

DROPPING THE DROPOUT RATE

A review of soft lens types and fitting strategies that can help reduce the dropout rate among soft lens wearers.

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At the 2020 Global Specialty Lens Symposium (GSLS), specialty lens topics from A to Z naturally dominated the program. However, soft lens fitting relating to all of its aspects is also one of the topics that the meeting covers, because the vast majority of contact lenses fitted worldwide are standard soft lenses, as confirmed by the annual Eurolens Research Survey published each year in the January issue of *Contact Lens Spectrum* (Figure 1).[1]

The main challenge within the soft lens category traditionally has been, and remains, the high dropout rate. In a specially dedicated session at the GSLS, we tackled this topic of soft lens dropout, with a particular emphasis on lens fit and lens options such as replacement frequency and material choice. In 1993, Weed et al were among the first to report that after five years of lens wear, approximately one-third of lens wearers had dropped out, primarily due to discomfort and dryness symptoms.[2] This number was confirmed in a larger survey in 1999.[3] What is stunning is that despite the many new soft lens materials, designs, care solutions, and replacement frequencies, the dropout numbers from more than 25 years ago remain largely unchanged today, as shown in more recent surveys in Canada,[4] the United Kingdom,[5] and the United States.[6]

Today, it is time for "A Clear View on Dropouts in 2020," as our session was called, to see what is needed to reduce the number of dropouts. The three of us on the panel agreed that reducing dropouts in lens wearers is multifactorial and highly complex. Tear film and ocular surface issues such as lid wiper epitheliopathy and meibomian gland considerations all play a role.[6,7] However, for several of these issues, eyecare practitioners (ECPs) have little influence. What ECPs do have ultimate control over is the lens fit. Our session at the GSLS, and therefore this article, focuses solely on that aspect: Can we do better when fitting our soft lenses? Taking this further: When was the last time that you actually *fitted* a soft lens?

Calculations by Morgan presented in *Contact Lens Spectrum* previously showed that small reductions in dropout rates can result in significant changes in the overall lens wearer base.[8] Simple calculations show that if we could reduce the dropout rate by as little as 3.5% yearly between 2020 and 2040, we could double the number of contact lens wearers in our practices.[8] Our aim in this article is to attempt to reduce the dropout rate by that amount just through evaluating—and optimizing—the lens fit.

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ALTERNATIVE LENS STRATEGIES

Sulley et al[9] looked at factors in the success of new contact lens wearers. A number of interesting facts could be gleaned from this paper, the major one being that 12 months from the initial lens fit, the retention rate was only 74% (thus, a dropout rate of 26% in the first year of wear). Of note is that 25% of these dropouts discontinued during the first month, and 47% discontinued within two months. So, the strategy in our practices

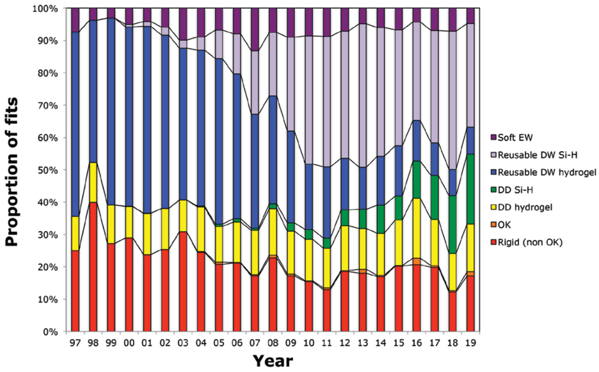

Figure 1. Overview of new fits and refits over the last two decades. Rigid lenses, including scleral lenses and orthokeratology, accounted for approximately 13% of lens fits in 2019 worldwide, although large regional differences exist.

Source: International Contact Lens Prescribing in 2019, *Contact Lens Spectrum*, January 2020.

should be to focus on the first two months of contact lens wear, with intensive follow up and close monitoring. But perhaps the most stunning finding of the paper was this: for 71% of the dropouts, no alternative lens or management strategy had been tried or offered to those who dropped out.

