Biophotonics
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Lecture 44
Laser Tissue Contouring: Ophthalmic Application

Hello, and welcome. We are discussing the module of tissue engineering with light. And as I said, the last two modules the last two lectures, I am going to take specific, specific examples, where a specific type of tissue is being acted upon by laser light for contouring it, for restructuring it, for, for betterment for curing a particular human ailment.

So, in today's topic, we are going to talk about laser tissue contouring for ophthalmic applications, basically, something to deal with eye or something to deal with the vision, vision or eye or the entire process is my favorite topic. So, today I am going to take two very common surgical procedures, two very common medical procedures and I will show you what they are, how laser has helped them have, how laser has improved them. And at the same time, what seems to be the future, where exactly laser light can be utilized in case of eye surgery in case of vision correction.

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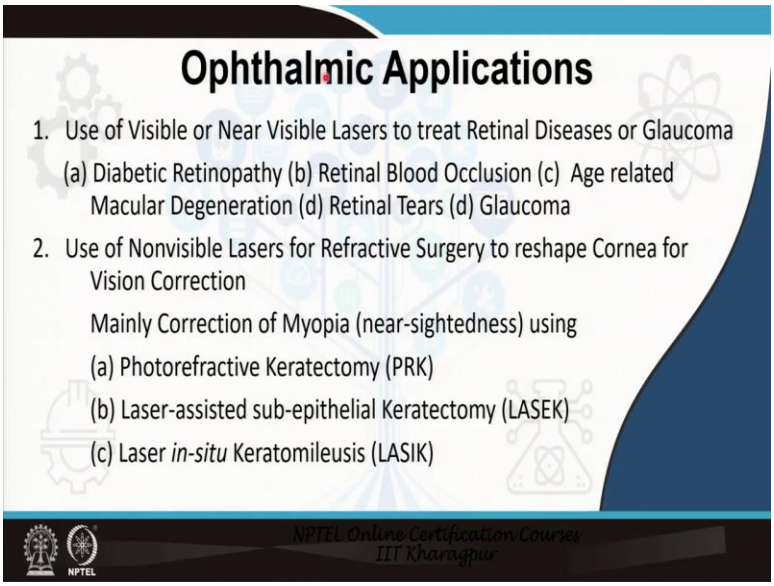

So, the application of laser light in particular to atomic application can be divided broadly into two different categories; the laser lights are either visible or near visible, they are very, very higher wavelength and then there is infrared lasers for, a separate purpose. Let us go step by step.

So, usually the visible or near visible laser, usually red laser or near infrared laser, they are used to treat mostly retinal diseases.

So, retinal blood occlusion where you have some kind of leakage or some kind of injury pertaining to your retina, diabetic retinopathy, you, you perhaps know already that there is some kind of a vision problem associated with a diabetes. And I have discussed age related macular degeneration where the central part of your retina starts degenerating, retinal tears injury in the retinal part.

And the run of the mill glaucoma, glaucoma is basically a whole set of diseases that basically affect or not necessarily always diseases, it can be an injury as well, but glaucoma mostly deals with some kind of problem with the optical nerve, remember optical nerve carries the information from our retina to the optical cortex of our brain.

So, if the connector, if the connector you have two circuits, they are connected by two thing or two electronic elements, they are connected by the, by a wire. So, the optical nerve is this connector, any problem with it and the signal will not to get converted or not be taken from, from retina to your brain for interpretation.

So, more or less the problems associated with optical nerve is the run of the mill glaucoma. So, these are where we use, generally though there are variety generally visible or near visible laser high frequency lasers. Now, there are other things like non-visible lasers and when I say non-visible laser do not generally think that this means infrared, this could be ultraviolet as well. And in fact, all of these, these days more or less are always using ultraviolet, ultraviolet lasers and therefore, refractive eye surgery.

You all know refractive eye surgery, and they are mostly to reshape cornea for vision correction. So, if you have farsightedness, nearsightedness, myopia, things like that. You can, you then refer to these kinds of medical procedures, these kinds of ophthalmic procedures medical surgery, which utilizes lasers, a specific type of lasers, it could be high energy, mostly ultraviolet excimer lasers, there are other varieties as well. And they simply reshape your cornea to correct your vision. Now, this thing correction of vision is different from here.

Here, there is some kind of an injury into your retina, or you have macular degeneration. All of these things are resulting in vision loss but they have, they are much more complicated. So, if

you have a glaucoma, you have damage to your optical nerve or these kinds of genetic things coming up. So, these topics are quite specialized and quite complicated.

