This unedited transcript of a AudiologyOnline webinar is provided in order to facilitate communication accessibility for the viewer and may not be a totally verbatim record of the proceedings. This transcript may contain errors. Copying or distributing this transcript without the express written consent of AudiologyOnline is strictly prohibited. For any questions, please contact customerservice@AudiologyOnline.com.

Verification and DSL in Bone Anchored Hearing

Recorded Date: July 7, 2020

Presenter: Susan Scollie, PhD

AudiologyOnline.com Course # 35137

Partner: OticonMedical

continued

- [Ravi] Great. So good morning, good afternoon everyone, depending on where you are. So it's still morning for me because I'm on the Pacific time. So thank you all for being joining us for this Oticon medical webinar session. So today is a sixth of a seven session series that we're doing with AudiologyOnline. I'm really delighted to introduce you today's speaker. Actually, she doesn't require much introduction, most of us know her, her work on DSL, so she is no other than Dr. Susan Scollie. She is a registered audiologist and a professor of audiology at the University of Western Ontario in Canada. She is the current director of National Center for Audiology, where she conducts research on hearing aid prescription, verification, and outcomes and collaborates on the development of simulators for teaching in audiology. So the topic for today is desired transition level in bone conduction devices, prescriptive targets for percutaneous bone conduction hearing aids. So without much ado, I'd like to hand the microphone over to Dr. Scollie. Thanks a lot.

- [Susan] Okay, thanks very much, Ravi. And thanks to AudiologyOnline and Oticon Medical for the opportunity to share this project and this work with everybody today. Thanks, everyone for taking the time to join. I know there's a lot going on these days, especially. And we nonetheless have to carry on with our work and have our good tools to do the best job that we can. So we'll just zoom into this particular topic and this particular set of tools and strategies. And what we're gonna try to do today is go over some of the background and where some of this has come from, so that you understand what the details are when you're using the software systems like that put these tools into your hands. So we'll go over the learning outcomes for today. So what we're gonna try to accomplish and please feel free to note any questions for at the end if there's something that was unclear, that I missed, I'd more than happy to talk about that with you towards the end. Participants will be able to describe the rationale for a prescriptive target for use with bone-anchored hearing devices, summarize the main steps of a fitting protocol designed for use with the skull simulator, and be able to explain the impact of changing signal processing in bone-anchored hearing aids on verification measures and interpret the results. So I'll show you a few case studies to help out with that one. So how we're gonna structure today is we're gonna talk about why we might want to prescribe, this is actually a pretty big topic of conversation when we started this work is why is it necessary or why would it be a good idea, potentially to have a prescription here. Why verify and what kind of clinical utility we have there? What bone-anchored hearing aid devices we're talking about in terms of types and terminology? And what lessons we have from the labs from previous studies that have been done in this device category? We'll go through the how we modified DSL to work as prescriptive target for bone conduction devices and where we've gotten to so far on that project. And then follow up with how to verify for that on the skull simulator. And then towards the end, we'll put it all together with a few clinical examples of verification with basic and advanced features. And then we'll open up the floor to all of you for any questions that you may have.

So we'll get restarted then. Okay, so I'll just say that from my background, I'm coming to this from the perspective of air conduction hearing aids, that's been the majority of the work that I've done. And so what we've tried to do is create some parallels to that and pull the knowledge that we have from that world over into the world of bone conduction devices. So we know from the air conduction world that when the field has changed it's practice to routinely pull in prescriptions and verification, what we see happen there is a promotion of consistent and beneficial levels of speech audibility across patients. So if you look at a big, big group of patients, what you see in the studies that are cited here is that the consistency of those fittings across patients tends to improve, the more that we follow best practices. So when we don't have that situation, what we see is a greater variability in fittings, but some people still getting good fittings, but some people maybe not getting such good fittings, and so it's a consistency goal as much as anything else. We also know that the technology has evolved considerably. Since we first started working with bone-anchored hearing aids worn on abutments to now, we've seen a great deal of evolution in the devices themselves. So they used to be mainly linear devices with maybe not a lot of programs, not a lot of accessories, and not a lot of signal processing. That's absolutely not the case anymore. And we know that they now offer nonlinear signal processing and directionality and streaming and all those kinds of things. So the prescriptions that we can take from the air conduction world have already been designed for use with nonlinear signal processing and they are based on well defined and realistic speech signals and built with speech based nonlinear input, output target functions, so we can kind of harness all of that and try to modify it to work within the space of bone conduction devices. But keeping that non linearity and multi channels and all the complexity that that brings in the prescriptive target. Zooming in on the third point more for bone conduction device evidence. There were some early studies when we started this work that looked at that it may be better to look at super threshold performance for bone conduction hearing aids too, so we know for air conduction hearing aids that aided thresholds don't really tell us everything we might wanna know. And there was this one study that sort of pointed to that same set of consideration for bone conduction hearing aids as well, that there may be some merit to looking at how does this hearing aid process speech at conversational levels as its own issue, as opposed to only looking at aided thresholds?

