CHAPTER XXVII

The Pmma Corneal Contact Lenses

Historians typically distinguish two periods in the evolution of pmma corneal contact lenses:
- The period of the birth of corneal contact lenses, which begins in 1948, lasted roughly four years. It corresponded essentially with the first publications and the trials of contact lenses manufactured by Solex Laboratories Inc. of Los Angeles.
- A second period beginning in 1952 was to follow. This period took account of the improvements, sometimes fundamental, in corneal contact lenses.

1 - The Genesis of Corneal Contact Lenses (1948-1952)

Introduction

The introduction of corneal contact lenses made from plastics by *Kevin M. Tuohy* in 1948 and the description by *Maurice M. Nugent* of their first clinical applications marked, without any doubt, the dawn of a new era in contact lenses. It must be said that, at this time in history, the sale of and the fitting of corneo-scleral contact lenses was stagnating and had no prospect of growth. As a contemporary witness described the situation: "*1946 and 1947 were very dark economic years in the contact lens field and something had to occupy a lens-maker's time.*" (1)

1.1 - The Discovery and the First Opinions (1947-1949)

1948	Maurice W. NUGENT: The Corneal Lens – A new Type of Plastic Contact Lens. - A preliminary Report. Presentation June 3, to the Los Angeles Ophthalmological Society.
1948	Kevin M. TUOHY, assignor to Solex Laboratories Inc.: Contact Lens. Patent # 2,510,438 was granted on February 28th 1948.
1948	Maurice W. NUGENT: The Corneal Lens - A new Type of Plastic Contact Lens. A Preliminary Report. Annals of Western Medicine and Surgery, 2 (June): 241- 246.
1948	John C. NEILL: Editorial - The Corneal Contact Lens. American Journal of Optometry and Archives of the American Academy of Optometry, 25: 399-400.
1948	Robert GRAHAM: The Corneal Lens - A Progress Report. December 5, 1948. Presentation to the American Academy of Optometry.
1948	J.E. TANSEY: An Introduction to the Corneal Lens. The Canadian Journal of Optometry, 25, 215-218.
1949	Robert GRAHAM: The Corneal Lens - A Progress Report. American Journal of Optometry and Archives of the American Academy of Optometry, 26: 75-77.
1949	George W. SPRATT: Tuohy Corneal Lens. April 10, 1949: Presentation to a meeting of the G.W. Spratt Optical Co.
1949	Maurice W. NUGENT, Kevin M. TUOHY: Report on the Tuohy Corneal Lens. June 6, Presentation to the American Medical Association, Section of Ophthalmology.
1949	Martin H. KANTER, David E. KRAUSS: Report on the Tuohy Corneal Lens. The Optometric Weekly, 40 (August 25, 1949), 1303-1306.
1949	Louis M. ZABNER: Applications of the Tuohy Corneal Lens. The Optometric Weekly, 40 (September 25, 1049)
1949	Sidney G. WEISS: Tuohy Corneal Lens. American Journal of Optometry and Archives of the American Academy of Optometry, 27 (8): 404-406 (1950)

Table 27-1
Chronology of the first series of the most important presentations and articles concerning the Tuohy corneal lenses (1948 - 1949).

1.1.1 - K.M. Tuohy's Discovery (1947)

It is generally agreed that the priority of the discovery, the use of and the marketing of corneal diameter contact lenses reverts to *Kevin M. Tuohy*. The latter started his career as a technician, then fitter at Obrig Laboratories, first in New York, then at the Canadian Branch in Montreal, before rejoining *Solon Braff* and *Xavier Villagran* in Solex Laboratories Inc. of Los Angeles. (2)
The story suggests that, while he was fabricating a corneo-scleral contact shell, *Tuohy* accidentally separated the scleral part of the shell from its optical component. (3) He had the idea of polishing the edges of the part that had become separated, then to insert this cupule in his own eye in order to correct his myopia and then next to try to do the same with his wife's eye. After several months of experimenting and trials, he was able

Figure 27-1
Kevin and Martha Tuohy.
The husband and wife team Kevin and Martha Tuohy were the first to wear contact lenses of corneal diameter. This photograph of the Tuohys appeared in popular press journals at the time of the first trials of corneal diameter contact lenses and illustrated their spectacular effect.

to improve on these preliminary experiments and obtain a relatively satisfactory tolerance.
According to *Joseph Soper*, who reports a discussion with *Martha Tuohy*, it was she who had given to her husband the idea of a contact lens of smaller diameter than the heavy ones that were thick and large 'classical contact shells'. She used to wear these in order to correct her high myopia. *Martha* has asked *Kevin* to reduce the diameter and the weight of these shells and had proposed that she appreciated the effect of these changes. After several months of experiments with cutting of sections of the haptic, she said to him: "*Give me the center of the lenses*". Thus it was that she got the scleral part removed. After polishing the edge, *Martha* was able to wear this first sample of corneal lens for more than three hours. It is possible that these experiments on *Martha*'s extremely myopic eyes explain the design 'big and flat' of *Tuohy*'s initial lenses. [4] In a retrospective description, *Tuohy* reminisces about the time of his experiments:
"*Prior to July 1947, four persons were wearing these lenses: my wife, Alvin Stitch Jr., Xavier Villagran and myself. Mr. Stitch, from the beginning until today, has proved a most interesting subject. He discarded his scleral lenses on the first occasion of receiving his corneal lenses, wore them all the time from that first fitting.*" [5]

In the same document, *Tuohy* describes other projects and experiments undertaken in the course of this period:
"*While working with the first corneal lenses, other projects and lenses occupied my time as well. (1946 and 1947 were very dark economic years in the contact lens field and something had to occupy a lens-maker's time). I made lenses with silver filings embedded in the scleral portion (…), a lens with a balsa-wood sclera and a plastic optical area, (...) a keyhole-shaped lens with a flange to rest on the upper sclera. (…) I made scleral lenses without corneal sections. This proved the most successful contact lens in my experience, an absence of discomfort and clouding of the vision, but unfortunately no means for refractive correction. But all else proved a side issue: the lens fitted within the corneal limits proving the most direct path to follow*."

He confirmed that the experiments that he carried out on his own eyes were verified by his optometrist friend *Edward Goodlaw*, then by the ophthalmologist *Raphael Koff*:
"*The first ophthalmologist to examine a corneal lens on my eye was the late Dr. Raphael Koff. I had been wearing the lenses for some months at the time. I came to Dr. Koff after first being examined with the slit-lamp by Dr. Edward Goodlaw, O.D., the first person to view the corneal lens in that manner. Dr. Goodlaw sent me to Dr. Koff believing the bubbles beneath the lens were cell degeneration. (…) Dr. Koff had to examine my eyes with and without the lenses in place to establish the presence of such bubbles and the absence of corneal damage.*"

After these preliminary experiments, *Tuohy* fit other members of his entourage: "*By this time, late 1947, I had fitted some dozen persons and of course recognized the radical departure from that day concept.*"

Tuohy also discusses his opinion regarding the origin of *Sattler*'s veil:
"*In a paper delivered before the American Academy of Optometry in December 1947, the writer expressed the opinion that Sattler's Veil was not caused directly by the solution used in a contact lens, but rather was caused by the interference with the normal metabolism of the cornea which resulted from pressure (physical and hydrodynamic) upon the limbal and/or paralimbal areas. The fact that the 12 control cases fitted with the Tuohy lens did not develop corneal edema would seem to support this hypothesis.*"

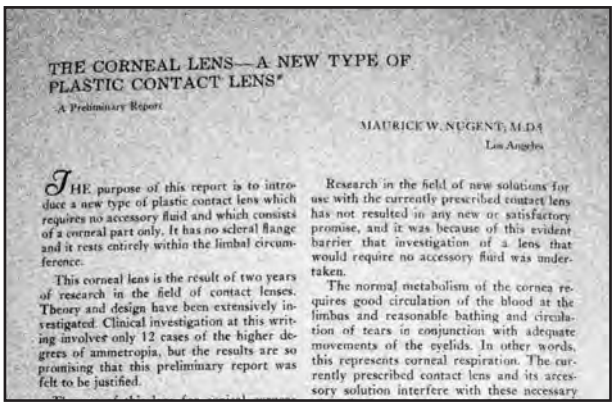
Xavier R. Villagran's evidence underlines the enthusiasm of the corneal contact lens pioneers from this time period: "*We in our sphere of fabricators and fitters, elected the most adequate materials, designed and built equipment and established methods that would adequately perform. My association with Kevin passed through a period of trust, a honeymoon that culminated after months of study and determined hard work, investigating how to improve the scleral contact lens, ultimately to reducing its size.*" [6]

In the following year, *Tuohy* showed his discovery to *Maurice W. Nugent*, Professor of Ophthalmology at the Medical Evangelists' College of Los Angeles (2007 Wiltshire Blvd), where he had a position as technical assistant. *Nugent* responded by conducting experiments on some of his own patients. The conclusions from his observations on the first twelve of his patients fit with these new contact lenses were encouraging and were the subject of his first communication and publication on them in June 1948. We should pay attention to the merit of *Nugent* whose commitment provided scientific caution to the concepts and inventions of *Tuohy*. Without a doubt, *Nugent*'s publications have contributed to the dissemination of the new idea of corneal contact lenses and also led the way towards obtaining a patent. On 28th February 1948, three months earlier, *Tuohy* had completed as assignor to Solex Laboratories Inc. of Los Angeles, an application for a patent, which was awarded two years later on 6th June 1950. In spite of that, after June 1948, or already two years before the patent was awarded, *Maurice W. Nugent* had unveiled the technique of his first clinical results. Following that, he made other presentations in the course of the next few months at various congresses in California: "*To the Pacific Coast Oto-Ophthalmological Society in convention in Seattle, July 1948; and to the Contact Lens Committee of the American Optometric Association in convention in San Francisco, July 1948. A report on the lens had previously been sent to the American Ophthalmological Society.* " [(7)]

1.1.2 - The Primary Publication of M.W. Nugent (June 1948)

In his communication of 3rd June 1948 to the Los Angeles Ophthalmological Society County Medical Association, *Maurice W. Nugent* reported his observations on the first twelve of his patients fit with *Tuohy* corneal contact lenses. The presentation took place under the title, 'The Corneal Lens - A New Type of Plastic Lens - A Preliminary Report'. [(8)]

The communication was published in the same month in the 'Annals of Western Medicine and Surgery', embellished with six illustrations showing, inter alia, the manipulative movements required for the insertion and the removal of the lenses. After describing the complications and failures of scleral lenses and of the solutions recommended for preventing complications with these, *Nugent* made the following recommendations: "*The corneal lens requires no accessory fluid and consists of a corneal part only. It has no scleral flange and it rests entirely within the limbal circumference.*"



THE CORNEAL LENS—A NEW TYPE OF PLASTIC CONTACT LENS*

A Preliminary Report

MAURICE W. NUGENT, M.D.†
Los Angeles

THE purpose of this report is to introduce a new type of plastic contact lens which requires no accessory fluid and which consists of a corneal part only. It has no scleral flange and it rests entirely within the limbal circumference.

This corneal lens is the result of two years of research in the field of contact lenses. Theory and design have been extensively investigated. Clinical investigation at this writing involves only 12 cases of the higher degrees of ammetropia, but the results are so promising that this preliminary report was felt to be justified.

Research in the field of new solutions for use with the currently prescribed contact lens has not resulted in any new or satisfactory promise, and it was because of this evident barrier that investigation of a lens that would require no accessory fluid was undertaken.

The normal metabolism of the cornea requires good circulation of the blood at the limbus and reasonable bathing and circulation of tears in conjunction with adequate movements of the eyelids. In other words, this represents corneal respiration. The currently prescribed contact lens and its accessory solution interfere with these necessary

Figure 27-2
Preliminary report of Maurice W. Nugent (1948).
Maurice W. Nugent's preliminary report: 'The Corneal Lens – A New Type of Plastic Contact Lens' was presented on 3rd June 1948 to the Ophthalmological Society of the Los Angeles County Medical Association. It was published several months later.
(Nugent M.W., 1948)

The manufacture and fit are relatively simple:
"*The manufacture and fitting of the corneal lens is carried out on the basis of ophthalmometric measurements, the lens having a posterior base curve slightly less sharp than the most curved part of the cornea. The anterior curve is that which is necessary to form the corrective lens. An area of approximately 1 mm at the periphery of the lens on its posterior surface is of a flatter radius of curvature than the curvature based on the curvature of the cornea. This beveled area increases the departure of the lens from the cornea at the periphery.*"

Figure 27-3
'Corneal Lenses and a penny'. Illustration for preliminary report by Maurice W. Nugent (1948).
Maurice W. Nugent illustrates his publication by comparing the size of an American one-cent piece (penny) and a corneal contact lens.
(Nugent M.W., 1948)

The observations and the fittings of the 12 patients of which the follow-up is sufficient are presented:
"*Twelve patients with high degree of ametropia have been fitted with this new type of lens, 10 of whom had previously*

tried contact lenses without success. At this writing, 10 of 12 patients are wearing their new contact lenses throughout their waking hours and without removing them for rest periods. The lenses are removed during sleep only. After the first three days, none of the 10 patients experienced discomfort and spectacles were discarded. (…) Careful medical control has been established for each case and repeated examination has shown no injuries to the corneal epithelium at any time. The corneas have all remained clear and healthy throughout."

Nugent concludes his presentation with the following comment: "*This lens appears to be a definite advance in the type and fitting of contact lenses for ametropia. Further clinical investigation is necessary and subsequent reports will be made as evidence is collected.*"

1.1.3 – The Tuohy Patent (1948 - 1949)

In his role as assignor to Solex Laboratories Inc., Los Angeles, *Kevin M. Tuohy* had registered on 28th February 1948 an application for patent entitled 'Contact Lens'. It was not until more than two years later, on June 6th 1950 that the patent was published and granted. [9] He described the four principal characteristics of the new contact lens as follows:

Patented June 6, 1950 2,510,438

UNITED STATES PATENT OFFICE

2,510,438

CONTACT LENS

Kevin M. Tuohy, Los Angeles, Calif., assignor to Solex Laboratories, Inc., Los Angeles, Calif., a corporation of California

Application February 28, 1948, Serial No. 12,840

2 Claims. (Cl. 88—54)

1

This invention relates to a contact lens adapted to be applied to the human eye for the primary purpose of correcting deficient vision.

Heretofore contact lenses have been produced that have been made of either glass or synthetic resin plastics which have portions resting directly on the cornea of the eye with a supporting flange or border resting on the scleral portion of the eye or which have central portions arching

2

bility of air and natural eye fluids the eye soon becomes exhausted.

An object of the present invention is to provide an improved contact lens which is characterized by the fact that when properly fitted to the eye of the person for which it was designed its maximum dimensions will be less than the dimensions across the limbus at the edges of the cornea. In the preferred arrangement, the con-

Figure 27-4
Title page of Kevin Tuohy's patent for 'Contact Lens'.
The application for 'Contact Lens' patent was made by Kevin M. Tuohy (patent assignor for Solex Laboratories) on 28th February 1948. The patent was granted on 6th June 1950. (Tuohy K.M., 1948a)

1/ The Tuohy corneal contact lens has a total diameter slightly less than the corneal diameter: "*In the present arrangement, the contact lens embodying the present invention is smaller in size than the iris, but larger than the maximum pupil opening.*"

2/ For fit, the central posterior radius of curvature of the Tuohy lens should be chosen flatter than the flattest corneal radius. Contact is thus produced with the central part of the lens optic with the corneal apex and clearance at the level of the corneal limbus: "*The inside or corneal surface actually is slightly flatter or may be regarded as having a slightly greater radius of curvature than the cornea. In this manner, the lens may actually contact the cornea near the center of the lens, while the portions of the lens adjacent to its margin are slightly spaced therefrom. The lens is slightly flatter on its concave side than the convexity of the cornea. In this manner, the major portion of the contact between the lens and the cornea will occur near the center of the cornea or in its neighborhood.*"

3/ The posterior surface of the Tuohy contact lens is spherical, except for a peripheral 'bevel' the width of which was not precisely indicated in the patent: "*I find it advantageous to bevel the concave surface adjacent to the margins.*"

4/ The Tuohy corneal contact lens is unique, in that it does not need fluid other than natural tears to permit good lacrimal exchange and [can] be worn more than 12 hours a day without causing symptoms or complications: "*No special fluid or solution is required. (…) Lenses of this character can be worn over prolonged periods of time - periods of twelve or thirteen hours of continuous use being not unusual - without causing objectionable irritation and without causing cloudiness or rainbow and halo effects*".

According to the author, the 'bevel' of the corneal lens has the advantage of avoiding pressure on the sclera: "*As the lens normally does not engage the sclera, the sclera is exposed to air and natural eye fluid and is not subjected to the*

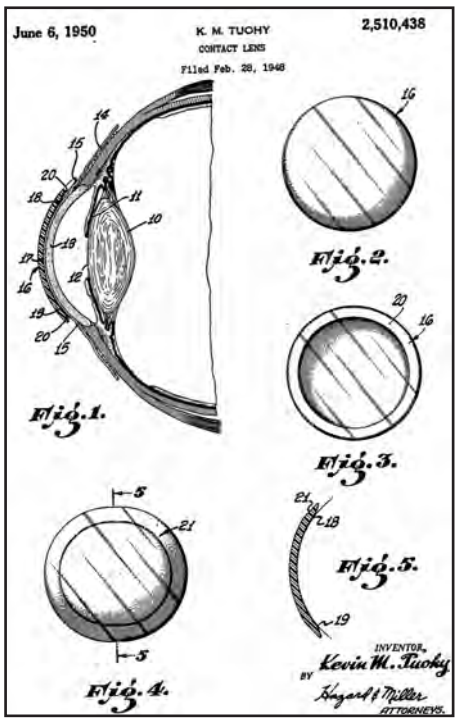


Figure 27-5
Illustration of Kevin Tuohy's patent for 'Contact Lens'.
Figure shows the anterior appearance of a contact lens, while figure 3 shows its posterior aspect. Figure 5 depicts its vertical section. The contact lens consists of a concavo-convex section 16 and a bevel 20 adjacent to the margin. (Tuohy K.M., 1948a)

objections arising from pressures applied thereto."

The spatial separation of the bevel margin favors, amongst other things, the circulation of the tears: "*This space affords an opportunity for the natural eye fluid to enter and relieves pressure on the cornea*."

The prescription and fit are simplified as compared with scleral lenses, for: "*The size and the shape of the sclera become relatively immaterial. (…) In its normal position, no portion of the lens contacts the sclera.*"

For *Tuohy*, the cases of intolerance observed with corneo-scleral lenses would, in effect, be due to the pressure from the haptic part of the contact shell on the nerves and vessels of the sclera: "*The pressure of the flange or border of the contact lens on the scleral portion not only applies objectionable pressure to the nerves in the eye but retards the normal blood flow through the veins in the scleral portion. The pressure on the nerves and the retarding of the normal blood flow is conducive to the development of irritation and is a principal reason for the appearance of the objectionable rainbows, halos and cloudiness*."

In 1948, *Tuohy* copyrighted a 'Fitting Manual' that describes the fit procedure for the 'Tuohy Corneal Contact Lens' in detail. It was followed in 1950 by a new updated edition. *Tuohy* also registered an application in the name of Solex Laboratories Inc., for a Canadian patent. This patent, entitled 'Contact Lens/Lentilles de contact,' was assigned in November 1952. [(10)]

1.1.4 - The First Opinions and Experiments (1948-1949)

The communication of *Maurice Nugent* was commented on after the end of 1948 by optometrists, *J.C. Neill, R. Graham* and *J.E. Tansey*. Then, in the year that followed (1949) and after a second communication from *M. Nugent*, new intimation and commentaries followed, notably those of *G.W. Spratt, M.H. Kanter & D.E, Kraus, L.M. Zabner* and *S.G. Weiss*. There were also several commentaries in major lay newspapers.

1) The Editorial of *J.C. Neill* (1948)
In an American Journal of Optometry editorial, entitled 'The Corneal Contact Lens', *John Collins Neill* published an opinion that included some reservations on the new Tuohy corneal contact lens and on the 12 cases described by *Nugent*. [(11)] He emphasized the fact that, if *Sattler*'s veil did not appear with the wearing of these lenses, its absence would indeed represent an important step forwards. However, he was afraid that the pressure of the lens on the central cornea might cause erosions and that the wearers might have lid irritation due to rubbing by the lens margin on the eyelid. He then cited the main points in *Nugent*'s communication and continued: "*The Tuohy lens is held in place by capillary adhesion between the lens and the film of tears, which separates it from the cornea. While the writer has not yet had the opportunity of seeing this lens in use, it seems that the lateral and vertical slide or lag would be prevented by the bulge of the limbus at the corneal circumference. It is interesting to note that the idea of a corneal contact lens is not new. The first contact lens fitted nearly a century ago was of this type. Contact lenses resting on the cornea without accessory fluid but having a scleral ring have been fitted with good results by Heine, Mueller-Welt, Dallos and others. (...) The writer has expressed the opinion that Sattler's Veil was not caused directly by the solution used in a contact lens, but, more likely, was caused by interference with the normal metabolism of the cornea which results from pressure (physical or hydrodynamic) upon the limbal and/or paralimbal areas. The fact that the 12 control cases fit with the Tuohy lens did not develop corneal oedema would seem to support this hypothesis. Those who have had experience in fitting the early types of contact lenses which had small contour diameters (20 mm) will remember the discomfort and irritation which was caused by the lid margin coming in contact with the edge of the lens. The use of lenses with a larger contour diameter eliminated this problem. We must await personal experience with the Tuohy lens to determine whether, in eliminating the cause of corneal oedema, we may not have, at the same time, reintroduced the problem of lid irritation. It seems to the writer that the experience of Heine and other who have fitted contact lenses which rested on the cornea, would indicate that no harm to the cornea results from such procedure*."
Neil, however, expresses some reservations: "*However, some of our experienced contact lens practitioners fear that an erosion of the cornea may result from such a method of fitting. Under the circumstance, it is logical to suggest that, until this question is definitely answered, we must proceed with caution. The development of the Tuohy lens is still in the experimental stage. It is being manufactured by the Solex Laboratories of Los Angeles, who are planning to give demonstrations of the lens in principal cities at early dates*."

2) The 'Progress Report' of *R. Graham* (1948, 1949)
On the 5th of December 1948, *Robert Graham*, who was at the time a close collaborator with *Tuohy*, gave his report at the Annual Meeting of the American Academy of Optometry at Winston-Salem, North Carolina. This was entitled 'The Corneal Lens - A Progress Report' describing how he had already fit corneal lenses in 407 patients: "*As of December 1, 1948, 407 cases have been fitted with corneal lenses by trained technicians under controlled conditions. Of the 407 cases, (...) 206 patients are wearing their lenses daily, none less than six hours, the majority for at least eight hours, many for the full working day. Of this number, fourteen have had their lenses from eight months to a year. All of these are still in constant use.*"

The article was published in February 1949 and confirms the relatively elevated diameter of the lenses, their flat fit and marginal clearance. It is to be noted that *Graham* attributed, without any ambiguity, the discovery and the development of corneal contact lenses to *Tuohy*: "*Full credit for the development of the corneal lenses is acknowledged to Kevin M. Tuohy*." (12)

3) 'An Introduction to *Tuohy* Corneal Lens' by *J.E. Tansey* (1948)
After July 1948, Canadian optometrist, *John E. Tansey*, had published a brief 'Introduction to the Corneal Contact Lens' that would resolve most of the problems of contact lens wearing. (13)

4) The 'Presentation' of *G.W. Spratt Optical* (1949)
On the 10th of April, 1949 *George E. Spratt*, President of the *G. W. Spratt Optical Company* announced at the Annual Meeting of the California Association of Dispensing Opticians, in San Francisco, that he was the distributor of the new corneal lenses: "*We were happy to be the dispensing technicians awarded the privilege of presenting this new lens to the ophthalmologists in our area and during the last few months have fitted approximately 300 pairs of Tuohy corneal lenses. The laboratory has reported to us a distribution of over 1000 pairs of lenses.*" (14)

After presenting eight clinical cases, the author described the reason for the success of his fittings: "*We have experienced a very small ratio of error in the fittings. (...) Proper selection of patients has undoubtedly contributed to the relative success. Reasons for failure have been extreme nervousness, lack of time to accomplish proper fit and lack of incentive to wear lenses because of low refractive error*."

5) The 'Report' of *M.W. Nugent* and *K.W. Tuohy* (1949)
On the 6th of June 1949, *Maurice W. Nugent* and *Kevin M. Tuohy* presented a report at a scientific exhibit at the convention of the American Medical Association, Section of Ophthalmology, in Atlantic City. The eight illustrations and their accompanying commentaries dealt essentially with three practical aspects of fitting: 'The Lens-cornea Relationship' - 'The Slit-lamp View of Lens in Place' - 'The Patient's Role'. (15)

6) The 'Report on the *Tuohy* Corneal Lens' by *M.H. Kanter* and *D.E. Kraus* (1949)
In August 1949, optometrists *Martin H. Kanter* and *David E. Kraus* (Los Angeles) published a 'Report on the Tuohy Corneal Lens', illustrated with three figures furnished by Solex Laboratories. The authors confirmed that, in keeping with their great success, the lenses were now being manufactured on assembly line for lathe and polishing. They were available in 27 radii of curvature and this had made possible the fitting of 1,300 patients with refractive errors, including several aphakic and keratoconus patients: "*At the time of this writing, a total of approximately 1300 Tuohy corneal lenses cases have been fitted. Because the lens has been available to the general public for only over a year and because the greatest number of these patients have been fitted in the last six months, it has not been possible to obtain reliable statistics*." (16)

The authors recommended moistening the lens with detergent solution before insertion:
"*Due to the surface tension of the plastic, prior to insertion, it is necessary to artificially wet both anterior and posterior surfaces of the lens with a few drops of any germicidal wetting agent. If such a solution is not available, any household detergent solution or the patient's saliva may be used, although the latter is not particularly recommended. This artificial wetting is necessary to reduce the surface tension to a point where the eye secretions will adhere to the plastic and keep it wet for prolonged periods. The desired results cannot be achieved by moistening a lens only with water.*"

7) The 'Application of the *Tuohy* Corneal Lens' by *L.M. Zabner* (1949)
In October of the same year (1949), *Louis M. Zabner* (Los Angeles), who was, in 1955, to become an associate of Solex Laboratories described, under the title 'Applications of the Tuohy Corneal Lens', the indications

and the technique of fitting for the new corneal lenses. He concluded his communication with a plea in favor of fitting by optometrists: "*If an optometrist does not encourage and refer the patient who even inquires concerning such lenses, he not only is being unfair to the patient, but also is going to lose the patient. (...) So let's not miss the boat! All optometrists should get behind contact lenses, their rightful field.*" (17)

8) The 'Preliminary Observations' by *S.G. Weiss* (1949)
In December 1949, optometrist *Sidney G. Weiss* (Torrington, Connecticut) read a paper, with the title 'Some Preliminary Observations on the Tuohy Corneal Lenses', at the Annual Meeting of the American Academy of Optometry at Cleveland Ohio. He indicated that his follow-up did not exceed six months from the time of fitting of the fluidless Tuohy corneal contact lenses. The publication of his manuscript in August 1950 lists the limitations of these lenses: "*The undesirable sequelae of wearing these lenses to or beyond the tolerance limit vary in severity. Some of these sequelae are corneal haze, circumcorneal injection (especially in the upper quadrant), mild corneal abrasion (rare), conjunctival injections (both palpebral and bulbar), overactivity of the Meibomian glands and the development of stationary air bubbles.*" (18)

9) The 'Report on a new Corneal Lens' by *F. Dickinson* and *N. Bier* (1949, 1950)
The first publication outside of the USA was probably that of the optometrist *Frank Dickinson* of London (UK) in September 1949. He is rather reserved in regard to corneal contact lenses as he had a personal preference for corneo-scleral contact lenses because he tolerated the latter better. In the following year, however, *Norman Bier* modified these reservations with a more encouraging opinion. (19)

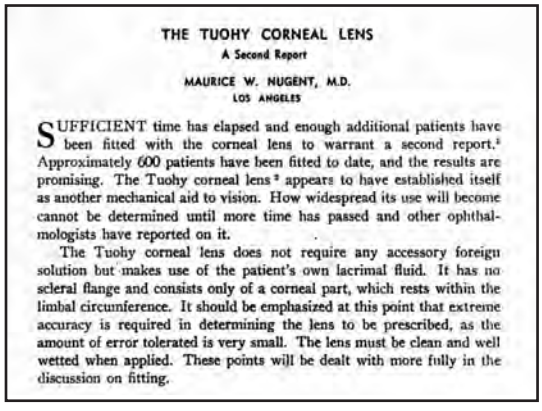
10) Comments in Major Newspapers
Right from the time of the publication of *Nugent* in June 1948, the popular health press and the major popular newspapers generally showed the interest in these new lenses. The titles and the commentaries are laudatory and demonstrate the sensational side of *Tuohy*'s discovery. The following three are selected from among the most reasonable of these:
- Tiny new lens held in place by tears;
- Corneal lenses are smaller than contact lenses and fit in a lipstick-like box when not in use;
- Inventor *Kevin Tuohy* peers around a sheet of lucite from which he has made the corneal lenses he also wears in his own eyes. (20)

It is very likely that the attribution of the patent to *Tuohy* after June 1950 was greatly assisted by the favorable reports and the publications of the successful cases by *Nugent*, amongst others (12 patients in 1948, 600 in 1949), by *Graham* (407 cases in 1948), and *Kanter* and *Kraus* (1300 cases in 1949).