On the other hand, these topic reshaping of cornea is relatively again, I know ophthalmologists are going to frown if I just differentiate their area of expertise into easy and hard but still from a very, very crude perspective. Refractive surgery, refractive eye surgery mostly involves this which is correction, vision correction and mostly deal with operating the cornea, operating the cornea and they are well mainly correction for myopia nearsightedness, farsightedness has also been done.

And they are dealing with the run of the mill all of you have heard of this, Photorefractive Keratectomy, PRK, Laser Assisted Sub-Epithelial Keratectomy, LASIK and the most common one which I think almost all of you have harmed LASIK, Laser in Situ Keratomileusis the popularity of LASIK for the past few years have actually gone down.

Now, everyone is going for refractive eye surgery, which is well laser LASIK is kind of a refractive eye surgery, but refractive eye surgery has gone into newer and different levels, but still, still LASIK and PRK are very common and very standardized eye operating procedures, very standardized and very common operating procedures eye surgical procedures for vision correction.

And I, it was my intention that I am going to tell you about these two processes PRK and LASIK in relative detail. If you are a specialist on the other hand, then these will come in, where probably you have to do some kind of an operation, especially retinal darked or macular degeneration, you have to do retinopathy, you have to do some kind of actual surgical procedure where you have to open it up and do things where laser will also be used as a tool, but you need bit more complications.

Whereas, these are relatively, relatively with an under line on the term, relatively standardized or common, I am refraining myself from using the term easy because whatever is easy for somebody may not be, and that is oversimplification. But these are something that you all have heard, you all have known probably some of your relatives, old age relatives of yours, maybe a father maybe a grandfather has gone through LASIK treatment of PRK, I know my father has gone through LASIK treatment and I had no idea what that used to be at that time.

But, therefore, I have a, I had this intention that since this is more common nearsightedness vision correction, let me teach you this. And maybe in the next semester or maybe in the next course, I will be discussing probably one of the very, very specialized topic of retinal tears or diabetic retinopathy. So, let us, let us try to see what, what these actually are.

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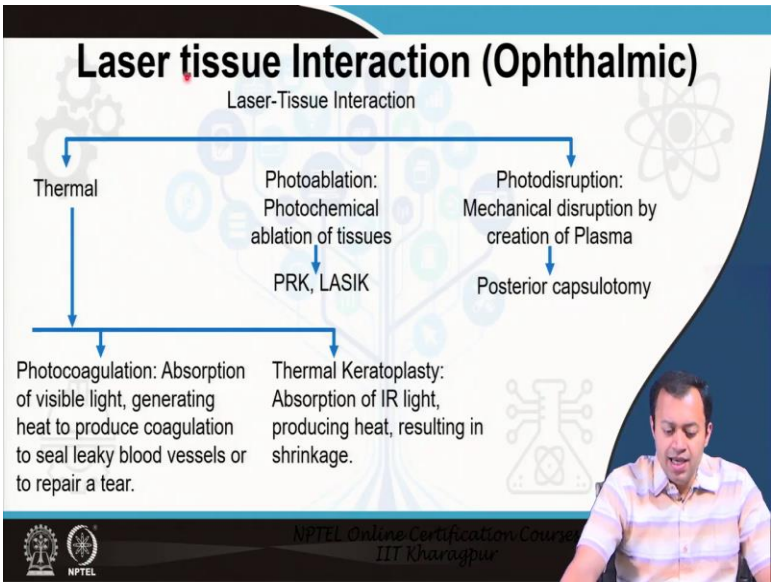

So, basically laser tissue interaction, the interaction of laser with ophthalmic tissue is mostly into three different categories; first is thermal, you basically heat up the tissue and you know by this time, you heat up the tissue to produce coagulation, and that will seal leaky blood vessels or repair a tear. So, something, some kind of a blood vessel somewhere in the back of your cornea is leaking and you have used light to produce heat and thereby sealing it all.

Then thermal keratoplasty where absorption of IR heat or IR light produces heat resulting in shrinkage, some kind of fluid as accumulated at certain part of your, of your inside your eye. Some, some sort of a body fluid has somehow because of internal damage internal leakage has happened and you need to evaporate that liquid.

So, you absorb, you shine IR laser light that produces heat that is absorbed by that body fluid which will mostly contain water anyway and you know by this time, water absorbs 3.3 micrometer, IR light, 3.3 micrometer wavelength. And the water or the body fluid that is containing water will evaporate resulting in shrinkage. So, some kind of an inflammation might have happened in your eye, some kind of fluid accumulation had happened that could be done.

Photo disruption on the other hand as you create some amount of plasma, you put huge, some kind of a femtosecond laser, we will slowly, I think there is a slide for me discussing about the generation of plasma. So, you ionize the area by sending high frequency pulses, ultra short pulses of very high frequency very high energy, so the all the electrons get so much charge that they can come out from the atoms of the molecules of the tissues and thereby create some kind of a plasma and the area become ionized and these plasma travels and thereby raptures, different areas.