So that sort of motivates, maybe we can and maybe we should have prescriptive targets for speech at conversational levels for the bone conduction device category. So there's a few different reasons or maybe advantages to using prescriptive targets together with verification. And here's seven that I can think of for this particular category. One is that the nice thing about prescriptions is they make use of an auditory map. Much like what's used in fitting of cochlear implants, you get a graphical representation where you see thresholds, you see upper limits you. This is the space in which you're gonna work with this device. And the fitter can see if the device output is presented within that audible range. So it really can help us interpret our fittings and have an understanding of what they are and are not providing in terms of speech audibility for the user. The second one goes hand in hand with that, the targets are really based on these running speech inputs, not tones, and are presented at realistic levels not at threshold level. So it gives you that functional view of what the device is doing. The third advantage is also sort of in comparison to aided thresholds, which is that the electro acoustic measures that we make with technical equipment to test hearing aids, make measurements that have known high acceptable test retest reliability. So usually within two or three dB. And so they give very high precision measurements, measured at many frequencies. And in that way, kind of exceed the reliability and frequency resolution that we can get from things like aided thresholds, so we might get better quality data, we might get more information by using this kind of strategy. The first one is really more of a research strength, but it does tend to help us out clinically in the long run. Is that if there is a set of prescriptive targets that can be used for a particular device category, it can then act as a reference point so that if you have four different studies from different labs around the world, that people have used bone conduction devices and looked at their benefits and that sort of thing.

If they've all used a particular fitting and verification method, then those studies are more comparable to one another 'cause they have a common shared reference point. So it can only evidence to build in a more constructive way when we do have those reference points available. The fifth point is that, as we said earlier, the use of prescriptions does support consistency of fitting across clinics. And that may lead to more consistently beneficial fittings across patients, we've seen that happen in air conduction, it's a bit early to say if that's gonna happen or not in the bone conduction space as well. And finally, having a prescription tends to lead to using verification equipment with devices, which provides us with cross checks of device function and that turns out to be useful for understanding our signal processing and streaming and those kinds of things as well. And we will look at a couple of examples of that later on.

Okay, so just for a little tiny bit of terminology to be clear before we get into the details, there's an umbrella term for bone conduction devices, but that umbrella term means a wide range of devices, sub categories, which tend to be named differently depending on how they're worn by the user, so if we're wearing it in this case on a bone-anchored abutment, then that would be considered a percutaneous device for the terminology we'll be using today. And sometimes that gets called BAHD, BAHS, that sort of thing. There's a few different terms for that BAHA, as opposed to devices that are worn on the skin, which would be considered transcutaneous. So I'm just showing you a little glimpse of the subcategories here. There are many, many, many more. And if you want to have a really nice recent flowchart of all of the different device categories that exists today and what people would maybe call all of those categories, thee link at the bottom of this slide has a really great, nicely, graphically designed flowchart for that. So for today's purposes, though, we are going to be looking at percutaneous specifically and zooming in on that particular device category.

So looking at that percutaneous category where we are wearing a device on a surgically implanted abutment, specifically. There have been some studies that have been done with that device category that help us work towards developing a set of prescriptive targets and verification procedures for these particular devices. So here's some things we know from past studies. One of the things that I think we know is that just like with air conduction hearing aids, audibility and bandwidth matter. So if you look back at the literature on this area, we'll see a wide range of strategies that different researchers have attempted to use for making verification of bone conduction hearing aids, especially percutaneous ones. People have tried placing really a probe tube microphones either in the ear of the person or in the nose of the person and measuring the sort of byproduct vibration that radiates out into either of those spaces as a surrogate measure of device function. That maybe could have been the clinical procedure that we wound up with, but it for various reasons, it's not There's been lots and lots of use clinically and in research studies of sound field audiometry, measuring either functional gain or aided thresholds. So essentially using the person as the hearing aid analyzer and that's usually done when we don't have another choice, right? Let's say, there's no other way to measure it, so we're gonna use this and it gives us some information, fair enough. The third category is specialized lab equipment. So if you look back at the literature, studies have used things like research grade skull simulators, laser doppler vibrometers, accelerometers, a bunch of different strategies to try to have something like a microphone making a technical measurement of the devices and getting measurements of things like speech spectra. So that that's where we sort of zoom in on maybe having dedicated device appropriate equipment that we can use to move forward with having a verification strategy that we can then pair up with some prescriptive targets. So here's an example of one such study.

So we know that in air conduction hearing aids, audibility and bandwidth matter, they drive an awful lot of benefit in speech recognition. So I'll just walk you through this particular set of results. And on your left hand side is a fitting screen for one bone-anchored hearing aid. And on the right is a different bone-anchored hearing aid fitting, so the fitting has been changed. And the little arrows that you see there show you that the fitting on the right has more high frequency gain, more for high frequency output and provides a greater deal of audibility in those high frequencies. So that's just over here. So this particular fitting here, has been improved, if you will, in this particular area. So the way that we can read that is as follows. On the x-axis, we've got frequency and on the y-axis we have device output. In this case, it's been measured in acceleration level using an accelerometer, which is not what we're gonna learn how to use today. But the fitting screen is pretty similar. We've got thresholds, we've got upper limits, and we've got the devices here. So the solid black line that you see in both of these curves is the device output for speech at 65. So the device on your right has better high frequency output and audibility for speech at all the levels. And I'm just looking at the 65 one for now. And the participants in this particular study had better speech recognition with the device fitting that you see on the right than with the device

continued

fitting that you see on the left. Neither of them are perfect. Neither of them are a good match to the targets, nor are they targets that we're using these days. But it just gives the idea that audibility and bandwidth do matter. We're using these devices as hearing aids, we want to make that speech audible for someone at a level that they're comfortable to wear it and where it's gonna give them good benefit. So that's just an early glimpse on that. More recently, and this is a study that just came out in 2020, also from the University of Alberta. And here we're looking at directional microphones. So just like with air conduction hearing aids, directional microphones provide benefit in people who are using bone conduction devices. So lemme just walk you through this. The top panel that you see here is the device when it's set to omnidirectional processing. And the bottom set of panels is in directional processing. The left devices on your left side, the right devices on your right side, so these two are both omni and the two on the bottom are both directional. What you'll see here is two curves, the solid curve is the device response for sounds coming from the front. And the dashed curve is the response for sounds coming not from the front, so side or back. And in omnidirectional processing, those two curves are pretty much overlapped. A little bit of separation, but really in the, especially in the lows to mids, they're quite overlapping. Whereas when we turn on the directionality, there's more separation between the two. So the sounds from that are not from the front are being attenuated. And that's what directional microphones are supposed to do, right?

