is degrading it is now been taken care by the freshly or healthy bone cells which has now start to which start to nucleate or precipitate at the bone bone and polymer interface and because of that, now the bone is a starts to increase, but, the area which was being earlier supported by the polymer that starts to decrease. So, bone has now take little higher and higher stress, but, in a gradual step.

So, what is happening? Polymer is now rendering stress to the bone in steps, in smaller steps. So, in that particular process we are achieving a gradual stress transfer and not gradient or a severe stress transfer with time. So, that is what is happening in terms of polymers. So, that is again a very very successful thing that we the polymer can degrade with time in this slower fashion that the bone or the natural tissue starts to heal in a gradual manner, it is not drastic. So, there is no sudden stress on the natural bone or the natural cell. It is again very slower and steadier. So, that a gradual stress transfer can occur out here.

So, there degradable sutures they have been they have been more successful in the human medicine because for very long there are certain synthetic sutures which are available such as polyglycolic acid and again copolymers of PGA and PLA which are nothing, but, the polyglycolic acid and the poly lactic acid. There also called (( )) in the normal surgical language and there also certain vicryl sutures which are available there also certain polydioxanone for the PDS sutures which are again available. But, despite all those things which were basically evolved in 1950, 1960’s during the post per era still there are no new sutures which are coming in the market. So, that is what is happening that they are certain synthetic sutures which are available such as PGA polyglycolic acid, poly lactic acid, PLA, PGA and a copolymer of those two which is called vicryl or again polydioxanone PDS. But, again these were developed in 1950s and 1960s and, but, after that there had been no competing sutures which are available, which can compete with the already available PLA or PGA.

This is also because that developing a new material or the new bio degradable material it requires a very lengthy process of its approval. So, the suture has to be tested in vitro, then in vivo and animals and then again it requires a proper seal of approval and it requires a very long duration of time in terms of its approval and again as there are so much complexity which are associated with assigning a particular assigning a particular bio degradable nature to a polymer. So, that is the reason there are there are not many or not many competing polymers which are available in the market.

Because it becomes very easier for a for a distributor or a seller to basically in market only PLA or PGA and do not go about approval of the other biodegradable polymers. So, there has been certain successful examples in such as in case of the gradual stress transfer.

So, like in bone we have we supplied with certain zones of polymers and then that polymer causes gradual gradual increase in the stress, which is now being borne by the bone and that is now being replaced the polymer polymer is now being replaced by a natural healthy bone as soon as it starts to degrade. And again that degradable sutures have been again successful very, very successful in the human medicine and despite there there development in the early 1950s, 1960s of polyglycolic acid or the poly lactic acid, there have not been many changes in the in the development because again it is very time consuming process and the approval of being bio degradable and at the same time non toxic; that has to be, that has generally takes a very long time and requires certain testing and those testing's are very, very lengthy in terms of years and. So, that is generally the overall ideology of using PLA, PGA even as synthetic sutures.

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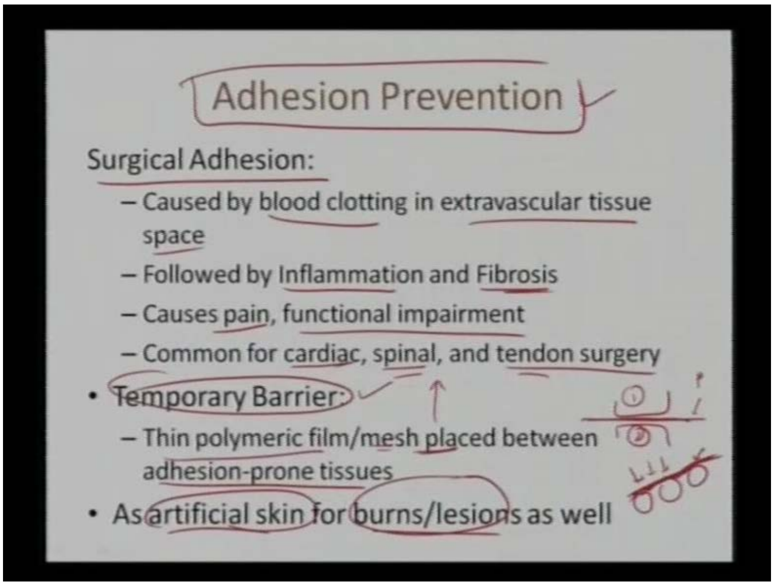