So, this is called femtosecond surgery or femtolaser surgery, and that is also coming up very strongly. However, we are mostly going to talk about this photo ablation, remember ablation we have been discussing. So, photochemical abolition of tissues, where you shine some amount of light, the light basically destroys the tissue by generating a photochemical process and that could sometimes be thermal, no doubt about it, basically cutting or destroying some part of the tissue. And here PRK and LASIK are the subsets of such as photo ablation processes, when it comes to ophthalmic vision correction, where you are actually trying to rectify the vision of a particular person.

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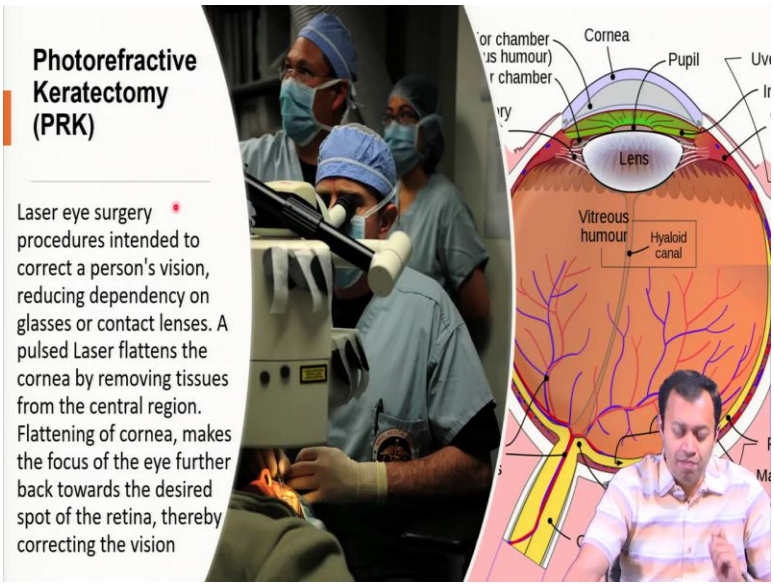

So, what does that involve? So, let us go step by step. So, PRK, photorefractive keratectomy. So, so this is the surgeon who is looking through the microscope this person's eye and you see how

good this eye hand coordination has to be to do this kind of a surgery, you are talking about a person's eye.

So, think about how much practice, how much diligence, how much sensitivity, these gentlemen need to have in their fingertips. So, this is something truly remarkable what surgeons achieve or surgeons do. So PRK, photorefractive Keratectomy a, it corrects a person's vision. So, what basically it does, you, you have already seen this picture, you know what this picture is, this is the same image of the eye that we have discussed previously, in when we are discussing how you see your, how light perception comes into your eye.

So, this is cornea. cornea is this transparent, soft tissue, which covers the pupil and the lens and the iris, this is the outermost part of our eyes. So, when you wash your eye, you are basically washing the cornea part. So, the cornea here, the main function of the cornea is to refract light, it is not going to focus the light though in some animals' cornea focuses as well.

But the main use of this outer whitish layer, which is called cornea, this is the outermost transparent, not white it is the outermost transparent layer is to refract light whatever is coming it accepts light, refracts it, because it is a, it has a refractive index of either 1.39 or 1.33, it refracts light and together all the light that gets bends, that gets convert falls on to this lens, which then focuses it into your retina and from retina, you know optical nerve carries it to your brain cerebral cortex.

So, the idea here is that as the day goes on, as you become old or some genetic reason or lifestyle habit, due to several different factors, age, genetics, your lifestyle habits, as the day go passed by this cornea this transparent, soft tissue that basically is refracting your light onto the lens for focusing purposes. Remember, cornea in human eye does not focus it refract, lens focuses, though, though in certain animals' cornea does help in focusing.

This part can be considered as the overall set of lens but nevertheless, cornea is mostly for refracting, it is bending the light. So, what happens usually cornea has a particular curvature. So, if this is your eye, this is the transparent, this is a particular curvature as the day go pass due to some disease, degeneration, genetics, age, lifestyle habit, it starts carving more and more this outer layer of your eye, the transparent the one that shines, which you see the lights getting reflected or refracted when you look yourself into the mirror.

The outermost part is the cornea, it carves, as a result, the refraction also changes, path length will also change. Previously, your cornea was like this, as the day passes by, it starts curving, it starts curving. So, the idea here is that when it curves the refraction of the light going through the cornea into the lens changes and as a result, all the lens needs to focus here, all the light, all the light which needs to come from here through refraction, through here focuses here actually focuses somewhere in the middle i.e. not in the retina it focuses somewhere in front of the retina quite inside the retina, quite in front of the retina not at the back of your eye, not at, at retina itself.