1.2 - The Second Wave of Commentaries (1950 to 1952)

1.2.1. – The 'Second Reports on the Tuohy Corneal Lens' by M.W. Nugent (1949-1950)

In fact, it was the fresh participations by *Maurice W. Nugent* and, in particular, his presentation in 1949 at the Annual Meeting of the Pacific Coast Oto-Ophthalmological Society plus the publication, in the following year, of a detailed report in the Archives of Ophthalmology that had the greatest effects.



THE TUOHY CORNEAL LENS
A Second Report
MAURICE W. NUGENT, M.D.
LOS ANGELES

SUFFICIENT time has elapsed and enough additional patients have been fitted with the corneal lens to warrant a second report.[1] Approximately 600 patients have been fitted to date, and the results are promising. The Tuohy corneal lens [2] appears to have established itself as another mechanical aid to vision. How widespread its use will become cannot be determined until more time has passed and other ophthalmologists have reported on it.

The Tuohy corneal lens does not require any accessory foreign solution but makes use of the patient's own lacrimal fluid. It has no scleral flange and consists only of a corneal part, which rests within the limbal circumference. It should be emphasized at this point that extreme accuracy is required in determining the lens to be prescribed, as the amount of error tolerated is very small. The lens must be clean and well wetted when applied. These points will be dealt with more fully in the discussion on fitting.

Figure 27-6
The second report of Maurice W. Nugent on the Tuohy contact lens (1950).
Maurice W. Nugent's Second Report was presented in 1949 to the Pacific Coast Oto-Ophthalmological Society and was published in the following year in Archives of Ophthalmology. (Nugent M.W., 1950a)

1) The Presentation at the Pacific Coast Oto-Ophthalmological Society (1949)
Nugent's communication in June 1949 under the title, 'A Second Report on the Tuohy Corneal Lens' at the thirty-third Annual Meeting of the Pacific Coast Oto-Ophthalmological Society was published in the Proceedings of the Pacific Coast Oto-Ophthalmological Society shortly after the presentation. The eight-page text is followed by an assessment of the discussions by *John P. Lordan* (Los Angeles) and *Peter Kronfeld* (Chicago). (21) This second assessment describes the 600 first fittings performed by 35 contact lens fitters residing in Sout-

1949	Maurice W. Nugent: A Second Report on the Tuohy Corneal Lens. Presentation to the Pacific Coast Oto-Ophthalmological Society.
1949	Maurice W. Nugent: The Tuohy Corneal Lens: A Second Report.Transactions of the Pacific Coast Oto-Ophthalmological Society, 30: 75-84.
1950	Maurice W. Nugent: The Use of Contact Lenses in Visual Deficiencies. Lecture at the Instruction Section, American Academy of Ophthalmology.
1950	Harold S. Harris: The Corneal Lens. American Journal of Optometry and Archives of the American Academy of Optometry, 27 (2): 64-87.
1950	Harold S. Harris: The Corneal Lens. Monograph # 90, American Journal of Optometry Publishing Association, Minneapolis.
1950	Samuel V. Abraham, Philip D. Shanedling: The Clinical Status of the Contact Lens. American Journal of Ophthalmology, 33: 933-938.
1950	Maurice W. Nugent: The Tuohy Corneal Lens. A Second Report. Archives of Ophthalmology, 43 (2): 232-237.
1951	John C. Neill: Contact Lens Fitting in the United States. American Journal of Optometry and Archives of the American Academy of Optometry, 28: 616-625.
1951	Robert Graham: Corneal Lenses - A Supplementary Report. American Journal of Optometry and Archives of the American Academy of Optometry, 29:147-141
1951	Solon M. Braff: The Corneal Lens in Use. Optometric World (February 1951)
1952	C. Berens, L.J. Girard, K. Force: Corneal Contact Lenses. A clinical investigation. Transactions of the American Ophthalmological Society 50: 55-75.
1952	McGraw J.L., Enoch J.M.: Contact Lenses: An Evaluation Study. Army Medical Research Laboratory Fort Knox, Kentucky. Report # 99.

Table 27-2
Chronology of the second series of the most important presentations and articles concerning Tuohy corneal lenses (1950 -1951).

hern California. *Nugent* had fit 50 of them, but his perspective is only significant for his first 12 patients, which he had followed since 1948. The author described the trial set he used: "*The stock series of inside curvatures numbers 27 in all, ranging from 7.50 millimeters to 8.80 millimeters radii of curvature in five one-hundredths of a millimeter differences. If lenses of longer or shorter radii of curvature are required, these are made as a special order. Clinical trial has shown that over 75 percent of cases can be fitted from the stock series. The plus or minus spherical dioptric power is cut and polished on the outside surface in 0.25 diopter differences. No cylinder is embodied in the lens because corneal astigmatism is corrected by the layer of lachrymal fluid which is present beneath the lens by reason of capillarity*."

Because of its centro-corneal contact, Tuohy's corneal lens creates a concave corneal lachrymal meniscus: "*This ever-present layer of lacrimal fluid is referred to as lacrimal lens, or the lacrimal lens factor, and always has a minus diopter value. It is thinner at the center than at the periphery because the inside base-curve of the corneal lens chosen is approximately thirty-one hundredths of a millimeter longer than the radius of curvature of the cornea, in its longest medidian, as obtained from the ophthalmometric readings*."

Nugent is insistent in regard to the beneficial role of the 'marginal bevel' of the posterior surface: "*Another important feature of the Tuohy corneal lens is its marginal bevel on the inside curve. This increases the departure of the periphery of the corneal epithelium and thus increases toleration by preventing contact. It also permits any periodic over-riding at the limbus without contact. The bevel promotes the formation of the lacrimal lens, its continued presence and the circulation, which is so vital to corneal respiration, as well as the correction of corneal astigmatism and corneal irregularities*."

The lens diameter is standard: "*The lens has a diameter of 11 mm in its regular size. Only occasionally is it found necessary to use a lens with a longer or shorter diameter. Large corneas and those not having a definite limbal sulcus do better with a lens of larger diameter of eleven and a half, or even twelve millimeters depending on the individual case.*"

Nugent describes in great detail the fitting procedure, based on glasses refraction, measurement of the vertex distance and on keratometry: "*The ophthalmometer reading gives the logical starting point for choosing the inside curve to be used. Having chosen this curve and knowing the longest radius of curvature of the*

cornea, the lacrimal lens factor is then computed or taken directly from the prepared table and its minus value included to arrive at the total dioptric power required. In practice, three lenses are chosen for the first trial, one pair arrived at by the above deduction, the second pair having an inside radius of curvature five one-hundredths of a millimeter shorter."

In spite of the fact that no actual statistics were presented on the first 600 fittings, the general impression remained very favorable: "*Statistics on the 600 cases fitted to date are not as yet available and cannot be included in this report. The majority of the cases are scattered over Southern California and have been fitted by at least thirty-five different men. This, plus the fact that the lens itself is little over one year old and that all but twelve of the cases have been fitted within the past six months is ample reason why complete statistics are not available. However, in general, the Tuohy Lens appears far superior to any of the previously used types of contact lens*."

Nugent did not hide the fact that he had observed several failures among his fifty fitted cases: "*The author's group of fifty cases is still under study. It is possible that five of these will be termed failures because of excess irritation and poor toleration. It is difficult, at this time, to estimate of what failure consists, because it is easy to obtain wearing-time of six or more hours. (...) Minor corneal abrasions occur if the fit is poor, if blepharospasm is present, or if the increase in wearing-time has been too rapid for corneal 'toughening' to develop*."

The periods of investigation of the Tuohy lens still continue: "*The Tuohy Corneal Lens is still in its infancy and deductions at this stage are not necessarily correct. (...) The margin of error between success and failure is extremely small and therefore accuracy is of paramount importance. More work and observation are necessary and the field of new plastics is to be explored*."

In the course of the discussion, *John P. Lordon* (Los Angeles) confirmed his favorable fitting experience of 51 pairs of corneal contact lenses that he had performed in the five previous months, whereas, in the past, he had only had failures with the 350 molded corneo-scleral shells that he had fit and followed: "*In the last four or five months, I have fitted something like fifty-one pairs of them. I have, in that series, five cases of conical cornea, who couldn't tolerate the molded contact lenses without Pontocaine in the solution. All five are tolerating beautifully this new lens. (...) You will have air bubbles under the contact lens. That probably is the secret and will be eventually the underlying physiological basis for comfort with the lens, in that they are loose. (...) About the wetting solutions. One of the patients came in and told me he dried the lens and put the lens on dry and it was much more comfortable. Looking around for extra means for putting it on, I have taken my finger and wiped it across the lower lid and moistened my fingertip with the patient's tears. When I have moistened my finger with a saline solution or any office solution, the patient always experiences thirty or forty seconds of discomfort*."

In the discussion that followed, *Peter Clemens Kronfeld* (Chicago) reported his experience in Austria of using glass contact lenses of corneal diameter made by *Zeiss* during operations for retinal detachment: "*About eighteen years ago or twenty years ago, we used in our retinal detachment work a forerunner of this lens to keep the cornea clear (...). It was made of glass and obtained from Zeiss in Germany. I convinced myself, at that time, that such a lens could stay with the patient's cornea during the entire operation.*" (22)

2) The Publication of the 'Second Report' of *M.W. Nugent* (1950)

The February 1950 publication by *Maurice W. Nugent* in the Archives of Ophthalmology with the title, 'The Tuohy Corneal Lens. A Second Report', was a reworked and improved version of an earlier presentation. It was to meet with great success and was at the basis of immense interest in the United States and throughout the world. After summarizing the essential parts of the preceding publication, *Nugent* concluded his paper as follows: "*A new mechanical aid to vision, namely the Tuohy corneal lens, has been further reported on. It appears to have established a new concept and is ready to table its place among other aids to vision. How widespread its use will become depends on the accuracy of all measurements and the proving of its safety. It appears to be superior to the older types of contact lenses so far as comfort, blurring (imbibitions) and wearing time are concerned. (...) More cases are required for statistical purposes, more time is needed for observations and the results of other ophthalmologists must be reported before the part the Tuohy corneal lens will play in the correction of visual errors can be established*." (23)

3) The Presentation by *M.W. Nugent* at the Instruction Course of the American Academy of Ophthalmology (1950)

Under the title 'The Use of Contact Lenses in Visual Deficiencies', *M.W. Nugent* gave a lecture in 1950 at the Instruction Section of the American Academy of Ophthalmology and Otolaryngology. He first described the difficulties with and the complications resulting from the use of scleral contact shells and went on to describe corneal contact lenses: "*During the past three years, a new theory has been developing which concerns the Tuohy corneal lens. It is made of plastic, but has only a corneal part and requires no accessory foreign solutions. (...) As with the contact lens, normal corneal metabolism is interfered with by the Tuohy corneal lens, but to a much less degree in that imbibitions is almost negligible and limbal, conjunctival and aqueous vein circulation is not affected. (...) To date, the average wearing time is nine hours, but it is much wiser [to] recommend an eight-hour wearing-time until more time has passed and further observations made.*" (24)

1.2.2 - The Presentation of the 'Corneal Lens' by H.S. Harris

In February of the following year (1950), optometrist *Harold S. Harris* (Bellflower, California) who was close to the manufacturer published under the title, 'The Corneal Lens' an exhaustive evaluation of the Tuohy corneal contact lenses. The article was to be reprinted and widely distributed in the form of a monograph by the American Journal of Optometry. *Harris* emphasized how well these lenses were tolerated:
"*The corneal lens is superior to the conventional contact lens in respect to: comfort, corneal fogging, insertion and removal, fitting technique, thinness and lightness of weight and appearance on the eye. (...) Basically, the adjustment, which the eye makes to the corneal lens, is 1/ adaptation of the lids, 2/adaptation of the cornea. (...) True corneal fogging per se does not occur when the corneal lens is properly fitted and the patient obeys the doctor's instructions. The lack of corneal misting permits eventual unlimited wearing-time. (...) A statistical approximation of the patients' wearing the lenses may be stated as follows: 30 to 40% wear the lenses all their waking hours; 30 to 40% have a limited wearing-time of five to ten hours; 30 to 40% are in the process of increasing wearing time. 3% of those fitted [have] conical corneas of whom 96% wear their lenses all their waking hours.*" (25)

1.2.3 - The Guarded Opinion of S.V. Abraham and P.D. Shanedling (1950)

At the time of the promotion of their questionnaire on 'The Clinical Status of the Contact Lens', ophthalmologists, *Samuel V. Abraham* and *Philip D. Shanedling* (Los Angeles) gave a somewhat reserved evaluation of the corneal lenses, of which their region had been the cradle: "*Recently Nugent described the Tuohy corneal lens, which has acquired many enthusiastic supporters in the short time it has been manufactured. This lens, used without special fluids and without a scleral portion, has many promising advantages, especially [those] of long tolerance and elimination of the troublesome use of special fluids. It has, however, certain disadvantages, not yet completely eliminated. Some of these are (1) the mobility of the lens, sometimes disconcerting; (2) the difficulty of applying the lens to very high ametropia and keratoconus; (3) the rather frequent presence of superficial keratitis even in cases without complaint (probably due to mobility of the lens, drying spots of cornea, abrasive substance in tears and secretions and so forth). The superficial keratitis, although it usually disappears rapidly in a few hours, is a potential source of danger to the patient, especially in cases of pathologic conditions of the cornea. From a medico-legal aspect, it may be troublesome to the physician.*" (26)

Taking these considerations into account, the authors came to the following prudent conclusions:
"*Until the problems connected with contact lenses are well appreciated and cared for, ophthalmologists would do well to discourage dispensers and manufacturers from over-enthusiastic exploitation.*
It would seem that contact lenses, including the corneal lenses, require further research and close observation by the prescribing doctor before widespread acceptance by the public is encouraged."

1.2.4 – J.C. Neill's Second Commentary (1951)

In 1951, *John Collins Neill* (Philadelphia) presented to the International Optics Congress of London a second evaluation (still relatively cautious) on corneal contact lenses. This was entitled 'Contact Lens fitting in the United States'. He designated these lenses as 'corneal cap contact lenses'. He described two methods of fitting that were being used.

The one was keratometric and the manufacturer recommended this method:
"*In the method suggested by Solex Laboratories, the keratometer reading of the weakest meridian in diopters is converted into millimeters with the aid of a table. This table gives the correct radius of conversion, from which value a series number is obtained with the help of another table. By the use of other tables, the lachrymal lens factor is determined and this value is then added to the spherical element of the patient's lens prescription. This information is sent to the laboratory. The fitter receives three pairs of lenses from the laboratory: one pair exactly as ordered, one pair, which has a radius series number lower, and another pair which has a radius one series number higher than the pair ordered*." (27)

The second method, by trial, is reserved for fitters possessing the trial lens box of 27 Solex Laboratories contact lenses: "*Another system of fitting corneal contact lenses uses a trial case of the lenses. (...) The lenses are marked with their true power or radii and the fitter must modify his keratometer readings by allowing either one and one half diopter or 0.3 mm for the flatter radius required for the corneal lens*."

Neill's reservations concern mainly eyelid sensitivity, insertion and removal of the lenses and the risk of losing them due to ejection by the lids: "*The major problem in the fitting of the corneal lens is that of comfort. Many persons have been found who are unable to relax their palpebral muscles sufficiently to allow the lids to pass over the edge of the lens without irritation. When a person is able to obtain lid adaptation so that there is no irritation, the lens seems to be ideal.*"

Neill summarizes his opinion as follows: "*The corneal cap lens is relatively easy to fit and has long wearing time for those who are able to develop the lid tolerance necessary for comfort*."

1.2.5 – The Prudent Optimism of R. Graham (1951-1952)

In 1952, *Robert Graham*, who, in this era was a member of the Los Angeles College of Optometry and Lecturer in the Department of Ophthalmology of the Medical Evangelists in Los Angeles, published a new study based on the data of the first 6.000 Tuohy corneal lenses sold by Solex Laboratories. This study was entitled, 'The Corneal Lenses - A Supplementary Report'. In a short memo, *Graham* noted the merits of *Tuohy*: "*The first successful type of corneal lens was invented in 1947 by Kevin M. Tuohy, a staff member of the College of Medical Evangelists in Los Angeles*." (28)

For a successful fit, observation of the lachrymal circulation is fundamental:
"*No artificial fluid is employed with corneal lenses. A lubricating layer of natural tears always separates the lens from the corneal tissues. Adequate circulation of tears beneath the lens can and must occur. One of the principal objectives in fitting is the determination of that lens which permits the optimum tear flow to the cornea beneath it. Lacrimal circulation can be observed under the slit-lamp or demonstrated by instilling a solution of fluorescein above the lens*."

The first 100 patients had been followed with special attention without detection of any irreversible changes in the corneal tissues. The two patients, in whom the follow-up was the longest, were the inventor *Kevin Tuohy* and his wife *Martha*. *Kevin* had four diopters of myopia and his wife seven. They had been wearing their lenses from morning to evening for three years. Most of the patients wore their lenses for more than eight hours a day, some for the whole day. A certain motivation was nevertheless necessary. Alternating with regular glasses was a possibility, eventually. The best results were observed with myopes of more than 3.5 diopters, hyperopes of more than 5 diopters, anisometropes, patients with irregular astigmatism, moderate keratoconus patients and aphakia. When the upper eyelid was very sensitive, it was sometimes necessary to revert to scleral lenses. The most unpleasant sensation with corneal contact lenses occurred during blinking when the eyelid came in contact with the upper margin of the lens. On the other hand, corneal clouding was very rare.

Graham was optimistic about the future of corneal contact lenses and was convinced that such lenses represented a major advance and one able to give a certain impulse to the profession: "*The pronounced decline in contact lens usage just prior to the introduction of corneal lenses was evidently due to dissatisfaction with the performance of the prior types, rather than to transient interest in contact lenses. The revival of contact lens activity since the introduction of corneal lenses is sufficient to show how sincere is the desire of many individuals for a type of protection which provides normal vision together with natural appearance, eye safety and unrestricted freedom of activity for the wearer*."

1.2.6 – The Clinical Trials Carried out by C. Berens, L. Girard and K. Force (1952)

At the Congress of the American Academy of Ophthalmology in 1952 at Hot Springs, Colorado, *Conrad Berens, Louis Girard* and *Kenneth Force* gave a presentation with the title, 'Corneal Contact Lenses: A Clinical Investigation'. This was a serious and very detailed report of three years of studies at the New York Eye and Ear Infirmary, using corneal contact lenses that had been put at their disposition by Solex Laboratories. These authors were of the opinion that corneal contact glasses represented real progress forwards, their toleration remaining the most important obstacle and dependent on corneal sensitivity: "*Tolerance to the lens remains the greatest obstacle to more frequent use and appears to be most closely related to the degree of corneal sensitivity.*" (29)

Trials were carried out on highly ametropic eyes in 54 patients. From among the thirty two myopes of up to -27 diopters, only 9 of these were able to be fit, the five hyperopes were satisfactory, while the fitting of the three astigmatic patients and the four with keratoconus were the most difficult. The authors compared, in particular, the results using corneal lenses with those of their previous study on molded corneo-scleral lenses. In the 20 pages of their evaluation, the authors analyzed in detail the factors influencing tolerance and wearing-time. They noted the best tolerance in those patients who used their lenses by necessity and concluded: "*Corneal lens patients appear to use their lenses more frequently than the conventional contact lens wearers. On the whole, the corneal lens appears to be tolerated for a greater length of time than the conventional contact lens. (...) A greater percentage (78%) of the corneal lens group expressed satisfaction with their lenses. (...) The corneal lens appears to be a definite advance in the design of contact lenses. Tolerance to the lens remains the greatest obstacle to more frequent use. Although the corneal lens is a step forward, the entire topic of contact lenses remains a serious problem which requires continued careful study.*"

On the other hand, they also observed corneal erosions: "*Ten percent of our cases showed corneal damage of some type. Most of these were simple abrasions, which healed uneventfully. The abrasions occurred in patients who tried to increase their wearing-time too rapidly. In keratoconus patients, (...) a superficial infiltration can be seen over the apex*."

In the course of the discussion, *Alfred Cowan* confirmed the opinion expressed by the presenters and said: "*The Tuohy lenses are the easiest of all contact lenses for the ophthalmologist to fit. They eliminate the problem of solution. They also eliminate a number of factors that go to make contact glasses uncomfortable.*"

1.2.7 – Other Publications and Extension of the Indications (1951-1952)

In the same year, *Newton K. Wesley* and *Georges J. Jessen* expressed their satisfaction with the cosmetic use of corneal contact lenses. Added to that, *Solon M. Braff* reported the successful fit of a young myopic skater in Ice Capades, who said: "*I want corneal lenses because I need them for my work. They won't let me wear glasses when I skate and I can't see without them. Our ballet instructor told me I had to get contact lenses because I sometimes missed my cues*." (30)

Solon Braff also reported and in great detail how he fit two young myopes that he had been following for two years. He concluded from that experience that wearing these corneal contact lenses is comfortable and allows wearing-times of up to 16 hours a day without his observing any corneal changes in his patients: "*The success achieved in these reports can be multiplied many times in the several hundred corneal lens cases under the care of the writer in the past two and a half years and presents a decided increase in achievement over the results obtained with the scleral contact lenses.*" (31)

Max Shapiro produced a similar evaluation from his point of view, coming to the same conclusion. In other words, give precedence to cosmetic indications because one gets the best results in this group. And *J.W. Baglien* and *R.V. Middleton* described telescopic spectacles, the oculars of which consisted of a concave corneal contact lens of high power. (32) In the course of these years, the number of communications describing corneal contact lenses became so large that it would have been difficult and perhaps even superfluous to describe them all. This is all the more true because new laboratories were being set up for the manufacture of corneal contact lenses which recommended even smaller diameter corneal lenses that were easy to manufacture by grinding and polishing from pmma 'buttons'.

1.2.8 - The 'Army Contact Lens Evaluation Study' (1952)

The 'Contact Lens Evaluation Study' of the Medical Research Laboratory, Fort Knox, Kentucky by *J.L. McGraw* and *J.M. Enoch*, published in October 1952, included in the four types of contact lenses studied 'Tuohy's plastic corneal design lenses':"*The corneal plastic lens was included in the study because of its tremendous surge of popularity in recent years, as well for its simplicity of design and relative ease of fitting*." [33]

The fitting of the 10 patients selected for the trials had been entrusted to *Kevin Tuohy* himself: "*Mr. Kevin Tuohy of Solex Laboratories, originator of this particular design, did the fitting. The lens has a beveled edge corneal portion. The fitting is based upon ophthalmometric readings, corneal size, and lid aperture. The time required for the fitting of this lens to the ten subjects averaged two hours and fifty-five minutes in a total of five visits. The lens must be moistened with a wetting agent before insertion, but otherwise no fluid is required other than the natural tears. The wetting agent employed was a solution containing ½% methylcellulose and Zephiran."*

In the discussion, the experts demonstrate the advantages and disadvantages of this type of contact lenses: *"Advantages of the Tuohy corneal lens are: relative ease of fitting and reduplication; relatively unbreakable; rare development of corneal clouding and edema; only solution necessary is wetting agent; extended wearing time when lenses comfortably tolerated; corneal protection from foreign bodies. Disadvantages of the Tuohy corneal lens are: long period of adaptation required; jolts and jarring tend to displace the lens; small size lens is easily lost, especially while swimming; left and right lens easily confused; ocular irritant results in exaggerated discomfort; produces frequent corneal injury which results in drop in visual acuity, extreme photophobia and poor fusion; limited wearing time and individual efficiency; only limited protection against radiation; plastic becomes scratched with use; produces lid irritation*."

The authors had many reservations regarding their use by solders in the fields:
"*To evaluate the Tuohy corneal lens presents a difficult problem. Since the quality of the fit may be the cause of the frequent corneal injury that was observed, it was decided to ignore this and judge the lens on its overall performance. The mere fact that this lens is so small and easily dislodged and lost makes it impractical for general field use in the Army Forces. The disadvantages seemed to outweigh the advantages."*

2 - The Tuohy Corneal Lenses in 1952

2.1 - Documentations of Solex Laboratories (1948-1952)

Kevin M. Tuohy and Solex Laboratories Inc. are the authors of numerous descriptive documents completing presentations and demonstrations of practical aspects that they organize across the United States. These documents were widely distributed in the course of the first years of marketing of cornea lenses, some of which ware preserved and available for consultation in libraries and archives. [34]

1948	Kevin M. Tuohy, assignor to Solex Laboratories Inc.: Contact Lens US Patent # 2,510,438: filled February 28, 1948.
1948	Solex: Fitting and Ordering the Tuohy Corneal Lens, Solex Laboratories Inc., Los Angeles, CA.
1950	Solex: Procedure and Technique of Corneal Lens Fitting Solex Laboratories Inc., Los Angeles.
1950	Kevin Tuohy: Tuohy Laboratories: The Inventor's New Corneal Contact Lens Fitting Center. Solex Laboratories Inc., Los Angeles.
1950	Solex: Curvature and Thickness Charts for the Tuohy Corneal Lens Solex Laboratories Inc., Los Angeles.
1950	Kevin M. Tuohy assignor to Solex Laboratories Inc.: Contact Lens.- US Patent # 2,510,438: approved June 6, 1950.
1952	Kevin M. Tuohy: The Tuohy Corneal Lens. Quick Basic Facts. Including a Digest of 10 Professional Reports. Solex Laboratories Inc., Los Angeles.
1952	Kevin M.Tuohy: A Routine Procedure for the Use and Application of Contact Lenses. The Optical Journal and Review of Optometry 90 (17): 43-48.