Apart from temporary scaffolds, there also certain other applications such as adhesion prevention so, such as surgical adhesion surgical adhesion because once surgery surgery is being done there are certain surfaces which basically are cut and for the surgery. So, there can be excessive blood loss and again the blood can start clotting in the extra vascular tissue space. And, but, this particular clotting may not be that good because the clotting might occur between two surfaces which are not meant to be joined together. So, that can basically be that can basically follow inflammation and fibrosis and that can again lead to pain or functional impairment. In certain cases that may not be that may cause severe damage and it can cause the functional impairment of the organ itself and again it is very common this particular prevention is very much required for such as area where we have severe blood flow since in cardiac region spinal or tendon surgery. So, we have severe blood losses which can really occur in the extra vascular tissue space.

So, to avoid the inflammation and the fibrosis and the joining of the two functional parts and to reduce the pain; we require non adhering non adhering surfaces. So, we require a temporary barrier which can come out from a thin polymeric film or a mesh which is now being placed between the adhesion prone tissues. So, that is what is required of it here that we provide a thin barrier layer or a non adhering layer of polymer or which can polymer film or a mesh that can be kept between the two two addition prone tissues. So, we have one layer and we have second layer and then we place basically here polymeric mesh which will not allow the region one to join with region two. So, in this particular process, we can just leave this particular layer, temporary which is a temporary barrier out there itself and during the surgery and then it will automatically degrade with time. What the function it will do is it would not allow the region one to get adhere to the region two.

So, the adhesion can be avoided between the region one and region two or the or the adhesion prone tissues which are one and two. So, we can avoid that particular adhesion between the two by providing a thin polymeric mesh or a film. Apart from that, apart from creating assisting that in terms of non adhering surfaces so, this particular process can allow us in terms of reducing the blood loss or also it will reduce the overall pain or the functional impairment. It will would not allow the adhesion between the two tissues apart from that it can also be utilize as a artificial skin because sometimes when there are certain burns there are certain fire somewhere and then person gets severe degree burns then, our burns or lesions then it can also serve as a artificial skin. So, this polymeric film can be supplied as a, can be applied as a artificial skin and then that will serve as a temporary, that will serve as a temporary functionality of serving as a skin.

So, the direct contact with the environment can be avoided and with time, this particular polymer starts degrading and that is been replaced by the natural skin. The skin also starts healing itself. So, overall this particular polymeric film or a mesh can also start serving as a artificial skin and with time this polymer will start degrading and that will be basically been covered by the natural skin.

So, the adhesion prevention can be, this particular adhesion prevention can be taken care by providing certain temporary barriers and that barrier will reduce the the pain or the functional impairment will avoid the chances of pain and functional impairment. And that can serve very well in a surgery which are common where this particular phenomena is common such as in cardiac spinal or the tendon surgery because what happens the blood clotting in the extra vascular regime regimes it starts joining that to adjoining tissues which are not meant to be joined together. So, to avoid that particular joining we need a non non-adhesion layer which is one nothing, but, a polymeric layer and that polymeric layer during the surgery it avoids the joining of the two surfaces.

And with time it starts degrading itself. So, by that time the natural tissues are already healed, there is no more blood flow along those those lines. So, already the particular part has healed and with time this polymer also starts degrading and those organs or the tissues which are which were apart earlier, they remain apart without getting adhere to each other.

So, that is the prevention which is being supplied by the polymeric layer and apart from that this particular polymer layer can also serve as a artificial skin. So, during in any injury or burn it can also provide as a support or as a temporary protecting layer for the skin and it can be utilized once the person has incurred certain burns and lesions. So, that is what the overall ideology of using the adhesion prevention and serving the as temporary barriers for the polymeric polymeric materials.

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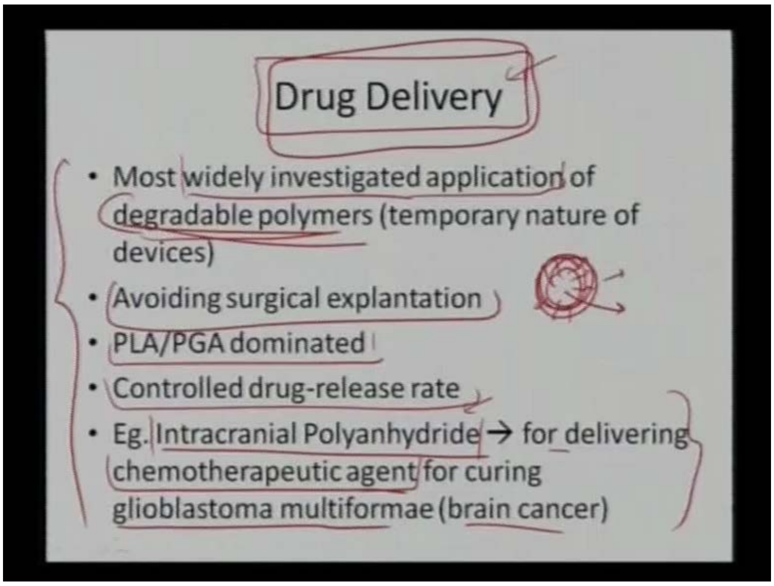