Having said that—and in defense of ECPs—where do we begin with offering alternative lens strategies when it comes to soft lens fitting? If we have established that "lens A" does not work, what, then, is the next lens that we should try? If we look each other deep in the eyes in this visionary year of 2020, we have to be quite frank and note that we do not have much control over soft lens fitting—or even what lens to select next. And yes, we are blaming the internet and companies that bypass ECPs when selling lenses to patients for polluting the contact lens market.

But, to put things bluntly, and playing devil's advocate a little, what are we doing differently or more than what many of the online "services" do? Don't ECPs mostly just try an average lens from the shelf to see whether it works or not? And, in line with this, on what do we actually base our fitting fees?

SOFT CONTACT LENS CATEGORIES

To gain some perspective on the soft lens fitting procedure, it appears that we can best subdivide soft contact lenses into three categories.[10] The first category is the standard "off-the-rack" stock lenses, which typically are limited to one design and to one or two sizes.

Category number two are the "out-of-standard" lenses. These typically have a fixed geometry (or maybe a number of geometries, but they are still standard lens designs), but they have a parameter range that goes beyond that of the standard stock lenses. These are manufactured individually (lathe-cut).

Category three lenses are made truly individually and specifically for each particular eye. There are virtually no limits to shape, power, design, etc.—i.e., they are tailor-made lenses to accommodate the shapes and patterns that may be present on the ocular surface.

FINDING NEMOS

The biggest question in this scheme of things is: When do you know what lens to fit out of which category? First and foremost, we have to find "normal eyes," because they are most likely the eyes for which our normal, standard lenses would succeed—and in fact, standard lenses are designed for normal eyes.

To determine whether an eye is "normal" or not, this is where technology comes to the rescue. Based on corneal diameter, corneal eccentricity (the amount of flattening toward the periphery) if available, and the central keratometry values (in that order of importance), we can obtain an approximate idea of the overall shape of the eye by calculating the overall sagittal height (sag) of the ocular surface (typically measured or calculated over a 15mm chord). Although a keratometer and a ruler are a good start, ideally we would measure this sag value over that chord. Corneal topographers are typically quite good at measuring the cornea and extending this out to 15mm (our workbench) based on extrapolation, which is beneficial. Newer instruments can also directly measure this.

Microns of Height Is the New Millimeters (or Diopters) of Radius New technology over the last decade or so has helped us tremendously to analyze ocular surface shape beyond the limbal borders.[11] Initially, this was accomplished using optical coherence tomography (OCT); this was followed first by different profilometry instruments, and most recently a Scheimpflug system became the latest addition to the arsenal of instruments.

Interestingly, and as you might expect, they have all produced similar results. From a practical standpoint, the "normal eye" (excluding corneal ectasia, etc.) appears to have an ocular surface sag of about 3,750 microns over 15mm in the horizontal meridian. Microns seems to be the new terminology in lens fitting.[12] As we all know, there are 1,000 microns in 1 millimeter; and, to put everything in perspective, the cornea typically is in the 540-micron range. As a reference, the thickness of the tear film is no more than 2 to 5 microns. Or, as another example, in scleral lens fitting, the aim is typically to strive for about 200 microns of central clearance. In fact, much of the new understanding in soft lens fitting with regard to height values comes from scleral lens fitting techniques. Of interest, too, is the range of normal eyes, which is at least 900 microns on average (among the different studies). So, that would represent the complete spectrum of normal eyes with which we would be confronted in clinical practice, from the flattest eye to the steepest eye.

If you look at the bell curve of normal eyes (Figure 2), then it is obvious that our standard soft lenses—whether available in one or in two base curves (BCs)—would fit the top of this bell curve. It has to be noted that we have better lenses available to us now than we ever have, both in hydrogel and in silicone hydrogel materials and with replacement frequencies up to daily use for these normal eyes.

