Biophotonics
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Lecture 42
Laser Tissue Contouring: Dermatological Application

Hello, and welcome. We will continue our discussion on laser-based tissue engineering. And today I am giving you some very, very specific example of laser tissue contouring, contouring mean reshaping or restructuring and some amount of ablation as well. And here I am utilizing dermatological application, basically skincare, basically something related to the skin.

And obviously skin, since skin is the outer part you can bring in laser very, very closely towards it, you do not have to worry about some kind of an internal organ. And skin is more or less strong enough. Some people's more than others of course, and it, it can take some amount of heat as compared to several other internal organs which, which might get damaged. So, there is a fair bit of flexibility when it comes to tissue engineering when it come for from skin.

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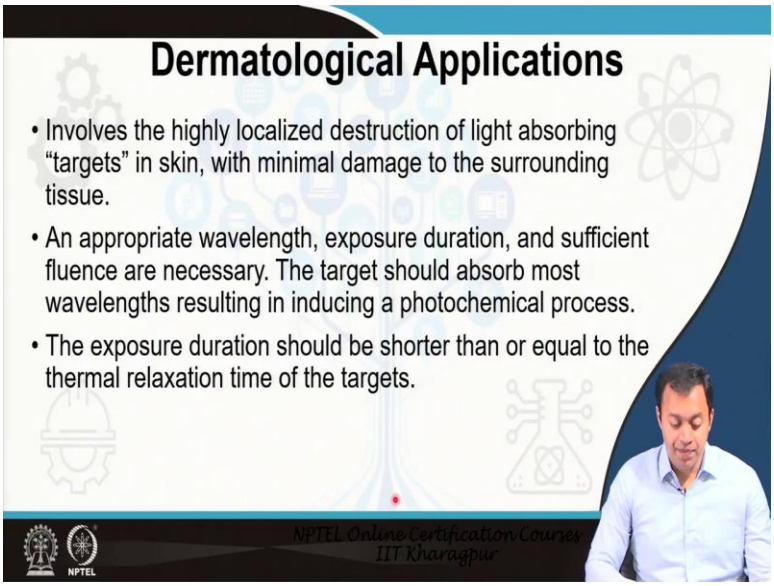

So, what does it involve, dermatological application, so it involves highly localized destruction of light absorbing targets in skin with minimal damage to the surrounding tissue. Skin tissue can take some extra damage, but that is not our idea. It gives you some amount of leeway, some amount of flexibility but overall, it involves highly localized destruction of light involves target.

So, you need to figure specific, specific targets inside skin that you want to destroy or change or reshape or as they say, contour.

An appropriate wavelength where exposure duration and sufficient fluences are necessary the target should absorb most wavelength resulting in some kind of a photochemical process. So obviously a specific wavelength that is absorbed by that specific part of the skin, specific component of the skin, how long have you exposed it, 5 second, 10 second, 100 seconds. And what is the overall fluence, fluence as in energy per unit area.

So, 5 joule per centimeter square, 100 joule per centimeter square, 1000 joules per centimeter squared, do not go 1000 joules. You get the point, that is the idea. And, how long have you, well the exposure duration has to be shorter than the thermal relaxation time of the targets. Why do you think that is required? Why is the exposure duration the amount of time the pulse laser is hitting the cell is shorter than the thermal relaxation time of the cell?

Why is that requirement? Think about it, this is something that I want you to discuss among yourselves as well as read something about this and come back to me in the forum. I have not given you enough questions for the past several, several topics outside the assignment to go for self-study. So, this could be a good topic. This is quite interesting. The exposure duration should be shorter than the thermal relaxation time of targets.

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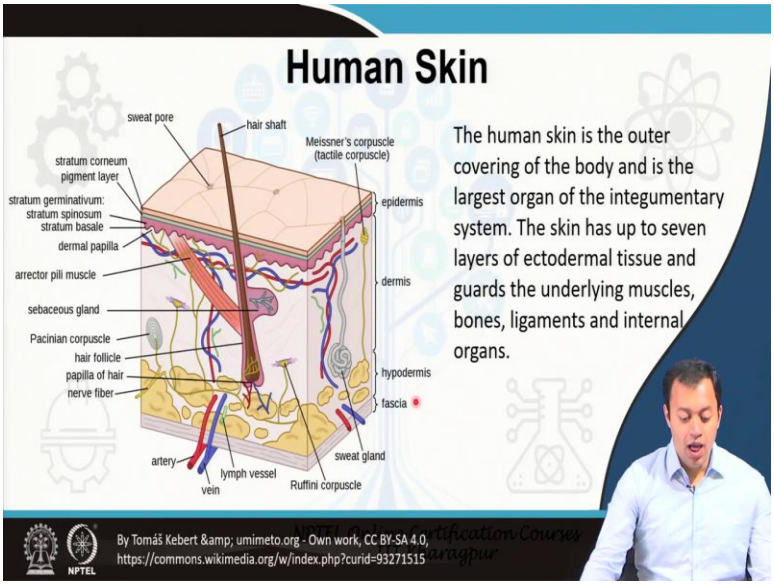