It focuses somewhere here or here because this thing instead of like this, this curves because of age, because of lifestyle habit as the day passes by. The idea here is to correct it, so what it does, this PRK or LASIK overall, it takes out a chunk of the cornea. That is the surgery, it removes a part not the entire part, removes some part of the cornea then send excimer lasers, ultraviolet laser, that ultraviolet laser, because of the absorption etc. the of the molecule ultraviolet is absorbed by almost everything it flattens up.

So, a person's vision reducing dependency on glasses or contact lenses pulsed laser flattens the cornea by removing tissue from the central region. So, you remove some part of the cornea, send laser light to flatten it up, which has previously the molecular arrangement has been like this, you rechange the molecule arrangement by giving some amount of energy to the molecules So, they, they become straightened, so that when it has straightened back the cornea the refraction is now happening better or refraction is happening differently or the refraction has happened, how originally it was supposed to be.

So that, the focus moves back at the end of the eye, which is now focusing at the retina. So, simply this, you previously had your cornea more or less flat with a slight curvature as the day passed, it became like this, you open up this particular area, send more amount of laser light, ultraviolet laser light inside it, you energize the molecules of that portion that, that portion of the cornea which then rearranges itself, which then rearranges its molecular arrangement to its original position.

You obviously have to optimize, you obviously have to optimize how much dose, how much laser, what wavelength what etc., for how long that needs to be given all of that thing, but this is what this person has specialized in or these, these all these people have specialized in and she's

now working on this patient, she or he and thereby flattening the cornea. So, that is all what keratectomy or these kinds of laser eye surgeries are.

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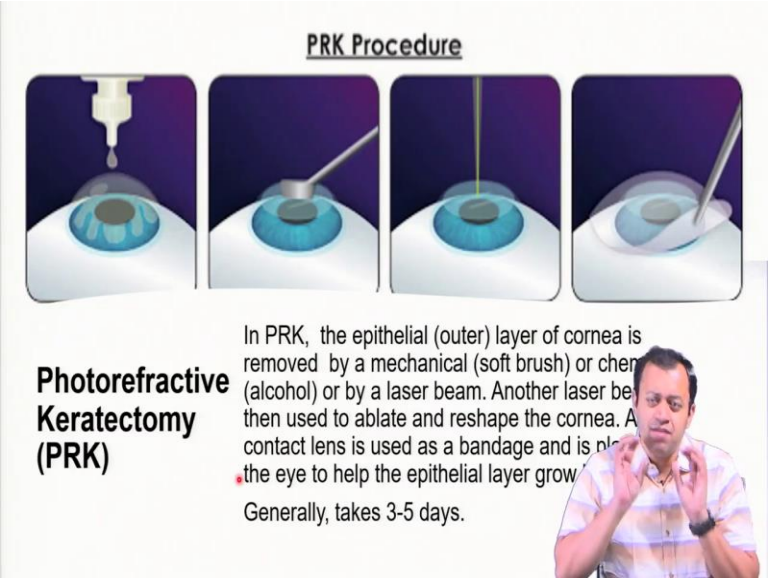

So, slight minute, minute differences between PRK and LASIK, PRK and LASIK. In PRK you first put some kind of a solvent either an alcohol or soft brush and then remove, then dissolve some part of the cornea, you dissolve some part of the cornea, cornea do not get frightened, this is run of the mill eye surgery everybody does that and probably some, you know someone who has undergone PRK or laser eye surgery, laser eye correction and this is the procedure.

Some part of the transparent cornea is removed like this part, and then you send laser light by laser beam is used to ablate and reshape the cornea, you then flatten it up, and some kind of a soft contact lens is used on top of it as a bandage. And this bandage, this contact lens helps the epithelial layer grow back, it generally takes 3 to 5 years. This is made up of some kind of a biocompatible material that your eye, that both heals your eye as well as your body accepts it and re grows this part of the cornea that has been alcoholly washed or alcoholly dissolved or alcoholly or using a soft brush being removed.

This is PRK, and that is an old technique. That is a pretty old technique since 1980s. It has been going on to the best of my knowledge, obviously, I am not an ophthalmologist, I will not be able to tell you the exact detail when it was started. But this is how you do vision correction.