But again, first and foremost, we need to define whether we are dealing with standard eye shapes before considering theses lenses. That is where "Finding NEMOs" comes in, in which NEMOs is an acronym for "Normal Eye Measured Ocular Surfaces." The typical standard deviation for normal eyes, as measured with the previously mentioned different instruments, is about 200 microns. This means that 68% of eyes (i.e., the normal eyes) would be approximately between 3,550 and 3,950 microns in height.[13]

FITTING THE TOP OF THE BELL CURVE

So, with the new technology that we have available to us today, we know a thing or two about normal eye shape. But what do we actually know about the shape of the soft lenses that we put on eyes on a daily basis? Until recently, the answer was not much, to be honest. That said, a number of recent studies have started to document overall sagittal depth of soft lenses from different manufacturers.

A study by van der Worp and Mertz from a few years ago[14] evaluated a relatively small batch of commercial lenses. More recent studies have analyzed a large cohort of commercially available lenses and measured all of their sagittal depths using a new OCT-based instrument.[15,16] In essence, here too technology comes to the rescue to help us better understand the lenses that we are fitting.

In the more recent studies, several daily disposable lenses, reusable spherical lenses, and even toric lenses were analyzed and put into graphs and grids for comparison.[15,16] From the bulk of the data thus generated, a few outcomes are apparent. First, it is obvious that lenses with a stated BC on the package are not interchangeable. In other words, one 9.0mm BC lens is not the

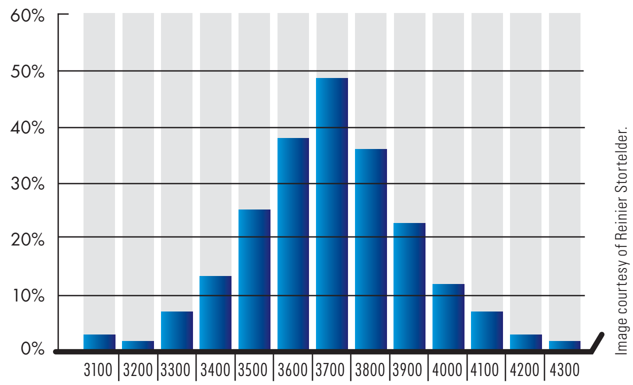

Figure 2. The bell curve of sagittal height values in the horizontal meridian over a 15mm chord in normal eyes (n = 219) measured with a profilometer.

TABLE 1

LENS MATERIAL FACTORS AND THEIR INFLUENCE ON LENS COMFORT[25]

POOR EVIDENCE TO SUPPORT A LINK WITH COMFORT	SUPPORTIVE EVIDENCE OF A LINK WITH COMFORT
Higher Dk/t	Good fit (avoid excessive movement and excessive thickness)
Bulk material charge (ionic versus neutral charge)	Shorter frequency of replacement
Modulus/stiffness	Shorter periods of wear (comfort is worse at the end of day)
Bulk dehydration	Low water content
In vitro (laboratory assessed) wettability	Good in-eye wettability
Tear exchange under the lens	Low friction
Total amount of deposition	—

same as the next 9.0mm BC lens. For daily disposables, the difference (n = 3) in sagittal height was as much as 384 microns between these lenses. In the reusable lens category, lenses with 8.4mm BCs from different manufacturers (n = 5) showed as much as 430 microns of difference between each other, and for lenses with a base curve of 8.6mm (n = 5), the difference was 339 microns.

What the data also made clear is that if a certain lens brand (within the reusable category only) was available in two BCs, then the difference between those BCs was typically somewhat limited. This was confirmed by clinical studies showing no significant change in lens fit in standard lenses between the BCs available.[17] This "proves" that these standard lenses are all designed to fit the top of the bell curve, even though they have two different BCs. The average difference between two BCs of the same design was 274 microns. Again, as a reference, the total range of normal eyes from flattest to steepest is about 900 microns.