So human skin, we need to understand. I am, I am not trying to make you a skin specialist. I am not trying to make you a skin doctor. You know this is a specialization after doing their medical degree people specialize in skin. So obviously one slide will not you specialists but you need to know what the exact human skin is. So, the overall epidermis, this is the topmost layer, this is the topmost layer, that is what we see, when we see a person. And it contains basically three separate layers.

I will not try to pronounce their names for the amusement of medical students. Here they are written you will get the slide so you try to pronounce it yourself, you pronounce it yourself I am not going to do that. What I am saying is that the epidermis is the top layer. The epidermis is the top layer which has itself divided into three different layers with three different names. Obviously medical jargons are there and then the final part is dermis and then this fascia etc. below that is only your muscles and flesh and blood and etc. forms well.

The blood tissue comes here as well. But this is, this overall when we talk about skin per se this is the overall skin tissue, overall skin tissue and below it is all our muscles and organs and everything else that is almost everything that is covered by tissue. So, this thick part is your tissue it contains the hair follicle, where your hair grows, these are the sweat glands, then you have lymph vessels and lymph nodes obviously, you will have veins and artillery, arteries and capillaries.

There are several corpuscles, nerve fiber of course, there has to be nerve fiber that is, that is takes the information regarding pain, heat cold, or, or anything any skin-based sensation that you feel are because of this nerve fiber. So very, very simply, I am again not trying to make you a specialist in skin. You have blood capillaries, you have nerve fibers, you have hair follicles, and you have sweat glands.

Obviously, the opening is sweat pore and the inner layer dermis and the outer layer epidermis, epidermis have several of this stratum basale, stratum, I pronounced it anyways spinosum, stratum germinativum. I know, I understand. So, this is, this is what basically skin is. It has several layers of ectodermal tissues that guard the underlying muscle, bones, ligaments and internal organs. And it is the largest organ of the body system.

Remember, skin is an organ. In fact, the largest organ of your body is skin. It comes in general knowledge questions all the time, what is the largest organ on your body and people think it is brain or heart or lungs, maybe it is actually your skin, think about the length of your skin. So, this is the overall skin and now let us try to understand the effect of laser on the skin.

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Laser based skin tissue rejuvenation is this skin port wine stain. What is a Port Wine Stain? this is a port wine stain. Any of you know who this gentleman was, believe it or not, at one time he was the second most powerful human being in this planet. And he received Nobel Peace Prize for probably preventing the planet from destroying itself is Mikhail Gorbachev the last Soviet Premier. So, this is the port wine stain. This is a congenital defect. This is a congenital defect, it is usually happening in faces, but also happens in head, neck and hands.

This is discoloration of the human skin caused by vascular anomaly. So, this is port wine stain from the port wine that is, that is the specialty of portable this is this specific color. And what it basically means, is capillary malformation, so you have blood capillaries forming in abnormal areas. So, these are blood. This is not simply a pigmentation well pigmentation has happened but this is not some kind of discoloration which you can rub and it will go off and it is not also a birthmark per se.

This is not necessary, well there are different types of birthmarks dermatologists will tell you that, but this is happening simply because blood veins or blood capillaries are mal forming in a

specific area. So, there are different formation of blood capillaries in this area, this area rather than the other area part. So, this is, and hence the coloration is port wine this is a reddish rather than blackish or brownish.

This is, this is something that is containing blood there are tiny, tiny capillaries of blood vessels that has malformed usually they are supposed to go like this, but they have gone like this. And this kind of pigmentation has happened. And the area of the skin affected grows in proportional to the general growth. So, it is not that if you grow older, this will simply cease to exist or this will become smaller or the other part of your body or other part of your head or skin will, will expand and these become tiny and tiny.

So, this is not that, this is just malformation of the capillaries, malformation of the blood vessels forming as such. So, what do we do, we target the hemoglobin, oxyhemoglobin is our chromophore. This is the one which, which we are trying to destroy basically, this is the Chromophore oxyhemoglobin that our laser light should target, should heat, should heat as well. And the laser is absorbed by the hemoglobin and converted to heat which damages the endothelium, which is, which is damaging the endothelial cell, this is the outer cell this is the, this is the cell that covers the blood vessels.

