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The Development of Contact Lenses[1]

The oft-told history of the development of contact lenses is an interesting one, and its highlights are presented in table 1. The history usually begins with the theories of Leonardo da Vinci that a water-filled glass “half circle” could neutralize the refractive (light bending) power of the cornea and substitute the refractive power of the curved glass to improve the clarity of the image received by the retina. Leonardo suggested at least two demonstrations of his theory: 1) a water-filled glass bowl in which the person placed his or her face (presumably for brief periods) and looked through the bottom, and 2) a water-filled glass hemisphere actually worn over the eye and remarkably like a contact lens. His ideas far exceeded the ability of his times to actually implement them. However, he had correctly identified several key principles of contact lenses; neutralizing the refraction of the natural cornea by means of an artificial surface; substituting the refractive powers of a curved, clear lens in its place; and positioning that lens directly on the eye.

Almost a century and a half later, the philosopher-mathematician René Descartes suggested placing a lens at the end of a water-filled tube, the other end of which was placed on the cornea of the eye. His concept was not really practical as such tubes would require external support, but time has shown that his idea of placing the lens only over the cornea instead of including the sclera (white portion of the eye), as Leonardo had proposed, was most perceptive.

In ***1801,*** Thomas Young, an English scientist, actually made a rudimentary set of contact lenses on the model of Descartes. Using wax, he affixed water-filled lenses to his eyes, neutralizing his own refractive power, then corrected for it with another pair of lenses. His optic device affirmed the principles formulated by both Leonardo and Descartes.

Next in the progression of the science of contact lenses was Sir John Herschel, an English

[1]Except as noted, this discussion was drawn from: Graham, 1981 (15); Lowther, 1982 (21); and Ruben, 1976 (30).

Table 1.—Summary of the Historical Development of Contact Lenses

Year	Individual(s)	Development
1508	Leonardo da Vinci	Described glass contact lens
1636	René Descartes	Tube of water used to neutralize the cornea
1801	Thomas Young	Used Descartes' principle to study the eye
1827	John Herschel	Described how a contact lens could be ground; concept of molding the eye
1887	F. A. Muller	Fitted a glass blown lens for a patient to protect the eye
1888	A. E. Fick	Described first glass lens to be worn to correct vision
1888	E. Kalt	Designed and fitted glass corneal lenses; Used ophthalmometer to fit lenses
1936	W. Feinbloom	Made lens with glass central optic and plastic surround (first plastic used in contact lens)
1938	Mullen and Obrig	First all-plastic (PMMA) contact lens
1947	N. Bier	Fenestrated minimum-clearance haptic lens
1947	K. Tuohy	All-plastic corneal lens
1950	Butterfield	Designed corneal lens to parallel the cornea; used peripheral curves
1960	Wichterle and Lim	Hydrogel polymers for contact lenses
1968		U.S. FDA became involved in regulating contact lenses
1971	Bausch & Lomb	First hydrogel lens approved in United States
1970s	J. DeCarle	Extended wear with high water content hydrogel lenses
1970s	Rynco Scientific	Use of CAB polymer for contact lenses
1970s		First clinical marketing of soft silicone lenses
1978	Danker Laboratories	U.S. FDA approval of CAB lenses
1979	Syntex Ophthalmic	U.S. FDA approval of a PMMA-silicone copolymer lens

SOURCE: G. E. Lowther, *Contact Lenses: Procedures and Techniques* **(Boston, MA: Butterworths, 1982)** astronomer, who in the 1820s suggested principles for accurate lens grinding and fitting. His first contribution was to suggest grinding the inside curvature of a glass lens to conform as closely as possible to an irregularly surfaced cornea, and the outside curvature of the same lens to duplicate a normal cornea. He also proposed taking an actual mold of the eye to use in rendering an accurate interior curvature fit and using a gel-like filling for the cavity between the cornea and interior curve.

The actual making of contact lenses became possible as the necessary technological capabilities slowly emerged. The development of anesthesia in 1884 allowed for making a mold of the shape of the eye, as proposed by Herschel. Advances in optics, particularly precision glass blowing and lens grinding, made possible the accurate duplication in glass of the curvatures of the eye. Usable lenses thus were developed, but their first applications were for pathological conditions of the eye (as opposed to correcting a refraction error), since only the correction of severe problems justified the wearing of these large, heavy, and uncomfortable devices, which were tolerable only for brief periods. In Germany, F. A. Muller, a maker of artificial glass eyes, made a transparent lens in 1887 to protect a diseased eye that seems to have worked for many years.

The following year, two important developments occurred. A. E. Fick, a Swiss physician, employed a small glass bowl—more accurately, a segment of a glass sphere "bounded by concentric and parallel sphere segments"—to correct refractive errors. These appear to be the first true contact lenses, and Fick went on to design and use both corneal and scleral lenses. Concomitant advances in lens making, led by the Zeiss enterprise in Germany, made Fick's work possible and allowed for further experimentation with contact lenses in Germany, Switzerland, and France. For the most part, however, such lenses were not comfortable enough for much use in other than pathological conditions such as keratoconus, where the pressure of the lens might help suppress the conical distention of the cornea and protect it; other severe distortions of the cornea in which correction by the use of spectacles was not possible; and in cases where the cornea needed protection from infections and encrustations of the eyelids.

By the end of the 19th century, then, a plateau had been reached in the progress of contact lenses. Fairly well-fitting and carefully made glass contact lenses were available but were used on a limited scale only for occasional therapeutic purposes. Glass, even thin-blown or finely ground, is relatively heavy. Thus, small lenses would not adhere reliably to the surface of the eye, and large lenses which extended under the eyelids impeded the lubrication of the cornea and the flow of oxygen (and carbon dioxide) because they were essentially impermeable. The results of wearing these large, scleral lenses were: discomfort, irritation, swelling, and perhaps infection or other damage; the need for continuous and usually not successful artificial lubrication of the eye; and/or a cycle of short-term wearing and longer rest periods. Additionally, wearing highly fragile lenses in the eye was considerably dangerous, and the glass material itself was affected by tears. The regular use of contact lenses for simple vision correction, although nearer to reality than before, was not yet feasible. The development of contact lenses thus remained static at this point, waiting for supporting technology to catch up.