What we can conclude from this is that, in terms of lens fit, there is not all that much that we can do for normal eyes. In other words, if we have normal eyes, or NEMOs, then it makes much more sense to consider other variables such as material properties (friction, on-eye wettability, water content), replacement frequency, and, potentially, lens care systems used rather than (just) the lens design or fit. It also proves that these standard lenses are good for normal eyes, but they cannot "fit" all eyes.

THINKING *INSIDE* THE BOX

The left side of the flow chart in Figure 3 summarizes this. If we have normal eyes, or NEMOs, then we have to think inside the box, quite literally, and fit standard or "category 1" lenses. It seems unwise to replace the superb and sophisticated lenses that we have in the frequent replacement category, which are cast-molded and ultra-thin, with relatively thick, lathe-cut, custom-made lens designs that typically are also more expensive.

However, the opposite is also true: It does not make sense to fit a standard lens to an out-of-standard eye; it's a losing game. If we have a more extreme (but non-pathological) eye shape (e.g., at either the left or the right end of the bell curve), then we should consider looking at other lens alternatives. This would be where extended-parameter lenses or tailor-made lenses come in. More on that later in the article.

Optimizing Lens Fit for Normal Eyes But first, what are the options for normal eyes? In his portion of our GSLS presentation, Dr. Wolffsohn focused on the importance of ocular shape, emphasizing and representing the left side of the Figure 3 flow chart. The goals of a standard lens fit for normal eyes include comfort, good-quality vision, and prevention of complications, all of which are linked with dropout. Work by Young[18,19] and later from Hall and the Wolffsohn laboratory[20] demonstrated that keratometry alone has little bearing on lens fit, whereas video topography has some bearing on the fit, stitched corneal topographies are better, and mapping the corneoscleral junction starts to explain why lenses fit differently in different individuals. There are differences in shape between Caucasian, Asian, and African eyes, and the corneoscleral junction is surprisingly smooth except for nasally.

Kikkawa noted that soft lenses can be modelled as a series of rubber bands of increasing diameter,[21] a model that Young further refined in a 2014 paper in which he quantified the induced "edge strain."[22] If a lens is placed on the ocular surface, the "rubber bands" that theoretically comprise the lens expand outward based on the amount of edge strain created. In other words, the diameter of the lens on eye will be greater compared to the diameter of the lens on the finger just prior to application (with the assumption that the temperature of the lens stays the same). He then combined the model with the data of Hall et al to demonstrate that NEMOs are well fitted, with little edge strain, by standard commercially available lenses; but in non-NEMOs, the edge strain increases or decreases to create tight or loose fits, respectively.[23]

Rubber Band Theory Applied If we combine the ocular surface data from Hall et al with the mathematical model from Young, for an example lens of 3,750 microns in depth with a 14.2mm diameter, this lens on the eye would expand to 14.6mm in diameter, inducing a strain of 3.1%, while the lens sag would "drop" to approximately 3,570 microns. This is the "flexing" of the lens that we see every time that we put a standard soft lens on the ocular surface. An edge strain of 0% to 6% would occur with NEMOs, leading to a "good" fit. Based on these calculations, it can also be predicted that 60% to 90% of eyes could be fitted with standard lenses, and, to our earlier point, that two BC radii have limited influence on lens fit. The model could also predict that in theory, an 8.6mm BC/14.0mm diameter lens would be the most optimal lens for the average, normal eye.

In summary, practitioners should fit individual topography (and optics) with a lens, not fit the patient to a lens. It is important to optimize lens diameter, which is a more significant parameter for soft lens fit as compared to BC and/or central curvature measurements. Comfort and vision are the key components (together with lens handling) when it comes to preventing dropouts, but they go hand-in-hand with each other (e.g., if the fit is not good, poor comfort and/or suboptimal vision could be the outcome).