So, you have capillaries, their inner side is endothelium and blood are coming through it. So, you are targeting the hemoglobin in it, this is dissipating the heat and this is damaging the endothelium that the inner layer of your capillary inner layer of this malformed capillary, this is followed by thrombosis blockage of blood vessels. And, if the blood is removed or a clot is formed, after certain time the lesion regresses into a more normally colored skin area. Meaning, you are destroying these abnormal capillaries that has been formed here.

You are sending a laser light, you are sending a laser light that is absorbed by the hemoglobin that is flowing through, this hemoglobin is dissipating the heat, that heat is destroying the inner cellular layer of the capillary, the capillary is getting damaged, the capillary is getting damaged, blood clot is forming, after certain time the blood clot is getting absorbed and the capillary itself those, those networks of capillaries that has formed here, the networks of capillaries that has formed body will absorb it by itself or it can be excreted depends on several different factors.

So, the abnormal venules, removal or abnormal venules occurs and the skin regresses into a more, more normally colored skin area. So, this network, this mesh of abnormally formed capillary you are simply cutting it down, you are simply breaking it down, you are simply melting it down let us put it that way. Very, very crudely you are melting it down that abnormal network of capillary that has formed in, in different areas. So, that is skin port wine stain that, that can be rectified or contoured using laser light.

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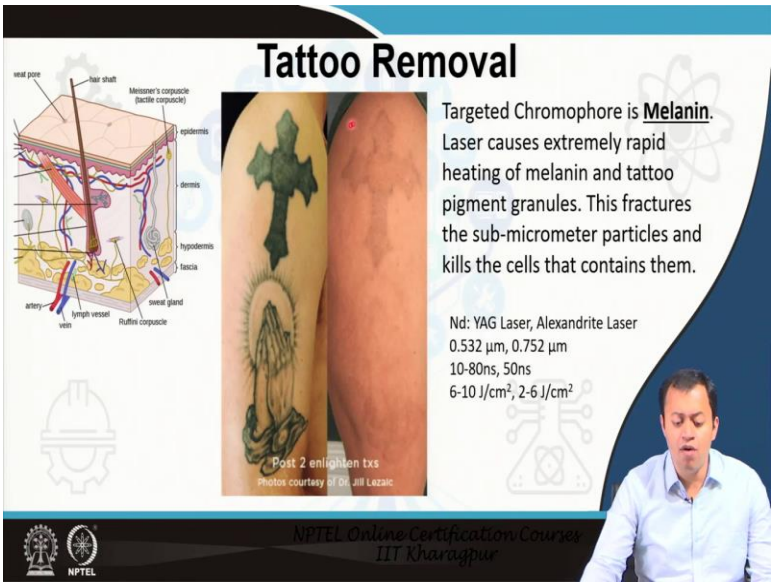

Then obviously, tattoo removal. So, what happens for those of you who have tattoo will be able to confirm that the ink, this is the ink they now they have started making colorful ink, they put it below the epidermis and above the dermis. So, it the ink this ink actually goes below your epidermis, below the top layer of the skin. So sometimes doing tattooing, you will see blood comes out. So, if they use some kind of a syringe or some kind of a needle, now everything is electronic, now everything is much more computer controlled.

So, though they basically pour the ink of at a specific location just below the epidermis, just below the epidermis, so that the ink stays in a position which is at the interface of dermis and epidermis. It penetrates through the epidermis and goes to the dermis where it stays and thereby from outside it cannot be touched or cannot be removed or you cannot simply rub it off or normal aberration, normal wear and tear will not be able to dislodge the inks.

So, tattoos are more or less considered more or less considered permanent with several years of living, the pigmentation can be discolored so those, those effects are separate, but remember in tattooing, in the process of tattooing inks, permanent inks are actually penetrated actually inserted through the epidermis into the dermis region, at an area which is between epidermis and dermis, at a region at the interface, which between epidermis and dermis.

But sometimes we need to remove them. Sometimes we need to remove them. How do we do it, we target the chromophore that is melanin, melanin, you know the pigmentation. The laser causes extremely rapid heating of melanin and tattoo pigment granules. So basically, you either heat the ink so the ink dissolves or ink evaporates because of intense heat, these are inks basically. So, at a specific temperature lack, extremely rapid heating, you can evaporate or melt it.