They're supposed to give more emphasis to sounds coming from the front. So we have a technical measure here that tells us that there's a significant difference between the processing in the omni condition and the processing in the directional condition. What about the benefit that people may have received from this particular study? So in omni, the percent correct for sentences and noise was 69%. And that's a pretty good score. 69% is nothing to sneeze at, it's pretty good. But when the directional microphone was activated for the same listeners, their scores went up to 93%. That is a huge benefit. That's a huge amount of benefit. And that's true for air conduction hearing aids, too.

We know that directional signal processing is one of our most reliably beneficial technologies that we can use. And here we have it for this device category as well and a technical measurement that lets us see that directionality for ourselves, lets us know if it's stronger in one program or another. Lets us with confidence counsel people about the use of that program in environments that would be appropriate for it. You can measure this with your clinical equipment and we will go through how to do that in a little while. Okay, just like with air conduction hearing aids, we know when we put devices that are percutaneous on the abutment, that it's gonna have that individualized response when worn in situ compared to what it will do on a standard coupler. So hearing aids do one thing in a coupler, they do another thing in the ear. For air conduction hearing aids, that's what's shown on your left. And we capture that with a measurement called the real ear to coupler difference. There's a similar issue for bone conduction hearing aids that are worn on an abutment. And it's been looked at in this particular study. So there's an example of what that looks like. It's a really different shape than an RECD, but it's the same idea. It's actually the real head to coupler of difference.

So, we can we can have that as a concept in our transforms work that we do kind of behind the scenes when we're putting together prescriptive targets. And when we're making verification systems, we can have an idea that we need to account for the different response when it's on someone's head versus when it's on a skull simulator. And we can have corrections for that. And there's published data that we can turn to that gives us information about that. So that's a helpful set of transforms to have. Another thing that we can pull over from air conduction to bone conduction is that how are our thresholds being measured? So with air conduction prescription, we like to define our thresholds in the same units that we're gonna use for device verification. So in DSL for air conduction hearing aids, we pull everything into dB sound pressure level in that ear canal and get the thresholds, the targets, and hearing aid all measured in the same scale, so that we can compare them all to one another. And that helps us out, that helps us make a fitting screen. We have a similar issue with abutment worn bone conduction hearing aids and it is that the conduction of sound through that abutment is a more direct path than through tissue. So audiometric bone conduction thresholds don't necessarily equal abutment based bone conduction thresholds. If you think about it, when you're doing a bone line with an audiometric oscillator, you're going through skin and connective tissue and all the soft tissues that lead into that mastoid. Whereas with a direct situation, you've got an abutment that is actually osseointegrated into the mastoid process and is directly delivering sound right into the mastoid. So it's gonna be better, right? How much better will it be? These data tell us that we're looking at about maybe 10 dB or so on average. And also that there's some individual variability, with some people getting a lot more and some people getting a little bit less benefit of abutment driven versus through the skin driven bone conducted sound.

So one of the things that you'll see show up in the clinical workflow that we're talking about today is that a good first step is to remeasure the person's thresholds using a direct bone conduction audiogram through the device programming software with a device worn in situ on the abutment and get that sort of the real direct bone line as the starting place for the prescription in order to individualize it. And that's gonna help the whole process be somewhat more accurate 'cause it will capture the individual variability that you see shown on the screens here. Okay, another thing that we can know from studies in the past is that compared to air conduction, there actually is a difference in loudness growth by bone conduction. So this was a study done at Stefan Stenfelt's lab in Sweden. And what they did was they played sounds of different levels. So just going across here on the x-axis from very, very soft sounds to very, very loud sounds to the same set of listeners. And then they had them rate on a loudness category, which is shown over on your left here. How loud are those sounds? They delivered the same sounds by air conduction and by bone conduction in the low frequencies and in the high frequencies. And what they got was a different result depending on how they presented the sounds, there's a little bit of a separation here

continued

between the air conduction and the bone conduction for loudness. So we don't necessarily experience loudness the same way when we're listening by air versus by bone. And this was most pronounced in the low frequencies. And what we see is if this is the bone loudness curve for low frequency sounds, here's the air loudness curve for low frequency sounds. So there is a bit of a separation there. So we did want to build this in as a correction to the DSL prescription for bone conduction hearing to help account for the fact that the loudness growth actually isn't quite the same. Final limiting factor and a really important one here between air conduction and bone conduction prescription is the output limiting of the device. So we know when we're working with air conduction prescription, the main thing that governs the maximum output portion of the targets is the person's upper limit of comfort. It's not really the device, it's more more about the person's hearing and not so much about the device. In this device category, what we knew going into it was that traditionally speaking, bone conduction devices don't have a very high maximum output, they tend to have a low output limiting level. And there's also a lot of between device variability.