Table 27-3
Chronology of the most important publications by K.M. Tuohy and Solex Laboratories (1950 - 1952).

1) 'Fitting and Ordering of the Tuohy Corneal Lens' (1948)
This document of several pages in length had been published and distributed at the time of application for the patent. In order to confirm his copyright, *Tuohy* was thinking that he would thus and after a fashion guarantee his priority. (35)

2) 'Procedures and Technique of Corneal Lens Fitting' (1950
This booklet was copyrighted in 1950, as soon as the patent had been assigned. It went through several re-editions and revisions. It was 27 pages long and richly illustrated. It described, after an introduction enumerating the disadvantages of corneo-scleral contact lenses, the following aspects: design of the corneal lens, the lens-corneal relationship, factors controlling the cornea-lens relationship, a glossary, enumeration of subjective reactions peculiar to the corneal lens and their probable causes. Some chapters were devoted to aphakia, keratoconus, the fluorescein test, cosmetic and absorptive corneal lenses. The booklet closes with a 15-item bibliography. (36)
The document also lists tints available for these lenses:
"*The corneal lens is available in color for cosmetic and/or light absorptive purposes. The standard colors are Smoke Green #1 and Smoke Green #2, Blue #1 and Blue #2. Not only are the numbers of shades of tint and color limited to those used for commercial fabrication and therefore available from Du Pont or Rohm & Haas, manufacturers of the plastic, but limitations are experienced in the acceptability of a color in combination with the iris color. The colors mentioned above as standard are the most acceptable for absorption and cosmetic. The smoke green colors are best on all eyes where the prominent iris color is not blue. And the blue shades are the most satisfactory where the prominent iris color is blue.*"

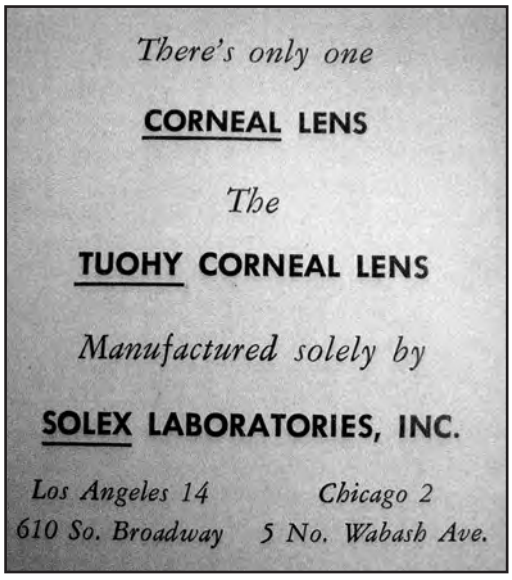


Figure 27-7
Advertisement from Solex Laboratories in 1952. *This advertisement highlights the risk of confusion with corneal contact lenses made by other manufacturers who did not provide a Tuohy and Solex Laboratories guarantee.*

3) 'Tuohy Laboratories: The Inventor's New Corneal Contact Lens Fitting Center' (1950)
A widely distributed flyer after the assignment of the US and Canadian Patents announces the opening by *Tuohy* of a Fitting Center in Los Angeles, 6515 Wiltshire Boulevard: "*Mr. Kevin M. Tuohy, inventor of the Corneal Contact Lens, has opened an office for the purpose of fitting Corneal Contact Lenses to those people who desire to eliminate eye glasses. (...) Rowie Kirk and Kay Boland, long associated with the inventor in his research, development and the manufacture of Tuohy Corneal Lenses are with him now in his direct service to the doctor and the public. (...) The cost of lenses and services is not expensive, for it is the intention of Tuohy Laboratories to make available all who need and want to use Contact Lenses, the opportunity to do so.*" (37)

4) 'Curvature and Thickness Charts for the Tuohy Corneal Lens' (1950)
These charts that were first published in 1950 are included in the fitting manual. They indicate, first and foremost, the radius of curvature of choice as a function of the corneal radius and of the refraction, be this for minus or plus lenses. Secondly, the charts show the thickness of the lens as a function of its diameter and power. (38)

5) 'The Tuohy Corneal Lens, Quick Basic Facts. Including a Digest of 10 Professional Reports' (1952)
Solex Laboratories published this booklet in 1952. It is made up from a summary of ten favorable publications from the two previous years, preceded by two pages filled with praise including a historical recollection that merits citation: "*Development and Research. Early in 1948, after a year and a half of private research on the Corneal Lens at Solex Laboratories Inc., further research was done under the supervision of the Department of Ophthalmology, College of Medical Evangelists and the White Memorial Hospital, Los Angeles. Six months later, at the time the College released its findings in June 1948, the Corneal Lens was officially announced to the professions through the Los Angeles County Ophthalmological Society and the Los Angeles County Optometric Association; to the Pacific Coast Oto-Ophthalmological Society in convention in Seattle, July 1948 and to the Contact Lens Committee of the American Optometric Association in convention in San Francisco, July 1948. A report on the lens had previously been sent to the American Ophthalmological Society.*" (39)

According to this document, corneal contact lenses give the best results "*in all types of high refractive errors, including antimetropia, and anisometropia, irregular astigmatism, keratoconus, monocular and binocular aphakia. (...) The lens is not indicated in minor refractive errors, active corneal pathology, or when the patient is unable to offer reasonable cooperation. (...) Motivation based on need and desire is necessary on the part of the patient.*"

The extracts from professional reports concern the publications and communications of *Nugent, Nugent & Tuohy, Graham, Harris, Kanter & Krauss, Zabner, Braff, Weiss* and *Berens*. Some texts which had unfavorable comments were deleted.

6) 'A Routine Procedure for the Use and Application of Contact Lenses' (1952)
In November 1952 *Tuohy* presented in Los Angeles, before the Californian Optometric Association, a communication that included an assessment of his 5-year experience of trials of corneal contact lenses and how these have been improved. Under the title, 'A Routine Procedure for the Use and Application of Contact Lenses', he showed the differences in fitting of corneal contact lenses in comparison with that of corneo-scleral contact shells that were used up to that time. The presence of a corneal and palpebral sensitivity was, in fact, a new observation and specific to corneal contact lenses. The management of this sensitivity was not easy, but compensated for the most part for the disadvantages due to metabolic disturbances associated with corneo-scleral contact shells. There were, nevertheless, numerous problems requiring resolution. As evidence, he reported his own observation of visual blurring at times of stress: "*Now, in round figures, my eyes have supported my lenses for some 34,914 hours. (...) I am as familiar with something on my eye as I am likely to become. But, as I stand here this evening, I have, what one eloquent ophthalmologist termed, hysterical vacuolation of cytoplasm in the surface layers of corneal epithelium on my left eye. Subjectively, the vision in my left eye is hazy. Objectively, a multitude of tiny pinpoint bubbles are present on the surface of my cornea. This phenomenon occurs only when I am obliged to speak in public. When I approached this platform, my vision was clear. The vision of my left eye is now cloudy, but an hour after I leave this platform it will again be clear. (...) My metabolism is undoubtedly affected and my particular reaction is not solved by lens changes in radius of curvature or overall size. (...) In my own small problem, the ophthalmologist suggests the care of a psychiatrist.*" [40]

2.2 - The Tuohy Corneal Lens in 1952

2.3.1 - Presentation.

The classical and original Tuohy Corneal Lens, the one that was recommended at the time of the first years after its discovery, had the following characteristics:
- a standard total diameter of 11.50 mm;
- a posterior surface with a radius of curvature from 7.50 to 9.00 mm in steps of 0.05 mm, surrounded by a peripheral 'bevel', 1.50 mm in width , in general, ground from 0.3 to 0.6 mm flatter than the central radius;
- an optically-ground anterior surface;
- a central thickness of 0.25 to 0.35 mm depending on the refraction.

The recommendations made by *Tuohy* during this epoch strictly indicate the fitting procedure and the indications.

	Overall diameter of the lens					
Central corneal radii (mm)	11.5 mm (Standard)		11 mm (Small)		12 mm (Large)	
	Clearance widths	Variations in radii of curvature	Widths of clearances	Variation in radii of curvature	Clearance widths	Variations in radii of curvature
7.7 to 8.0	1.25	0.3	0.75	0.2	1.75	0.4
8.0 to 8.50	1.50	0.4	1.0	0.3	2.0	0.5
8.5 to 9.0	1.75	0.5	1.25	0.4	2.25	0.6

Table 27- 4
Curvatures and clearance widths usually recommended by Tuohy in 1952.

2.3.2 - Fitting

Tuohy used to recommend that a lens be chosen with a central radius of curvature 0.50 mm flatter than the flattest corneal radius of curvature. One starts with 'Standard' type lenses of 11.50 mm, felt to be suitable in 80% of cases. Roughly 10 minutes after insertion, inspection with fluorescein concentrates on central contact and clearance: a good fit is manifested by a fluoro-negative area of central contact of about half the corneal diameter and a fluoro-positive peripheral clearance of 0.50 to 1.00 mm. Generally speaking, tolerance lasts for the whole day without evidence of Sattler's veil. The appearance of bubbles in the center indicates a too steep fit, while bubbles in the periphery show a too flat fit.

2.2.3 - Indications

In the course of the first years of trials and assessments, corneal contact lenses were fit for the same indications as corneo-scleral shells, essentially for high refractive error patients, keratoconus and aphakia. Aside from some exceptions, notably *Wessley* and *Jessen, Braff* and *Graham*, they were not used for cosmetic indications in low myopes or low hypermetropes. Taking into account that corneal diameter contact lenses were more comfortable and were subject to fewer complications than corneo-scleral shells, the indications were rapidly extended to cosmetic fits for mild refractive errors.

2.2.4 - Appreciation

When *Kevin Tuohy*'s invention became known in June 1948 through *Maurice Nugent*'s communication, followed by *John C. Neill*'s editorial, and when the first skepticisms and doubts were lifted, this new concept gained approval, because it was confirmed that corneal diameter contact lenses were more comfortable and had fewer complications than corneo-scleral shells and responded also to the demands of patients with low refractive errors. The recommendations forthcoming from the first two years of marketing of the first corneal contact lenses were quickly criticized. As it turned out, the 'big and flat' Tuohy lenses were imperfect, monocurved and covered practically the whole of the corneal surface. Their total diameter (11.00 to 12 mm), their posterior central radius of curvature to be chosen flatter than the flattest corneal radius of curvature, their unique peripheral clearance and their coarsely ground margins, caused a number of complications.
It was soon confirmed that, for a good fit, the size of the radius of curvature for clearance had to vary as a function of the corneal radius of curvature and the total lens diameter. More and more, fitters chose smaller diameters to give better performances than those achieved with the initially recommended 'big and flat' lenses.

3 - Contemporaries, Precursors and Contestations

3.1 - Contemporaries of the Discovery

Several contemporaries of *Tuohy* who had had the same idea of a corneal contact lens are usually cited. These had either not been able to market their lenses or did not have the necessary financing. The following are cited in the USA: *Dennis C. England, Xavier R. Villagran, Georges H. Butterfield, Samuel W. Silverstein, Noel O. Stimson, Joseph J. Hornstein; in Europe, Heinrich Wöhlk, Jean Cabarrouy* and *Adolf Müller-Welt*.

1945	D.C. England	Patent: Improvement in Ophthalmic Contact Lens
1946	X.R. Villagran	Colleague of M.Tuohy at Solex Laboratories
1949	G.H.Butterfields	Patent: corneal lens, paraboloid periphery
1950	S.W.Silverstein	Patent: "vented" corneal lens
1951	N.O.Stimson	Patent: corneal lens with "facets"
1952	J.J. Hornstein	Patent: corneal lens with vaulted apical zone
1952	H. Woehlk	Claims in Germany (1950)
1950	J. Cabarrouy	Claims in France (1947)
1950	A. Müller-Welt	Claims in Germany (1948)

Table 27-5
Contemporaries of Tuohy often referred to in connection with the discovery of corneal contact lenses.

3.1.1 – D.C. England (1946)

Optometrist *Dennis C. England* registered an application for a patent at the US Patent Office for 'Improvement in Ophthalmic Contact Lens'. The application was worded as follows: "*A contact lens that rests directly on the corneal portion of the eye (...) eliminates the use of saline between the lens and the eye, (...) has an inner surface that conforms to the exact curvature of the cornea*." (41)

The document specifies that the curvature of this corneal lens would be determined by keratometry and that the lens would conform precisely to it, leaving no clearance. The reasons given for the rejection by the patent office were motivated by the impossibility of relying on the keratometry, taking into account that numerous corneas have irregular keratometry and that corneal clearance is essential for conformity of the fit. The rejection also indicated that *Kalt* had already used such a lens in 1887 and that fitting would have failed. The official and the expert charged with the patent application did in fact follow the opinion that was current during this era. *England* had registered two new similar applications for patent in 1947 and 1949 that were also denied for the same reasons. It should be noted that the patent of *Tuohy* had also been registered in 1948 and it was granted in June 1950 without rejection on the same pretexts. Contrary to *England*, he had benefited from the scientific caution of *Maurice Nugent* in June 1948 and then from the authors cited above.

Figure 27-8
Xavier Villagran polishing the first corneal contact lenses.
This illustration from a contemporary journal shows Xavier Villagran monitoring the polishing of contact lenses. The photo was taken in 1950 for an article in a popular journal describing the new contact lenses and how they were tolerated by all eyes and did not require solutions other than natural tears.

3.1.2 – X.R. Villagran (1946)

It has often been claimed that the idea of using the corneal portion of a corneo-scleral contact shell in order to make a corneal contact lens out of it originated with *Xavier Villagran*, associated with *Solon Braff* in the Solex Laboratories, where *Kevin Tuohy* was employed as technician. According to *Edward Goodlaw*: "*When Villagran (...) [accidentally ground] through one of the scleral lenses and came out with the optical section and showed it to Tuohy, Tuohy said: 'Well, Goodlaw says that the cornea needs oxygen and this is going to be a better way to get oxygen (smaller surface area)' and I [Goodlaw] also pointed out that (...) [the cornea] is not as sensitive as we thought (...). 'Let's try it!' So they put it on the eye and that was the birth of the corneal contact lens, right then and there. (…) There was a lot of development after that (...) their lenses (...) were lathe-cut and they put the edges on with a razor blade and it was pretty crude. I can remember the hour I spent smoothing out those little developments, because the scleral lens wasn't going anywhere*." (42)

According to *Mandel*: "*Tuohy's discovery began one day in 1946 when his partner and lab. technician, Jay Villagran, entered his office to show him and his partner Solon Braff a laboratory mistake. Villagran had errored in lathing a scleral lens so that the lens was cut in two at the transition between the corneal and the optical section*." (43)

Several years later, *Xavier R. Villagran* commented personally on the circumstances of the discovery and its more or less happy consequences: "*Both Kevin M. Tuohy and myself were picked by fortune to improve the scleral contact lens. The resulting interest that followed our success brought expert contributions from other professionals to perfect a budding idea. (...) My association with Kevin passed through a period of trust, a honeymoon that culminated after months of study and determined hard work, investigating how to improve the scleral contact lens, ultimately by reducing its size.*
Most unfortunate to us was my idea that a patent of protection should be obtained. Protection was never obtained and personal distrust and greed disturbed our relations, finally breaking them." (44)

In this note, *Villagran* also emphasized the merit of *Maurice W. Nugent*:
"*No mention has been made as yet of the basic contribution given to Kevin and myself by a philanthropist*

Professor Maurice W. Nugent M.D. His public report (...) opened the doors to ophthalmology and optometry for study and recognition of a 'Corneal Lens'. His substantial influence supplied the initial impetus and publicity we desperately needed. Dr. Nugent's scientific knowledge and capital investment helped launch Solex's corneal lens." *Villagran* remembers *Kevin Tuohy*, who committed suicide on 28th October 1968 at the age of 46 years: "*I pay tribute to a friend, co-worker, a partner, devoured by his desire to win the world and to lose it, once it was in his hands*."

3.1.3 - G.C. Butterfield (1949-1951)

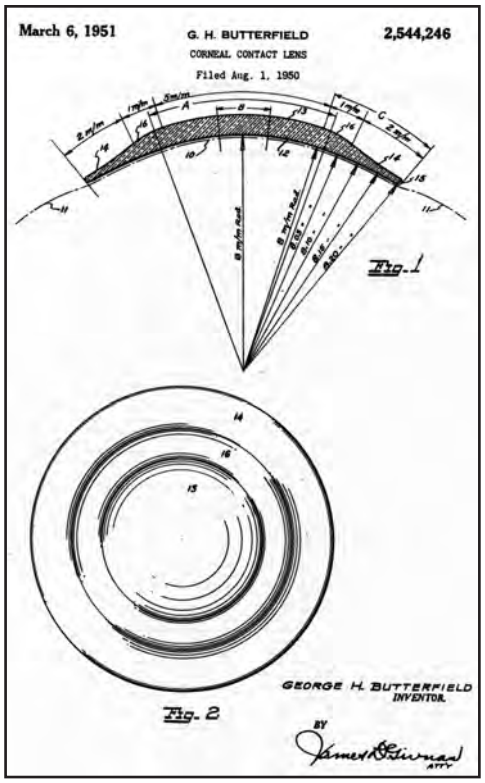


Figure 27-9
Illustration of George Butterfield's patent for a 'Corneal Contact Lens' (1950).
According to this patent, the contact surface of the lens is very close to the shape of the eyeball and has an inner central spherical area with remaining surface extending radially out towards the limbus. The anterior marginal area is gradually reduced in thickness and has a smooth transition that allows the eyelids to pass freely over the lens edge. (Butterfield G., 1950)

In 1949, therefore one year after *Tuohy, George Hiram Butterfield* (Portland Oregon) had registered an application for a 'Corneal Contact Lens' that was granted in 1951 and marketed under the denomination of 'Para-curve Corneal Contact Lens'. [45]

The patent describes a corneal contact lens, of which the geometry, both anterior and posterior makes it distinguishable from Tuohy's corneal lens. This lens possesses, in fact:
- A posterior surface with a spherical zone of 5 mm diameter in its central part, surrounded by a peripheral zone of clearance, paraboloid in lateral view.
- An anterior surface of which the optic zone is surrounded by a rim of 2 mm in width, then again is surrounded by a transition area of progressive thinning.
- The total diameter increases to 11.00 mm with a corneal curvature of 8.00 mm. According to technical documents, it could be manufactured with diameters between 10 and 12 mm.

Butterfield foresaw numerous advantages for this lens construction. Firstly, the paraboloid clearance of the periphery of the posterior surface was felt to conform to the corneal profile. Secondly, the slipping of the upper eyelid over the anterior surface of the lens would be favored by the bevel rim on the one side and by the transition zone of the periphery: "*The applicant has provided a contact lens which needs no accessory fluid, which does not give the eye a bulging appearance, which is the perfect form from the viewpoint of cosmetology and ophthalmology, which is self-cleaning, which is easy to fit, which is free of marginal aberrations, which can be used by persons with pathological conditions of the cornea and which may be easily and inexpensively manufactured*."

Thus *Butterfield* specifies: "*If the space between lens and cornea is too great, the capillary attraction will not exist and the lens may fall away from the eye. The applicant, by providing a contact lens whose contact surface is very close to the shape of the eyeball, has brought about the ideal contact lens condition. (...) The particular shape provided allows the eyelid to slide smoothly over the edge of the lens. The result is that there is not pain or sensation in the eyelid and there is no opportunity for the eyelid to pry the lens away from the cornea*."

He claims to cause the usual defect of corneal contact lenses to disappear: "*The tendency to fall away from the eyeball due to insufficient surface tension or capillary attraction or due to the eyelid lifting the lens away from the cornea*."

Under consideration, therefore, is a lens developed at one and the same time by its posterior surface that conforms to the corneal profile as well as by its anterior surface, which allows the palpebral border to slip over it. For the first time the idea of alignment of the peripheral curvatures of the lens with the corneal curvatures is recognized, which stands out clearly from the flat fit of *Tuohy*. However, the total elevated diameter of the Butterfield lens made its selection delicate. According to his contemporaries, the fit was

judged according to the mobility of the lens during movement of the eye in the cardinal directions of gaze: "*If the lens does not have a reasonable amount of lag during the cardinal movements, it is too tight. If there is too much lag, it is too loose. The tight lens indicates the need of a lens of longer radius of curvature*." (46)
At the time of the various lawsuits dealing with recognition of his patent's validity, a sequence of events occurred, leading one to believe that *Butterfield* had taken account of the publications of *Nugent* and *Graham* in the first version of his application. After *Tuohy*'s patent had been published, *Butterfield* submitted a new version, inspired by this document and this was modified a third time before being finally granted in March 1951. (47)

3.1.4 – S.W. Silverstein (1950-1953)

In February 1951, *Samuel W. Silverstein* published the results obtained with 'a new contact lens' for which a new patent application had been registered in December 1950. The lens was known under the denomination of 'Vented Lens'. The proposal was to manufacture a 'hybrid' lens that was situated halfway between scleral and corneal contact lenses and would combine the advantages of both of these: "*The author (...) reports that, while the recently introduced small contact lens has provided certain advantages over the large, solution-type lens, it is not entirely successful. The author has developed a 'vented lens', which he states provides the benefits of both the full-sized and the wafer type lenses by providing adequate tear drainage and elimination of haze. The 'vented lenses' are full-sized stock lenses adjusted to the eye so that a minimum lens solution is formed over the apex and perforations are added. When some tolerance has been attained, the refractive correction is incorporated on the outside corneal curve. A selected number of practitioners have been fitting the 'vented-type lens' with gratifying success*." (48)

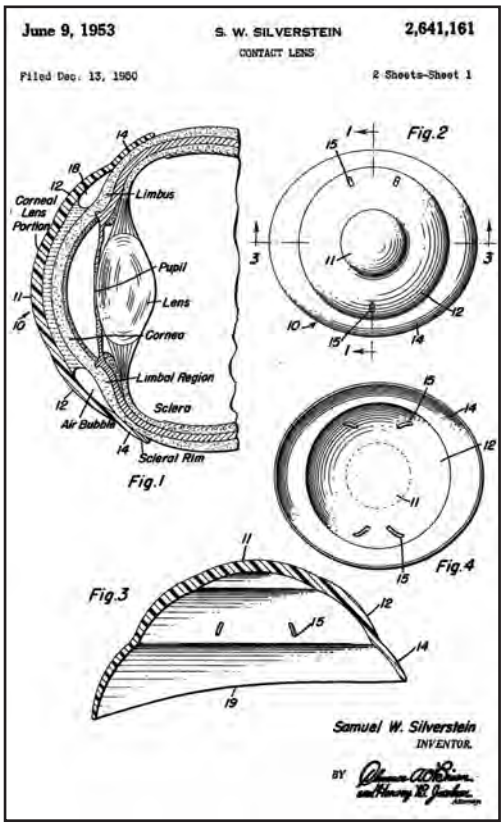


Figure 27-10
Illustration of Samuel W. Silverstein's patent (1950). *Samuel Silverstein describes a 'hybrid' contact lens in his patent. This combined advantages of scleral contact shells and corneal contact lenses, thus avoiding the disadvantages of both.*
(Silverstein S.W., 1950)

In actual fact, the 'Vented Lens' is a small corneo-scleral contact lens. It is a tri-curved lens with a central part, the corneal section, a marginal scleral section and a transitional section. The corneal part has a very steep curvature capable of creating a tear meniscus able to correct refractive error. The scleral part is reduced to a tangential perilimbal support, while the annular transitional part covers the limbus and neighboring sclera and is provided with ventilation orifices, i.e. channels, holes or openings that are at right angles to the lens surface. Air pockets are thus created under the peripheral part of the lens, which are felt to ensure continuous oxygenation. The 'vented air lens' of *Silverstein* did not, however, have the success its inventor hoped for.

3.1.5 - N.O. Stimson (1951-1953)

Optician *Noel O. Stimson* (Los Angeles) owned a patent for a 'Corneal Contact Lens' that was manufactured and sold under the trade name of 'Keraform' by Trufit Contact Lenses. It was to achieve a certain level of success: "*A contact lens in which the concave posterior surface of revolution about the lens axis is instead toroïdal (...), the concavity of which has a given radius in the horizontal meridian and a different radius, generally smaller, in the vertical meridian. Further (...) the posterior concavity is provided with one or more discrete areas, which extend out from general concave contour. These protuberant areas or bosses may be of any degree of protuberance (...). The protuberant areas, or facets, constitute the only portion of the lens which actually contact the cornea*." (49)

According to the description of the patent, the *Stimson* contact lens is of corneal diameter and has a posterior surface, either toroïdal or spherical. In the toroïdal version, the horizontal radius of curvature is generally shorter than the vertical radius. Near to the periphery are positioned two or more, generally four, protuberant areas called 'facets' that are felt to stabilize the lens by preventing it from rotating and, at the same

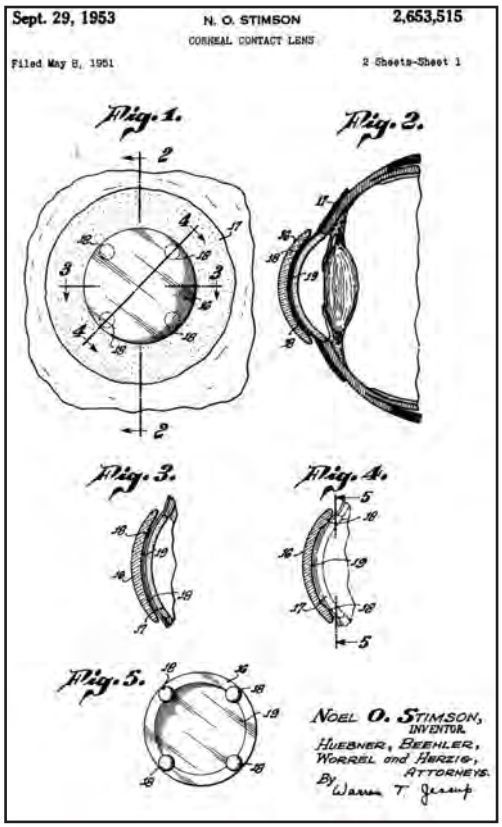


Figure 27-11
Illustration of Noel O. Stimson's patent (1951).
The contact lens described in Noel O. Stimson's patent included 'facets' on its posterior surface intended to stabilize the lens position and favor lacrimal circulation. (Stimson N.O., 1951)

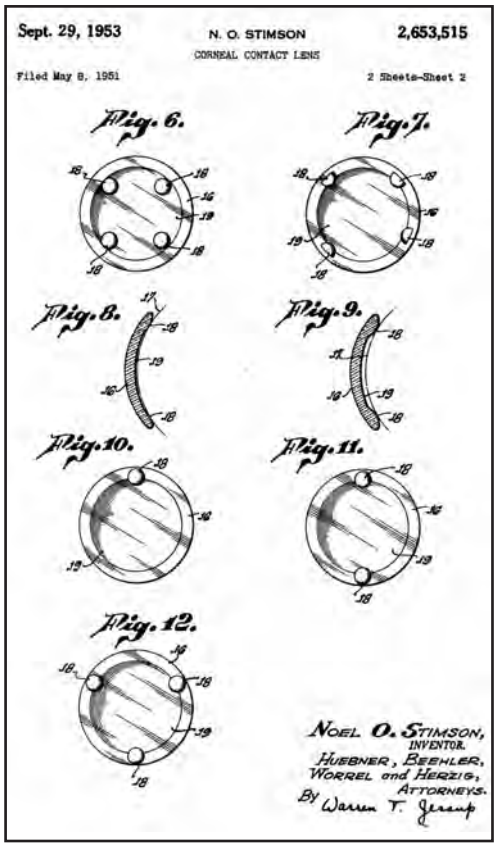


Figure 27-12
Illustration of the 'facets' described in Noel O. Stimson's patent.
The patent describes the possibility of equipping the posterior surface of a corneal contact lens with one or more 'facets'. (Stimson N.O., 1951)

time, improving the circulation of tears and reducing corneal metabolic disturbances. The 'facets' consist of flat-surfaced elevations or elevations that are slightly convex. According to the inventor, the lens will align itself by spontaneous rotation on the axis on the corneal astigmatism. Fitting of the *Stimson* corneal contact lens is performed by starting with a reduced set of 16 trial lenses varying from 7.40 to 8.90 mm central posterior radius of curvature, in 0.10 stages that should correspond with multiple varieties of peripheral corneal curvature. The author recommends starting with the 8.00 mm radius lens and, should it remain immobile, to replace this by another lens of 0.10 flatter radius. The lens must remain centered, but be easily mobilized by blinking. The *Stimson* lenses were manufactured by molding, felt to produce a lens that was thinner and more resistant. Later modifications recommended a toroïdal posterior surface better adapted to astigmatism cases, and lenses with more reduced diameter.

