Picture: Frank Sonnenberg

Thickness and weight of ophthalmic lenses

Possibilities to reduce the parameters via software

Ophthalmic lens weight is a rarely considered parameter when purchasing spectacles, both by opticians and end customers, even though too heavy spectacles may feel uncomfortable. On the other hand, much attention is paid to the thickness of the lenses, as thin spectacles are considered high-quality by the public. Let us discover the relationship between thickness and weight of ophthalmic lenses and the possibility of reducing these parameters via software. *By Gaetano Volpe and Pasquale Fanelli*

The relationship between weight and thickness in ophthalmic lenses is far from obvious. First, we have to consider all the factors that contribute to determining lens weight and thickness: material of construction, lens diameter (size), shape of the front and rear lens surfaces. Ophthalmic lens material can be divided into two major categories, mineral lenses, made of glass materials, and organic lenses, made of plastics polymers. Nowadays, mineral lenses have almost completely fallen into disuse, so let us consider organic ones.

In ophthalmic optics, materials are often recognized by their refractive index, a dimensionless number that identifies the optical properties of the medium. In fact, the optical power of a lens is determined solely by its shape and its refractive index. Leaving aside the mathematical discussion on the refractive index, we need only to consider that the higher this number is, the more the material is able to deflect light beams (altering the ray vergence) and for this reason a lens made of a high-index material will be thinner (at the same optical power).

Although it is easy to understand the relationship between index and thickness (higher index leads to thinner lenses) the same cannot be said for lens weight: as the refractive index increases, the material density also increases.

Figure 1 shows the average density in grams per cubic centimeter for the main organic materials classified by their refractive index; obviously the denser the material, the greater the weight in a given volume. High-index lenses occupy less volume as they are thinner, but are they heavier because the material is denser? Does the reduction in thickness always compensate for the increase in density, resulting in lighter lenses? We try to respond using optical calculation software.

Refractive index, weight, and thickness

To investigate the relationship between these parameters, we must make comparisons for different optical powers; therefore, we calculate the weight and thickness of ophthalmic lenses with powers ranging from +8 dpt. to -8 dpt., with 1 dpt. steps. To simplify the analysis, we consider circular lenses with a diameter of 65 mm, and we impose that all the lenses have a flat outer surface (outer base has 0 dpt. optical power). In this way we only investigate concave plane or convex plane lenses and thus eliminate the problem of choosing the outer base curvature.

Figure 2 shows the negative lens weight values in grams as the optical power varies for each refractive index. In this graph there is a significant reduction in weight when comparing 1,5 refractive indices with 1,6 refractive indices for each optical power, indicating that in this case the lens thickness reduction can easily compensate for the increase in density. Comparing a refractive index 1.6 with 1.67, on the other hand, the weight reduction becomes more subtle, and you need at least -4 dpt. power to appreciate a 0,5 g weight reduction between these two refractive indices.

Moreover, using refractive index 1.74 does not result in lighter lenses, compared to 1.67 and when the power is lower than -6 dpt., the lenses are even slightly heavier, meaning that the reduction in thickness cannot compensate for the increased density. Nevertheless, lenses produced with 1.74 refractive index material have a significantly lower edge thickness in all cases as shown in figure 3, although the advantage is greater for higher optical powers.

For positive lenses, similar considerations can be drawn from the graphs in figures 4 and 5. However, in this case, the data are less reliable since we have simplified the analysis by considering only lenses with an outer surface of 0 dpt. (plano-convex lenses). In fact, negative lenses are often constructed with flat outer surface (so our data are reasonably reliable), while the choice of outer base curvature can significantly vary the weight and thickness of a positive lens.

These considerations are far from obvious, as in the past when mineral lenses were mainly employed, using high-index glass materials meant producing significantly heavier lenses, and people had to accept this drawback in order to have thinner and thus more aesthetically pleasing spectacles.