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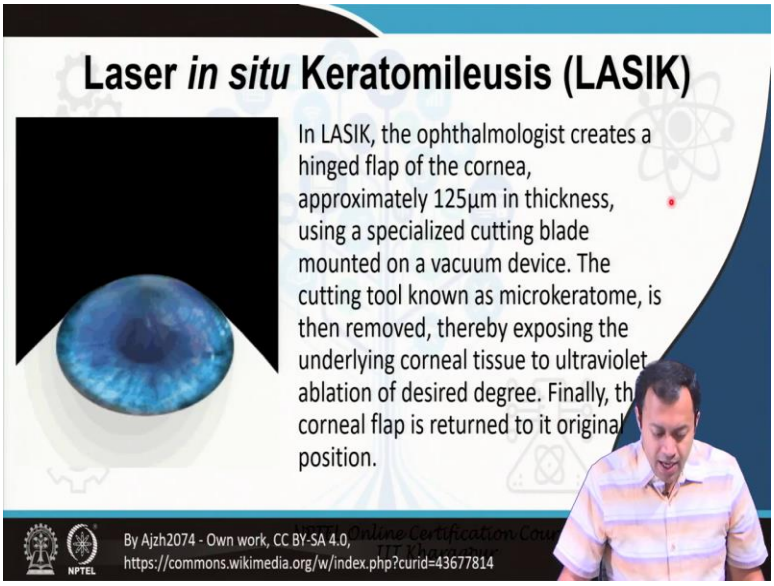
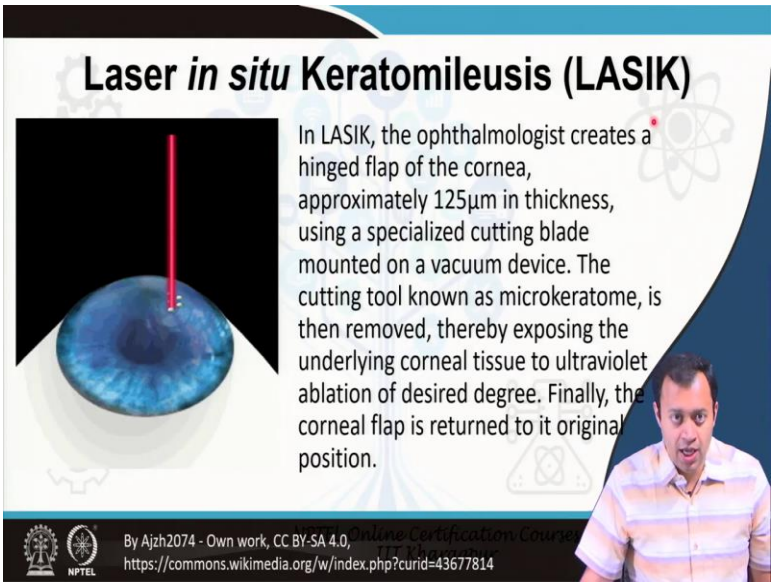
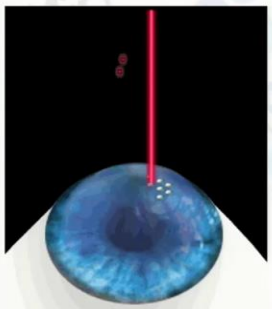




Laser *in situ* Keratomileusis (LASIK)



In LASIK, the ophthalmologist creates a hinged flap of the cornea, approximately 125µm in thickness, using a specialized cutting blade mounted on a vacuum device. The cutting tool known as microkeratome, is then removed, thereby exposing the underlying corneal tissue to ultraviolet ablation of desired degree. Finally, the corneal flap is returned to it original position.

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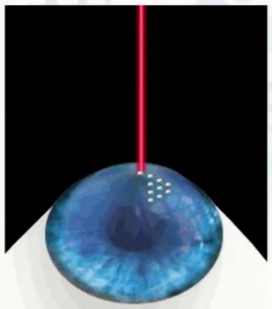

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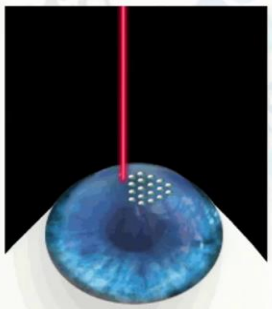

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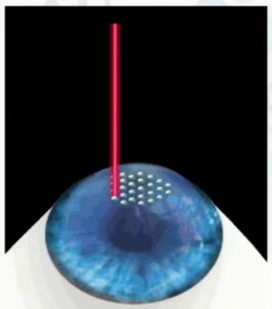

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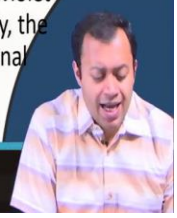

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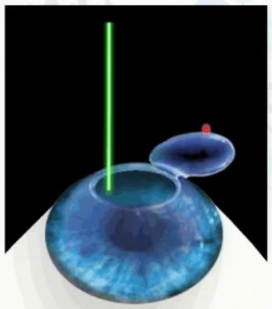