Comments from contemporary witnesses are relatively reserved: "*According to the development by N.O. Stimson, four facets situated on the posterior surface of the lens are claimed to aid the distribution of corneal contact and positioning. These elevated areas are located quadrangularly, i.e. at 90-degree intervals near the periphery of the lens, to rest on the negative zone of the cornea. The facets consist of flat to slightly convex elevations and may be incorporated on a spherical or toroïdal surface. The posterior lens curve is generally steeper than that of the cornea, giving apical clearance. The facets tend to hold the lens off the cornea, thus restricting contact to the facet elevation, allowing free lacrimal circulation and minimizing visual after-effects. In later designs, the overall lens diameter is reduced to 8-8.5 mm. Toroïdal corneal lenses have been used experimentally in cases of high corneal astigmatism, the resultant uneven thickness proving the main criticism. (...) Oval spherical lenses and other regular and irregular shapes failed to give material advantages over standard constructions*." (50)

3.1.6 – J.J. Hornstein (1952-1957)

In 1952, *Joseph J. Hornstein*, acting as assignor to *Dr. Ritholz & Sons Inc.* (Chicago, Ill.) registered an application for a patent 'Contact Lens'. According to the description of the patent, the 'Hornstein Corneal Lens' is a bi-curve lens of corneal diameter, which consists of:
- An inner spherical optical zone, corresponding to the apical zone of the cornea, of which the radius of curvature is "*smaller than the radius of the apical area*".
- *A "peripheral, or marginal zone, which follows substantially the radius of the corneal peripheral area."*
- *A total diameter of the lens, which "corresponds to, but never exceeds, the diameter of the limbal area, may vary in specific cases from 11.50 to 14 mm"*. (51)

Hornstein claims several advantages stemming from the steep fit and the central clearance:
- There is no possibility of corneal abrasion or ulceration of the corneal area.
- The lens has excellent capillary attraction and will not fall out or dislodge readily.
- The lens requires no accessory fluid, is free from marginal aberrations and may be easily and inexpensively manufactured.
- Overcomes all of the known objectionable characteristics attributed to known types of corneal contact lenses.

The author insists on the advantage of apical clearance: "*The center area of the lens, the optical zone, is spaced from the apical area or pupil of the eye by a distance sufficient to prevent flattening of the apical area or causing corneal abrasions or ulcerations*."

The fit is vaulted in comparison with the corneal radius of curvature: "*It is not a difficult matter to fit a patient with the lens. Having determined the dimensions of the corneal radius and the diameter of the limbal zone, it is a relatively simple matter to select a blank having the required dimensions and then grind the necessary optical correction therein*."

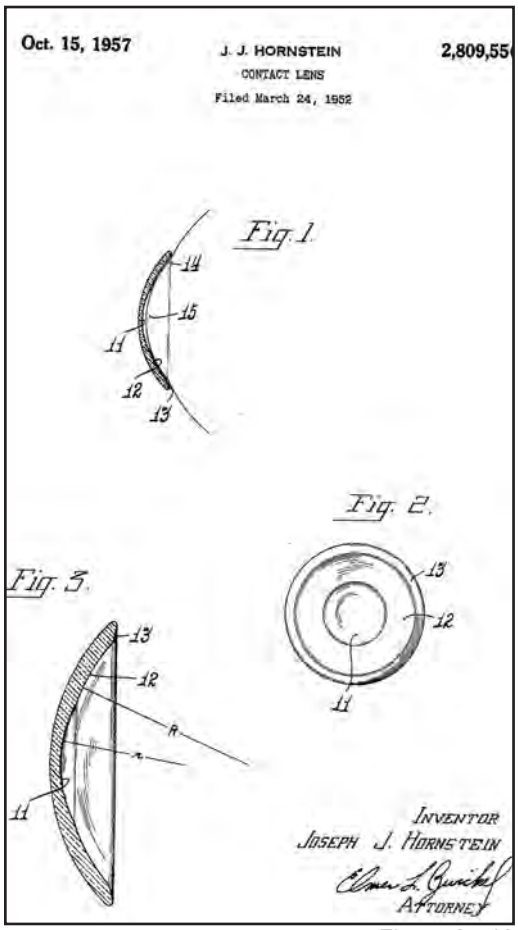


Figure 27-13
Illustration of Joseph J. Hornstein's patent (1952).
The patent awarded to Joseph J. Hornstein claimed a steep fit with significant apical clearance permitting "center area of the lens to be separated from the apical area of the eye."
(Hornstein J.J., 1952)

It should be noted that the delay of more than five years that elapsed between the filing (1952) and granting of the patent in 1957 demonstrates that the process was not an easy one. It is more than likely that *Hornstein* had to modify his request in order to take account of contemporary publications and patents, considering that he cites *Stimson*'s patent in his references, although this was 18 months after the date of filing his application. Notwithstanding this delay, 'The New Hornstein Lens' had already been marketed in 1954, as was noted in a contemporary advertisement: "*Advantage of the new Hornstein invisible corneal contact lens - The new Hornstein lens (patent pending) has a released (domed) ground and polished central zone, which make it impossible for the lens to touch the central part of the eye, or in fact, any part of the eye, as the lens 'floats' on the tears, (...) They are tiny; invisible; no fluid or impressions are needed; made of plastic, they are guaranteed not to break and actually protect the eyes; (...) can be worn instead of glasses by persons who now wear thick glasses, with strong correction, post-cataract cases, in keratoconus, mixed astigmatism, strong far-sightedness and near-sightedness*." (52)

It is also to be noted that *Hornstein* introduced in this era the notion of apical clearance, which marks the rupture with the flat fitting of the Tuohy lenses and his successive imitators.

3.1.7 – H. Wöhlk

Engineer *Heinrich Wöhlk* is famous in Germany for having invented corneal contact lenses. He was a far-sighted person (hyperope of +8.00 diopters) and he had in 1936, when he was 23-years-old, undergone several trials without benefit by *Heine* in Kiel of Zeiss corneo-scleral shells. The company *Anschütz* that employed him in Kiel was using Plexiglas for the making of gyroscopes around this period of time. This was to give him the idea of using samples of the material for his experiments in making contact lenses. In 1938 and 1939 he made scleral contact shells from pmma using molds made from wood and plaster and he also tried to model these after wax molds taken from his own eyes. In 1940, he succeeded in placing a shell without optical part in his own eyes. After the war was over, he started his experiments again and produced, in the Ophthalmological Clinic of Professor *A. Messmann* of Kiel, a series of wax ocular moldings, from which he derived several standard scleral models. He was thinking he could complete these scleral portions with interchangeable lenses. These optical parts were initially ground, and then they were produced by mol-

ding between two glass matrices following the aspherical profiles of corneal moldings. In spite of the fact that the junction between the two parts left much to be desired, he dreamed of marketing these lenses. In April 1948, he founded the company 'Heinrich Wöhlk, Gewerbe zur Herstellung unsichtbarer Haftgläsern' (Manufacturing Facility for Invisible Adherent Glasses). This company was less successful than he had hoped and had to be liquidated following its failures. While pursuing his researches, *Heinrich Wöhlk* was ready to try out the optic part of the lens, but deprived of scleral support in his own eye. This rough version of a corneal contact lens had initially a diameter of 12.00 mm, which he reduced progressively. After rounding off its margin, he was able to wear his corneal contact lens for the whole day. He improved the new corneal contact lens, the parabolic profile of which took its inspiration from ocular moldings that he had carried out. In 1951, he registered himself once again in the Trade Register, employed two collaborators and started to distribute 'Parabolar' corneal contact lenses. If we take into consideration that there are few testimonies regarding this development, the historian must rely on second-hand statements and publications: "*Around the time of Tuohy's introduction of the corneal lens and possibly earlier, Woehlk was in fact working with smaller single curve lenses having a standard 9.85 mm diameter, but also less, some being as small as 8 mm. Knowledge of these lenses was not received until the early part of 1953. They were available in steps of 0.12 mm radius from 6.62 to 9 mm in any optical power and have not materially altered since 194*8." (53)

Another account reported follows:
"*After the war, (Wöhlk) started experimenting making scleral lenses from pmma, made molds from quartz glass; hole was drilled in the center, interchanging optics was inserted into the hole to form a complete scleral lens. Moulds powdered pmma optics was inserted between the molds and the lens polymerized between them. (...) Between 1946 and 1948, he (Wöhlk) found that, by inserting just this separate optic part into his own eye, he got much better results. Working with smaller single curve lenses having a standard 9.85 mm diameter, but also less, some being as small as 8 mm, this became Wöhlk's first PMMA corneal lens known as the 'Parabolar'. He made some lenses to his own correction and found he could wear them for eight hours right from the start. The back curve was based on the many casts made by Prof. Meesman at the University Eye Clinic Kiel in order to follow more closely the shape of the cornea. The firm of Heinrich Wöhlk was registered on 7th April 1948 to make contact lenses and contact lens machinery. There were some queries raised in the UK in 1978 when Wöhlk referred to these dates in advertizing copy. He reassured Andrew Gasson of Wöhlk Contact Lenses UK, that these dates were correct and had been upheld in German Courts of law*." (54)

3.1.8 – J. Cabarrouy

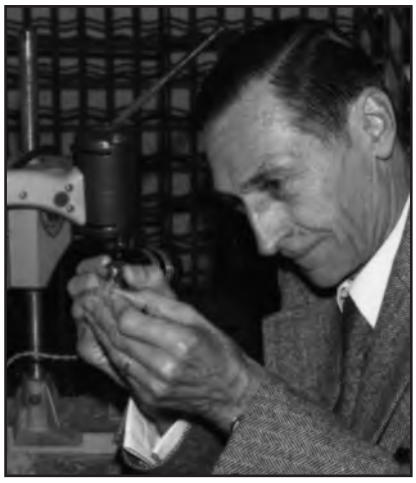
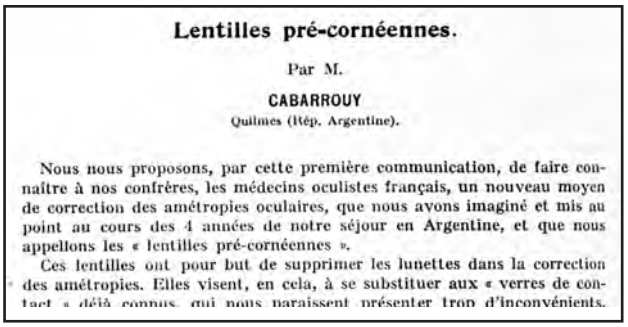


Figure 27-14
Jean Cabarrouy.
Jean Cabarrouy was a French ophthalmologist who manufactured corneal contact lenses from corneo-scleral shells that he produced by compressing sheets of pmma. He progressively reduced the diameters of the scleral shells in the process.
(Private Collection)

The French ophthalmologist *Jean Cabarrouy* must also be cited. He reported that he had invented, fabricated and fit 'pre-corneal contact lenses' (lentilles pré-cornéennes) in 1947 during a stay in Argentina. In his accounts, he reported that, after several unsuccessful attempts at molding sheets of Plexiglas between calibrated bronze matrices, he had the idea to gradually suppress parts of the haptic, and then the entire scleral zone. The contact glasses were reduced to the corneal part and were calibrated with steel balls. They had a total diameter of 11.5 mm to 12.5 mm with posterior radius of curvature flatter by 0.03 to 0.1 mm than the flattest corneal radius of curvature and a widening in the periphery using three polishing spheres. (55) Unlike *Tuohy*, he



Lentilles pré-cornéennes.

Par M.

CABARROUY

Quilmes (Rép. Argentine).

Nous nous proposons, par cette première communication, de faire connaître à nos confrères, les médecins oculistes français, un nouveau moyen de correction des amétropies oculaires, que nous avons imaginé et mis au point au cours des 4 années de notre séjour en Argentine, et que nous appellons les « lentilles pré-cornéennes ».

Ces lentilles ont pour but de supprimer les lunettes dans la correction des amétropies. Elles visent, en cela, à se substituer aux « verres de contact » déjà connus, qui nous paraissent présenter trop d'inconvénients.

Figure 27-15
Jean Cabarrouy's publication.
His 1951 publication described attempts to manufacture and fit 'Pre-corneal Contact Lenses' during his previous four years spent in Argentina.
(Cabarrouy J.E., 1951)

tried to distribute the weight of the lens on the largest corneal surface and also to avoid the closed space below a vaulted lens and resting on its periphery. These advantages allowed moderate displacement of the contact lenses and the regular exchange and renewal of tears. In spite of these differences his application for patent was rejected.

3.1.9 – A. Müller-Welt

Adolf Müller-Welt (Stuttgart) is also cited for inclusion among the first users of corneal contact lenses. It is known that he made corneo-scleral shells in separate molds for the scleral and the corneal parts. The two parts were joined together by injection. He knew the optical effect of the corneal part and would have tried to use it on its own. After he emigrated to Canada, then to the USA, he associated with *Breger* and manufactured corneal contact lenses. (56)

3.2 - Some Precursors of Corneal Contact Lenses

Introduction

After the production in 1948 of the first corneal contact lenses that were actually distributed, sold and worn for the correction of a refractive error and after the publication of *Tuohy*'s patent, the concept of producing corneal diameter contact lenses was attributed correctly or incorrectly to several precursors. This was particularly true when there occurred a wave of competitors contesting *Tuohy*'s priority, the validity of his patent and/or using this as an argument to attack it. Aside from several Court decisions, the most highly elaborated texts from this era are those of *T. Obrig* (1957) and *R. Graham* (1959). These documents later served and still serve as a reference in the historical introductions to numerous treatises and, because of their being cited, translated and copied, they have acquired a veneer of apparent truth, even if the original documents were erroneous as frequently occurred.

Year	*Author*	*Attribution*	*Reference in this treatise*
1505 to 1827	Leonardo da Vinci, Descartes, De La Hire, Herschel, etc	no	Vol. I, Chapter 1 & 2, etc. Vol. I, Chapter 4 & 8, etc.
1888	August Eugen Fick	no	Vol. II, Chapter 10, p. 4 - 57
1888	Eugène Kalt	dubious	Vol. II, Chapter 11, p. 59 - 82
1889	August Muller	no	Vol. II, Chapter 12, p. 83 - 120
1912	Zeiss for physiological optics	yes	Vol. II, Chapter 16, p. 244 - 249
1914	Zeiss for optical correction	yes	Vol. II, Chapter 16, p. 284 - 285
1932	Zeiss for Weve (Diathermy)	yes	Vol. III, Chapter 27-3.2.6

Table 27-6
Summary of actual or alleged predecessors of corneal contact lenses before 1948.

In the republication in 1957 of his treatise, *Obrig* presented a 'History of Contact Lenses' in which he stated the arguments in favor of his priority in corneal contact lenses. He cited the lenses of *Kalt* in 1888, those of *August Müller* in 1889, the lenses of *Zeiss* in 1912 and those of *Weve* in 1932. (57)
In 1959, *Robert Graham* published and widely distributed an article entitled, 'The Evolution of Corneal Contact Lenses' which exposed the arguments for denying the priority of *Tuohy*. The author of this polemic succeeded, omitting citation of *Tuohy* only in order to trash his priority. He cited neither *Butterfield* nor *England, in* both of whom we referred to in the previous paragraph. It is to be noted that *Graham* had confirmed the *Tuohy*'s priority in 1948 and in 1952, but he retracted this in 1958, during a lawsuit in which he was engaged against Solex Laboratories:

"*The writer of the present report [Graham] wrote in 1948 in an article which described plastic corneal lenses: 'Full credit for the development of corneal lenses is acknowledged to Kevin M. Tuohy'.*
This statement was inserted into the article so that no one could assume that the writer was taking credit for the development of the lenses he was presenting. Nevertheless, the statement would not have been left in its unqualified form, had the writer then have been aware of the prior work on corneal lenses which has since come to his attention. It is important not to ignore earlier contributors to a science. In deference to them and to the facts, the above statement is herewith retracted." (58)

These publications, which appeared in the very specialized context of Court proceedings and legal judgments, are often readily contestable. We will try to analyze the principal arguments advanced and to confront these by the use of objective evidence.

3.2.1 - Attributions to Da Vinci, Descartes, Herschel and Others

In his polemic, *Graham* (1959) quoted his preceding publication on *Leonardo da Vinci* with *Hofstetter*. He did admit, however that *Leonardo* "*did not describe corneal lenses, but did suggest the principle upon which they, as well as scleral lenses, function*."

For *Descartes*, *Graham* returned to the article 'Descartes Contact Lens' published by *Jay M. Enoch*. From that article, he concluded that the *Descartes* tube filled with water was positioned on the cornea within the confines inside of the corneal limbus and was therefore the precursor of corneal contact lenses: "*His proportions were poor, but his principle was quite correct.*" (59)

In order to cite *John F.W. Herschel* amongst the forerunners of corneal contact lenses, *Graham* depended on the argument that the facsimile suggested by *Herschel* was that of the 'irregular cornea' and "*adapt a lens to the eye of nearly the same refractive power and having its surface next to the eye an exact intaglio facsimile of the irregular cornea*."

Graham inferred the conclusion that this contact lens was corneal and not corneo-scleral: "*There is nothing in Herschel's writing to show that he considered any contact other than corneal contact. (...) Herschel had a place in the evolution of corneal lenses, not because he made corneals, or described them as such, but because his sound and widely circulated proposals pointed out that corneal lenses, as we know them today, were possible*."

3.2.2 - A.E. Fick's Contact Lenses (1888)

In order to show the priority of *Adolf E. Fick*, *Graham* uses a personal translation of the original German language article of *Fick*, rather than quoting the translated English version by *C. May* for the Archives of Ophthalmology. That allows him to translate 'contact spectacles' by 'contact lenses', thus simplifying certain extrapolations that are manifestly erroneous. (60) *Graham* correctly described the two types of lenses used by *Fick*:
- The first ones were single-curve shells used in rabbit's eyes and he confirmed that he was using simple spherical shells: "*It is unmistakably clear that many of the structures which Fick used in his early investigations were simple segments of hollow glass spheres*." However, *Graham* fails to note that this choice was made because of the sphericity of the eyeballs of rabbits observed on moldings from their eyes and, above all other considerations, the fact that *Fick* had not inserted these single curve shells into human eyes. (61)
- For the second type of lenses, the ones that were used later by *Fick* for experiments on himself and on his patients, *Graham* maintains confusion around the term 'protrusion': "*Fick repeated the word 'protrusion', thus emphasizing that only the protrusion was used. He was still making lenses without a scleral flange*." (62)

The protrusion created by *Fick* in a glass bubble 30 mm in diameter corresponds effectively with the protrusion of the corneal part with reference to the scleral plane. However, the cutting off of the shell had not been carried out at the periphery of this protrusion, as *Graham* admits, but along 'an oval line' similar to the periphery of an ocular prosthesis. Indeed, an oval shell cannot correspond with a corneal lens. This reasoning escaped *Graham*, who concluded erroneously: "*He makes it clear that he himself initially wore a simple lens produced by cutting off a blown glass protrusion*."

If there is a possible imprecision in *Fick*'s article in the Archiv für Augenheilkunde, it is not the case in his

'Memorandum at the Saxony Academy of Medicine', in which *Fick* states that the shell that he inserted into his own eye for his first experiments had an oval diameter resembling that of an artificial eye. It could therefore not have been a corneal contact lens: "*I had blown for me a glass bubble of about 30 mm in diameter and in this bubble I had a protrusion blown the same size as the cornea, then one drew an oval line, resembling the contour of an artificial eye around the glass cornea and on this line the glass was cut*." (63)

Of course, *Graham* did not know of the existence of the 'Memorandum' and based his interpretation of events on his own translation of Archiv für Augenheilkunde. In order to confirm that his own statements were well founded, he also checked the citations of *Friedrich Müller* (Wiesbaden) and *Donald O'Rourke*. We have already drawn attention to the errors of these authors. It must not be forgotten that *Müller* wished to prove in his thesis the superiority of the glass contact shells blown by his parents' firm, which would be due to the wide blown scleral part, which would explain their superior tolerance as compared to the *Fick* and *Sulzer* shells ground with a spherical haptic. Taking into account that *O'Rourke* had only a translation of *Müller*'s thesis at his disposition, he reproduced the errors contained therein. (64)

Graham maintains, furthermore, the confusion caused by certain illustrations. The legend of his figure 3, "*A thin, very small, glass bowl bounded by concentric and parallel sphere segments*", refers to the contact shell made for rabbit. In his figure 4, he compares using diagrams drawn by his own hand, firstly spherical contact shells that he claims *Fick* wore, but were, in actual fact, used for experiments on rabbits' eyes and made from blown glass in Zurich, and, secondly, Zeiss corneo-scleral shells delivered by *Abbe*.

3.2.3 – E. Kalt's Monocurved Small-diameter Lenses (1888)

Starting with the first edition of his manual, *Obrig* had cited *Eugène Kalt* as being among the first users of corneal lenses. The mistaken citations of *Obrig* were also repeated without modification in later editions. We have made an inventory of these and their corrections. To summarize, one must be aware that *Kalt* had successively used two types of contact lenses:
- The 'prosthesis-like blown shells', monocurved, from 16 mm to 22 mm in total diameter, described by *Photinos Panas* in 1888 and intended for compression of keratoconus.
- The 'ground contact lenses of small diameter', used in *Kalt*'s second attempt, ground, monocurve, of 11.00, 11.50 and 13.00 mm total diameter, without a scleral rim and described in *Abadie*'s discussion in 1893. (65)

Unfortunately, the erroneous *Obrig* texts were very broadly reproduced and distributed and were used as evidence before American Courts. In the same way, *Graham*, while rectifying certain errors and completing them by using citations of contemporaries, does not distinguish between the two types of *Kalt* lens and amalgamates the citations of 1888 (Panas) with those of 1893 (Chevallereau, Abadie) and of 1937 (Haas). He takes care to describe that two successive types of lens are under consideration: the first are large-diameter blown lenses, the second are smaller diameter ground lenses, of which the smallest models can be effectively compared with corneal contact lenses. Furthermore, *Graham* relies on second-hand erroneous citations from other authors in order to support his arguments.

3.2.4 – Müller's Corneal Lens (1889)

In spite of the use of the expression 'Corneal Lens' (Hornhautlinse) by *August Müller* in order to define the corneal shells employed for his experiments in 1888, described in his thesis of 1889 and preserved in Munich at the Deutsches Museum, he was using corneo-scleral shells and not corneal contact lenses. Numerous historians have allowed themselves to be misled by this ambiguity, which became widespread when the priority of the *Tuohy* patent was being contested. (66)
Obrig thus refers to *Dallos* (1936) as having cited the 'small contact lens': "*August Müller (...) calculated the measurements of a small glass lens, which would correct his sight. (...) Happy as Müller was when he adjusted his lens and experimented himself that his theory was correct, he had to admit after many lengthy experiments that the small corneal lens (Hornhautlinse) cannot be worn for a long time*."

Graham (1959) was content to state that *August Müller* was the first to use the term 'Hornhautlinse'.

3.2.5 – Zeiss Corneal Contact Lenses for Stock, Rohr and Erggelet (1912-1921)

In a preceding chapter, we described that, after 1912, the engineers at the Zeiss Optical Institute joined forces with the physicians at Jena Ophthalmology Clinic and undertook studies in physiological optics in order to try out spectacle glasses that could be used in aphakia and anisometropia. They produced artificial refractive errors with contact glasses, some of which had the geometric characteristics of corneal contact lenses. These were glass lenses, ground, surfaced and of corneal diameter. They were worn after instillation of topical anesthesia in order to produce a transient anisometropia in the researchers and in order to analyze the causes of intolerance of glasses prescribed for the correction of unilateral aphakia and anisometropia. We have described in detail the diverse publications on the trials carried out with corneal diameter contact lenses between 1912 and 1922. *Graham* cites further evidentiary documents that confirm their use for trials of physiological optics. Thus, *Hartinger* in 1950 also confirms the use of these lenses at *Obrig*'s request: "*Contact Lenses without scleral portion have been manufactured already in 1912 by Carl Zeiss Jena. Amongst others, Professor Dr. H. Erggelet has worn those special contact lenses; by that, he made himself artificially ametropic and, in this way, tested the optical quality of the corrected curve eye glasses*." (67)

However, *Zeiss* had also envisaged using corneal diameter contact glasses for the correction of refractive errors: *Zeiss* also delivered some of these lenses to certain particularly interested physicians. In 1916, *Georges Weill*, Professor at the University of Strasburg, reported how he had fit several patients unsuccessfully with corneal diameter contact lenses that had no scleral part. In 1926, *Weill* reported once again the failure of the trials of these ground experimental lenses that had been sent to him by *Zeiss* before World War I: "*The first models of Zeiss, the ones before the war, although they gave better results than those of Müller, were, however, poorly tolerated because they used the cornea as sole point of support. Since the Zeiss Company modified its shape by adding a collaret that was applied to the conjunctiva, like I recommended for it so many years ago, this shape of prosthesis seems to me to fill the desiderata that one should ask of a contact lens.*" (68)

3.2.6 – Zeiss Corneal Contact Lenses for H.J.M. Weve (1932)

In May 1932, the Director of the Utrecht Ophthalmological Clinic in the Netherlands, *Henricus Jacobus Maria Weve* had presented the results obtained with Zeiss contact glasses fabricated for the protection of the cornea, the elimination of its astigmatism and to facilitate the observation of the fundus of the eye in the course of treatment by diathermy of retinal detachment. (69) *Zeiss* had delivered corneal diameter contact lenses to him:
"*The examination of the fundus is facilitated by the placement of a small corneal contact lens of Zeiss in the eye. Insertion of this small shell is easy, for placing it without air bubbles on the cornea, one performs some delicate maneuvers. The cornea remains clear and does not produce any irregular astigmatism by desiccation. One should note too that this small shell performs useful services in locating the meridian and thus avoiding localization errors due to astigmatism.*" (70)

Weve confirmed this use in 1951 in a letter to *Obrig*, but added that he had tried in vain to use these lenses apart from surgical indications: "*Zeiss has made the contact lenses you are writing to me about in 1931 or 1932 in order to keep the cornea clear during detachment operations. (...) Later I have experimented with them in cases of irregular astigmatism, but, as I found that patients lost these glasses quite easily, I went back to the usual form of lenses resting on the sclera.*" (71)

In the course of our researches in the Zeiss Archives at Jena, we found the confirmation of the manufacture and of the sale of glass corneal contact lenses. An accounting document mentions there that actually, in the course of the 16 months after they were put on the market (between September 1932 and April 1934) *Zeiss* had sold 62 orders of 'special lenses according to Weve'.