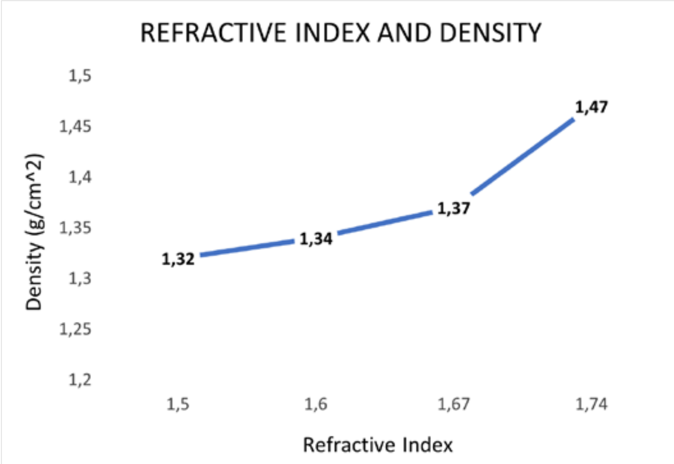

Fig. 1: *Density of the most common organic materials with their refractive indexes, expressed in grams per cubic centimeter.*

Software optimization

Besides refractive index considerations, we cannot ignore software algorithms that can improve thickness and weight of ophthalmic lenses by refining the surface calculation process. In the first production phase the software determines the minimum diameter needed to manufacture the required lens, calculates the dioptric surface, and therefore determines the lens thickness (the volume and consequently the weight can be derived accordingly).

This process can sometimes be optimized using an elliptical calculation method, or by exploiting advanced thickness optimization technologies.

Elliptical calculation

The elliptical calculation, also called pre-calibration, consists of using an ellipse rather than a circumference when determining the minimum diameter required to produce a lens. Let us try to understand step by step how this is achieved.

First of all, the frame shape must be registered to start the calculation, together with the centering data (interpupillary half-distance, mounting height). The software starts by fitting this shape within a circle, that identifies the semi-finished that will be used to produce the lens. In this stage, the semi-finished center is aligned with the lens optical center (determined by the centering parameters).

Next, it is necessary to determine the minimum possible diameter to produce the lens, since the smaller the diameter, the lower the lens weight, the thickness and the production costs will be. To derive the minimum diameter, the software applies an optimal decentration (within a threshold range) by aligning the frame shape geometric center with the semi-finished center. Then it reduces the circle diameter until it touches the lens shape edge. Thus, the minimum (circular) diameter to produce the lens has been determined and the lens can now be produced (Fig. 6-a, thickness graphs in millimeters).

The elliptical calculation can now be made by reducing the vertical diameter of the circle until it reaches the frame shape, thus inscribing it in the optimal ellipse (Fig. 6-b).

Fig. 2: *Negative lenses weight in relation to power and refractive index, diameter is 65 mm, front power 0 dpt.*

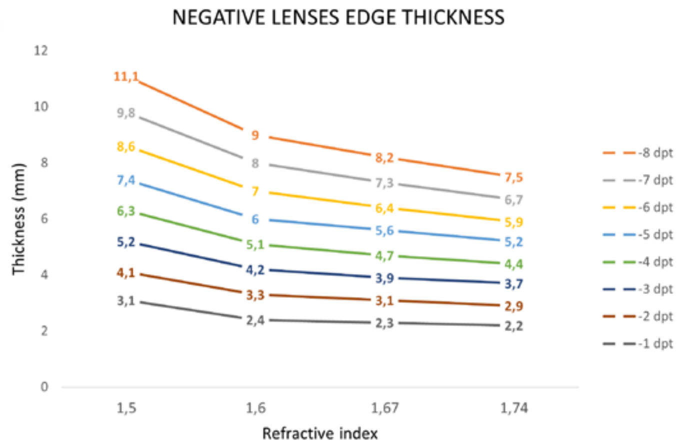

Fig. 3: *Negative lenses thickness in relation to power and refractive index, diameter is 65 mm, front power 0 dpt.*