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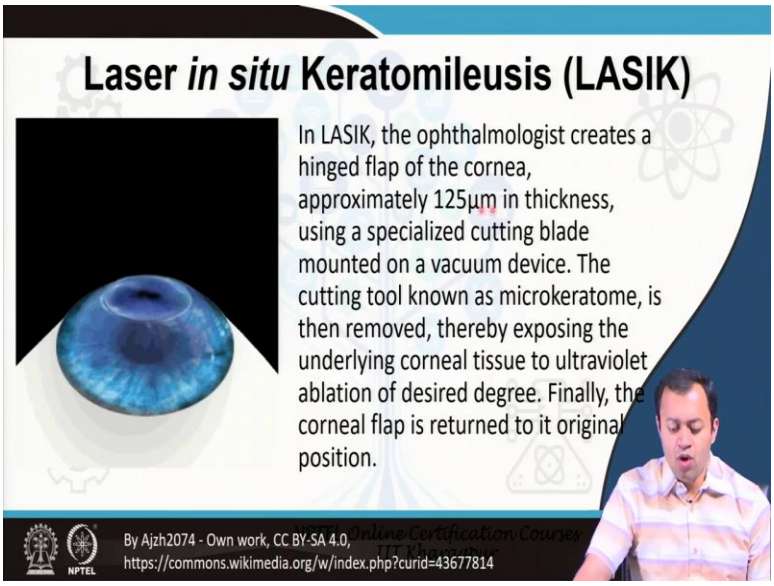

There is also LASIK surgery, all of you know LASIK surgery and I am asking you to look at this GIF to know. There is a very small difference between PRK and LASIK eye surgery. Here as you can see from the picture, you used a particular laser and approximately make a flap, a hinge some kind of a lead of 125 micrometer thickness, either you use a cutting blade, you scoop it off using a blade, how precision you have to be precise, you have to be using a vacuum device think about it or these days, it is always laser.

So, you take a, you scoop some part of the cornea up, you do not remove it altogether you leave it like a lid, like you open up a tin can, leaving some part attached. So, like this part of the cornea is you know cut and opened with this part remaining intact.

You then send laser inside the green laser you will see in a moment, the green laser go inside ablates it, reshapes it and then this lid, you fill it up, instead of putting an external bandage or an external contact lens, you simply put it back and give some kind of a medicine or some kind of a growth factor so that this part of your body this, this used to be part of your cornea finally dissolves and re grows and the corneal flap is returned to its original position. So, you make a lid, a flap and then through that flap, you drop laser light, you drop laser light this ablates, this reshapes the cornea flattens it up and the lid the mouth was open and now it is shut. You are not putting anything external in PRK.

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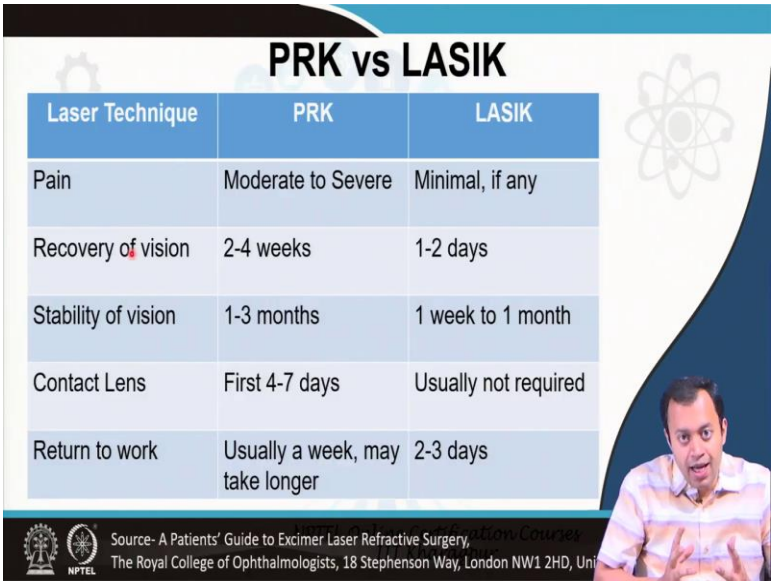

In PRK, you gave an external, you give some kind of an external bandage or external contact lens something that your body may have difficulty to absorb, here since it was part of your body, it simply returned back to its original position. So, that is very crudely, very easily some amount oversimplified analysis of LASIK eye surgery.

You must know someone in your family or distant family some old relative might have gone through because believe it or not cataract eye operation is also associated with this. In cataract eye operation there is some kind of a scale that forms in your eye. They remove it, and they also do the vision correction because cataract eye operation is mostly associated with old people who have started developing nearsightedness or farsightedness.