This catchup took another half-century and appeared in the form of plastics, which overcame some of the more serious limitations of glass lenses. Feinbloom, in the United States, was the first to use plastic in contact lenses. In 1936, he produced a scleral lens by bonding the glass corneal portion to an opaque, molded resin scleral band. Obrig and Mullen, also working in the United States, made the first all-plastic scleral lenses in 1938, using a new material, polymethylmethacrylate (PMMA), which was particularly easy to shape to ultra-thin dimensions and greatly superior to glass in safety, lightness, and workability. The step from plastic scleral to plastic corneal lenses was a short but difficult and important one and was accomplished by Tuohy in 1947, and the modern era of contact lenses had begun.

Tuohy and others, including Butterfield, made great progress in both the construction and design of corneal plastic contact lenses. The results were a small, light lens of high optical quality and a design that conformed very closely to the shape of the central cornea, but with a slight "stand off" at the edges for better tear spreading for greater lubrication and oxygen delivery to the cornea. As a result, PMMA or "hard" corneal contact lenses for correcting refractive errors became commercially practical in the early 1950s, and for the next two decades, they were virtually the only type of lenses used.

The search for new lens materials and designs was partly spurred by the wide range of corrective and therapeutic requirements that one material and a few design configurations were unlikely to serve, but more so by the limitations of PMMA for routine refractive corrections. A serious limitation of PMMA is that because it is nonpermeable, oxygen-bearing tears may not be able to diffuse through the lens to reach the cornea in sufficient quantity. Without oxygen, the cornea swells and makes lens-wearing difficult. For many people, natural blinking and movement of the lens allow for an oxygen supply adequate for upwards of 16 hours of wear, so-called "daily" wear. But for many others, shorter wearing times and higher levels of discomfort can be expected, perhaps to the point of their forgoing lenses totally, especially since many wearers of contact lenses choose them over glasses essentially for cosmetic reasons.

If PMMA lenses represent the first generation of modern contact lenses, "soft" lenses, designed largely to overcome the limitations of hard PMMA lenses, represent the second generation. For the most part, soft lenses are made of hydrophilic (water-absorbing) plastic materials called "hydrogels." The basic hydrogel plastic is hydroxyethylmethacrylate (HEMA), although new hydrogel materials and other soft-lens plastics have recently been developed. These plastics absorb water (as much as 85 to 90 percent by weight) and become soft and flexible in proportion to their absorbency. In 1960, Wichterle and Lim, Czechoslovakian chemists working with Dreifus, an ophthalmologist, researched hydrogels, and with Dreifus began to formulate hydrophilic contact lenses.

Although hydrogels have become the main type of contact lenses currently on the market, they were not a practical alternative to hard lenses for a decade or more after their invention. Being soft and permeable, they were comfortable on the eye, but their water content made them difficult to handle, of poor optical quality, and raised questions about the absorption of infectious bacteria. However, within several years, improved materials and lens designs were formulated. After a few years of experimentation and improvement, Wichterle granted to National Patent Development Corp. (NPD), a U.S. firm, exclusive Western Hemisphere rights to the new hydrogel materials and to a novel molding process, now called "spin casting," for the fabrication of hydrogel contact lenses. NPD, in turn, licensed Bausch & Lomb Inc. to use these product and process patents. In 1971, after considerable improvement and careful testing, Bausch & Lomb obtained approval from the U.S. Food and Drug Administration to sell hydrogel lenses in the United States. After several years, other firms began to obtain similar approvals for their hydrogel lenses, and many firms are now in the market.

Today, there are more than 30 manufacturers of soft lenses (31,48). For any given use, different brands of lenses may differ slightly in design and hydrophilic capacity, some higher for greater comfort and permeability, others lower for greater durability and visual acuity. Soft lenses are now available for a wide variety of vision problems and for extended wear.

The decade of the 1970s thus marked the introduction, acceptance, and ultimate dominance of soft lenses over the older PMMA hard lenses, but as the decade ended a new type of lens, perhaps a third generation, was introduced. This lens is a gas-permeable hard lens, made of either cellulose acetate butyrate (CAB), PMMA-silicone combinations, or pure silicone. These lenses allow oxygen to reach the cornea through the lens as soft lenses do, while also offering the optical clarity and ease of handling of hard lenses. In 1979, the first gas-permeable hard lenses were approved for use in the United States, and recently, others have followed. Currently, in addition to the wide range of soft lenses available or being tested, experimentation with newer gas-permeable hard lenses, including extended wear lenses, is active.

The history of the development of contact lenses is considerably more detailed and complex than is suggested by a discussion of its significant developments or a chronological listing of its highlights. Today's wide range of precision-made, carefully fitted, and extensively used contact lenses represents the contributions of a large number of scientific areas and industrial sectors which played key roles. These include: physics, biology, and chemistry and their continually expanding theoretical and empirical foundations; precision glassmaking, which made possible early lenses of thin optical glass; the plastics industry, which has developed an expanded inventory of sophisticated polymer plastics that are the foundation of today's contact lenses; the precision machine tool industry, which has provided ultra-fine grinding, lathing, and molding machines for lens finishing; the optical instruments industry, for its provision of precise ophthalmic measurement and examination technology and eye-care practitioners and technical personnel, who have utilized the new technologies and encouraged their continued evolution.