At the end of 1932, *Zeiss* had also exported these special lenses to the USA to 'Uhleman Optical Company, the American Optical Company, the Western Optical Company, the Eye Institute of the Presbyterian Hospital in New York City and to others' as well as Obrig Laboratories. (72) According to *Obrig*, who examined some of them, these Zeiss corneal lenses "*have longer radii than the eyes to which they were applied*".
According to *Obrig*, *Zeiss* had also delivered corneal diameter contact lenses according to *Weve* to *Emerich Rakos* of Budapest, who still owned them when, in 1938, he emigrated to New York City. *Obrig* also cites *L.L. Forchheimer* who confirmed in September 1950:

"*I read with great interest the article by Mr. Rakos (...) and also the letter by Prof. Hartinger, both of which state correctly that corneal lenses have been used for many years. I myself fitted the first contact lenses which were made by Zeiss around 1931 in Berlin, Germany.*" This evidence from *Forchheimer* is, however, ambiguous in the sense that the date of 1931 corresponds with the distribution in Germany of the lenses of *Zeiss-Heine*, that he had probably tried, like the majority of ophthalmologists of the country. The lenses of corneal diameter for the operation of retinal detachment were only placed on the market after *Weve*'s publication in September 1932. In 1949, *Peter C. Kronfeld*, in the discussion that followed the reading of *Maurice Nugent*'s second report on corneal contact lenses stated: "*About eighteen years or twenty years ago, we used in our retinal detachment work a forerunner of this lens to keep the cornea clear (...) it was made from glass and obtained from Zeiss in Germany*." (73)

3.2.7 - Other Attributions

1) The Corneal Contact Lenses of A. Osborne
According to certain authors, the first corneal contact lenses to be made in the UK were made by *Arthur Osborne*, foreman of *Hamblin*'s (Aybrook Street, London). These glass corneal contact lenses were made at the request of *Benjamin Rycroft* (St George's Hospital Hyde Park, London) to fit rabbits. (74)

2) Monocurve Contact Lenses of V. Gualdi (1934)
Graham recalled the monocurve contact shells of *Vicenzo Gualdi*, but correctly declined to attribute to these the characteristics of corneal contact lenses. They were actually destined to determine the scleral curvature of the eye, to which their radius of curvature between 10.5 mm and 13.0 mm had to fit. They did not concern the cornea. (75)

3) The Gonioscope of E.L. Allen (1944)
For his evidence given before the Courts, *Robert Graham* had also cited the description in 1944 by *Edwin Lee Allen* of a gonioscope made from plastic with contact to the cornea exclusively: "*The prism, which does not extend beyond the limbus, is placed directly on the cornea and, at the same time, lubricates the contact surfaces. Contacting surfaces conform to the curvature of the anterior surface of the average cornea*."
But *Graham* notes: "*Here is a lens with a special purpose (observation of the angle of the anterior chamber), not for correction of vision"*. This argument is also used in evidence by a Court in 1958: *"The user of the lens would be an examiner of the eye rather than a person using some form of eye glass for correction of visual deficiencies. (...) This lens is an examiner's instrument rather than a reader's lens.*" (76)

3.3 – Protests and Lawsuits

In the course of the years following the discovery of corneal contact lenses, one notes a series of lawsuits initiated by patent holders wishing to defend their privilege in order to collect the royalties claimed from the manufacturers and fitters of ever increasing numbers of prescribed contact lenses. Whereas in 1950, six major laboratories were quoted in the United States, by 1966 there were approximately three hundred more or less large manufacturers of corneal contact lenses. The royalties were claimed at 50 cents U.S. a pair by the owners of the patents, primarily Solex, then The Plastic Contact Lens Company, Butterfield and, accessorily, by *Hornstein*. After 1950, Solex Laboratories Inc. filed a complaint in order to defend the company's patents for corneal contact lenses. After the purchase of Solex and its patents by The Plastic Contact Lens Company in 1960, the latter pursued the lawsuits, initiated by Solex, against, amongst others, *Butterfield* and Frontier Contact Lens Inc. Then, in 1971, *Butterfield* initiated several further legal suites against a group of fitters in order to defend its priority rights.

3.3.1 – Lawsuits Launched by Solex Laboratories (1950-1960)

1) Solex Laboratories Inc. *versus* Pacific Contact Laboratories Inc. (1950-1953)
As soon as, (on June 6, 1950) Solex Laboratories Inc. had obtained confirmation of its patent (USP #2,510,438) they warned Pacific Contact Laboratories Inc. that the corneal contact lenses the latter was selling contravened the patent it had just obtained. As Pacific continued to manufacture and sell contact lenses, Solex filed a complaint against Pacific and its owners (Dr. *Morris Green* and *Lee W. Hogan*) for inf-

ringement of its patent and for using the deceptively similar name 'Cornea'. (77)
On the 17th November 1950, the District Court found the patent valid and infringed and that the use of the words 'Cornea' and 'Corneal Lens' amounted to unfair competition with Solex's words being 'Cornea Lens' and 'Tuohy Corneal Lens'. Pacific was enjoined and Solex was awarded damages in the amount of $5.00 per pair of contact lenses sold by Pacific, plus costs and fees. Pacific appealed.

Before the Court of Appeal, Pacific contested the validity of the *Tuohy* patent:
"*Appellants challenge the validity of Patent No. 2,510,438 on four separate grounds: (1) Tuohy did not invent the corneal type contact lens; (2) The corneal type contact lens claimed by Tuohy lacks any flash of creative genius; (3) The claims do not describe the alleged invention in a clear and definite manner; (4) The Tuohy patent is, at best, a 'method' patent and, as such, cannot be protected by an 'article' patent*." (78)

In answer to the question 'Did Tuohy invent the corneal type lens?' Pacific contests that the corneal contact lenses were anticipated by an invention of *E. Kalt* as described in 1942 in *Obrig*'s book entitled 'Contact Lenses'. This book was admitted into Court as evidence. However, the Court did not uphold the argument because:
"*The District Court considered the Kalt lens and rejected it as an anticipation. The quotation itself shows both that the objective, which Kalt sought to reach, was different from Tuohy's objective and that the Kalt lens was unsuccessful. (...) A prior unsuccessful experiment does not constitute invention and cannot therefore be anticipation. (...) And there is evidence that the corneal lens met with wide acceptance and success only after Tuohy put it on the market.*"

The Court of Appeals therefore concluded that the District Court's finding that *Tuohy* invented the corneal type lens "*is not clearly erroneous.*"

In regard to the other points that were raised: 'flash of creative genius', 'no adequate description of the alleged invention' and 'the method patent', the Court referred to preceding case law and concluded by confirming the validity of the *Tuohy* patent: "*There is no clear error in the conclusion of the Patent Office and of the District Court that this lens is a patentable invention. (...) The District Court found upon substantial and convincing evidence that the Tuohy lens was patentable and concluded that the appellant's infringement was both deliberate and willful*."

The Court of Appeals held that the District Court did not make an error in awarding the attorney fees in this case. As far as the complaint is concerned (the use of the terms 'corneal' and 'corneal lens'), the Court of Appeal judged that these terms represented a 'technical trade mark' and, on this point, therefore, unfair competition had not been established. Finally, the Court of Appeal "*affirmed as to finding of patent infringement, and reversed as to finding of unfair competition*".

2) Solex Laboratories Inc. *versus* Robert Graham and Others (1958)
1958, Solex conducted a much-publicized lawsuit against several fitters and manufacturers of corneal contact lenses. *Robert Graham, John L. Roberts Optical Co., Charles May, George W. Spratt Optical Co., Doctors' Contact Lens Service, Sterling P. Dunham, Barry Bleek and Lon Kasow* were each cited as correspondents. (79)
Solex reproached these retailers and fitters using corneal contact lenses manufactured by companies that had not paid their royalties: "*It appears by substantial evidence and the Court finds it be true, that the contact lenses sold by defendants Robert Graham and John L. Roberts d.b.a, John L. Roberts Optical Co. were produced by the Plastic Contact Lens Company of Chicago, Illinois. The defendant M. Charles May has vended lenses, which were manufactured by the Mueller-Welt Contact Lenses Inc. of Chicago, Illinois.*"

Tuohy also attacked the 'Stimson' and 'Vent-Air' lenses:
"*Defendants Dr. Barry Bleek and George W. Spratt Optical Company have sold contact lenses which completely embody the Tuohy invention. To this structure their manufacturer has added tiny facets on the rear faces of the lens. These facets are so microscopic that they cannot be detected by gross observation. (...) The Vent-Air lens embodies exactly the structure of the Tuohy lens with the exception that there are very shallow depressions located on approximately the same point as the Vent-Air lens that Stimson has selected for facets on the Stimson lens*."

The Court concluded in favor of Solex: "*The lenses from these sources embodied the principle protected by the Tuohy patent*."

3) Solex Laboratories Inc. *versus* The Plastic Contact Lens Co. (1957-1959)
In March 1957, Solex Laboratories Inc. filed a complaint against The Plastic Contact Lens Co. of *Wesley and Jessen* for infringement of the *Tuohy* patent. Plastic retaliated by filing a counter-suit against Solex for spreading false information consequent on the lawsuit 'Solex versus Graham', because the Plastic Contact Lens Co. had manufactured certain of the contact lenses under discussion.
In fact, Plastic had acquired a license from *George Butterfield* & Son for the manufacture of corneal contact lenses under patent # 2,544,246 (the *Butterfield* patent). The District Court took the advice of Solex, who made reference to the *Graham* lawsuit, as well as to the lawsuit versus Pacific, confirmed on appeal and where the judges, in 1950, had found that the *Tuohy* patent was valid and infringed.
Judged in 1959 on Appeal, the decision of the District Court in favor of Solex and of the validity of their patent, as compared with that of *Butterfield*, was confirmed. The Plastic Contact Lens Co. of *Wesley & Jessen* was found guilty of infringement of the *Tuohy* patent.

3.3.2 – Lawsuits Conducted by the Plastic Contact Lens Co. (1960-1969)

However, in 1960, *Kevin Tuohy* and *Xavier Zabener* sold Solex Laboratories to The Plastic Contact Lens Co. of Chicago with all the rights and patents possessed by Solex. By this acquisition, Plastic not only ended its legal action against Solex, but also became the proprietor of the patent that it had just contested. First, they continued the lawsuit already underway against *Butterfield*, then sued Frontiers Contact Lens Inc. and a about a hundred other fitters, manufacturers and retailers of contact lenses. (80)

1) Plastic Contact Lens Co. *versus* George H. Butterfield (1962-1966)
During the preceding years, Solex Laboratories had also sued *Butterfield* and *George H. Butterfields* and Son for infringement of the *Tuohy* patent at the US District Court of the District of Oregon. This lawsuit was underway when, in 1960, Plastic had acquired the capital and the patent of Tuohy Laboratories. The suit against *Butterfield* was maintained by Plastic, in spite of the fact that the latter previously itself used the *Butterfield* license (USP. # 2,544,2460) and had contested in 1957 and 1959 the validity of the *Tuohy* patent which it now owned. In April 1962, the District Court of Oregon decided that both the *Tuohy* patent, owned by Plastic and the *Butterfield* patents were valid.

The Oregon suit, in which Plastic was the plaintiff ended with a compromise: Plastic and Butterfield reached a settlement under which Plastic released Butterfield and its licensees from all claims of infringement of the *Tuohy* patent, paid Butterfield $66,000 and granted *Butterfield* the right to grant royalty-free licenses under the *Tuohy* patent to itself and to four named *Butterfield* licensees. In return, *Butterfield* dismissed all claims against Plastic and granted Plastic a royalty-free license under the *Butterfield* patent: "*It was specifically agreed that both Plastic and Butterfield might, by solicitation, seek to enter into license agreement with existing licensees of the other and that both might enforce their right to respective patents against such licenses in the future*." (81)

However, in July 1963, only fifteen months after the settlement of the previous litigation, *Butterfield* launched a suit against Plastic, alleging rupture of the settlement agreement of April 1962 and 'unlawfully, deliberately and, in bad faith, unfair competition'. Plastic filed a response in which the company denied *Butterfield*'s accusations of wrongful acts. Plastic also interposed a counterclaim, making charges against *Butterfield*, which were somewhat similar to those made by *Butterfield* against it, also claiming damages as well as injunctive relief. Following trial, the District Court arrived at legal conclusions, which supported the contentions of *Butterfield* in all substantial respects. It issued an injunction against The Plastic Contact Lens Co., ordering that there be an accounting, adjudged that, upon the determination of *Butterfield*'s damages, the amount therefore be trebled. Plastic appealed and on 31st August 1966 and the Court of Appeal quashed this judgment. "*The judgment against Plastic is reversed. Upon remand, the complaint will be dismissed and, with it, also falls the counterclaim*." (82)

To reach this conclusion, the Court relied on several arguments, notably the 'technical difference' of the two patents: "*There is, of course, a technical difference in the arts defined in the two patents. The Tuohy patent calls for a contact lens, which, on its inner surface, has a curve of greater radius than the portion of the eye, which it covers. This is to provide 'a small but gradually increasing clearance' between the lens and the tissue of the eye, thus allowing for lubrication, which is claimed to be desirable. (...) Tuohy patent was senior. Butterfield patent generally discloses a contact lens with two or more concentric curves on the inner surface, designed to conform to the eye's underlying curvature throughout the area covered by the lens*."

One of the comments of the Court of Appeal compared the evolution of the corneal contact lens market in the United States between the years 1962 and 1966: "*The trial Court observed that there are some three hundred manufacturers of plastic contact lenses in the United States. Plastic has licensed about one-half this number. At the time of trials, Butterfield had only solicited about fifty of these, of which twenty-three had purchased licenses from him. During the period following the 1962 settlement and before the trial of the present case, Butterfield nearly doubled his number of licenses*."

2) Plastic Contact Lens Co. *versus* Frontier Contact Lens Inc. (1962-1971)
Other lawsuits opposed Plastic Contact Lens Company and Frontier of the North East Inc. (ex Frontier Contact Lens Inc, of New York). Judged in October 1969 for breach of contract with Solex, Frontier Contact Lens Inc. pursed the lawsuit against Plastic Contact Lens Company (successor to Solex). On 6th January 1961, Solex had given a license to Frontier for a non-exclusive license to manufacture, use and sell lenses under the *Tuohy* patent and, in return, Frontier should pay rights, which it did between February 1961 and October 1962. At this point in time, Frontier notified Plastic that it had the equivalent license from *Butterfield* on more favorable conditions. In October 1969 the District Court again distinguished the difference between the patents of *Tuohy* and *Butterfield*, but rejected Frontier's argument that not using the *Tuohy* patent after 1962 exempted the company from its requirement to pay royalties for the manufacture of corneal contact lenses of whatever type until the expiration of the *Tuohy* patent: "*The two patents are so similar that it is not always possible for the manufacturer of these lenses to tell under whose patent the lenses are fitted by the eye doctor. (...) The same royalty provision used in the license calling for the payment of sums for all devices made, whether under the Tuohy, Butterfield or another patent*." (83)

In March 1971, in Appeal, the same questions were again asked: Is it required to pay the license for products manufactured outside of the agreement? How is one to know if the lens is manufactured according to this or that patent? The Court of Appeal confirmed that Frontier must pay royalties to Plastic for all lenses, of whatever model they may be, that it has manufactured between the period after its rupture with Solex-Plastic and up to the time of the expiry of the *Tuohy* patent on 6th June 1967. (84)

3.3.3 –Lawsuits Initiated by Butterfield

Butterfield *versus* Oculus Contact Lens and 38 other Contact Lens Manufacturers (1971)
In 1971, a complaint by *George H. Butterfield* & Son against Oculus Contact Lens and 38 manufacturers of contact lenses, some in Chicago, Ill., for infringement of the *Butterfield* patent, issued March 6th 1951 was judged before the US District Court of Illinois. In order to judge the validity of the *Butterfield* patent, the Court made reference to the historical development of contact lenses from the time of *Leonardo da Vinci*, *Eugen Fick*, and *Joseph Dallos* until *Tuohy*, and then continued: "*About 1947, Kevin Tuohy developed a plastic corneal lens which was basically mono-curved but the posterior edge of which was beveled. (...) The Tuohy lens still resulted in cases of corneal abrasion and was largely supplanted in commercial use by the so-called bi-curved corneal lens*." (85)
Then the Court detailed the history of the deposition and the acceptance of the *Butterfield* patent. *Butterfield* claimed to have manufactured his first bi-curved contact lenses in the summer of 1948. On the 1st August 1949, he filed a patent. This request was rejected and it was replaced by a second application on 1st August 1950. The Court determined that the rejection of the first request for patent and its replacement by a modified version was due to the fact that the original application was most likely inspired by publications of *Nugent* and *Graham*: "*The Patent Office Examiner had rejected all of the claims of the first applications as 'obviously met' by the corneal set forth in either of the two articles, one published by Dr. Nugent, an assistant of Tuohy's in June of 1948 and one by Graham, read publicly before the American Academy of Optometry on December 7, 1948 and published in February 1949*."
This first request was unacceptable because it copied what had been published on the *Tuohy* patent:
"*The original Butterfield applications was for a corneal lens, the curvature of which followed the curve of the cornea in its central or optical area, with the outer or peripheral portion having a curve flatter than the corneal curve in the adjacent corneal area*."

On 1st August 1950, or one month after *Tuohy* was granted his patent for his lens, *Butterfield* filed a second application for a patent. On January 11, 1951, the Patent Office rejected his amended patent request. A new amended application was filed on February 6, 1951 in which the words 'conforming to the central area' and 'corresponding in curvature to the peripheral area' were added.

February 28, 1948	Tuohy filed an application for a Patent (S.N. # 12,040)
June 3, 1948	Nugent described the Tuohy lens
December 7, 1948	Graham described the Tuohy lens
August 1, 1949	Butterfield filed a 'First' application (S.N. # 107,948)
June 6, 1950	Tuohy's Patent granted (US Patent # 2,510,438)
	Butterfield's 'First' application is rejected on the basis of the Nugent and Graham articles and of the Tuohy patent
August 1, 1950	Butterfield filed a "Second" application
January 11, 1951	Patent office reject any Butterfield's claims of the 'Second' application
February 6, 1951	Butterfield filed an 'Amended' application
March 6, 1951	Butterfield's Patent granted (US Patent # 2,544,246)

Table 27-7
Chronology of the granting of the Butterfield patent as contrasted with the Tuohy application and the descriptions of corneal contact lenses by Nugent and Graham.

In order to respond to the question: *"Is Butterfield the inventor of the modern bi-curved lens?"* the Court responded in the negative for, according to the advice of the expert *Robert Mandel*, the patent does not describe and cover all bi-curved workable corneal contact lenses. Such a lens defines rather a lens in which the posterior curvature is similar to the corneal curvature. A modern contact lens is deliberately designed to have a clearance particularly in its peripheral area between the lens and the cornea.

A lens which has a peripheral curvature *"corresponding in curvature with that portion of the corneal peripheral area to which the lens is applied,"* such as the Butterfield patent specifies, is not wearable: *"It is undisputed that a wearable contact lens must have a curvature particularly in its peripheral area flatter than the corneal curvature and that a lens which conforms with or corresponds to the corneal curvature is not wearable."* (86)

Ultimately, however, *Mandel* will admit, to being wrong and that the profile described by *Butterfield* is, in actual fact the most physiological and represents the first conception of an aspheric profile: *"Butterfield must be credited with recognizing that by adding various peripheral curves to the posterior surface of the corneal lens, the central curve could match or nearly match the radius of curvature of the cornea. He described his lens as having the approximate surface of a paraboloid, which would provide a lens whose posterior surface was very close to the shape of the eyeball. This represents the first introduction of the modern concept of fitting the lens on K or contouring the cornea."* (87)

4 - Twenty Years of Progress in Pmma Corneal Contact Lenses

Introduction

In 1954, the pioneer manufacturers of corneal contact lenses had placed their brands on the market: Solex Laboratories Inc. of Los Angeles, makers of *Tuohy* corneal contact lenses, had, in fact, the greatest success at this period of history. However, these lenses had a large diameter, were very thick and had a small peripheral bevel. They were fit flat and pressed on the corneal apex.

Other contemporary manufacturers tried to force themselves into the birth of corneal contacts. Thus *Butterfield* sold a large diameter lens with multicurve posterior periphery, while *Stimson* offered a large diameter lens equipped with facets in order to prevent contact with the central cornea. *Hornstein* had patented a lens with apical clearance and *Silverstein* was manufacturing an extra-large lens with arched fit equipped with channels and holes to facilitate tear flow. The idea of corneal lenses for the correction of low refractive errors had not yet convinced the vast majority of fitters and the market still remained partially in the hands of the 'old guard',

i.e. major manufacturers of corneo-scleral shells. [88] A fierce competitor for Solex Laboratories, The Plastic Contact Lens Company of *Wessley-Jessen* (Chicago) was quickly added, with a big advertising boost.
In the course of the first decade following the birth of corneal lenses, the competition between the principal actors and the appearance of new manufacturers caused the situation to evolve rapidly in the direction of new lens design: first was the reduction of total diameter, then the abandonment of flat-fit in favor first of on-K fit with apical alignment, then with apical clearance, finally the addition of ever more sophisticated peripheral bevels to the posterior surface.

Over the years, the dogma had persisted among professionals that corneal contact was bad for the eye. Because of this, the new idea of a floating lens or one resting on the cornea was poorly received both by optometrists and surgeons. This explains why the acceptance of corneal lenses by certain fitters remained hesitant: "*There were still a number of professionals who believed that contact lenses were a passing fad and would eventually lose their popularity. Some even felt that, over time, corneal lenses, because of their direct contact with the eye, would cause irreparable harm to the corneal structure*." [89]

Nevertheless, certain voices about breaking this taboo began to be heard. Thus *Bier*, in a letter to the American Journal of Optometry, asks the question, "*Is it not a crime for patients, in the present days, still to be fitted with deep fluid contact lenses*?" He elaborates: "*Unlike early days, when no promise whatever could be made to prospective patients, it can be said today with reasonable certainty, that the wearing time desired by the individual can be achieved in nearly every case. (...) Any desired tolerance, with one or two provisos, is now within our grasp with the knowledge at hand. (...) Despite the conflicting reports circulating amongst members of the public and the profession it would be safe to affirm that patients in the present day can confidently anticipate the wearing time they desire.*" [90]

THE DECADES
Usually, historians class this period of evolution and dissemination of corneal contact lenses into three periods in which major developments occurred :
- 1950s: the decade of contact lens optics and lens design.
- 1960s: the decade of corneal physiology and oxygen need.
- 1970s: the decade of new contact lens materials.

This chapter is dedicated to corneal contact lenses made from pmma and concerns essentially the two first periods.

4.1 - The Decade of Contact Lens Optics and Lens Design

4.1.1 – The Micro-lens Episode (1954)

After 1954, the introduction of 'Micro-lenses' allowed corneal contact lenses to be presented like a real alternative to the *Tuohy* corneal lenses. They, by small monocurved micro-lenses jointly proposed by *Frank Dickinson* (UK), *John C. Neill* (USA) and *Wilhelm Peter Söhnges* (Germany) allowed corneal lenses to be distributed and guaranteed their development and progress. [91] Micro-lenses, also called 'Minilens', 'Cap lens', 'Microcap Lens', or 'Pupil Lens', were simple to manufacture and fit, as contemporary authors noted at the time: "*If the rim element of the lens were cut away, a single radius lens of 8–9 mm diameter would be left.*" [92]

The manufacture of the micro-lens is actually very basic: it has only two radii of curvature, i.e. a single posterior radius and an optical anterior radius. Its standard diameter is 9.50 mm, varying between 9 mm and 10 mm as a function of the corneal diameter. Its thickness is moderate, i.e. 0.20 mm for an afocal lens. The edge thickness varies between 0.15 and 0.25 mm. These parameters made the lenses more comfortable than *Tuohy* lenses.

For fit, it is recommended to choose the first lens with a posterior curvature of 0.30 mm flatter than the flattest corneal radius. A well-fit lens is often slightly decentered in the superior or supero-nasal zone and is, when the patient blinks, slightly mobile in the vertical meridian. The fitter looks for objective signs when tearing ceases on examination with fluorescein, where a correct fit is shown by a fluoro-negative central zone of contact 4.50 to 5.00 mm in size and a large fluoro-positive area, evidence of border clearance. The presence of a central air bubble means that the lens is too steep and sometimes radii of curvature flatter by

0.60 to 0.70 mm than the flattest corneal radius are necessary.
Usually, a total diameter of 9.5 mm is sufficient to cover the pupil when the lens moves. If the edge reflections are troublesome or when there is a large corneal diameter, the diameter of the contact lens should be increased. The authors note that enlarging the diameter by 0.50 mm requires also an increase of the posterior radius of curvature by 0.50 because of the risk of too steep a fit. By reason of their smaller diameter, the micro lens allows to correct a moderate corneal toricity. The success of this easy-to-manufacture and easy-to-fit lens encouraged manufacturers to modify the profile of the lens edge. Thus, some have introduced clearances of 0.50, 1.00 or 2.0 mm flatter than the central corneal curvature, or a standard corneal bevel of 12.00 mm. These modifications, which improve the mobility of the lens, are recommended for the correction of astigmatism. There would exist many varieties of size and radius for peripheral clearance with 'microflange', 'microrim', 'paracontour', 'corneal flange lens' and other similar varieties, each having their periods of success or failure.

Table 27-8
The Micro Lens fitting set.