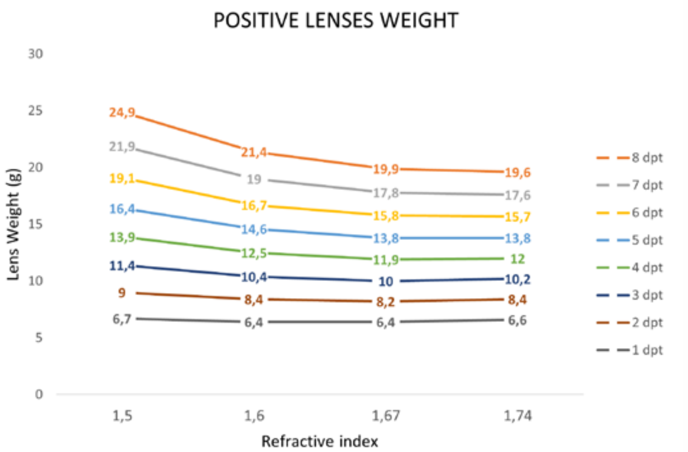

Fig. 4: *Positive lenses weight in relation to power and refractive index, diameter is 65 mm, front power 0 dpt.*

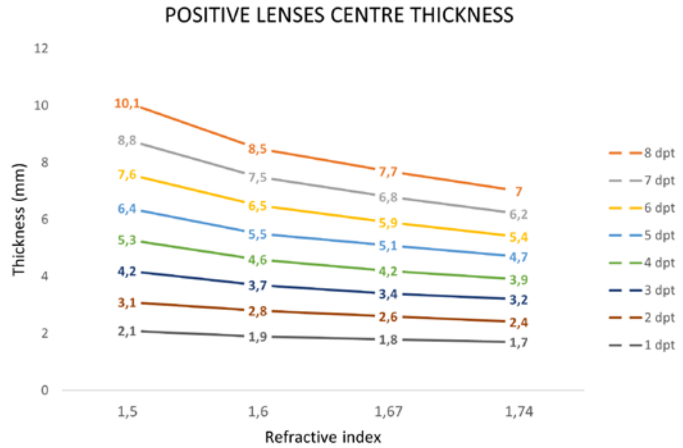

Fig. 5: *Positive lenses thickness in relation to power and refractive index, diameter is 65 mm, front power 0 dpt.*

Figure 6 shows the difference in lens thickness between the spherical (6-a) and elliptical (6-b) calculations, with the center thickness decreasing from 6.24 mm to 5.20 mm, and the edge thickness also decreasing both at the thickest point (in red) and at the thinnest point (in blue). However, it is important to note that this software optimization is only effective on positive astigmatic lenses that have the highest positive power across the vertical meridian; in fact, the lens shown in figure 6 has the following power: sph. +4,50 dpt. cyl. -2,50 dpt. axis 90°.

Advanced calculation methods

Unlike the elliptical calculation, advanced optimization algorithms aimed at reducing lens thickness are usually effective for both positive and negative lenses. Furthermore, there is no unique method to reduce lens thickness, as it is possible to approach the problem in various ways.

Classically, lenticularization is used to reduce high dioptric power lens thickness. Lenticularization consists of a very rapid curvature change at the lens edge so that the surface is rounded, blunted. However, in that lens area the optical power deviates greatly from the ocular prescription, putting this zone of the peripheral visual field out of focus.

This technology can be taken to the next level by governing the curvature change through the frame shape, and this is the core of the Crea Size 2.0 algorithm that we developed. Leveraging Crea Size 2.0 technology it is possible to further reduce lens thickness, by implementing a light and thin lenticularization that follows the frame shape in its most peripheral edge, affecting vision as little as possible.

The results of this calculation method can be seen in figure 6-c, where the center and edge thicknesses result even lower than those calculated with the ellipse (Crea Size 2.0 center thickness is 4,65 mm vs 6,24 mm for standard calculation and 5,2 mm for elliptical calculation). Naturally, this also leads to lightening the lens, as you have reduced the lens volume (while maintaining the same material).

