WHAT EXACTLY IS FREE-FORM?

Even though millions of patients are wearing these lenses worldwide, there’s still confusion about how they are designed and produced using free-form technology.

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Optimized lenses are generated to 0.01D, frametized account for frame dimensions, while customized consider position of wear and viewing habits. (Photo courtesy of Shamir.)

Free-form, digitally surfaced, cut-to-polish, and direct-to-surface are but a few of the terms being used to describe the same category of lenses. Confused? Well, you should be, especially because lens manufacturers are coining different terms to describe the same process, or conversely, the same term for different processes. Basically, free-form consists of three separate but totally dependent parts—a lens design, a software program, and very specific processing equipment.

THE DESIGN
Free-form lens design may be categorized into three basic types:

Optimized free-form designs overcome optical aberrations and mechanical limitations of traditional surfacing. All lenses designed with digital free-form technology are effectively “optimized” because they can be precisely generated to a power of 0.01D.

Frametized lenses are modified to specific fitting, frame, or adjustment characteristics. Some account for frame measurements such as the ED, A, and B, along with the patient’s fitting height and monocular decentration.

Customized designs are created specifically to the prescription and individual viewing habits of the user. They consider position-of-wear measurements such as vertex distance, pantoscopic tilt, and face-form wrap.

Every free-form design is optimized and may or may not also be frametized and/or customized.

ABERRATIONS
Any ophthalmic lens with refractive power placed in front of the eye will cause aberrations away from the optical center of the lens. Progressive addition lenses (PALs) compound the problem inasmuch as they use asymmetric curves to correct for distance, intermediate, and near vision, creating physical distortions on the lens surface.

The design and manufacture of prescription ophthalmic lenses has been one of compromise between good optics, cosmetic considerations, machinery limitations, and inventory concerns. When surfacing compound lenses using hard fixed power tools (laps) with a standard index of 1.53 and lens materials

Free-form-produced lenses require specialized equipment, such as Satisloh's on-block manufacturing technology.

other than glass, the computed powers will differ from the lap powers. As the power increases, the variance in calculated powers to lap powers increases.

For example, the computed cylinder power may be -6.0626D. However, the laps are either
-6.0000D or -6.1250D. When this occurs, choices have to be made to choose one tool over the other. In either case, the resultant measured power would be 0.07D off.

For multifocal lenses, additional compromises had to be made relative to intermediate and near vision placements. Insets were averaged. Segment lengths for PALs were also a matter of the manufacturer's design, ranging initially from about 22mm to 24mm in length and now modified to be as short as 13mm. PALs caused additional distortions because the powers for distance, intermediate, and near were pushed all over the front surface of the lens.

We, as an industry, have been providing compromised optics to our patients!

Free-form lenses may be designed to correct, as much as is optically possible, these compromises, resulting in significantly improved vision. The software can calculate the "perfect" curve(s) and cylinder cross-curve(s) to 0.01D, the optimal corridor length based upon the fitting height and frame B measurements, and the near vision inset based upon add power and PD. The free-form machinery available today can produce those curves.

THE SOFTWARE

The key is the software that calculates the curves for the individual designs and drives the machinery to manufacture the lenses. The process starts with a theoretical design model, not unlike conventional PALs, using the front surface, the back surface, or a combination of both. The optimal curves are calculated for every possible prescribed power at thousands of points on the lens surface resulting in a "point file" that describes, in mathematical terms, the surface of the lens. Inasmuch as various lens materials all have a different index of refraction, the optimal curves must be calculated for every material too. This information is ultimately used to drive the production generator and polisher used to manufacture the lens.

Some lens designs place both the progressive design and the power parameters on the backside. Others use both the front and back surface for powers and progressive designs. Some require a distance measurement as well to approximate the distance from the back surface of the lens to the front surface of the cornea, but most do not. Others require the analysis and measurement of how a patient's eyes move under reading conditions as part of the lens calculations. Whatever the requirements, the resultant lens can be significantly more accurate than any lens currently available on the market and provide the user with a new level of clarity.

THE EQUIPMENT

Today's free-form process can deliver a near finished quality surface off the cutting generator. This is typically done by using two tools—a roughing tool to crib the lens and to generate the surface curves to a reasonable quality, then a single-point diamond tool to skim the surface of the lens, leaving a finish that can be polished using a CNC polisher and a soft, rotating tool also driven by three-axis (or more) technology and the operating software. Power tolerances of less than 0.01D are possible. The surface smoothness necessary off the generator for polishing is 1 micron…1/25,400th of an inch!

Most lens manufacturers are already providing their patented designs of lenses produced using free-form technology…with millions of satisfied patients worldwide already wearing them.

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