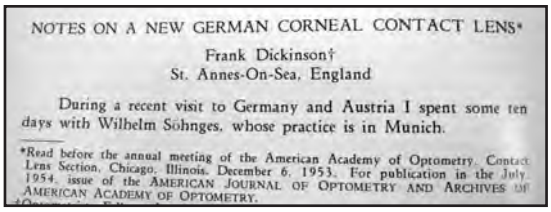
Posterior radius of curvature of the 20 Micro-lenses in the trial set.

7.50	**7.80**	**8.00**	**8.20**	8.50
7.60	**7.85**	8.05	8.25	8.60
7.70	**7.90**	**8.10**	**8.30**	8.70
7.75	**7.95**	8.15	**8.40**	8.80

The Micro-Lens fitting set.
The standard trial contact lens box is composed of a minimum of 10 lenses (bold), but 20 trial lenses are recommended. The posterior radii of curvature are in 0.05 steps between 7.30 and 8.90; the ones used most often are between 7.85 and 8.25 mm.
(Bier N., 1957 p.176).

The advantages of the mini-lenses as compared with the *Tuohy* lenses are evident. Their total diameter of 9.50 compared with 11.00 to 12.00 mm ensures reduced thickness, weight and covered surface. Mini-lenses corrected up to 4 diopters of corneal toricity compared with only two for *Tuohy* lenses.
But both types of corneal lenses have in common apical contact and a zone of central pressure exposing to the risk of corneal erosion caused by friction, intolerance and post-wear refractive changes sometimes deliberately planned by followers of the nascent science of orthokeratology: "*A great criticism of micro lenses is the severe refractive changes, which frequently occur consequent to wearing the lenses. In most cases the corneal dome is flattened, and patients with low myopia may find themselves temporarily emmetropic or even hypermetropic after lens removal. Many patients use this transient loss of ametropia and manage without any correction until such time as the cornea assumes its original shape*." (93)

These disadvantages have not impeded the success of the micro-lenses as *Norman Bier* notes: "*The impetus given to these small single-curve lenses through the work of Dickinson, Neill and Soehnges in 1954, has greatly enhanced the popularity, performance and development of corneal lenses. Standardizing the size of the lens to 9.5 mm and its thickness to 0.20 mm, they have named it the 'micro lens'. Compared with the Tuohy lens, the lighter weight of the finer and smaller micro lens effectively reduces friction between the lens and eye and therefore offers much better tolerance.*" (94)


NOTES ON A NEW GERMAN CORNEAL CONTACT LENS*

Frank Dickinson†
St. Annes-On-Sea, England

During a recent visit to Germany and Austria I spent some ten days with Wilhelm Söhnges, whose practice is in Munich.

*Read before the annual meeting of the American Academy of Optometry, Contact Lens Section, Chicago, Illinois, December 6, 1953. For publication in the July, 1954, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

Figure 27-16
Frank Dickinson's presentation of the 'Micro-lens'.
In December 1953, Frank Dickinson reported his experimental trials with 'Micro-lenses' developed in conjunction with Wilhelm Söhnges of Munich (Germany).

There occurred a general competition in favor of ever more 'mini' corneal lenses, a fact that did not fail to irritate the initiators of these lenses, as *Bier* notes: "*Some of the publicity which has been given to corneal lenses by the lay press and laboratories does not always throw a fair light on the true situation. The logic applied that progress is of necessity made by lenses becoming smaller and smaller is of course erroneous*." (95)

Certain manufacturers, by inventing new grinding and polishing instruments, have improved the profile of the edge and its transition towards the bevel. Nevertheless, the mini lens still had the disadvantages of a flat fit and great thickness. (96)

4.1.2 – The Apical Alignment and Clearance Design

The criticism of the *Tuohy* lenses and the micro lens concerned essentially their flat fit. They had an apical contact at the origin of pressure zones, frictions, erosions and post-wear refractive changes. These were remedied either by apical alignment or apical clearance.

1) The Apical Alignment Principle (1955)

A significant modification representing definite progress can be attributed to *Bier* who, in 1955, introduced a contact lens of micro-lens type, but with central alignment. This was the 'Contour Lens'. For the author and promoter, this new conception of geometry and fit cut radically into that of micro-lenses. There would be only advantages, as he himself noted: "*Following a study of the cornea and extensive lens and clinical experiments, the author introduced in 1955 a multi-curved corneal lens, later named the contour lens, quite different in construction and fit to the micro lens. Whereas all corneal lenses normally must be fitted flatter than the cornea, the contour lens substantially conforms to the curve of the cornea offering definite advantages in wearing performance*." (97)

In actual fact, though resembling micro-lenses, the alignment of its central posterior radius reduces apical contact, which is at the origin of the principal objection to these lenses: "*Contour lens of similar size and thickness to the microlens could, by virtue of its smaller BCOD (Back Central Optic Diameter) be fitted nearly in alignment with the central zone of the cornea, thereby minimizing to a considerable degree the central erosion problem. Edge clearance was still maintained by a peripheral curve some 1.25 mm wide*." (98)

The first lenses with apical alignment of *Bier* were presented with a standard diameter of 9.65 mm that was considered satisfactory for most cases, but which can vary between 8.00 and 10.50 mm depending on individual requirements. It was provided with three posterior curvatures:

- a central zone of 6.50 mm diameter, available in curvatures from 7.10 to 8.70 mm in steps of 0.05 mm;
- a parabolic-like area showing sharp peripheral flattening, from 0.4 to 0.7 mm flatter than the central curvature. (The flattening is 0.4 mm for a central radius of curvature between 7.1 and 7.35 mm, 0.5 mm for 7.8 to 8.0 mm, 0.6 mm for 8.05 to 8.24 mm and 0.7 for 8.3 to 8.7 mm);
- a transitional third curve of 0.25 mm large, which blends the two main parts of the lens, with a radius of curvature 0.05 mm greater than the average of the two neighboring zones.

There is an edge bevel of 0.65 to 1.25 mm.

The basic set of trial contact lenses is composed of 10 lenses. It is recommended to complement this set with 10 lenses that have intermediate curvatures.

Table 27-9 (a)
Composition of an 'Apical Alignment' fitting method set as proposed by Bier.

7.10	**7.50**	**7.80**	**8.00**	8.20
7.20	6.60	**7.85**	8.05	8.30
7.30	**7.70**	**7.90**	**8.10**	8.40
7.40	7.75	**7.95**	8.15	8.50

The basic set contains 10 lenses (bold), the standard set 20 lenses.

For the fit, the first choice is a lens with a central radius equal to the flattest corneal curvature or which is flatter by 0.05 mm. The fluorescein image shows that the dry area has been chased from the central area towards the periphery and does not modify with time. The lens must remain mobile, but not crossing the limbus. An increase in or reduction in the central radius of curvature does not require any modification of diameter in compensation. Because of this fact, the only variable remains the central zone's radius of curvature.

Close to the lenses introduced by *Butterfield*, this profile was improved and widely distributed throughout the United States by *Wessley-Jessen* under the trade name 'Sphercon'.

Surprisingly, the method of fit for these first lens models with apical alignment was not widely accepted in spite

of advantages, but *Bier*'s idea represented a step forwards in the light of later developments. It was recognized, in fact, that this lens possessed sufficient similarities (diameter, thickness) to *Tuohy* lenses and differed only by its alignment on-K and therefore by the choice of a smaller posterior curvature. Numerous variants were created, such as 'decentered contour lenses' that featured decentration of the corneal apex and, most significantly, reductions in total lens diameter to 9.20 and 8.00mm.

Central corneal radius (mm)	*Peripheral zone flatter than K (mm)*
7.10 to 7.75	0.4
7.80 to 8.00	0.5
8.05 to 8.25	0.6
8.30 to 8.50	0.7

Table 27-9 (b)

The connection between the peripheral and the central corneal curvatures was expressed according to the following table:

2) The Apical Clearance Principle

The next step was the introduction of 'apical clearance fitting', with lenses having a central zone steeper than the corneal radius, often associated with a more significant peripheral flattening. A discrete endeavor had been initiated by *Bier*. In this case the central zone has only a diameter of 5.5 to 6 mm and the transition remains 0.25 mm wide, but 0.10 mm flatter than the average of the central and peripheral radii of curvature. The trial lens set is often similar to the alignment method, but is used with a central radius of curvature that is 0.10 to 0.20 mm steeper, and extends from 6.90 to 8.40 mm. At fit, the fluorescein image is that of a steep fit, but the width of peripheral contact is greater. Lens movement remains sufficient, but there is a tendency for the lens to remain low until a blink occurs. Among the advantages of apical clearance, one notes most importantly that there is no change in the refraction in keratometry readings after prolonged wear and that it is possible to correct mild to moderate degrees of astigmatism. But the selection from the variety of possible clearances from multiple variables seemed very complicated, making the choice of the best lens difficult. Furthermore, if one considers that keratometry does not measure the radius of curvature of the corneal apex, selection was sometimes hazardous. Besides, the 6.5 mm standard diameter of central curvature is not often suited to the actual diameter of the corneal apex. Soon, ever-larger apical clearances were recommended. Thus, towards 1960, *Charles Bayshore* recommended a lens 7.00 to 8.00 mm in diameter, fit one diopter flatter than K with an optical zone of 6.00 to 6.60 mm. To reduce the risk of corneal edema, the central part of the Bayshore lens was fenestrated.

4.1.3 - The Aspheric Design

The trend towards intermediate and peripheral zones for tri-, tetra- and penta- curve lenses caused variation in lens profiles, the aim of which was lenses with an aspheric periphery. For the design and manufacture of aspherical contact lenses multiple peripheral curvatures were substituted for a posterior surface with a continuous periphery, aspheric, that was thought to conform the most perfectly to the natural shape of the human cornea. One of the theoretical advantages of the aspheric design is to produce a uniform distribution of the forces of pressure, in such a manner that no part of the cornea is subjected to excessive pressures. The aspheric surfaces are geometrically continuous and have a regular contour intended to come as close as possible to the contour of the corneal profile. [99] Aspheric lenses are defined by their apical radius and their eccentricity, which is the degree of flattening from the apex to the periphery. This factor adds however a new dimension to the complexity of the interpretation of the fluorescein image: in fact the central area can be more or less vaulted because it varies not only in accordance with its diameter and radius of curvature, but also as a function of the degree of flattening of the aspheric curvature as expressed by the eccentricity. Any modification of one of these factors affects all the others. In order to resolve these difficulties, a steep fit is recommended that facilitated the choice of parameters of these lenses. Be that as it may, fenestrations are provided for these lenses in order to facilitate circulation of tears, generally two or three central orifices, but up to a total of 20 for certain varieties. In 1962, *Charles W. Neefe* applied for a patent for a corneal lens of 'wide fitting range with sine curve concave surface'. Starting in the same year, several patents were registered by *David Volk* on 'lens generating method', on 'method and apparatus for production aspheric contact lenses', on 'method and apparatus for grinding and polishing aspheric surfaces of revolution', on 'method and apparatus for measuring aspheric surface'. [100]

Table 27-10

Peripheral flattening in 'Apical Clearance' fitting method as a function of the central curvature.

Central corneal radius (mm)	*Peripheral zone flatter than K (mm)*
6.8 to 7.35	0.5
7.4 to 7.75	0.6
7.8 to 8.9	0.7
8.05 to 8.25	0.8
8.3 to 8.5	0.9

In the Apical Clearance fitting method one uses the same set as for the Alignment Method. However the peripheral flattening is preferably chosen according to the above table. (Bier 1957)

Finally *Volk* recommended a lens, the posterior surface of which was aspheric: "*The posterior surface is an aspheric surface of revolution which decreases in curvature from its apex to its periphery and which varies in a continuous and regular manner in eccentricity from its apex to its periphery. This novel surface is defined in terms of three parameters: apical radius of curvature, apical eccentricity and collectively one or more derivatives of eccentricity*." (101)

There was thus created a large variety of profiles of aspheric clearance following the lens with tangential conic periphery design of *Penrhyn F. Thomas* up to the continuous offset tricurve lathe-cut and the continuous aspheric lens of *Ruben* and *Nissel*. In parallel, numerous instruments were developed to capture qualitatively and quantitatively the aspheric nature of the anterior surface of the cornea, the most popular of which were the 'cornealometer' and the 'toposcope', which were added to the moldings and photography of the corneal profile. (102)

The historian will have noted that, from 1945, *Raoul* and *Adrien Fritz* (Brussels) had registered an application for a patent for a corneo-scleral shell, "*wherein the lens portion forms with the eye an aplanatic system*". Then, in 1950, *Georges H Butterfield* had registered a patent, and then manufactured lenses with multicurve paraboloid clearance where the central optical spherical zone is surrounded by a series of annular spherical zones of which "*the radius of curvature increases by 2 ½ % from the central spherical area to the edge*" and "*approximates the surface of a paraboloid*". In the following year, *Noel O. Stimson* had envisaged in his patent application a corneal contact lens, the posterior surface of which had several protuberances, also a toroïdal surface with "*a given radius in a horizontal meridian and a different radius, generally smaller, in the vertical meridian*". In 1964, *Daniel O. Elliot* wrote a paper 'A preliminary Report on the Use of Gradient Ellipsoidal Curves relating to the Fitting of Contact Lenses' and described a corneal lens of which the posterior surface had a spherical optical zone and is ground in spherical annular steps. (103)

4.1.4 - Evolution and Special Design

Between the years 1950 and 1970, corneal contact lenses experienced fantastic success and impressive distribution. The number of manufacturers increased in proportion to the demand: "*It has been estimated that there are over 10 million contact lens wearers in the United States with over 600,000 new patients per year using the 'stable' contact lenses, which certainly appear to have made their place in the contact lens market.*" (104)

The manufacturers competed in new formulations, with both classical shapes and in special shapes. The first played with the varieties of clearance and diameter, but kept the concept of parallel adaptation or apical clearance, using lenses of the least thickness and reduced diameter. The special shapes of lens tried to adapt themselves to particular requirements: bifocal lenses, astigmatic lenses, lenses made from colored materials, aphakic, keratoconus, presbyopia, hypermetropia, albinism and aniridia. (105)

Lenses for the correction of presbyopia have particularly stimulated the imagination of manufacturers. In fact each one of these felt he had lost 'status' if he had not offered bi- tri- and multifocal contact lenses in every possible design imaginable. A count of the thousands of models would be tedious, the more so because the efficacy and the comfort of the correction rarely matched the promises made, if we consider the stability of the lens designed as a bifocal.

The 1.49 refractive index was supplemented by a higher refractive index material (1.61), which reduced lens thickness for aphakes, and also by a low refractive index material (1.38) for toric lenses. The polymethylmethacrylates with reticular structure allowed lenses to be ground thinner and sturdier. By providing a coating, one can give the lenticular surfaces more wettability, brought about with more or less success by different rigid co-polymers. For fit, the practitioner would use either the 'trial lens method' or the 'custom fit method'. These methods were described in detail in reference books from the era.

The 'trial lens method' consists of an evaluation starting with a trial lens set in a lens glide. Some fitters possessed large trial lens sets. But it is a question of compromise always and no lens is suited exactly to the ocular state of the patient. Usually, the trial lens sets have average characteristics, with diameters around 9.4 and 8.5 mm and a power of -3.00 diopters. Depending on the keratometry, the fitter might chose a parallel fit or one slightly steep depending on his observation of the movement of the lens and the appearance of the fluorescein pattern seen with the Burton lamp. Of course, these appearances are variable depending on the geometry of the lens, whether be it monocurve, bicurve, tricurve or aspheric. Finally, slit-lamp observation should confirm a good fit.

The 'custom lens design' is based on modification by the practitioner of semi-finished lenses furnished by the manufacturer. These lenses have anterior and posterior curvatures and specify diameter and lens design. The fitter can modify these lenses with relatively simple equipment and depending on his observations, diameter, edge design, peripheral curvatures, but not the central thickness, or the power, or indeed the central posterior curvature. He cannot increase the diameter. It was established that, between 1960 and 1970 in the hands of adept practitioners: "*Small thin lenses, fit on the apical clearance principle and custom fitted to the individual cornea, give the best wearing performance and optical results (...) from corneal contact lenses. Wearing time is limited only by sleep and corneal insults are reduced to a clinically acceptable level.*" (106)

In spite of the numerous successes reported in the lay and medical press, certain authors had reservations. Thus, at the time of a symposium held in 1965, numerous problems with corneal contact lenses were revealed, expressing the reality experienced during this era and observed by fitters in the field. Aside from the special difficulties in pathological cases, including aphakia, keratoconus, high astigmatism, etc a severe problem occurred when corneal contact lenses were fit, namely discomfort from the fitting process: "*To wear contact lens a patient must be sufficiently motivated to endure the initial pain and tearing (…) The first week of adaptation often bring edema of the eyelid and hyperemia of the bulbar and palpebral conjunctiva, conjunctival scruffing, and subconjunctival hemorrhage may occur*.„ (107)

The 'overwear syndrome' posed a problem for which there was no available treatment:"*The exact mechanism responsible for adaptation by a cornea to the adverse effect of the presence of a contact lens, also has not been thoroughly explained, nor do we know why some corneas adapt more readily do others. (…) Edema is almost always – if not always-present in the initial stages of adaptation to contact lenses*.„ (108)

Explanations, sufficiently plausible, could, however, be found for the subjective syndrome of 'insertion awareness': "*Insertion awareness is a symptom to be expected for short period in the adapted wearer (…) There are several explanations for excessive awareness: poor edges design, improper lens-cornea relationship: to flat or to steep, and foreign body*." (109)

Failures happened quite often during this period. In a statistical analysis of 200 contact lens patients selected and one showing all the criteria of honesty and seriousness during the fitting process, the following findings were reported after one year of wear:"*Forty-four patients (22%) were classified as partial or complete failures in contact lens wearing. (…) The fact that contact lens failures made fewer follow-up visits to the fitter is thought to be especially significant. It is not known whether patients did not return because of failure or failed because they did not return*." (110)

4.2 –The Decade of Corneal Physiology and Oxygen Need

In the course of the second decade in the history of corneal contact lenses, there was enormous progress in the understanding of physiology and anatomy of the cornea, conjunctiva, tears and lids. These researches were stimulated by the observation of the structural and functional modifications that were produced by contact with corneal lenses and corneo-scleral shells. Thus there opened a new page in ocular physiology devoted to these aspects with several hundred publications, as many on the phenomena of normal metabolism as disturbances in metabolism by external elements. Of course, the corneal epithelium received the most observations, with corneal erosions and cicatrisation associated with such erosions being the most visible to the fitters. The physiology and the pathology of the corneal stroma were directly impacted by the observations of corneal edema. But interest was also focused on repercussions involving the deeper corneal layers, Descement's membrane and endothelium. Nor did the conjunctiva, tears, palpebral motility, and blinking escapes this scrutiny by researchers. Nor, indeed, the study of the innervations of the ocular tissues, their sensitivity, both corneal and conjuctival sensation and variations in these aspects in the presence of a contact lens. The explanations accepted up till then for corneal transparency, now judged insufficient and inappropriate, were replaced by new theories. The maintenance of transparency is dependant on forces that limit corneal hydration. These forces are liable to be disturbed by the insertion of lenses and are linked to metabolism. The role of the surface bed, epithelium, and endothelium in the maintenance of corneal transparency was studied in greater depth. The metabolic pump, studied by *Farris, Donn, Takakashi, Mishima* amongst others, and collaborators, would create deturgescence directly linked to transparency, thickness and even opacification. The researches were also aimed at determining the importance of the metabolites

and their role respectively, which, in view of the avascularity of the cornea, are the perilimbic vessels, aqueous and the tears. The first fundamental studies on corneal transparency and modifications of this because of contact lens use were started in 1952 by *Georg K Smelzer*. He and his collaborators had shown the role of oxygen deprivation in the appearance of corneal edema. They were not however able to quantify this. This was realized ten years later when the first publications of *Richard Hill* and of *Irving Fatt* appeared from the laboratory of the Contact Lens Clinic of the School of Optometry at the University of California, Berkeley. The fruitful collaboration of these two researchers continued over the years, even when *Hill* returned to Ohio State University to which he transferred his research. Of note is that *Hill* developed a test, later to be known as the 'Equivalent Oxygen Pressure', which became an early method for measuring contact lens oxygen transmission. *Fatt* developed new electrodes for oxygen measurement and published the results of his many fundamental researches. These included, amongst others, measurement of oxygen consumption by the cornea, the effect on corneal swelling, oxygen tension during blinking and under a contact lens. [111] Among the thousands of publications during this period, one can note fundamental research on corneal topography, innervations and corneal sensation, palpebral motility, plus the nature and the residue of tears. The study included both the effects in the normal eye and the eye in which a contact lens is worn. These numerous publications are indexed in a copious scientific literature. It must be said, however, that a few of these publications are of substandard quality. Fortunately, others are very complete studies and will serve as reference articles for many years. [112] Among these same thousands of publications, several synthetic works appeared, some very complete. There are also review articles published uniquely in contact lens journals (Contact Lens Forum, Contact Lens Spectrum, International Contact Lens Clinic, Contacto, etc.) to which future historians will be directed and will have to confront so as to select essential data and thus determine future developments. Unfortunately, in our era, announcements lead often to unproductive paths for the profit of short-term commercial interests.

4.3 – The Decade of New Contact Lens Materials

See table 27-1 page 253

Although such an important development, it was only thirty years after the discovery of corneal lenses that these new materials made their real breakthrough. However, precursors had already appeared before that. Thus, *Otto Wichterle* applied in 1954 in the USA for his first patents for HEMA copolymers. Certain research projects were already underway to combine hydrophilic polymers with methacrylate in order to synthesize new polymers that would respond to the permeability criteria and factors revealed by *Hill* and *Fatt*.

4.4 – Major Pmma Corneal Lens Laboratories around the World

4.4.1 – In the United States

The success of corneal contact lenses went beyond all expectations in the USA. This was in spite of the fall in sales of pmma corneo-scleral shells, which stagnated at the end of the 1940s (about 15.000 pairs a years, essentially destined for high myopes, aphakia and keratoconus). In 1960, *Tuohy* recalled that Solex had sold 200,000 pairs of corneal lenses since their discovery. This was to be compared with 5 million pairs of corneal lenses sold throughout the USA. Ten years later, in 1970, it was estimated that there were 10 million contact lens wearers in the USA and 600,000 pairs of lenses were sold there every year. [113] If, starting with 1952, the market had literally exploded; it was in part due to the action of and certainly to the benefit of 'The Plastic Contact Lens Company' of *Wesley* & *Jessen*. In fact, after a ferocious judicial fight, above all against Solex, *Butterfield* and *Hornstein*, this company succeeded in dominating the American and even the world market for corneal contact lenses for several years.

1) The Wesley-Jessen Plastic Contact Lens Co. of Chicago

The Plastic Contact Lens Company was founded in Chicago in 1946 by two business associates: *Newton K. Wesley* and *George N. Jessen*. The beginnings of the company were modest and its founders concentrated mainly on improvements of corneo-scleral lenses for keratoconus, an affection with which *Wesley* himself was afflicted. Although they did not possess any specific patent, Plastic Contact Lens was involved with the manufacture of corneal contact lenses of *Tuohy* type, then with lenses with parabolic curvature, which

brought the company into several legal conflicts against Solex and *Butterfield*. Subsequently the company changed its name to 'Wesley & Jessen Company Inc.,' with the logo 'W-J'.
Starting in 1952, Plastic Contact Lens undertook an enormous advertising campaign. According to certain authors, "*they spent $500.000 annually on public relations in order to make the term 'contact lens' part of the American and universal lexicon and to create a market for their products*." [114] According to *Wesley*, it was important to advertize to the general public, not just to professionals: "*At this time there were so many doctors prejudiced against contact lenses, afraid of them because they did not understand them. They would state that one would need solutions of the proper type, that one would only wear them for a few minutes, etc. In the mid-fifties, I feel that we must bypass the doctors, go to the general public and let the public be the judge*." [115]
In order to educate professionals, *W-J* started with direct mailings in order to promote courses for the teaching of contact lens fitting across the United States. *Jessen* represented the clinical side as 'clinician', whilst *Wesley* ran the business. They were jointly responsible for the contact lens education of a great many practitioners and for developing the contact lens market around the world. *W-J* published and printed an impressive series of 'instructions' to explain the practice of the fitting and the follow-up of patients [116]. The success of the firm was staggering. It was repeated that in 1956 Plastic captured 85% of the American and worldwide market. [117]. Plastic Contact Lens Company, then *Wesley & Jessen* were involved in several lawsuits in regard to royalties for contact lenses. According to *Wesley*: "*There were many patent problems in the beginning of contact lenses. We got involved in almost every one of them. (...) A patent was owned by Solex Laboratories of Los Angeles, California. I did not believe that the patent would be upheld by the courts, but Solex won three different lawsuits and, in order to protect our clients, we indemnified the whole field. At one time our liability was $5 million. (...) On top of this, we also paid royalties to Butterfield in Portland, Oregon. His patent stated that there would be an alignment fit with conformity in the periphery. There was a third patent held by Hornstein that stated 'steeper than' in the center area and the rest of the fit would be conforming to the eye. It was a very complicated period, and it cost millions of dollars to fight the different lawsuits*." [118]

1948	Tuohy, Kevin M.: Contact Lens. US # 2,510,438 (February 28, 1948 - June 6, 1950)
1949	Butterfield, George H.: Corneal Contact Lens. US. # 2,544,246 (August 1, 1949 - March 6, 1951)
1950	Silverstein, Samuel W.: Contact Lens. US # 2,641,161 (December 13, 1950 - June 9, 1953).
1951	Stimson, Noel O.: Corneal Contact Lens. US # 2,653,515 (May 5, 1951 - September 29, 1953)
1951	DeCarle, John Trevor: Improvements in or relating to Contact Lenses. GB # 731,155 (July 20, 1951 - June 1, 1955)
1952	Hornstein, Joseph J. (assignor to Dr. Ritholz & Sons Co.): Contact Lens. US # 2,809,556 (March 24, 1952 - October 15, 1957).
1955	DeCarle, John Trevor: Corneal Contact Lenses. GB # 802,486 (October 4, 1955 - October 8, 1958)
1957	DeCarle, John Trevor: Improvements in or relating to Contact Lenses. GB # 831,546 (April 9, 1957 - March 30, 1960)
1958	Wesley, Newton K.: Bifocal Corneal Contact Lens. US # 3,031,927 (March 3, 1958 - May 1, 1962)
1958	Cepero, Gilberto R. (W-J): Method of finishing Contact Lenses. US # 2,990,664 (September 2, 1958 - July 4, 1961)
1959	Gordon, Stanley (C.L. Guild): Corneal Contact Lens with spiral vent ducts. US # 2,989,894 (June 22, 1959 - June 27, 1961)
1959	Neefe, Charles W.: Contact Lens of apparent variable light absorption. US # 3,034,403 (April 3, 1959 - May 15, 1962)
1959	DeCarle, John Trevor (W-J): Lens molding Apparatus. US #2,999,574 (June 8, 1959 - July 4, 1961)
1959	DeCarle, John Trevor: Lens Moulding Apparatus. GB # 905,288. (Sept 28, 1959 - Sept. 5 1962.
1959	The Plastic Contact Lens Co. (W-J): Improvements in Corneal Contact Lenses. GB # 905,289 (September 15, 1959 - September 5, 1962)
1961	Feinbloom, William: Corneal Contact Lens Having Inner Ellipsoidal Surface. US # 3,227,507 (August 16, 1961 - January 4, 1966)
1961	Salvatori, Philip L.: Bifocal marking Device for Contact Lens Blanks. US # 3,046,668 (January 4, 1961 – July 31, 1962)
1962	Becker, Walter E.: Corneal Contact Lens Fabricated from Transparent Silicone Rubber. US # 3,228,741 (June 29, 1962 – January 11, 1966)
1962	Wesley, Newton K.: Bifocal Ophthalmic lens having different color distance and near vision. US # 3,339,997 (July 30, 1963 - September 5, 1967)
1962	Neefe, Charles W.: Corneal Contact Lens of wide fitting range with sine curve concave surface. US # 3,187,338 (February 19, 1962. - June1, 1965)
1964	Bennet, R .W. & Salvatori, Ph. L. : Ophthalmometer and Methode of Measuring Curvature of a Cornea. US # 3,404,936 (October 1, 1964 – October 8, 1968)

Table 27-11
Chronological selection concerning the corneal contact lenses made from PMMA and used in the USA (1948 – 1970).