So, since they have to do it anyways, since they have to open up the cornea anyways, because the formation of this scale, cataract basically, why not just send another laser to recontour the underlying cornea, flatten it up, so that the vision gets corrected. So, LASIK is associated or used to be associated not always with cataract operation and cataract operation is also same. Here, the extra tissue cataract, you know an extra scale forms on top of your cornea, your vision starts blurring because of this, because of this sheet because of this curtain falling, the whiteness that that keeps on falling.

You have to remove it anyways; you have to remove it anyways. So, why not remove it, put some amount of laser to correct the, flatten the, inter, underlying corneal layer and thereby

improve the vision anyways. So, what are the other differences from a patient's perspective between PRK and LASIK? Well, the pain part in PRK is bit severe because you are going to use some kind of an alcohol-based solvent that dissolved part of your eye, cornea.

Nonetheless, it is dissolving part of your eye or brush, so moderate to severe and minimal, if any, the recovery of vision is two to four weeks, whereas in LASIK, it is one to two weeks, I think one to two days, I think it has something to do with the pain per se. The idea here is that laser produce minimal damage, it is very focused and the heat does not dissipate all over the area, it is very, very localized heat.

So, the pain is also quite, quite less per se. The stability of vision, one to three months as compared to one week to one month and returned to work as you can see, you can come and return back to work in two, two to three days. Now, those of you who might know someone who has gone through LASIK test and LASIK eye correction may disagree with the entire you know chart given here.

And in my defense, I will say that this comes from some of the top sources the Royal College of ophthalmologists of United Kingdom. So, this is the chart, this is my source, I have seen only people undergoing through LASIK surgery and I myself have not gone so, I cannot actually comment on the pain, pain to me is kind of relative.

So, do not hold me responsible for this. If you think, if you have gone through LASIK eye surgery or if you know someone and that person cannot return back to work within two to three days. This is a general run of the mill average that is not the standardized or it is not something that is specific to every single human being that has, that has undergone LASIK. So, LASIK is or it at least it used to be some of the most common laser eye correction.

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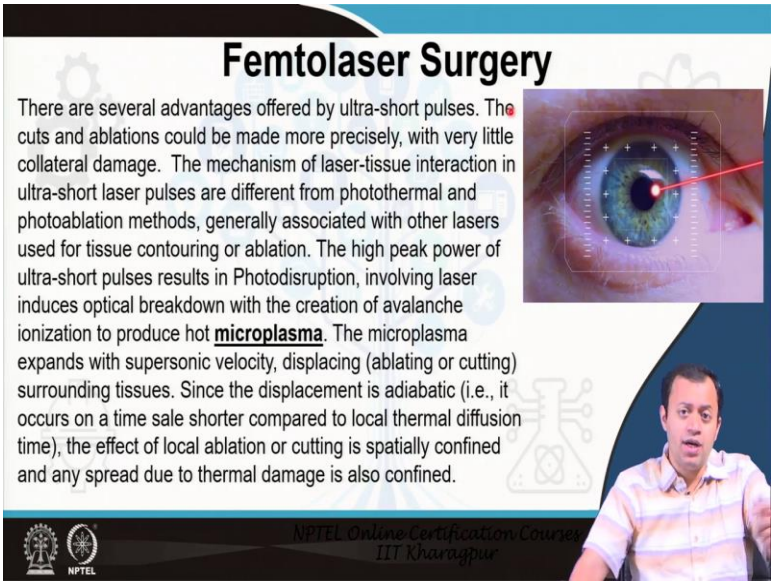

However, now it is as laser, there has been several improvements some quantum leap per se in laser technologies. We are going for Femtolaser surgery, we are going for femtolaser surgery and this is an epic paragraph I usually dislike putting entire paragraph into PowerPoint slides, slides are mostly visual representatives. So, you will see more picture on my slides than text, but I give you this to read so that you understand where it is going.

So basically, in film two laser surgery, ultra-short pulses produce photo disruption involving laser induced optical breakdown. I told you, the high-power high frequency laser, femtosecond they directly excite the molecule instead of creating vibration molecule or vibration they excite the electrons and the electrons can eject out of the molecule thereby creating ionization and produces hot micro plasma, this micro plasma expense with supersonic velocity destroying, ablating or cutting surrounding tissue.

And since the displacement is adiabatic it occurs on a timescale shorter compared to local thermal diffusion time. Remember, I gave you something to figure out in previous lecture, why the timing is different, time is shorter, the process occurs at a sale shorter than the local thermal diffusion. So, before even the Franck Condon principle the molecule or atom has a, has got the time to expand or rearrange itself the cause of excitement has moved away, the plasma, the micro plasma has moved away with supersonic velocity.