And there is one more most widely application of this polymeric degradable, polymeric materials is drug delivery. This is one of the very key functionality of a bio degradable polymer and this is the most widely investigated application and because for a drug delivery the overall device has to be temporary in nature because once the particular particular device has delivered the material its task is basically done. So, we do require by by the demand of this particular functionality that the polymer has to be degradable or the device has to be degradable.

So, this is one of the most widely investigated application and in this particular case the degradable polymer are the well suited well suited materials because those can be, those can serve as a temporary scaffold for temporary storage temporary store media for a particular drug and once it has gone to the drug side, once to the targeted side it can basically degrade and supply the drug and that side and that side it can degrade with time. And again, this temporary nature or the degradable nature of polymer now avoids the any surgical explanations because once a polymer has to be induced with certain drug into the body we require surgery and had the particular drug delivery device, had it been permanent then we require one more surgery to explant that particular device.

So, it is very, very nice if the polymer itself is degradable in nature. So, it avoids any surgical explanation and again this particular area is again dominated by the PLA or PGA; poly lactic acid or the polyglycolic acid. And what it does it has a controlled drug release rate. So, we have polymer and it has a drug absorbed into it and as soon as soon as with time it starts releasing the drug in the targeted area.

And as soon as it starts degrading automatically the drug is now being released it to the targeted area until it basically collapses completely. Again there certain basically materials such as intracranial polyanhydride polymers which can delivered drug basically for brain cancer which can be chemotherapeutic agents and they can be utilized utilize for curing glioblastoma multiformae which is nothing, but, a form of a brain brain cancer.

So, we can utilize this enterpreneual polyanhydride which is a particular chemical or a chemotherapeutic agent and that can be utilized for the curing the brain cancer. So, this can be again basically implanted into the PLA PGA and that can again be sent to the targeted area and once the drug is released as soon as the polymer starts to degrade. So, this is a very wide applicability of this temporary temporary nature of this particular polymer material. Then it starts degrade and it starts releasing the drug as soon as it is being degraded.

So, this controlled release rate assist in this particular fashion that as soon as the polymer is degrading, the concentration of the concentration of the drug can be controlled that once it is on surface the high drug is now being released as soon as it starts will degrade a lower concentration of drug can be released which is again can be engineer and that will assist the overall supplying of the drug to a particular targeted area.

So, initially when a person is suffering from a particular particular cancer very high doses are required in the start and to maintain maintain maintain the functionality of that particular part the drug container start this basically reduce to a certain extent and that can be easily controlled by the degradation rate of the particular polymer. So, drug delivery is one of the very important components of this component of the degradable polymers and it can be utilized for utilizing certain drugs intracranial polyanhydride for delivering chemotherapeutic agents for curing the brain cancer. So, this is all is basically the functionality of the drug delivery devices.

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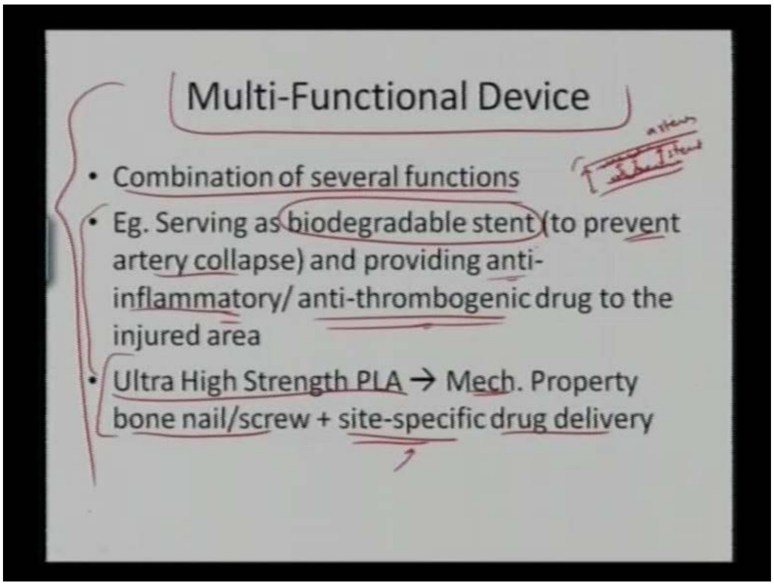