Having acquired the quasi-monopoly for making and selling corneal contact lenses, Plastic started manufacturing Sphercon lenses after 1956 using a basic design largely inspired by the *Butterfield* lens, except for its total diameter (reduced to between 6.00 and 8.90 mm). There was also a bevel of 0.40 mm. The fit of this lens with paraboloid peripheral curvature was simplified and was done on-K, aiming for parallelism of the central zone. The Sphercon Corneal Lens included several modifications and was useful for introducing and disseminating the concept of multicurve principle. This was a very small and thin contact lens, the edge of which was separated from the cornea in order to favor tear flow. It was also considered to be more adherent to the eye and less mobile. It also produced less irritation and the fit was faster. (119)

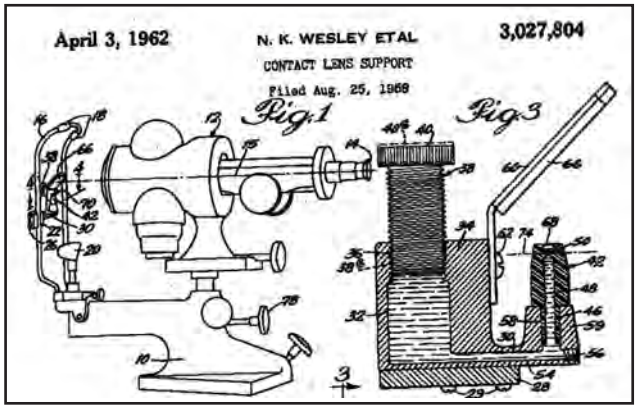


Figure 27-17
Illustration showing patent for a contact lens support.
Eventually characterized as 'Con-Ta-Chek', this optical device was patented by Newton K. Wesley and George S. Mattie. It neutralized the anterior surface of the lens by contact with a liquid and reflected, using a mirror, its posterior surface towards an ophthalmometer adapted to read concave surfaces.
(Wesley N.M., Mattie G.S., 1958)

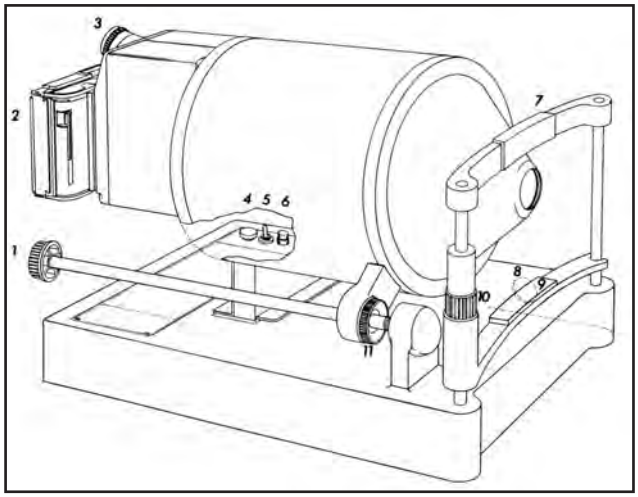


Figure 27-18
Diagram of 'PEK Mark 3 Keratoscope'.
The 'Photo-Electric Keratoscope' (PEK) made by The Plastic Contact Lens Company (Chicago) was based on the projection of and photographing the mire of a Placido disc on the cornea. Analysis of the photographic images obtained facilitated the choice and fit of contact lenses. (Feldman G. in Bitone JL., 1972)

Commercial development went along with research and innovation both in regard to the techniques of manufacture and the equipment for measurement of the parameters of the cornea and the lenses. In 1958, *W-J* produced 'Bifocal Corneal Contact Lenses' with "*an annular outer zone surrounding an inner zone, (...) one zone of one power and another zone of a different power*." They were not able to ignore a similar British patent of *John Trevor DeCarle*: 'Improvements in or relating to lenses' that was applied for in terms almost identical in April of the year before for "*a corneal contact lens which (...) has one zone of one power and another zone of a different power. One zone may be an annular outer zone surrounding an inner zone*".

This forced *Wesley* to collaborate with *DeCarle*; the collaboration was very beneficial and involved reciprocal changes of techniques and patents: "*During this period I had developed the Bicon Lens and have received the patent on it. (...) My interest in bifocals led me into a patent infringement with John De Carle in England and the next thing I know, the patent attorneys called me and said I had better go to London because John De Carle had also invented the bifocal lens about the same time and I would be better to make peace rather than fight. So, I did go to London. I did not know John De Carle, but I had written to him and asked for an appointment, and we discussed the matter. I asked him what he wanted for his patent, and he suggested a joint venture in London and so we did just that. He ran the London Sphercon office.*" (120)

Wesley and his collaborators proposed and carried out numerous innovations, over and above bi- and polyfocal lenses, the most interesting of these being lenses having different color for distance and near vision, lenses with blind spot aperture and aseptic lenses 'Aseptoplast', incorporating hexachlorophene. In order to simplify the control of the parameters of the lenses, W-J engineers developed a contact lens support for the ophthalmometer equipped with a mirror, the 'Conta-Chek', something that soon became essential for any fitter. For inspection *W-J* recommended a 'Conta-scope', for the measurement of edge thickness a 'Profiler' and a 'Contactometer', as well as an 'Adjustment Kit' for final improvements. Engineer *Martin G. Townsley* developed a 'Photo-Electric-Keratoscope (PEK)' based on projection and photography of the mire of a *Placido* disc on the cornea. The analysis of the photographs obtained was intended to facilitate the choice and the fit of appropriate contact lenses. However, according to contemporary authors, "*because of the complexity, variability and expense, it is unlikely to replace keratometery*." Finally, *Jessen* formalized

ideas for the "*reduction, modification or elimination of the visual defects by the programmed application of contact lenses*". He called this 'Orthofocus' and used a 'Cycon' lens. [121]
Wesley & *Jessen* purchased Solex Laboratories in 1960 although their bankers had reservations. According to *Wesley*: "*Since Solex had financial problems, we made an offer and they accepted it. We bought the whole laboratory and washed out the previous possible patent litigation in one fell swoop for $650,000. It saved Solex $1 million in trying to enforce their patent throughout the United States against many laboratories (at that time, approximately 350 laboratories), and we were the largest, doing about 85% of the volume of business. (...) We did manage to come out with a slight profit after buying Solex since we held the basic patent and other manufacturers paid us, but the laboratories were smaller at that time. We probably spent $2.5 million in legal fees and other costs to collect $3 million. The $500,000 that one might consider a profit was certainly not worth the management time, which was not considered nor the problems in fighting the patent*." [122]

1956	Wichterle O.	Process for Producing shaped Articles from three-dimensional Hydrophilic High Polymers. US # 2,976,576 (Apr. 24 1956 – Mar. 28, 1961).
1964	Wichterle O.	Selective Light Absorbing Contact Lens. US # 3,476,499 (Sept 1, 1964 - Nov. 4, 1969).
1965	Wicherle O.	Method of Manufacturing Soft and Flexible Contact Lenses. US # 3,496,254 (July 1, 1965 – Feb. 17, 1970).
1970	Wichterle O.	Method of Centrifugally Carting thin Edged Corneal Contact Lenses. US # 3,660,545 (Nov. 4, 1970 – May 2, 1972).
1970	Ewell D. G.	Hydrophilic Contact Lens Material. US # 3,647,736 (May 25,1970 - Mar 7, 1972)
1972	Gaylord N. G.	Oxygen-permeable Contact Lens composition, Methods and Article of Manufacture. US # 3,808,179 (June 16, 1972-Apr. 30, 1974).

Table 27-12
American Patents granted for "New Materials" to be used in the manufacture of Contact Lenses as replacement for PMMA.

Thanks to their commercial and diplomatic know-how, *Wesley* & *Jessen* succeeded in setting up branch offices and making connections across many countries worldwide. First of these was Japan, where *Wesley* profited from his connections and his linguistic facilities. On the American continent, Plastic Contact Lens Company founded joint ventures in Canada, Argentina, Columbia, Mexico and other countries. In Europe, *Wesley* created a business association in Scandinavia. In the U.K., rather than do battle with *John DeCarle*, he jointly founded in London the Sphercon Contact Lens Company in 1959. The chairman of this British company was *John DeCarle* and the remaining shares were the property of the Plastic Contact Lens Company.

The *Wesley* & *Jessen* episode marked a radical change in style of management, from the manufacture and the distribution of contact lenses, on the one hand, i.e. the change from craftsmanship to industry and, on the other hand, introduction of principles of industrial management, marketing and accounting. On the advice of lawyers and accountants, the promotion of *Wesley* & *Jessen* products was entrusted in 1956 to a non-profit-organization, The National Eye Research Foundation (NERF). [123] NERF was intended to sponsor an Annual National Contact Lens Congress (ANCLC), amongst other events. In 1959, there were nearly 1000 attendees at ANCLC. NERF also published Contacto, the first journal exclusively devoted to contact lenses. (124) To achieve this, NERF employed a public relations staff of 14 persons. It remained active for 5 years before it was dissolved after its objectives had been reached. According to *Wesley*: "*The NERF was our favorite charity, and Dr Jessen and I, through Wesley-Jessen, the contact lens company we had formed, donated more than three million dollars over many years. We held the first World Contact Lens Congress in 1959 at the Edgewater Beach Hotel in Chicago, and about 1200 delegates attended from all over the world.*" "*I felt it was time to go to the public since so many of the doctors could not be convinced about the value of contact lenses. (...) We hired Pat Morrisey as our public relations director and we disseminated information to the public. We developed a public relations staff of 14 people, and the story of contact lenses and eye care was told. It was amazing to us that eight out of ten interviews never materialized (...). Five years later, I did 600 interviews in one year nationally and had one refusal. In 1950, three national encyclopedias, including the World Book and Encyclopedia Britannica included contact lenses in their descriptive literature. It took five years of tremendous efforts, fourteen staff members working on nothing but contact lenses and eye care stories, and countless radio, television and newspaper interviews, but the words contact lenses went into the English language*."

The strategic financial management of the company depended on an attorney specialized in this aspect. His name was Mr. *Panter*. He was seconded from a Board of Directors comprising personalities recruited from the financial world (Banks and Insurance Companies) also from the world of industry. Included were such

names as Philip Morris, Abbott Laboratories, etc. This collaborative style of management, supported by the advice of consultants, was profitable, in that it favored investment in and purchase of a competitor holding a patent and of a certain know-how, rather than initiating a lawsuit of which outcome might be far from certain. The growth of *W-J* between 1950 and 1955 reached 10% a month. This made a good profit for the benefit both of shareholders and investors. (125) This company, which had created an international market of very much higher value, one that was growing rapidly. Of course, it interested investors in large companies in the Health Sector and, in 1981 the company was sold to the Shering-Plough Company. (126)

2) Other Larger Manufacturers

The share of the contact lens market left by *Wesley-Jessen* to other American manufacturers was estimated at between 15 and 20% in 1956. This was fiercely fought over by manufacturers more modest in size. It would take too long to list the more than 300 companies that were created in the USA in order to provide a market for corneal contact lenses. We will limit ourselves to listing the most known and most cited, many being royalty-paying licensees of patent- holding companies.

International Lens Laboratory & Breger-Müller-Welt Contact Lenses Inc., Chicago

Adolf Mueller-Welt (Stuttgart) had immigrated to Canada where he had entered in 1949 into a partnership with Donald Golden (Detroit) where he founded the 'International Lens Laboratory'. Then he associated himself with *Walter E. Becke*r forming 'Breger-Mueller-Welt Co.' in Chicago. At an earlier period, they had introduced fluidless corneo-scleral shells, which achieved great success. Then they entered into the corneal contact lens circuit with the 'Mueller-Welt Tri-con lens'. This lens was characterized by a posterior surface, the central zone of which was surrounded by two peripheral curves. Fit was recommended parallel to the flattest corneal curve. The total diameter of the lens was generally 1.20 to 1.70 mm smaller than the horizontal corneal diameter. Other types of contact lens were produced as knowledge developed, including the tri-curve A-AZ Lens, the multicurve M-AZ, the V-AZ lens (with one or several ventilation holes) and the Z-AZ lens. The latter was provided with channels designed to favor tear exchange. These were lathe-cut contact lenses. The manufacturer recommended office adjustment by an experienced technician. *Walter E. Becker*, patent application agent for Muller Welt Contact Lenses Inc. of Chicago, was ahead of his time when he filed as patent for a 'corneal contact lens fabricated from silicone rubber'. (127)

Georg H. Butterfield and Son, Portland, Oregon

The *Butterfield* patent for a corneal contact lens with a parabolic posterior periphery (contemporary with the Tuohy patent) had been the subject of lawsuits, because its profile was then the most physiological available. This was the Butterfield 'Paracurve' contact lens with a central spherical area, intended to cover the corneal apex and surrounded by a zone with progressive flattening intended to conform with the corneal periphery. On-K fitting was recommended. Control was by examination of mobility: a tight lens indicated the need for a lens of longer radius of curvature and a loose lens the need for a shorter radius. He used injection-molded lenses with polymerization between two dyes. Subsequently, *Butterfield* marketed the 'Micro-V' and the 'Spherex' lenses. The 'Micro-V' was provided with four channels extending in from the periphery and a secondary curve 0.2 to 0.7 mm flatter than the central area. Thus it was similar to the idea of the 'Ventair' lens. The 'Spherex' lens was a classical bicurve lens fit 0.5 mm flatter than K. For adjustments and minor modifications of these lenses in the office, *Butterfield* sold the 'Butterfield Mark II Paralathe' to fitters. He had also obtained patents for an apparatus for molded contact lenses. (128)

Solex Laboratories Inc., Los Angeles

Solex Laboratories experienced a fantastic success in the course of the first years after the introduction of the Tuohy Contact Lens. Subsequently, Solex abandoned the flat fit recommended in the course of the first years, however, the company continued emphasizing the advantage of the bevel (as described in the patent). *Kevin Tuohy* defended his priority and rights until of his financial ruin. In 1960, Solex recommended three systems of fit: 0.3 flatter, 0.15 flatter and 0.05 mm flatter than K. He also recommended bi- and tri-curve lenses. For thin and small lenses, he emphasized that these should be fit as thin and small as feasible. According to Tuohy, five million pairs of lenses were sold in the USA in the course of the ten years following their discovery. However, only 2 million were still being worn in 1960, ten years later: "*About 10% of recorded history has been associated with success. (...) Of the first group of six presented in 1949 to the College of Medical Evangelists and the White Memorial Hospital in Los Angeles for investigation and research, [all] are still, ten years later, using their lenses, never having returned to spectacles*." (129)

In contrast to certain promotions by his competitors, *Tuohy* adopted a more prudent and conservative position: "*The successful use of bifocal lenses appears, in our opinion, to be based on the not uncommon impro-*

vement in near vision associated with single vision contact lenses; at any rate there is not the precise, definite correction as accomplished with spectacles. (...) In our opinion, bifocal lenses are as satisfactory a means of eliminating reading spectacles, as is the over-correction in plus of single vision lenses. (...) Bifocal lenses are in much the same category as are tinted contact lenses. Tinted lenses do not provide sun protection equal to spectacle lenses; they do not reduce photophobia." The business operation of Solex Laboratories Inc. was concluded in 1960 when *Tuohy* and *Zabner* sold their laboratory and the *Tuohy* patent to their most aggressive rival: The Plastic Contact Lens Company of *Wesley* and *Jessen* in Chicago. (130)

Obrig Laboratories Inc. New York City and Sarasota Florida

In the course of the 1950s, *Obrig*'s Corneal Lenses, as recommended by their manufacturer had a total diameter of between 8.9 and 9.2 mm (usually 9.2), anterior and posterior single curve, with a posterior bevel of 12 mm radius of curvature. The width could be modified between 0.1 and 0.6 mm. Parallel fit was recommended. If the fitter were to choose fitting by keratometer, the manufacturer would send three lenses of central posterior radius of curvature close to the central sphere of the optic zone. The trial lens set recommended by Obrig Laboratories was composed of thirty corneal lenses having varying radii, powers and overall diameters. He recommended that one lens should be 1.0 mm smaller than the iris and to select a lens with a 7.8 mm radius of curvature as basic lens. One checks the movement and size of the lens with fluorescein and cobalt blue light. When the criteria have been realized, the patient should be over-refracted with the fit lens inserted in each eye and, using the trial frame, the appropriate correction ordered as a new contact lens for both eyes. In 1960, *Obrig* changed his approach by recommending bi-curve lenses with blended curve and fit on-K. He used a lens with a diameter 2.0 mm smaller than the corneal diameter.
Philip L. Salvatori directed Obrig Laboratories at that time. The founder (*Theo E. Obrig*) had meantime retired to Sarasota Florida, where *Salvatori* also became director of Obrig Laboratories, subsequently Salvatori Contact Lens Laboratories in Florida. (131)

Truffit Contact Lenses, Los Angeles

Truffit manufactured and sold the contact lens designed by *Noel O. Stimson*. This was a facetted lens, molded inside, cut outside, which had four facets on the inside near the periphery. Fit was performed with trial lenses. The fit was flatter than K, but the amount was not specified: the larger the lens, the flatter the lens must be. No office adjustment was possible. (132)

Contact Lens Foundation

This company manufactured bi-curve corneal contact lenses with an optic zone of between 6.5 and 7.5 mm in diameter and a flatter peripheral zone of between 0.4 and 0.8 mm. The fit is on-K. Initially, the 'roughs' (unfinished, uncut lenses) were imported from the U.K. and the anterior surfaces were ground in the USA. *Norman Bier* and his American friend *Harold Moss*, promoted this contact lens. Their principle was: 'the steeper the cornea the smaller the optical cap and the diameter'. He recommended a choice between two different approaches: on-K and steeper than K (apical clearance). Office adjustment was recommended. (133)

Contact Lens Guild, Gordon Contact Lenses

This organization was founded under the denomination of The Contact Lens Guild in Rochester, New York by the optometrist *Stanley Gordon*. The company changed its name to Gordon Contact Lenses in 1965. The founder owned a patent for 'a corneal contact lens with spiral vent ducts'. This 'Spiro-Vent Lens' included several grooves designed to ensure rotation of the lens and to favor tears circulation and flow on its posterior surface. The ducts are of decreasing width and depth from peripheral towards central area of the lens. They extend in the same direction disposed spirally around the center of the cornea. The 'Spiro-Conic Lens' also had several fenestrations. Constructed according to the same principle, the 'Ventair' lens was also used by numerous fitters. This lens had semicircular grooves on its posterior surface. (134)

William Feinbloom

This optometrist passionately pursued his own activities and followed their development into corneal contact lenses. In 1961, he applied for a patent for a 'Corneal contact lens having inner ellipsoidal surface'. (135)

Frontier Contact Lens Inc., Frontier Contact Lens Company of Florida, Advanced Contact Lenses

Allan Isen and *George Siterle* founded Frontier in Buffalo, New York in 1959. They underwent several complaints for infringement of the Tuohy patent. In 1962, *Seymour Marco* in partnership with the two founders set up Frontier Contact Lens Company in Jacksonville, Florida. Later, *Sitterle* founded his own company, Advanced Contact Lenses in Buffalo.

KONTUR KONTAKT LENS COMPANY INC.
Kontur was founded in Richmond, California in 1957 by *Harold Gates* and *David Garfield Ewell*. One repeats that the founders designed and constructed their own machinery for manufacturing lathe-cut bi- and tri-curved lenses. Their fit was 'on-K'. The smallest lens that stays centered and covers the pupillary zone is the lens of choice. According to the manufacturer, a trial set of about 60 lenses is helpful, but not essential. Office adjustment of lenses is recommended. *Xavier Villagran* joined up with them after leaving Solex. Kontur also stands out by having triangular corneal lenses, notable the bi- and multifocal ('Ultracon 3 Angle Bifocal'. (136)

NEEFE HAMILTON RESEARCH COMPANY
Neefe was founded by *Charles Neefe*, who had been granted patents regarding aspheric and multifocal lenses. In January 2002, *Neefe* had 98 contact lens patents to his name. He had applied for and obtained interesting patents, particularly for a contact lens of apparent variable light absorption with "*a small circular tinted, light absorbing area in the center of the lens*" and for a "*corneal contact lens of wide-fitting range with sine-curve concave surface*."
"*The concave surface of this lens has a continuous but gradual change from the center out to the edge, the center being of shorter radius than the flatter meridian of the central area of the cornea, the outer edge having an increasingly larger radius of curvature*." (137)

RITHOLZ SONS & CO., JOSEPH J. HORNSTEIN
Joseph J. Hornstein was the owner of a patent that was exploited by Ritholz Sons & Co, recommending from 1952 onwards a vaulted fit that avoided contact with the corneal apex: "*the present lens has an inner central spherical area or optical zone which is vertically deeper in relationship to the marginal area of the lens (...) to prevent flattening of the apical area or causing corneal abrasion or ulcerations.*" (138)
The vaulted fit was gradually adopted by the principal manufacturers, which forced *Hornstein* into multiple lawsuits for infringement of his patent.

SAMUEL SILVERSTEIN
Samuel Silverstein maintained his interest in contact lenses, starting with a half-scleral half-corneal 'Hybrid' lens: "*a contact lens with three sections, i.e. one being a central corneal section, a further section being a marginal scleral section and the third section being a transitional section*." (139)

3) VARIOUS MANUFACTURERS AND FITTERS
From amongst the numerous other manufacturers and fitters, one notes several frequently cited in contemporary documents:
- First of all, mention should be made of the *CONTACT LENS SERVICES* of the Schools of Optometry of Universities and Hospitals. These included amongst others the *CONTACT LENS CLINICS* at Berkeley, California, Columbus Ohio, Houston Texas and New York and others. The researchers at and the directors of these institutions organized interesting congresses and published an impressive number of reports and treatises.
The documents from this era allow one to cite in a random fashion and without claim to be exhaustive the following personalities, fitters and manufacturers:
- *Charles A. Bayshore*, owner of *BAYSHORE CORNEAL LENS*, produced small diameter lenses of between 7.00 and 8.60 mm, vaulted fit and central fenestration for tear exchange. (140)
- In 1960, *CONCENTRA CONTACT* changed from a 'steeper-than-K' to 'fit-on-K' approach. They also manufactured bi-curve contact lenses with blended curve,
- *CONFORMA CONTACT LENS* manufactured also a bicurve lens with a peripheral bevel 1.5 mm flatter as base curve and diameters between 9.2 and 10.5 mm. The fit was 'on-K' to the flattest corneal meridian. The lens was machine-lathed.
- *CONTINUOUS CURVE CONTACT LENS INC.* at San Diego was founded in 1960 by optometrist *Donald Brucker*. He developed a corneal contact lens with a progressive flattening of the anterior surface and a gradually flattening of the posterior surface as a 'continuous curve'. Continuous had later obtained a patent for a contact lens in CAB and for a laser apparatus for fenestration of contact lenses, the 'Laser-Con'.
- *DOMEX CONTACT LENS* uses a 'steeper-than-K' approach, thereby creating a 'dome'.
- *MEDICORNEA LABORATORIES* was created by ophthalmologist *Paul R. Honan* at Lebanon, Indiana in conjunction with *Herschel H. Boyd* in Seattle for the manufacture of contact lenses of small diameter for flat fit with unique standard clearance, used by physicians, with recommendation to drill fenestrations should corneal edema occur. *Boyd* recommended personal finishing of the lenses with reduction of diameter, modification of the posterior curvatures and fenestrations for which he designed an edge finisher and a contact

lens fenestration unit. [141]
- The *Murray Contact Lens Company* was known for lathe-cut lenses with tangential periphery and for keratoconus lenses. The secondary curve varies with the base curve. The fit based on assumption that 'steep corneas are small corneas and flat corneas are larger corneas' is not always true.
- *Pacific Contact Lens Laboratories Limited*, directed by *Morris Green* and *Lee W. Hoggan*, had manufactured lenses resembling *Tuohy* lenses. They lost their Court case when Solex launched the first lawsuit and the penalty imposed was used as a precedent for later complaints.
- *Precision Cosmet Corporation Inc.,* was responsible for a bi-curve lens with fit on-K and of diameter 9.5 to 10.5 mm. The lenses are ordered by dioptric power. Office adjustment kit was recommended. With this in mind, Cosmet sold an inspection kit with 'Comparator', 'Thickness Gauge', and 'Shadowgraph'; also an 'Automatic Precision Cutter' (for cutting a lens to adequate diameter) and a 'Precision Automatic Edger'.
- *Titmus Optical Company* (Petersburg, Virginia), *Utah Optical Supply Company*, *Rogers Brothers* and *Southern Contact Lens Inc* are cited as being *Butterfield* licensees for contact lenses with parabolic peripheral curvature.
- In 1967, *David Volk* (Cleveland, Ohio) collaborated with *Gene Hirst* (New Zealand). He granted several patents regarding method and machinery generating aspheric surfaces on contact lenses. *Daniel O. Elliott Jr.,* described in detail his method for producing aspheric surfaces. In 1969, *Volk* detailed a projected range of mass-produced corneal lenses with concave ellipsoidal surfaces and also covered the possibility of a conoidal front surface to reduce thickness. [142]
- *Paragon Contact Lenses* produced the 'Parabolic Multifocal Lens' in 1962.
- *Fused Kontakts Inc.* manufactured lenses for which *Georg Fumio Tsuetaki* held the patents. These were bifocal and multifocal contact lenses, oriented by inclusion of a metallic colored insert functioning as a colored iris for the patient. They were denominated as 'Invisible gradient Bifocal, Platinum oriented fused Bifocal, Pan-O-Side Bifocal, Double Fused Internal Oriented Bifocal, Tangent Streak Bifocal'.