At the same time, this, this sub micrometer can fracture the sub micrometer ink particles and you also kill the cell, you also kill the cell, the part of the epidermis, dermis cell, the interface cellular structure or intracellular junction, where the ink has formed or ink has nested, where the ink has done either you are evaporating the ink by rapid heating, or you are killing the cell that has absorbed the heat.

Several different days you require it is not a one-day process, it goes on for a, for a long period of time, and obviously it damages some part of your skin, but then skin has normal growth factor so skin will regrow. It is not causing a permanent damage. So, it was quite possible to remove the inks that has, that has penetrated through your epidermis inside it.

So, these are some of the common lasers either Nd: YAG or Alexandrite Lasers have been used. These are the wavelengths that they use for a pulse which exist for few nanoseconds and this is the fluence, these 2 to 6 joules per centimeter square. These are run of the mill typical examples. And obviously, what I am telling you is simply the basic of the basic parts, there are different ways of doing tattoo, now they are doing 3d tattoo.

And so, the removal of that will also not be this typical, this is merely an example, this is merely an example. There are other chemical procedures that could also be used which does similar things that chemical gets penetrated, but with laser the overall advantage here is localization

extremely rapid local heating. If you cover it with some kind of a skin-based cream, you do not know the overall effect of it.

Here, couple of cells will be destroyed, but your laser light is highly localized, you can localize laser into a spot size of 50 to 20 micrometer. So, 50 to 20 micrometers can destroy say 50 to 20 cells or even if slightly larger than that, those cells can regrow. And if you do a specific type of wavelength which will only be absorbed by this melanin, this pigment with a specific duration 10 to 80 nanosecond then the overall surrounding damage, basically the side effect can be controlled to a very, very large extent. I am not saying that that there are zero side effects, no one is claiming that but it is in a much more controllable manner. So, tattoo removal is one specific example of laser-based contouring.

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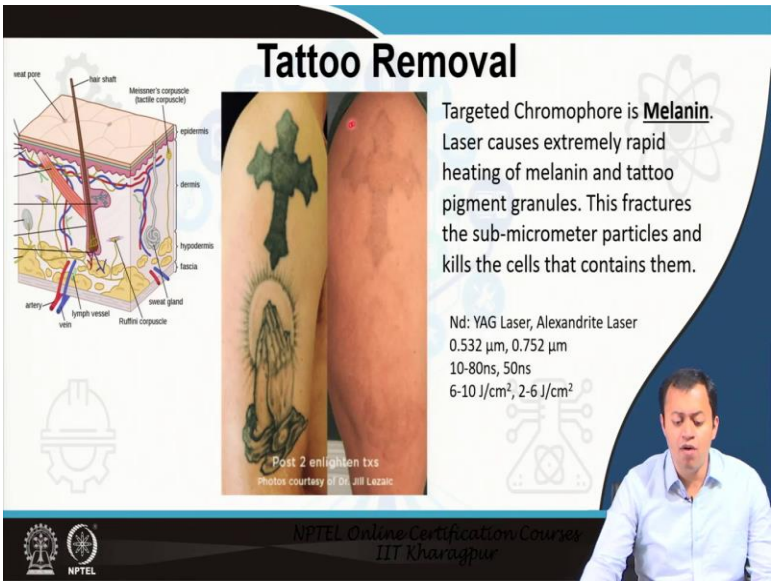

Then there is this very interesting phenomenon of skin resurfacing, where you put some sort of a laser light you cannot see the laser here because this laser is infrared into the skin. And this is basically removing either wrinkles or these kinds of creases or even acne or some sort of skin wound, some sort of skin lesions as such.

So, here, believe it or not the targeted chromophore is what a superficial layer skin is ablated destroyed with wrinkle removal. So, some part of the skin is actually destroyed very thin layer, layer, laser deposits energy in 1 to 20 micrometer layers of the skin. So, 1 to 20 micrometer, just very thin layer, one of the epidermis or one or two of the epidermis is being removed here as such.

And this evaporates the water, this also damages the skin but the upper layer and it leaves thermal damage and hemostasis that is, that is clotting basically to a 1-millimeter area of your skin. So, the thickness wise 1 around, 1 millimeter of the skin gets damaged. So instead of putting some kind of a collagen an injection or using some kind of chemical onto your face, this is this, is an alternate procedure.

I am again, not saying which one is better which one is worse, I am simply saying that laser can do this, laser basically will burn away the very top layer of the cell, as well as some water that has been deposited, it will evaporate, it will burn down the top epidermis layer the tissue and this will leave, this will leave some sort of damage but then your skin regrows or you hope it regrows. And that is, that is how it works.