So they're low and they're variable. Lemme just show you this particular set of data here. This is six different clinically available bone-anchored hearing aids. And this is across frequency, a measurement of the maximum output on a skull simulator that those hearing aids have. And what we see is that from the one with the highest output level to the one with the lowest output level, there's more than 20 dB variation. So they're low and some of them are very low. So that's gotten somewhat better because there are now some nutrients juicers that have been developed that have helped raise the maximum output up and smooth out the frequency response and increase our fitting range in ways that are really helpful. But overall, the point is that we do need to build in the device specific maximum output limiting into the targets because they vary so much and they do carry quite a lot of impact on the size of the auditory area that we're gonna use for our fitting. So one of the implications clinically that you'll see is that the targets change when you change the device type. And there is a menu that lets you say what type of device are you working with. What that does behind the scenes as it pulls in a curve like this that says this is the maximum output of that particular make and model of bone conduction device and we're gonna tailor the prescription to that. It also means that as new devices are introduced into the market, that those tables have to be updated and the menus have to be updated and we sometimes have to give that a little bit of time for everybody to implement. Okay, so how that impacts the dynamic range for prescription, there's a few different things to think about here. One is that normally, when we're prescribing, we would think about going from threshold to loudness discomfort level and saying a normal dynamic range probably has a fairly broad range of levels like that. And then for fitting hearing aids, we might have some threshold elevation, and we might have some specific loudness discomfort level to work with. In this particular case, because of that device specific limiting, the top end of that might come down even further as shown here. So we might go from a regular situation to a more limited situation depending on the maximum output capabilities of the device. And so building this in right here is what we get by having that device specific maximum output built into the prescription itself.

Okay, so those are some of the background factors that we had at hand when we worked on trying to put together a DSLB strategy for bone conduction devices. So what I wanna do now is go through how the prescription actually works and how it's different than DSL for air conduction hearing aids. Okay, so when we started, we wanted to have that fitting screen, we wanted to have something like an SPLogram, but for force levels for bone conduction hearing aids. And that was sort of the goal and some of the questions that we had were, what unit of measurement can we really be using? So if it's not going to be dB SPL over here, is it gonna be something like that? But it turned out to be dB force levels after a little bit of time and studies were done. We knew we had to limit the maximum output targets up here for the lower maximum output of bone conduction hearing aids. And we also knew we needed to have an in situ set of thresholds to drive the target calculations. And how can we define those thresholds for percutaneous devices. So, we wind up building this force level-O-gram. So on these fitting screens, you will see frequencies along the x-axis just like on an SPLogram, but the y-axis is changed to force level. And when they're referred to one micro Newton like this, they're appropriate for use with a properly designed skull simulator. So we can have a measurement scale here that says this is the output of the device. We can have a normal contour of threshold, so this is a zero dB HL line converted over into force level and we can have predictions of what the a limit of comfort would be for a particular degree of hearing loss. And then the difference between those two is the dynamic range into which we're going to be mapping those targets. So this would be the maximum dynamic range that we could potentially work with. And if somebody had a device that maybe had a little bit of a lower maximum device limit, that might bring that top end down a little bit like you see here. And cause the dynamic range to be a little bit more limited. If somebody had mixed hearing loss or a greater degree of hearing loss for whatever reason, that might elevate the threshold line a little bit higher. And then that would limit the dynamic range from the bottom end. Either way, we now have a dynamic range that has both patient and device limitations built into it. So we know what size of output dynamic range we have to work with for prescriptive targets. We also needed some transforms and some normative data in order to make it all work. You know that percutaneous bone conduction devices are worn behind the pinna, and therefore have a different microphone location effect than, say, a BTE or a CIC, or anything like that might have.

So we measured some devices specific microphone location effects for this device category and built those into our transforms and corrections. We defined the transforms for the real head to coupler difference that we talked about a little while ago. And we also consulted the literature to have a good definition of force levels at normal threshold. And choosing the Carlson and Hakansson study that's cited here as the reference for that. We also put together some equations for defining thresholds and defining hearing aid responses on a common scale of dB force level. So if we have a

continued

dial level at threshold, if we're doing our direct bone conduction audiometry, we would take the dial levels at threshold and add to them the RETF fall for a normal hearing, what is normal hearing by direct bone conduction, plus the real head to coupler difference and all of that transforms the thresholds to dB force level threshold on the abutment. So that's one particular important point to say what is the threshold and dB force level. And then a second important point is we know we're gonna be measuring the hearing aid output on a skull simulator and not on the abutment. And there's this slight real head to coupler difference between those two. So we'll take the hearing aid response that's in force level on the skull simulator, we'll add to that, the microphone location effects and real head to coupler difference and wind up having dB force level on the abutment. So now we've got thresholds, and we've got a hearing aid curves all on the same scale. So as long as we can make targets that will match that as well, then we'd have a complete fitting screen.

So defining a clinical workflow so that we can get there, includes step one, assessing the hearing aid in situ by taking a direct audiogram measured via the abutment because it's highly individualized. And then step two, making a prescription to prescribe the shape and the compression and the limiting of the hearing aid fitting that is device limited to that device's specific maximum force output. And then finally, verifying the device output on a skull simulator with transforms and testing the fit to targets and fine tuning to optimize. So that's the general steps that you would do. And what we did to make the middle step part of that is we took DSL5 by air conduction and just completely re-mapped it onto that workflow. So we said, if it's all in force level, let's take all of our variables and convert them over to force level with transforms and see what just a straight up mapping would look like for those targets. So we have our lower limits of audibility in force level and normal reference for that. And upper limits of comfort with device specific limiting and loudness growth for bone conduction. So that created an initial set of audibility driven targets. So on the fitting screen that you see here on your right, this is a force level O-gram. So FLogram, so we've got frequency