Lens Edge Finally, within the category of lens fit and design, there is the factor of lens edge design. In essence, there are two defined shapes: chiseled and knife

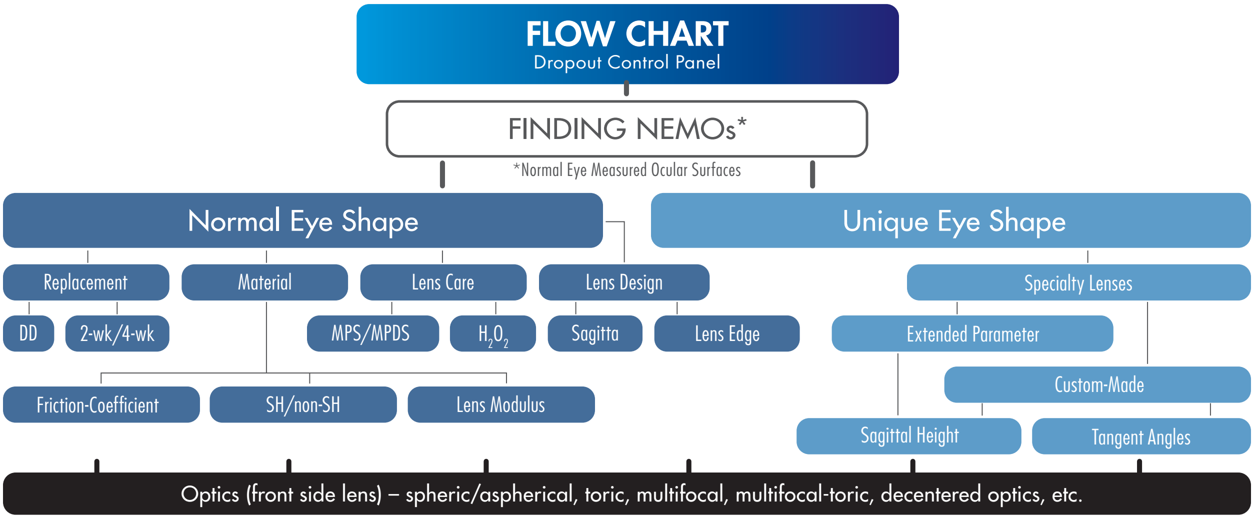

Figure 3. Proposed flow chart for soft lens fitting, starting with subdividing into normal eye shapes (left side of the chart) or more unique eye shapes (right side of the chart) and lens variable options in each category.

edge designs. These could have an effect on the mobility of the lens and on comfort. The limitation here is that it is not an individual parameter that ECPs can alter or choose for a given lens. Changing to a different manufacturer with a different edge design could be beneficial for patients, but then overall lens design, sag values, and material properties change too. In lenses that have higher modulus, edge design may have a bigger impact.

INFLUENCE OF LENS MATERIALS ON COMFORT AND DISCONTINUATION

Dr. Jones, in the third part of the three-stage model in this session, emphasized the fact that discomfort and dryness are major contributors to contact lens discontinuation both in younger patients and in presbyopes,[4] although vision was a bigger problem in the older wearers (presumably because of their presbyopia). In a systematic, evidence-based approach, The Tear Film & Ocular Surface Society (TFOS) Contact Lens Discomfort (CLD) Workshop looked at material and solution factors that may impact contact lens discomfort[25] and, therefore, indirectly impact dropout. There is solid evidence showing that some factors do not have a direct impact on comfort, but other factors appeared to have a body of evidence supporting their role in impacting comfort with lens wear (Table 1).