Apart from that, there can be multifunctional devices and this polymer can also serve as a multifunctional components because it can combine several functionalities such as like in the stent area like once we have artery collapse we can send the biodegradable stent and that will initially prevent the artery collapse. At the same time it can provide anti inflammatory or anti-thromogenic drug. So, it would not allow the thromboses or the information to occur in the particular area that might arise because of the foreign,once there is some foreign body into the area. That can be avoided by the anti inflammation or the anti thromogenic nature can be basically negated by the particular drug which is now coated on to the stent surface. So, we have the stent surface and then we have the artery and once this particular stent starts to open up it has a coated drug on to it.

So, the stent surface are;a this is the artery, this is the overall artery and then this is the overall stent and stent is now coated with the particular drug that can prevent, that can basically be supplied for the anti-inflammation or the anti-thrombogenic activity in the induced area. So, this is the artery area which is injured and now the stent is now taking its place and that stent is also covered with certain drug to provide certain anti-thromogenic or the anti-inflammation to this particular regime. So, again there is one component of it that multi-functional device that is serving two folds. First of all it is servicing as a providing a mechanical support because the stent is to open up, it is to keep the artery arteries from collapsing. So, it has support to that particular opening up of the artery and the same time it is providing a drug.

So, it is serving as a multi-functional device at the same time let such as an ultra high strength poly lactic acid, it has to supply certain mechanical strength to the bone or nail screw. At the same time it has to supply certain site specific drugs. So, again we can see that ultra high strength poly lactic acid can also serve as a support material for the scaffold of the bones, the bone bone nail. At the same times supplies certain drugs to it to for certain for certain site specific functionality.

So, we can see that one multi functional components can also basically be sort by the degradable polymers. So, in entirety, we see that the biodegradation can happen once we have the degradation occurring in presence of certain enzymes or microbes in certain, which is basically causing degradation. So, we have enzymes or microbes which is or which is causing the degradation of the polymer and that is resulting the biodegradation part. Then we had bioerosion in that particular case we had the physiological conditions plus which are basically causing the dissolution and secondly we had some chemical chemical activity which is breaking the back bone of the chain to cause the cause the dissolution of the particular polymer. So, then we had this bioerosion and then it was followed up by by absorption by a re absorption. In this particular case we had certain biological environment of others is a cellular activity which is degrading the particular polymer.

So, from that we learnt the different classes of the bioabsorbable polymers or bioresorbable polymers or bio degradable polymers from that particular (( )). So, we had couple of couple of classification in terms of them. But, there is no sacrosanct or accepted definition of all these so this is still still in basically discussion or then being acceptance by all the researchers and biological, in the biological community. Again we learnt about the temporary scaffolds. How they are being utilized in terms of providing certain functionality to a broken or an injured part which can come out from sutures.

So, sutures serve as a temporary PLA PGA type polymers which can apply the stitching on a injured area or they those can also be coming out from the anti adhesion surfaces. So, anti adhesion surfaces will not allow two nearby parts to join each other. They can also serve they can also be provided from the also from the they can also come out from the multi-functionality; they can also be drug delivery part. So, a drug can be delivered by using a certain polymer and that can degrade with time and provide particular chemical or drug to a particular, specific site. Those can also be multi-functional in terms of in terms of providing drug as well as serving as a mechanical mechanical support for a particular regime.

So, those all those part can also come out and those can also be certain temporary vascular vascular support, those can also come from the temporary scaffolds or adhesion prevention or it can also be the drug delivery and multi-functionality of a particular biodegradable polymer. So, we can see in how myriad applications biodegradable polymer can have starting from supporting as a sutures or serving as a temporary, non adhering surface or it can also come out from delivering drugs or it can also serve as a multi-functional devices for drug delivery as well as certain mechanical mechanical support. So, that is the overall feel of the bio degradable polymers and basically I will end my lecture here. Thanks a lot. Thank you.