continued

here and dB force level output here, we've got our thresholds for a particular patient that had been mapped in and then a set of targets for soft, average, loud, sounds, and the device specific MFO here. These targets here, as you can see, had been completely mapped for audibility, we're trying to put as much of that into the audible dynamic range as we can. And that was an initial set of targets, they take into account the number of channels in the device, the compression thresholds of their full nonlinear target mapping. And they provide more gain for soft speech inputs. And they use a compression ratio to provide less gain for loud sounds. And they're something that we could plot on a fitting screen. So at this point, we were as far as creating prescribed frequency response shapes, including slope, the compression ratio, and the maximum output all from one prescriptive algorithm. But we didn't know if it was something that would work or not. It was more of a theoretical thing. So what we did was, we did a retrospective file review project from 39 successful fittings that were fitted in Edmonton at the iRSM clinic. These were adults percutaneous users, and they had all received sufficient follow up visits for fine tuning, so that the devices were at sort of a stable final setting that people felt they could wear and benefited from and they had worn those devices for eight hours per day for at least two months, so these were stable fittings. They also had a wide range of force level thresholds ranging from 44 to 81 dB force level for frequency pure tone average.

So they represent people that have more just straight up conductive losses and also some mixed losses with sensory neural components, so that we're really kind of gonna probe the compression side of the algorithm a little bit. So those devices, were all measured at the user's own settings using a prototype lab system that has the same components that we use in our clinical verifications today. So it was testing the hearing aids with running speech. They were shaped appropriately, they had the microphone location effects mixed in, and they were measured on a skull simulator. So a TU-1000 is research grade scale simulator and it's electric. Measurement wise, it's equivalent to the clinical skull simulators that exist for clinical re-layer systems. So that's a sort of a early look at what verification would look like. So what we saw in this data set is that those original targets that were really just mapping for full audibility provided significantly over fitted targets in the low frequencies. So basically, nobody's hearing needs were fit like that. I'm showing you here two different case studies of what actual fittings from this project really did look like. So for the fitting on your left, we've got frequency here, we've got level on the y-axis, we have the person's thresholds shown by the dotted lines or the the circles, sorry. These are circle thresholds. And we've got the initial DSL-BCD targets that we're mapping for audibility here, so we've got thresholds and a target thresholds and a target, so we're striving for some amount of audibility in the low frequencies here. But the person's device was not fitted that way, the person's device is shown by the straight line that you see coming down and dropping well below audibility at the low frequencies, so a significant low cut was being fitted by the clinicians. But if you map a target for full audibility, it would ask you for something very different. It would ask you to increase the gains in the low substantially compared to what was actually fitted. That was the major difference. And we see that on both of these two cases, that both people were fitted with much less audibility and much less gain and output in the low frequencies compared to what an audibility driven target would request.

We saw in the high frequencies, though, that the audibility levels that we were looking at actually matched quite nicely with what these people tended to wear in their hearings aids on a day to day basis. So these are two cases of the 39, I just tries to pick two different ones. And what we did to take in that information into the prescription was we actually modified the prescription in the low frequencies to attempt to better match the actual fittings that were being used by these people. So that's the DSL-BCD 1.1 target that shown here by the diamond symbols. So we've pulled this target down to here. And we've pulled this target down to here. So then we went and looked to see once we make that change, how close are we in agreement and the revised target agrees with the observed fittings within two dB on average. And there is still some individual variability there, but it's a closer first shot than then a straight up audibility target would have given us. So that's the target that is actually implemented in clinical systems. We also looked at aided speech intelligibility index values from those 39 fittings and we see that aided SIIs are actually nice and high for these bone conduction fittings. There was a clear trend of the value is being high particularly below 60 dB force level. And then the trend slowly drops down as you get a little bit more hearing loss happening. And that's very similar to the trends that we observe also for air conduction hearing aids is that the higher we go in output level to give audibility for people with greater degrees of hearing loss, the SII does tend to roll off just a little bit, so that's fairly expected. And it isn't necessarily a problem of the fittings. It's sort of more how the SII works itself. So we've got that nice, consistent audibility happening with most people getting a very consistent amount of speech audibility to one another.

Okay, so that's kind of all the background stuff in terms of what we were thinking about in trying to put this target together in a way that might work clinically. And then what we're gonna do is move over now to the clinical equipment that one would use if you were gonna try and do this with using clinically available equipment. This part of the course is fairly specific to the audio scan hearing aid analyzers and requires that the analyzer has been fitted with a skull simulator accessory. So just as full disclosure there. This is a picture of the skull simulator if you haven't seen one. So it's a coupler like device that goes into the test box. And it has an abutment out the front of it that you snap the hearing aid onto. And it has markers for setting up correctly for blue for left red for right and I'll show you in a moment how to use that. You have to update software to get the targets. This has been available for a few years now, so most likely, you have that, but if you haven't updated in a while that may be necessary. The skull simulators work with a Verifit two and they work with newer models of the Verifit one and you can check the serial number on their website to see if your Verifit one is recently produced enough that it can actually receive that software update. Okay, so we said this, this is a device that gets used inside the test box. So we have to actually unplug the air conduction couplers and replace them with the skull simulator. Good idea to remember to calibrate the air conduction microphones first though because air conduction reference microphones have to be calibrated against the air conduction coupler microphones, so do that first and then remove the coupler, otherwise you may have to go back and do it. Other than that, you are going to plug the, see here where it says, coupler. That's where you're going to plug in the the skull simulator to the thing that is labeled as normally for the coupler, for the air conduction coupler microphones. So that's where you connect that. And you have to position the skull stimulator sideways to the speaker. The reason for that is we're going to point the directional microphone on the hearing aid to the speaker. So as you know, often if you're ordering a percutaneous bone conduction device, you have to order it as a right or a left and what that does is it orients the directional microphone array to the front of the listener, so you're gonna do that on the skull simulator as well. And you're gonna do that by putting the skull simulator sideways to the speaker.