Of note is that there was insufficient evidence to support the fact that either lens Dk/t (oxygen transmissibility) or lens modulus (stiffness) had a clear effect on comfort, which are often factors that ECPs change in an attempt to improve wearer comfort. Rather than these bulk characteristics, it appeared that surface properties and wearing time/frequency of replacement were more likely to impact end-of-day comfort.[25]

Another surprising finding is related to the presence of tear film deposition. Historically, it has been proposed that increasing levels of deposition resulted in reduced comfort.[26] However, with modern lens materials being typically replaced in four weeks or less, it was questioned as to whether this was still the case. The extensive literature review as part of the TFOS CLD report was unable to relate increasing deposition with reduced comfort for both protein and lipid deposition.[25] The one exception to this was a paper by Subbaraman et al,[27] who were able to show that increasing levels of total protein or total lysozyme did not impact comfort, but there was correlation between reduced comfort and increased amounts of denatured lysozyme. Thus, buildup of denatured lysozyme should be prevented as much as possible.

So, what material factors do appear to have an impact on lens comfort (Table 1)? These include controlling lens movement and thickness as well as using materials that have good in-eye wettability and that exhibit low friction.[25] Other factors that have been fairly consistent in improving comfort over the years are to use a shorter lens replacement frequency and to revert to shorter periods of wear over the day.[25,28,29]

Another option with varying degrees of support relates to the use of low-water-content materials, of which the prime contemporary example is, of course, silicone hydrogel. In addition to bulk material changes, many of the major changes to contemporary materials over the past decade have related to the addition of internal wetting agents such as hyaluronic acid and polyvinyl pyrrolidone. Surface-based technologies that aid in-eye wetting such as polyethylene glycol (PEG)-based coatings to enhance wettability in corneal and scleral GPs have proven beneficial and are applied to soft lenses now as well. Elution of high-molecular-weight polymers and water-based (hydrogel-like) interfaces over silicone hydrogel base materials can be an additional tool to aid in-eye comfort. Silicone hydrogel lenses are now prescribed in 72% of all lens fits.[1]

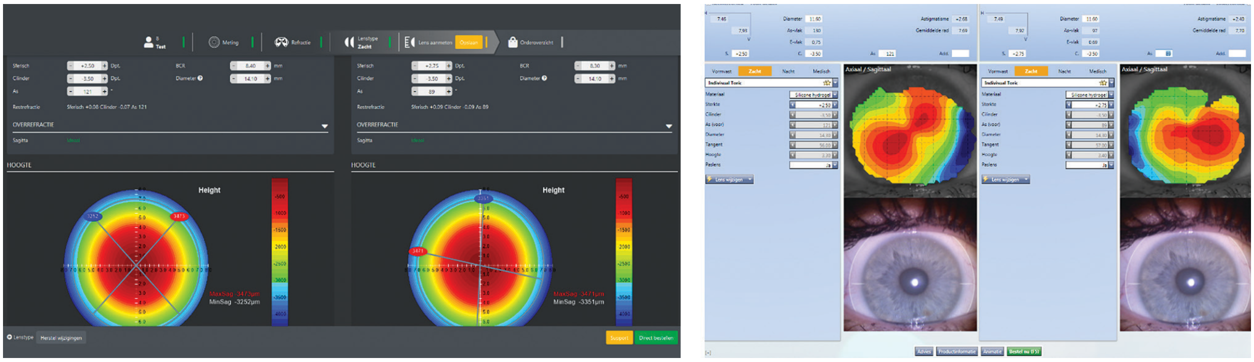

Figure 4. Examples of sophisticated databases of two different large contact lens manufacturers that use uploaded corneal topography maps to match patients' eyes to thousands of eyes in their database.

CONTACT LENS CARE OPTIONS TO IMPROVE COMFORT

What evidence is there that lens care options can impact comfort? There is conflicting evidence as to the role of care solutions on dropout and the overall "winner" when it comes to which solutions work "best."[25,30] However, Tilia et al[31] appear to suggest that ocular comfort and symptoms in symptomatic lens wearers can be perceptibly improved by switching to an alternative lens-solution combination. The complicating factor is that it is difficult to establish what combination would work for each patient and would have no or minimal effect, as there are many variables. In other words, changing care solutions is certainly an option, but there is no "magic bullet" as to which lens/solution/eye combination would work best.