So, the electrons have already gone or the electrons have returned back to its ground state before even the molecule can react. So, Franck Condon principle remember. So, the effect of local ablation or cutting is spatially confined, so the pain or the heat or the damage is confined within few femtometer, picometer, nanometer area. So, think about it. You would not feel it if one cell or a part of the cell is damaged and that is what this, this does. So basically, the claim is painless surgery. The damage is also confined and you are able to do a lot more in a much more precise manner.

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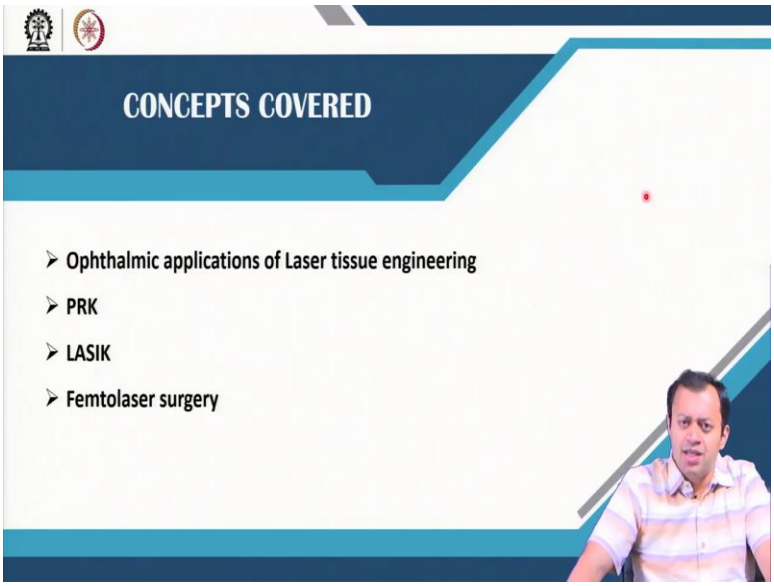

So, that is a very overly simplified how laser can be used for vision correction. Remember, people specialize in ophthalmology, people specialize not only in ophthalmology, they specialized in this PRK, LASIK operation, there are doctors and surgeons who spent their entire life perfecting this process.

So, I cannot, cannot comprehend the amount of practice they have to go through to precisely do that and achieve whatever they are able to achieve to give proper vision to people. So, under no circumstances, I am telling that everything of what they have done or their skill or the knowledge I can transfer to you within these 30 minutes of time.

However, it was my intention to tell you what is the overall procedure. And obviously in medical science, like in any other science, it keeps on changing, modifying itself, improving all the time, but this is the run of the mill, this is the standardized, very common, very standard laser eye

surgery. Whenever we are mostly talking about vision correction, laser correction, laser eye surgery, LASIK or PRK is the one which we at least used to refer mostly.

Nowadays, it has become a little different femtosecond these that is coming. But LASIK is something that I thought all of you need to know. And how laser eye photons are being utilized on a biological matter that is our eye to cure an ailment that is short sightedness. So, that is basically it.

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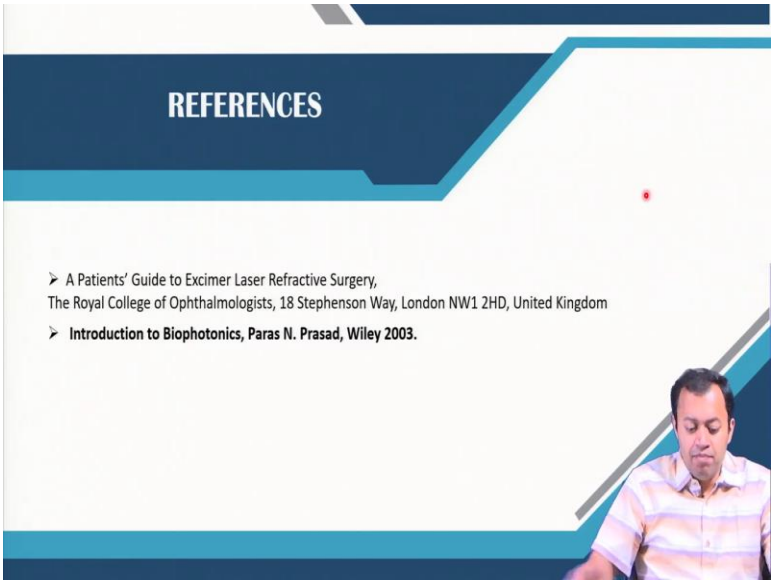

Please go through the references This is a nice book, it is, it is actually made from the point of view for a patient, so that even I can understand, if I can understand you can understand without going into the specialization. And obviously professors Prasad's book gives are my companion. So, thank you very much. I will take another topic in next class. Thank you.