So here's the speaker, and it's oriented sideways, so you don't point his nose at the speaker, you point him sideways to the speaker, so that when you come with the hearing aid here, it's going to be pointing the hearing aid microphone array to the speaker. If you see the blue stripe, that means you're fitting a left. If you see the red stripe, that means you're fitting in right. And then you're set up for directional testing as well, which we'll talk about in a little bit. On the software menus, you do have to tell the system that you're working with a bone-anchored hearing device and so you'll see that BAHD menu and when you click on that particular menu item, it will move you into the software mode that works together with the skull simulator, so it'll change the whole screen over into a force level screen. When you connect the device to this skull simulator, you're gonna snap it onto the abutment. And you're going to orient it to the speaker and you're going to place the reference microphone to the front of the two microphone ports. So usually, you can see two microphone ports, there'll be one at the front and one at the rear, there'll be one at the front and one at the rear. So here we're working with a right ear hearing aid. And here we're working with the left ear hearing aid. And in both cases, the reference microphone has been put to the front port, reference microphone has been put to the front port. So that's how we wanna do that. So then, when you get to the point of measuring the hearing aid, you're going to get this fitting screen that's gonna give you a lot of familiar items if you're used to working with air conduction devices, you're gonna have targets for the upper limit of the device output. You're gonna have targets for speech, you're gonna have the device response for speech, the users thresholds in dB force level, and the normal thresholds in dB force level. So on this particular system, the targets are the plus signs and the device curve is the solid lines. So it'd be matching the solid pink line, the heavy one that's in the middle through the pink targets in this particular case, and this is what it would look like for 65 dB speech. Once you've run a test like that, over on the right, you'll get some other information, you'll get your aided speech intelligibility index value. So in this case, this fitting is making 86% of the speech available to this person.

So although speech is dropping a little bit below threshold in the low frequencies, which we've intentionally shaped the targets that way in order to avoid occlusion effect problems. But it's nonetheless 86% of the speech has been made audible for this person across a pretty good bandwidth, including audibility in the high frequencies. So that's a nice fitting that should provide good benefits. We can look at, is the fitting smooth? Is the fit to targets good? We can do listening checks for sound quality. And I can show you how to do that in just a few minutes. We can look at the bandwidth over which the fitting is providing audibility. And here we see that we've got audibility up to and above 8000 hertz. So really quite a good bandwidth of audibility from this device. We can also run other tests to look at soft, average, loud speech, and maximum output. And for each of the levels of speech, we'll get a speech intelligibility index value for that. So in this case, we're going from 70% up through 86 and 83% for those three different speech test levels. That gives us some insights as to multi level processing and nonlinear processing from the compression aspect of the system. And we can also look at the output limiting of the device and make sure it's not providing excessively loud outputs. Okay, so that's a good glimpse at a basic fitting for speech in quiet and also a multi level verification. So that gives us a lot of information about conversational speech and how somebody is gonna be able to function in a quiet place. But in addition to that, there's nice advanced tests that are available that give us insights on distortion, noise reduction, and directionality. And all of those are also available. This gives us the ability to compare devices between if a device has two or three programs, you can look across the programs and see how they differ from one another. You can make sure that over time, you've got device function in those programs that is meeting the needs of the listener and is remaining stable. It facilitates clear reporting of the properties of devices and research studies like that 2021 that I showed you where they actually were able to report this is what the directional microphone was doing in this device and relate that back to their benefit measures.

There's also measurement of streaming, so we now have streaming capabilities in this device category, which is great for use with the phone and remote microphones and all that stuff, but it's also nice for us to have objective documentation that we set up the streaming properly. And also that we can do a listening check using that same equipment to make sure that we've verified for ourselves that yes, we paired successfully, the streaming is working, and that everything has been set up properly. So let's put that all together then. I just wanted to show you a couple of case examples of some basic fitting verification of some advanced signal processing features and we'll end off with some streaming. Okay, so we're just gonna do a quick video. This is the basics. It's the same basics that I showed you in the slides, but in video format, so I thought you might like to see it sort of in real time. So we're gonna do fitting two targets with the skull simulator. This is gonna recap a little bit of what we talked about already. So first, you want to sort of gather up your equipment and make sure you've got your skull simulator, hearing aid. We'll need the streamer later and headphones are always good. So first we're gonna calibrate those air conduction microphones, right? We don't wanna do that first and then we're going to switch the system over to work for bone-anchored hearing devices. So we'll switch into that software mode. Then we're going to set up our skull simulator in the test box, we're going to remove the air conduction microphones, connect the skull simulator to that coupler port and position its toes on the cross with the correct ear pointing out, I'm working with the right hearing aid. So I've got the red stripe pointing out here. And then we're gonna connect to the abutment, we're gonna place the reference microphone to the front mic port. And we're gonna close the lid. So now, we're all set up for doing fitting to targets or anything, we would program the device with the programming software. We would measure the direct bone thresholds with the device in situ and do both of those jobs over in the programming software that I'm not showing you in this particular video. Once we have those direct bone thresholds, we would then carry those back over to the Verifit, so that's the next step that I'll show you here.