Conclusions

Using lens calculation software, we verified that the relationship between lens weight and thickness is not obvious, since high-index materials, which generate thinner lenses, are also the densest. So, increasing the

refractive index does not always reduce lens weight, although a thickness reduction is always present. Using simplified calculation, we presented weight and thickness data for positive and negative lenses with varying power from +8 dpt. to -8 dpt., to draw general considerations.
In addition to the refractive index variation, it is possible to reduce the thickness of ophthalmic lenses by exploiting software optimization algorithms.
The elliptical calculation process, which is very effective in positive toric lenses, was explained in detail to gain awareness of how thickness reduction is achieved in those cases. We also showed how Crea Size 2.0, an advanced algorithm that is an evolution of classical lenticularization, succeeds in obtaining even lower thickness values than the elliptical calculation. These considerations come handy in our daily work, as lighter eyeglasses are often more comfortable and more in harmony with a person's daily life. ◆

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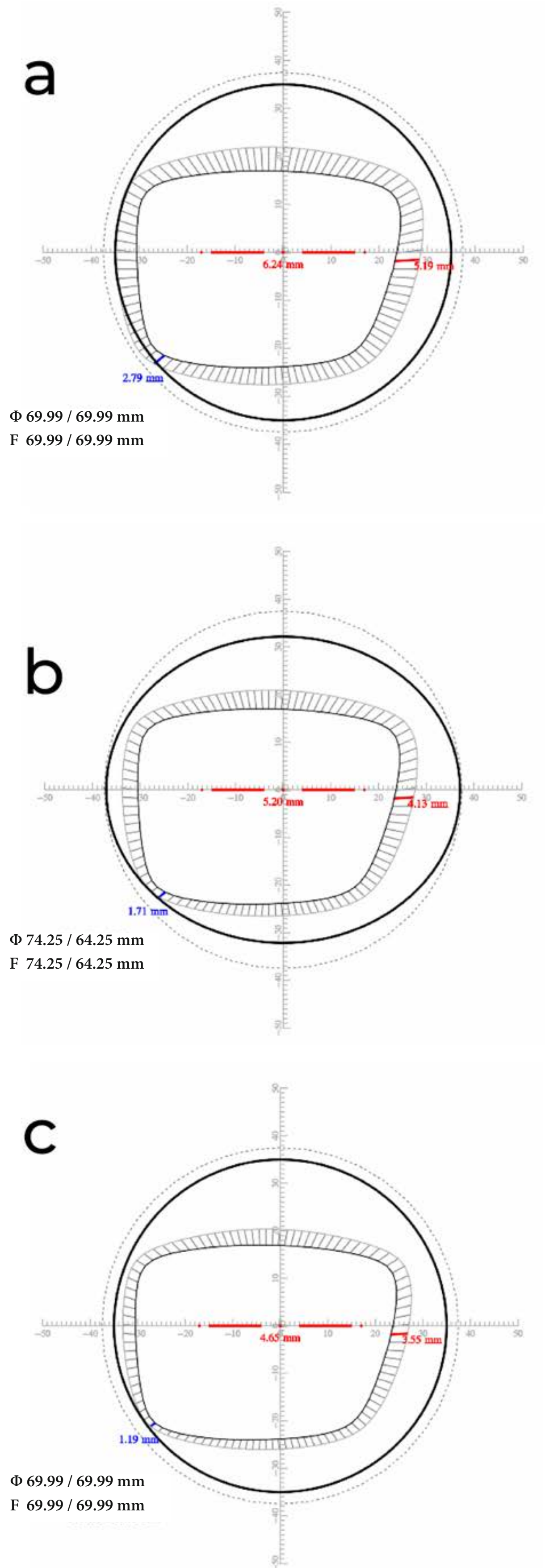

Fig. 6: *Thickness simulation comparison between standard minimum diameter method (a), elliptical calculation (b), advanced calculation with Crea Size 2.0 (c); refractive index is constant n= 1,6 and optical power is: sph. +4,50 dpt. cyl. -2,50 dpt. axis 90°.*