So, basically you can remove moles or some kind of warts or acnes or other benign epidermal lesion, remember benign is the term here you will not go for skin cancer treatment using this targeted chromophore. So, this is the overall, overall. The, so this is usually CO2 laser, infrared 2.94 or 10.6. So, therefore, you cannot see it here because there is an infrared laser, which is mostly absorbed by water and for a slightly longer period of time. And these are the, these are the particulates.

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The second and this is becoming very, very popular is laser based hear removal. So, this is here we are targeting the hair follicle. Hair removal is gaining popularity in urban areas, not just in this country but every other country. And not just in women but a significant proportion of men are using hair remover, hair removal products on a daily basis. This is becoming as common as you know shaving kits. So, here your laser is targeting the follicular melanin, the hair follicular melanin these are the areas that it is targeting.

And this part, this this hair follicle, basically the root of the hair is to be destroyed. The hair root that helps you grow hair, basically the follicle, follicular melanin, this is the area from which your hair grows and there are, grows and here there are capillaries and blood vessels and whatnot and nerves of course. This follicle is targeted and that is destroyed without damaging any other part of the skin. That is the promise or at least that is the potential.

However, this is debatable if this hair removal achievement is permanent or not. Have you permanently damaged the hair follicle? Usually after a few months this the hair might come back, the hair might come back and because diode lasers the same lasers that you used in, in your laser pointers could be utilized at 0.81 micrometer wavelength that is 800 nanometer wavelength, 750 nanometer wavelengths for this many millisecond.

It has, it is steadily gaining popularity because diode laser is cheaper. And instead of shaving or putting some kind of a chemical or waxing which damages or chapped or inflates, causes inflammation or causes irritation into the entire skin because you are not only damaging just the hair, but you are damaging the sweat pore or other areas as such, or you are scratching the entire epidermis area this is simply targeting the root.

Root the hair follicle, the hair root and thereby destroying it, resulting in hair removal treatment. Again, these are alternative to already existing techniques. I am not a dermatologist, so I cannot recommend you any specific method if you want to utilize it in your own, own day to day life. But go, go and speak with an expert.

But what I am telling you is that, biophotonics can also do that. If you can do it chemically, if you can do chemotherapy, we can do phototherapy or photodynamic therapy. And if shaving can do this, so can laser-based tissue ablation, why not? We are targeting a specific area. And the promise here is, there are the side effect is comparatively controlled, comparatively controlled.

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So, those are some of the, the topics that I discussed today here. I am having a feeling that few amongst you, the minority here will scoff at this topic considering this as part of aesthetic medicine or so-called cosmetic medicine that there are several other types of surgeries that are important like curing cancer and whatnot. So why are we trying to discuss something which many of you might considered as vanity. Well, I would like to say that we are scientists, we are engineers, we are medical professionals.

So, we should not be passing judgments. And then secondly, why would these procedures be the prerogative of our select few, the rich and the famous and the celebrities who utilizes this on to their day-to-day life and look good, and we appreciate them. Why can not a common person in the street utilizes laser skin resurfacing? Why it is always the prerogative of the rich and the powerful? Why cannot we democratize medicine? That is just an argument that, if this is available, why not make it available to everyone?

Why would this only be available to a specific group of people whom we will appreciate and if a common person starts utilizing this, we will consider it as, we will utilize, we will pass out, we will start passing our judgment, that is my point. At the same time remember, if these easier procedures are not available to common person, there is a chance that she or he will try to get it from dubious sources, basically quacks. People who sell you know screen rejuvenation cream and skin therapy you see that in advertisement. I am not saying that all of them are bad product or all of them are wrong.

I am simply saying that several of them could be, several of them could be and instead of going to pseudo-scientific quack, why not we understand the overall scientific mechanism behind this and make this laser tattoo removal or laser skin resurfacing or laser hair removal products available in the market at a cheaper rate.

So that, instead of destroying your skin by adding some dubious product, something that some sharp corner, someone is selling, utilize this. Just a thought, feel free to disagree with me. Feel free to disagree with me. I know even in the medical community cosmetic surgery is treated with a healthy amount of derision. But I hope the, the process changes, I hope that this concept changes that a specific surgery will be available, a specific medical treatment should be available for celebrities and rich people and powerful people and common man or common person should not be should not be having them.

So, laser can democratize this, laser can make these things cheaply available. And by knowing the overall science and overall side effects and the risk associated with it, you can therefore make an informed choice, rather than blindly apply some facial cream that someone has said will make you look younger, like 20 years. You know what I am talking about. You have seen this in television all the time. So, think about it.

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Anyways, this was the overall topic that I wanted to discuss, this is my reference, and we will continue our studies in next class. Thank you very much.