So we've said, we're gonna go into audiometry, we're gonna tell it what make and model of hearing aid we're actually working with. And here's where we would enter those direct bone thresholds from the programming software. And then that's what's gonna create those targets for us. And then we're gonna to take an initial verification and this device, it wasn't necessarily fitted to any target. It's a little over in the lows, a little under in the mids and highs. So this is just a fast forwarded video of me reprogramming it to get it a little bit closer. So I'm doing some low cut, I'm increasing the gains in the mids and I ran into limits in the highs, I wasn't able to get any more than what you see there, but it's still pretty good. Running a maximum output and making sure that that's not exceeding any targets, which it's not and then we could carry on and look at soft, loud, any of that kind of stuff as well from there and do listening checks with the headphones. So that's basically the end of doing a basic fitting, it doesn't take too long. And it's very similar to fitting an air conduction hearing aid, if you're familiar with that world. So we would at that point be in a position to say,

continued

is there anything else we wanna think about for this particular person? Most people benefit from maybe having some noise management, maybe having some directionality, maybe having some accessories, and we might be layering some of those other things on to the fitting as well. So what if we wanna think about directionality. Here is an example of a hearing aid that has two different settings available in the programming software for its directional system. And so if you just wanted to know if those two programs were the same or different and how, this is a set of tests that you can run under the directional mode. You've already set up the hearing aid correctly in the test box with the front microphone pointed out the front speaker and the reference point microphone at the front microphone of that microphone array. So you're already positioned to run a directional test. When you run this test, what you're gonna get is two curves. So looking at the one on your left across frequencies, you're gonna get a thicker curve. And that's the response from the front speaker and a thinner curve and that's the response from the non front speaker. So when you see separation between them like this, what that means is that you're looking at a directional system. And it's attenuating sounds that are not coming from the front. The other program is, it's got some directionality, but it's a little bit more subtle.

We see that sometimes when people are trying to provide just a slight touch of directionality like to match up to directionality of a normal pinna or something like that, or sometimes adaptive systems that need special settings to activate them. You need to know a little bit more about the device to interpret that thoroughly. But we do know that the two programs are quite different, with one of them being affixed full band, directionality, which is the one that's shown on the left. So that's for sure gonna provide a directional impact for this person. And is similar to the one that we saw in the study that we looked at from Westover 2020. Okay, another thing that you might think about in terms of noise management systems for people is putting noise reduction signal processing in the hearing aids. And again, there's two settings in this particular bone conduction device for noise reduction. And on each of those two tests, you get a couple of curves, so let's just walk through that really quickly. So you get a thick curve, and you get a thin curve. Same thing here, a thick curve, and then a thin curve. The system will display the thick curve at the beginning of the test, and then it will run the test, in this case, for 30 seconds. And the thin curve gets plotted at the end of the test. So when they're different like this, what that means is that the noise reduction system brought the hearing aid response down from here at the beginning of the test to there at the end of the test. I'm just gonna zoom in on that for you in, just one second. This is the summary display that you get on on the right hand side, it's very tiny here. So I'm just making it bigger. So the summary display tells me that we ran this test for exactly 30 seconds. And that over that 30 seconds the the response shown in green attenuated the sound by nine dB over the duration of the test. And that's providing a nine dB noise reduction was sort of like a medium strong kind of noise reduction, as opposed to the other one, which provided minus one, which might as well be zero, that's probably a noise reduction off. We're probably looking at off versus on kind of a difference here between those two programs and the hearing aid.

When you're running the test, you can see how quickly does the noise reduction system take to act 'cause some of them will come down very quickly and some of them will gradually come down and take a little bit longer to reach their maximum strength. And then in addition to seeing that for yourself, you can also see how many decibels of noise reduction does it provide by the end of the test. So that gives you some nice structured information about what they're doing in the signal processing and we can compare programs devices, see how things evolve over time as new hearing aids are issued to the market. Okay, the final thing that we're gonna look at is streaming. So we're gonna pull up a video, just looking at how we might use our equipment to provide listening checks of streaming. Same thing, you're gonna need to gather up your equipment. So like before, we're gonna need our skull simulator, our hearing aid. This time, we're gonna be using a streamer. And this time, we're definitely gonna be using those headphones. So let's get that set up. So we would start with a basic fitting that is somewhere that you're happy with, that the person is able to wear as a hearing aid. And then we're gonna supplement that by pairing the streamer to the hearing aids and pairing the streamer to the phone. So you get the streaming setup. And then what would we do next? So really, often, the devices will ship with a bite bar. So that's the device that you see in my left hand here. And we can take the bite bar and bite on it and listen through your teeth or we can hold the bite bar to our triggers and listen through our triggers through soft tissue conduction to say, is this hearing aid transmitting sound at all? Or you can use it for streaming listening jacks. The challenges that I find with that, there's a few one is the levels tend to be fairly soft because especially if I'm listening through my triggers, there's some soft tissue conduction, but it's not as good as what someone's gonna get through their actual device. So I don't feel like it gives me a good representation of the levels they're getting. Two, I find it feeds back quite a lot, and I don't like holding it close to my head with it feeding back 'cause it's unpleasant. And three, if I myself had hearing loss, I don't know that I'd be able to do a listening check successfully that way, so I don't see that as a highly accessible solution. So what we're gonna do is look at maybe a better way of doing that. And instead of using the bite bar, what we're gonna do is take the device off the bite bar, and we're going to instead place it back on that skull simulator or just leave it there in the first place, I suppose. And set that up, and then we're gonna set speech live. So speech live, which is marked here turns off the test signal on the Verifit and lets you transmit stream signals to the devices, to the hearing aid instead of a pre-canned speech test signal, it just turns the test signal off. So here, what you're gonna see is me dialing and you'll see beeps happening on screen, and you can hear them as well when you listen to it. And this is a telephone call being streamed in through the hearing aid. How would you listen to that, you would connect the headphones that come with the Verifit and put them on your head. We'll talk about other options to here.