Another study set out to determine the optimal solution to use with one contemporary silicone hydrogel lens material. The result was that the greatest comfort for many subjects was to use the material on a daily disposable schedule and thus avoid the use of solutions altogether.[32] So ultimately, for patients who are complaining of discomfort with their lenses, switching to a daily disposable modality may provide the improved comfort needed to keep the wearers in lenses.[32,33]

THINKING *OUTSIDE* THE BOX

Switching to the right side of the flow chart in Figure 3, what if the shape of an eye does not fall into the NEMOs category? In the Netherlands, for instance, sophisticated databases of large contact lens manufacturers use uploaded corneal topography maps (Figure 4) to find the best match of a patient's eye among thousands of eyes in their databases. This way, it is fairly simple for the software to distinguish a normal eye from an out-of-standard eye. It seems that in this case, therefore, artificial intelligence comes to the rescue to optimize lens fit and to get ECPs back in charge of the procedure again.

Calculations based on contact lens sag measurements—if compared to the sag values of the ocular surface—indicate that depending on the exact mathematical model used, between 68% and 78% of normal eyes can be fitted with standard "off-the-rack" or category 1 lenses.[34] This also means that in approximately 25% of normal eyes, this is not the case. In practices that specialize in contact lenses, this percentage could be higher, as more extreme-shaped eyes may present themselves to such practices.

Extended-Parameter-Range Lenses This is where the "category 2" lenses come in—the out-of-standard or extended-parameter-range lenses. Specialty lens manufacturers, both in Europe and in North America, are capable of making monthly replacement lenses with a large range of options, both in BC/diameter and, if needed, in other optical variations (multifocal, toric, center-near, and center-distance in any power). But with regard to fit, these lenses offer all of the sagittal depths needed to cover the entire range of flat-to-steep eyes in our practices. In addition, some of these companies have now started to list the sag values of their lens options as well. This means that if an ECP is not happy with "lens A" and wants to switch to "lens B," within the same design and the same material, the ECP can choose to change the lens fit by a desired sag value. This provides more opportunities to improve the fit in a more frequent replacement modality.

Tailored Mates The third and final category are the tailor-made soft lenses, which are fully made-to-order based on specific eye shape. This of course becomes more relevant as the anterior ocular surface becomes more out-of-standard. It may sound slightly futuristic, but the technology to do this is already available. Investigators at the University of Liverpool (United Kingdom) have developed a method to convert the overall sagittal height data of eyes measured with a profilometry instrument to a data file that then can be sent to a lathe to make a custom soft lens for that eye.[35]

A company in the Netherlands now offers an affordable custom-made lens (e.g., in the price range of daily disposables) in a monthly replacement modality that is 100% customized to the topography of a given eye.

The lens can be made in a silicone hydrogel material, so material is not a limiting factor. This may be a good option for those eyes that cannot be served with one of the "off-the-rack" options, and it may be a good tool in the dropout prevention arena.

GET BACK IN CONTROL OF SOFT CONTACT LENS FITTING

This cascade of options, from finding NEMOs and fitting them with standard lenses to extended-parameter lenses to custom-made lenses, allows ECPs to get back in charge again—at least to some degree—in actually choosing and fitting the most optimal soft lens for a given eye. We on the panel in this dropout session at the GSLS are convinced that if we adhere to this philosophy—and take soft lens "fitting" seriously again—then the dropout rate could be reduced by something in the range of the targeted 3.5%, with the given benefits as described previously. In addition, there are other practice management tools and vision options to keep people in their lenses to even further reduce dropouts, although that is beyond the scope of this article. It is up to us—the researchers, industry, educators, and certainly the ECPs—to make this possible together. Let's start with the lens fit. **CLS**

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