- [Phone operator] Welcome to Western University. If you know the extension of the person or department you're trying to reach, you may dial it now. You can also say the first and last name.

- [Susan] Okay, so that type of an option lets us listen at and see the levels at the same time. You can take a technical measurement that you can keep for your records. It's using the appropriate input to the hearing aid. You don't have to bite it, you don't have to put on your triggers, if you don't have normal bone conduction hearing yourself, there's a couple of options with those headphones. One option is you can put the headphones over your own hearing aid microphones and listen to the hearing aid through your hearing aid or cochlear implant. And another option is you could patch your remote mic system if you're using what we used to call an FM, your remote mic system into the microphone port instead of the headphones and patch into the Verifit and listen using your own assistive listening technology, that provides perhaps an accessible method for audiologists who themselves have hearing loss, but wanna do a device listening check.

So I'm going to switch back to the slideshow, please, thank you. So that's just a nice option to know about. It's a great way, listening checks through the headphones that are provided with many of the realer systems that exists on the market today, is a nice thing to get into doing for hearing aids in general, not just bone conduction hearing aids. It can be really helpful if you have device intermittency, distortion, if you wanna check streaming, if you wanna check streaming from ear to ear, it's really, really a straightforward way to do those kinds of listening checks. And we have more and more of that technology these days. So it's really a nice option for this particular type of device 'cause I personally find listening checks otherwise to be a little bit challenging. Okay, so let's put all that together for Monday morning. And we'll open it up for your questions in just a moment. So we know that objective validated equipment now exists for prescription and verification for bone-anchored hearing devices. We've got validation evidence to some degree for the adult users of percutaneous devices and more work to do for other populations and some of that's in progress. We are hoping that the consistency of audibility and bandwidth benefit may be enhanced by the use of an objective approach as we've seen in the air conduction category. And we do know that verification of advanced features can help reveal device properties to us, enable easier listening checks, and may help provide accessibility for listening checks for clinicians who use hearing technology themselves. I think I will wrap it up there by saying, thank you very much for taking your time to share with us today. And just mentioning that the original publication for the DSL prescriptive targets is an open access publication available at the link here. So if you're interested in having a copy of that article, you do not have to have a subscription to the journal to get it. Thank you very much.

- Hey, there.

- And I see that Melissa is opening up the floor to questions.

- [Ravi] Do you have any questions at all from the attendees?

- [Susan] A couple of thank you, you're welcome everyone. Nobody wants to ask about softband, really? I feel surprised.

- [Ravi] It must be because it's an excellent presentation, everybody has to do everything Susan had to say.

- Yeah.

- Either that or they were asleep

- [Susan] Though softband people are starting to chime in at this point. So any recommendations on how to use the skull simulator with children who are too young or unable to perform in situ measurements to enter as thresholds into the DSL target software? So my colleague, Marlene Legato, is working on that and I see some of you here today that are part of her working group and thank you for your participation with that. I think there's gonna be consensus protocols coming out on that shortly. One thing that we have been talking about trying here and that we've set up for is trying VRA with a device in situ by running a patch cord through the panel and a programming device such as a high pro inside the booth, so that you can successfully set up the child, for instance, where you would normally do the VRA. So I don't know how universally successful that will be, but we have had some children able to do that particular type of tasks. There will always be some kids for whom that's not gonna be possible. And we will need to be able to work from the audiometric bone conduction line for some kids. I think one thing to be aware of is that that transmission is gonna be softer, right, than a direct device would be, probably also gonna be fairly more similar to a softband situation than it would be to an abutment situation.

So I think, that's a really solvable problem and we are really working hard on it. What we're sort of recommending right now is that the current system gives you something that describes the fitting, it doesn't really prescribe, it more describes the fitting, so it gives you a descriptive way to look at the fittings, but I wouldn't necessarily use the targets as, you know, match them within two dB kind of a situation at this time for a softband situation. Another question came in, should you be cautious about drastic changes in programming of a device if the software does not have DSL as an option? I'm not sure what you mean by a drastic, oh, you mean if you're reprogramming. Because the targets have been developed using the device specific maximum force outputs, if those haven't been factored in for a given device, and they are very, very different, it could potentially affect the fitting and the targets. So I'm not sure that we can successfully, it's a bit unfortunate, actually, that they're so device specific, but it's

continued

just the way this device category works. And it means that I can't really say that you should use this one as the most generic one or use that one as the next most similar one. It's really difficult to know what to recommend there. And I think getting as universal implementation as we can is certainly a goal. And I wish I had a better answer for that, I'm sorry. Okay, so stay tuned for further developments on that, we are working on it everybody and have been out of our facilities that I'm sure many of you have. So we're looking forward to getting back to that and trying to finish off some of those projects just as soon as we can.

- [Ravi] Great, thank you, Susan, for the excellent presentation. I'm sure everyone enjoyed or learned as much as I did. So thank you for your contribution today. There are no further questions, just like to end the session today. And thanks, everyone for attending the session. Thank you.

- Thanks, everybody.

continued