From amongst numerous other bi- and multifocal lenses, one should also note that the 'Camp Fused Bifocal', the 'Jessen Lumicon Fused Bifocal' and the 'Contour Comfort Bifocal were also available in the U.S Market.
- *American Optical, Bausch and Lomb,* etc. These companies, as established furnishers of traditional equipment for eye examination, had introduced instruments specific to the fit and control of contact lenses: refractometers, keratometers, keratoscopes, corneographs, photokeratoscopes, etc. as well as radiuscopes, shadowgraphs, Burton lamps, measuring magnifiers, holders, lensometers, thickness gauges, etc. Certain of these instruments became indispensible for fitters in their desire for better quality control, taking into account the lack of confidence that they had in the quality of mass production of most manufacturers.
Other manufacturing companies made instruments more specifically on the initiative of local researchers like Ophthalmic Supply Inc (Houston, Texas) who were famous for their modification and polishing instruments. Quality Optics Inc manufactured spindles for reducing diameter, repolishing and refinishing lens edge. Wesley-Jessen, so it was reported, would deliver a complete set of examination instruments for alteration and retouching of contact lenses.
The Pharmaceutical Industry was not content to observe passively the disappearance of their market of products for scleral contact lenses at the time when corneal contact lenses became available. These, after all, did not require any liquid other than natural tears. New products became available in order to take over the lucrative market for cleaning materials, disinfection and the insertion of corneal contact lenses. *Barnes Hind Pharmaceuticals Inc., Burton Parsons & Co.* and *Allergan Pharmaceuticals* rapidly invaded the market. One was soon to ask the question whether the dry preservation of lenses made from pmma might not be safer or whether pharmaceutical products were really necessary. [143]

In order to gain a reliable impression of the fitting techniques during this era, we quote a 1960 survey of 19 major companies by *Max Shapero*: "*About 19 companies surveyed: 13 companies recommended on-K parallel to flattest central, 6 parallel to intermediate zone, 2 parallel to peripheral zone and 3 steeper than flattest central zone. All companies claimed success with their lenses. Fitting approach of flatter than by 0.3, or on-K peripherally, is just about extinct – Solex and Stimson are now abandoning that approach. Steeper than K has lost many of its adherents in the past years. The concept of parallel to intermediate has gained in favor*." [144]
Shapero notes in 1960 that there is an overall consensus regarding corneal contact lenses with: "*Diameter 9.8 plus or minus 1.0; optical zone varies slightly with diameter; secondary and tertiary radius related to BC; edges are tapered with a well-rounded tip; for height astigmatism and keratoconus, special fitting techniques.*"

As a matter for the record, professional opinion was divided at this moment in contact lens history. Whereas optometrists selected low-grade ametropias for cosmetic indications, these being supported by advertising

campaigns oriented in this direction, ophthalmologists insisted on medical indications. Their publications dealt essentially with the correction of keratoconus, high refractive errors and unilateral aphakia, the last being addressed during this era by the first intraocular lens implants. Several publications drew their attention to the 'contact lens problem' and encouraged them also to invest in the correction by contact lenses of low refractive errors, and many rose to the challenge. (145)

The prevalence of pmma corneal contact lenses continued until the millennium. Thus, *Dow Corning Ophthalmics* still recommended pmma corneal contacts in their advertising material in 1980, emphasizing the advantages of pmma, the indications for which would be more robust than if so-called 'new materials' were used because of their stability for the following cases: "*Spherical lens for patients with normal parameters, thin center thickness for patients with hypersensitivity or central problems, ultrathin lenses with an ellipsoidal posterior curve for patients with higher amounts of corneal astigmatism, lenses with an aspheric curve on the anterior surface for patients with residual astigmatism of a diopter or less, back toric lenses for high amounts of corneal astigmatism, front toric lenses to correct residual astigmatism, ellipsoidal lenses for patients with centering problems which can fit up to 4 diopters of corneal astigmatism and lessen edema, bitoric lenses in combination of back and front toric designs, bifocals with crescent internal segment, in variable focus, in annulus bifocals with distance power in the center and near power in the periphery (...), segment bifocal design*." (146)

4.4.2 - Major Pmma Corneal Contact Lens Laboratories in Europe

1) In the **United Kingdom**

Linguistic and technical interchange between the USA and the UK made Great Britain the center for the most enterprising and innovative companies manufacturing corneal contact lenses in Europe. A rapid survey allows us to note a certain number of manufacturers, fitters and specialists.

- *The Contact Lens* and *Prosthetic Department* at Moorfields Eye Hospital, High Holborn, City of Westminster (London) had engaged ophthalmologists, opticians and technicians to make it into a center for fitting and research in the country and in Europe. *Frederic Ridley* worked both with flush-fitting shells and the corneal lenses until 1968, when *Montague Ruben* succeeded him and took over his responsibilities.

- *Norman Bier* was referred to above for having developed the 'Contour Len's' and the 'Apical Clearance Lens' with its three contours and a spherical zone of 6.50 mm in diameter. He was the source of numerous innovations, including monovision, in which one eye is corrected for distance and the other for near. He also dedicated himself especially to low vision using a Galilean system in which a spectacle lens is combined with a contact lens.

- *CLM* (Contact Lens Manufacturing) was founded in 1964 by *David Clulow* and *Philip Cordrey* for the manufacture of contact lens materials, pmma blanks and contact lens manufacturing instruments. CLM first sold lathe-cut lenses, then developed a compression-molding technique with dry powdered pmma placed between two molds in a heating tunnel. These lenses had a very good surface, but needed slight finishing of the edges. The glass molds used initially were changed to metal molds which ensured a better heat transfer and allowed mass production which transformed the basic cost from very expensive to cheap manufacture.

- *Frank Dickinson*, after introducing scleral lenses into South Africa, used microlenses on his return to the UK. He tried to improve the profile of these lenses that had been lathe-cut by *George Nissel* and *Bernard Shiels*. Some of them were also molded lenses from the corneal profile.

- *GT Optics* was founded in 1954 by *Robert Turner* who also opened contact lens fitting centers in large British cities. He designed a corneal lens with negative anterior periphery in order to avoid indentation by the superior eyelid. *GT* is proud to have presented lenses with 28 different colors. The company also makes spindle machines and manufacturing machines, complete laboratories, radius lathes, automatic polishing machines, also gonioscopes and ocular surgery instruments.

- *Joseph Dallos* opened his own office and manufacturing laboratory in 1964. While he continued manufacture and personally to fit corneo-scleral contact shells, he did not neglect corneal contact lenses which he also manufactured for sensitive patients, following corneal molding to in some patients. (147)

- The optometrist *John Trevor DeCarle* had applied for a patent for the 'improvement in or relating to lenses' with bifocal capability. As described previously, that entailed collaboration and exchange of procedures and patents with *The Plastic Contact Lens Company* of *Wesley-Jessen*. Thus *De Clarle* introduced the 'Sphercon' contact lens into the UK. He sought to improve this lens by adding supplementary peripheral curves. (148)

- *Kelvin Contact Lens Company* (*Raymond Kelvin Watson*) developed a manufacturing process for corneal contact lenses by compression with a molding system between two metallic molds, similar to what he had previously used for corneo-scleral contact lenses. However, this procedure required that the contact lenses had to be edged to remove the flash, (excess material resulting from the molding process). On the other

hand, the molding allowed the manufacture of 'continuous curve lenses' which was not achievable with the lathes available at that time. *Kelvin* even obtained, with this in mind, special plastic materials developed by *Imperial Chemical Industries*. The automatic manufacturing process became less expensive and one cites, at the end of the 1970s, that Kelvin was regularly making more than 1000 lenses a day and the company had become the UK's largest manufacturer of corneal lenses. In 1968, it created Kelvin Contact Lenses Canada.
- In 1947, *George Nissel* produced the first commercial lathes and polishing machines specifically designed for contact lens manufacture. He was one of the first to recognize and produce aspheric contact lenses.
G. Nissel and Co. supplied lenses and machinery to countries all over the world. *Nissel* had welcomed *Frederick Burnett Hodd* who designed the 'Hodd tapered lens' which defined the degree of flattening for the peripheries of corneal lenses. He also conceived the first continuously flattening peripheral curve in advance of the lathing technology to manufacture it.
- *Omega Contact Lenses*, under the direction of *Gunter Wingate* successfully manufactured lenses and instruments.

2) In **Continental Europe**

In **Germany** and thanks to the lead from Heinrich Wöhlk Contact Linsen GmbH in the manufacture of corneal lenses, this company became the first manufacturer of corneal contact lenses in the country. Initially, *Wöhlk* produced ground lenses who which he designed and manufactured himself, using his own machines and tools, which he also delivered to other manufacturers, i.e. *Danker*. Then *Wöhlk* manufactured lenses with parabolic clearance using polymerization between two precision molds made from quartz. His lenses, first 'Parabolar' then 'Parabolet' (small diameter lenses) achieved tremendous success. The company expanded and by 1971 was producing 2.000 corneal contact lenses a day.
- *Söhnges Optik GmbH*, whose founder was *Wilhelm Peter Söhnges* took the initiative, along with *John C Neill* and *Frank Dickinson* of 'microlens' corneal lenses, to become the supplier for numerous subbranches and contact lens fitting institutions. The 'German Microlens' was initially manufactured by molding and compression of a sheet of pmma between calibrated steel dyes. In 1961, *Söhnges* also developed a multifocal micro-pupil lens. (149)
- In 1964, the optician *Herbert Schwind*, with *Titmus Optical* (Petersburg, VA, USA) participating, founded *Titmus Eurocon* at Aschaffenburg. The company introduced the first ground aspheric contact lens. In 1967, *Schwind* became the sole proprietor of a flourishing industry, which supplied the whole of Western Europe, either directly or through its subsidiaries, with pmma corneal lenses of the type 'Selecon'.
- *Müller-Welt & Co*. (Stuttgart) manufactured corneal lenses made from pmma and owned several fitting centers in large German towns.
- *Hecht Contact Linsen GmbH* was founded in 1978 by *G. Hecht, D. Muckenhirn* and *R. Norch*. They specialized in 'Ascon' aspheric lenses, fit by topometry and which were quite successful for difficult fittings.
- After the war was over, *Zeiss* had been divided into two entities separated by the 'Iron Curtain'. *Carl Zeiss* (Jena) were in the German Democratic Republic and they remained faithful to glass. Starting in 1965, they made extremely fine ground glass corneal contact lenses from 'Silikatglas'. These corneal lenses were available with a total diameter of 10.00, 10.50, and 11.00 mm with posterior radii of curvature from 7.00 to 8.00 mm in steps of 0.10 mm. Trials of these carried out by *Emmerich* were encouraging, the more so because there were no other lenses available in this region. (150) The part of the business that remained in the German Federal Republic (*Zeiss-Oberkochen*) did not restart the manufacture of contact lenses. The same thing was true for *Müller* (Wiesbaden) who specialized in ocular prostheses.

In **Belgium**, the first 25 fittings of Wöhlk contact lenses were presented by *P. Mathieu* (Liège) who, by eliminating astigmatism patients with more than two diopters of astigmatism, keratoconus and aphakia patients, observed good results. The discussion that followed this presentation was, however, filled with great doubts. Thus *L. Weekers* said: "*Since the arrival on the market of corneal contact lenses, we have become aware of a certain infatuation for which there is no justification. Certain opticians have succumbed to unbridled advertizing with intentions that are far from scientific. (...) Contact lenses are a poor solution for ordinary refractive errors. I think that, in present day conditions, the duty of the physician is to warn patients who consult us and who are often ill-informed of the dangers involved*." (151)
These reservations were raised when *Weekers* created a Contact Lenses Department in his Ophthalmology Service at the University of Liège. He comes out in favor of a 1967 report on this subject by *P. Crochet*, *C. Maréchal-Courtois* and *E. Prijot*. (152)

In **France**, *Raymond Dudragne* pursued his pre-war activity while employed by the Lissac Company, then,

in 1947, set up his own laboratory and fitting center. He did not however involve himself in corneal contact lenses. *Lissac* and *Pierre Rocher* used licences from *Bier* and *Müller-Welt* and manufactured corneal contact lenses from aggregates press-molded between two precision molds, similar to the system used by *Söhnges*. Following several amalgamations, Lissac became Essilor, whose lenses had acquired a quasi-monopoly in France and the company organized interesting congresses and instruction courses that were aimed primarily at opticians. (153) Fitting and sales were, in actual fact, monopolized for practical purposes by the last-named company, while the ophthalmologists were content to refer patients with appropriate indications and oversee the results. In 1958, *Albert Bronner* and *Jean-Paul Gerhard* (both of Strasbourg, France) presented a report, entitled 'Contact Glasses and Precorneal Lenses' (Verres de contact et lentilles précornéennes). This showed which contact lenses were available in France at this particular period: first, there were imported *Woehlk* molded lenses; secondly, ground Microlis of Dencott, numerous models of *A. Dudragne*, including a triangularly-shaped contact lens. There were also the Keralis contact lenses of Lissac and the Trisphere contact lenses from Isoptic. The researches of *Bonnet* and *Cochet* on corneal aesthesia formed the basis for a new 'report' presented in 1966 to the Paris Ophthalmological Society by *Bonnet*, *Gerhard* and *Massin*. (154)
This situation lated until 1972, when ophthalmologist *Philippe Baronet* founded Médicornéa France in Toulouse, with the support of *Hershel Boyd* from Seattle, USA. The growth of the company was rapid because of its medical orientation and, ten years later, the company was the leader within the French, Belgian and Spanish markets.

In **Switzerland**, the ophthalmologist *O. Knüsel* (Aarau), became in 1953 the ardent advocate of corneal lenses, notably the 'Schwimmende Corneallinse' (The Swiming Corneal Lens) that he had discovered while on a trip to the USA. Several opticians manufactured and later adopted these lenses. Thus, *R. Brückner* reported that corneal contact lenses are manufactured by 'Visus' in Zurich. (155)

In **Hungary**, *Istvàn von Györffy* had drawn attention to corneal contact lenses. According to this author, they are to be preferred to scleral contact lenses, in spite of their disadvantages, i.e. risk of loss. This is because they are easy to manufacture and fit (156). *Györffy* had perfected a simple and cheap manufacturing method by compression molding, starting with thin pmma plaques. The technique was later adopted in most of Eastern Europe.

4.4.3 – Major Pmma Corneal Contact Lens Laboratories in other Countries throughout the World

In **Mexico**, in 1953, *Da Silva* published a study comparing contact lenses that were available there at that time. He paid special attention to corneo-scleral shells, some of which were manufactured locally. He repeated the technical fitting details for Tuohy lenses. However, he cautioned that corneal contact lenses were generally reserved for low refractive errors. When the refractive error requiring correction was more significant, then preference should be given to corneo-scleral shells. At around the same time, *Tuohy* introduced these in Mexico with a great publicity boost helped by local professionals, notably *Ignacio Rodriguez Caballero* who headed the Mexican subsidiary of Solex Laboratories. (157)

In **Japan**, the optician *Kyoici Tanaka* learned about the existence of corneal contact lenses in 1950 and was successful in copying several of these and trying them out in his own eyes. In 1952, he became associated with ophthalmologist *Yutaka Mizutani*, whose experience with scleral lenses was useful when he founded the Nippon Contact Lens Research Institute. The first trial set of 20 lenses was marketed in 1954. Ground polished lenses were used. These would be more and more developed in the course of the next few years.
In May 1957, *Newton K. Wesley* was invited to the congress of the Japanese Society of Ophthalmology, where he lectured on the advantages of corneal contact lenses. The manufacture of these new lenses was encouraged on the initiative of Juntendo University. This was how the Tokyo Contact Lens Research Institute was founded (*Hisau Magatani* & *Hironubu Atsuzawa*), whilst *Mituzani* kept the Nippon Contact Lens Research Institute in Nagoya and separated himself from *Kyoici Tanaka*. The latter then founded his own company Nippon Contact Lenses Inc, the title of which was changed in 1965 to Toyo Contact Lens Company Ltd and became the second largest manufacturer in the World after *Wesley-Jessen*, manufacturing 30,000 pairs of contact lenses a year. The company became Menicon Contact Lenses in 1967, also distinguishing itself by producing the smallest rigid contact lens in the world, 8 mm in diameter with a thickness of 0.12 mm. The number of contact lens manufacturers in Japan continued to increase, rising to fifteen in 1977. Universities, fitters and manufacturers founded the Contact Lens Research Association in 1958. This Japanese association

was responsible for numerous publications and research papers. It is to be noted that *Koichito Akiyama* described a rectangular contact lens 10 to 11 mm wide that was designed to adhere to the inferior part of the cornea and to be held in position by the lower eyelid. Its use was intended solely for correction of near vision. [158]

In **South Korea**, the ophthalmologist *Gong Byeong*, on his return in 1958 from the USA presented corneal contact lenses that were later to be manufactured by KuKje Contact Lens.

In **New Zealand**, *Peter Heginbotham* introduced micro-lenses after trying out *Tuohy* lenses. He developed production machines for manufacturing micro-lenses. Hirst Contact Lenses Ltd started in 1970 in New Zealand to manufacture aspheric lenses. They also had a license to manufacture conocoid lenses. He also produced the 'V Contour Lens', which was a multicurved contact lens with meticulous blending.

In **Australia**, Precisions Contact Lens Laboratories was founded in 1946 in Sydney in a partnership with *Penrhyne F. Thomas* and *Mate Ware*. In 1948, *Thomas* founded Corneal Lens Corporation Patenty Ltd for manufacturing Tuohy lenses, then micro-lenses and finally (in 1952) Conoïd Contact Lenses with tangential peripheral curve. Conoïd was patented in all countries throughout the world and was in fashion for a period of time. It was supported by a textbook, entitled 'Conoid Contact Lenses' that was translated into many languages. In the light of the success throughout the world of 'Conoïd', *Thomas* founded Contact Lens International Ltd with agencies and manufacturing laboratories in numerous countries. [159]

Notes in Chapter XXVII

1. Tuohy K. M., 1964.
2. The name Solex was derived from the first name of the original owners: Solon Braff (the Sol- of Solex) and Xavier Villagran (the –ex of Solex).
3. Another version attributes this episode to Xavier Villagran.
4. Soper J., interview by Garcia Al., 1993.
5. Tuohy K.M., 1964.
6. Villagran X.R., 1979.
7. Tuohy M.K., 1952.
8. Nugent M.W., 1948.
9. Tuohy K.M., 1948a.
10. Tuohy K.M., 1950; Solex 1952b; Tuohy K.M., 1952c.
11. Neill J.C. 1948a.
12. Graham R., 1949.
13. Tansey J.E., 1948.
14. Spratt G.W., 1949.
15. Nugent M. W., Tuohy K. M. 1949c.
16. Kanter M.H., Kraus D. E., 1949.
17. Zabner L.M., 1949.
18. Weiss S.G., 1950.
19. Dickinson F., 1949; Bier N., 1950b.
20. Daily News, New York, January 27, 1949.
21. Nugent M.W., 1949b.
22. Kronfeld P., 1949.
23. Nugent M.W., 1950a.
24. Nugent M.W., 1950b.
25. Harris H.S., 1950a, 1950b.
26. Abraham S.V., Shanedling P.D., 1950.
27. Neil J. C., 1951.
28. Graham R., 1952. (Submitted for publication November 30, 1951).
29. Berens C., Girard L., Force K., 1952.
30. Wessley N. K., Jessen G. J., 1951; Braff S. M., 1952a, b.
31. Braff S. M., 1951a, b, 1952a, b.
32. Schapero M., 1952; Baglien J.W., Middleton R.V., 1952.

33. McGraw J.L., Enoch J.M., 1952, 1954; McGraw J.L. 1954, 1957.
34. Tuohy K.M., 1989.
35. Solex, 1948; Tuohy K.M., 1948b.
36. Solex, 1950; Tuohy K.M., 1950a.
37. Tuohy K.M., 1950b.
38. Tuohy K.M., 1950c.
39. Tuohy K.M., 1952b.
40. Tuohy K.M., 1953. Presented November 10, 1952.
41. England D.C., 1946.
42. Goodlaw E., 1980.
43. Mandel R., 1988: p. 14.
44. Villagan X.R., 1979.
45. Butterfield G.H., 1950.
46. Obrig T.E., 1957 : p 397.
47. Patent application for first version on 1st August 1959, newer modification in February 1951, approved March 1951. See later § 3.3: "Protests and Lawsuits".
48. Silverstein S.W., 1950, 1951, 1954.
49. Stimson N.O., 1951.
50. Bier N., 1957 : p.145-146.
51. Hornstein J.J., 1952.
52. Hornstein J.J., 1954.
53. Bier N. 1947 : p. 142-143.
54. Bowden T., 2009 : p. 94-95, p. 169-170.
55. Cabarrouy J., 1951, 1952, 1980.
56. Bowden T., 2009: p. 172.
57. Obrig T., Salvatori P., 1957: p. 375-381.
58. Graham R., 1959; Solex, 1958.
59. Hofstetter H.W., Graham R., 1953; Enoch J. M., 1956; Graham R., 1959. See more details in volume 1.
60. Fick A.E., 1888a, 1888b.
61. See volume II, chapter 10, § 1.1.3, p. 5: 'Experiments on Rabbit's Eyes'
62. See volume II, chapter 10, § 1.1.5, p. 7-8: 'Experiments on the Eyes of Human Beings'
63. See volume II, p. 53; Fick A.E., 1887: « ich lies eine Glasblase von etwa 30 mm Durchmesser ausblasen u. aus dieser Glasblase eine Stelle von der Grösse de Hornhaut vorblasen, dann wurde eine ovale Linie, etwa wie der Contour eines künstlichen Auges, um die Glascornea gezeichnet u. auf dieser Linie abgesprengt. »
64. See volume II, chapter 17, § 1.2, p. 267-268: 'Friedrich E. Müllers "Inaugural Dissertation" (1920)'
65. See volume II, chapter 11, p. 59-81: 'Eugène Kalt's "Optical Treatment" of Keratoconus'.
66. See volume II, chapter 12, p. 84-120: 'August Müller's "Hornhautlinse".
67. See volume II, chapter 16, p. 239-257; Graham R., 1959: p. 63-64; Hartinger H., 1950: « Haftgläser ohne Skleralteil sind von Carl Zeiss, Jena, schon im Jahre 1912 hergestellt worden. Unter anderen hat solche besondere Haftgläser Prof. Dr. H. Erggelet getragen; er machte sich damit künstlich ametrop und erprobte auf diese Weise die optische Gute der punktuell abbildenden Brillengläser.“
68. See volume II, chapter 18, p. 284-285; Weill G., 1928 : « Les premiers modèles de Zeiss, d'avant-guerre, tout en donnant de meilleurs résultats que ceux de Müller, étaient mal supportés puisqu'ils prenaient la cornée comme seul point d'appui. Depuis que la maison Zeiss en a modifié la forme en y ajoutant une collerette qui s'applique sur la conjonctive, comme je le lui avais déjà recommandé il y a bien des années, cette forme de prothèse me paraît remplir les desiderata qu'on est en droit de demander à un verre à contact. »
69. Weve H.J.M., 1932a, 1932b. Presentations to the Deutsche Ophthalmologische Gesellschaft in Leipzig (May 1 - 9, 1932) & to the Neederlandsch Oogeheelkundig Geselschap in Amsterdam 22th July, 1932.
70. Weve H.J.M., 1932a: « Diese Spiegeluntersuchung wird sehr erleichtert durch das Aufsetzen einer kleinen Hornhautkontaktschale von Zeiss. Hat man eine Undine mit physiologischer Kochsalzlösung zur Hand, so ist es ein Leichtes, das Schälchen nach eventueller Verschiebung wieder ohne Luftblase auf die Hornhaut zu bringen. Die Hornhaut bleibt klar und unregelmäßiger Astigmatismus infolge von Eintrocknen bleibt aus. Es sei noch bemerkt, dass dieses Schälchen auch bei Meridianbestimmungen gute Dienste leistet, da dadurch der sog. Meridianfehler infolge von Astigmatismus vermieden wird."
71. Weve H.J.M., 1951.
72. Obrig T.E., Salvatori P.L., 1957: p. 377-379.
73. Kronfeld P.C., 1949 : in Nugent M.W., 1949.

74. Bowden T.J., 2009: p 165.
75. Gualdi V., 1934, see chapter 23, § 3.1.
76. Allen. E. L., 1944, 1945a, 1945b; Graham R., 1959: p. 11-12.
77. October 25, 1950.
78. December 9, 1953: Pacific Contact Laboratories Inc. versus Solex Laboratories Inc. US States Court of Appeals, Ninth Circuit. <1953: 9Cir.,209F.2d529, 532, 533>. (100 U.S.P.Q.12 No 13333).
79. August 6, 1958. Solex Laboratoriess, Inc. versus Graham: 165 F. Supp.428. United States District Court S.D. California, Central Division.
80. Zabener emigrate to Israël and Tuohy started his own laboratory in Wiltshire Bouleward at the Miracle Mile. He committed suicide in 1968.
81. Solex Labs, Inc. versus Butterfield, 202 F.Supp. 461 (D.Or. 1961) April 1962. - The four licenses of Butterfield were: Titmus Optical Co., Utah Optical Supply Co., Rogers Bros and Southern Contact Lens Laboratories Inc.
82. Plastic Contact Lens Co. versus George H. Butterfield Sr. 366 F.2d 338 (9th Circ. 1966).
83. October 29,1969: Plastic Contact Lens Co versus Frontier of the Northeast, Inc. US District Court for the Western District of New York. <324 F. Supp. 213 W.D.N.Y. 1969>
84. The Plastic Contact Lens Company versus Frontier of the Northeast Inc. U.S. Court of Appeals, Second Circuit <441 F.2d 67 169 U.S.P.Q. 689, 1971>.
85. October 6, 1971: Butterfield versus Oculus Contact Lens Co. US District Cout N.D. Illinois, E.D. <332 F.Supp. 750, 1971>. The historical memoir is partially in error and contains typographical errors such as "Fisk" for "Fick" and "Dallas" for "Dallos".
86. Mandel R., 1965, first edition, p.15.
87. Mandel R., 1988, fourth edition, p.15.
88. See chapter 24.
89. Mandell R.B., Polse K.A., Harris J.D., 1998.
90. Bier N., 1953b.
91. Dickinson F., 1954a, b; Neill J.C., 1954; Soehnges W.P.
92. Bier N., 1957, p. 143.
93. Bier N., 1957, p.190.
94. Bier N., 1957, p.143.
95. Bier N., 1957, p.144.
96. Bayshore C.A., 1962, 1964a, b; Davis H.E., 1964; Rosenthal, 1966; Sarver, 1966; Hodd, 1966, 1968; Loran, 1969.
97. Bier N., 1957a, p.143-144.
98. Stone J., Phillips A.J., 1980, p.23.
99. Salvatori Ph.L., 1972.
100. Neefe C.W., 1962; Volk D., 1962, 1965a, b, 1967, 1977.
101. Volk D., 1987.
102. Thomas P.F., 1967; Ruben M., 1966, 1975; Nissel G., 1967.
103. Fritz A. & R., 1945a, b; Butterfield G.H., 1950; Stimson N.P., 1951; Elliot D.O., 1964.
104. Wesley N.K., 1972.
105. The documentation and the description of these specialized shapes go beyond the scope of the historical survey of this era.
106. Girard L.J., 1964 p. 39 & 1970 p.15.
107. Girard L.J., 1967; Agatston H.J., 1967.
108. Wohlrabe R.G., Moore J.W., 1967.
109. McGuire W.A., 1967.
110. Sanning F.B., 1967.
111. Smelzer, G.K., 1952; Smelzer, G.K., Ozanics O., 1952, 1953; Smelzer, G.K., Chen D.K., 1955; Hill R.M, Fatt I., 1963a, b, 1964a, b, c.
112. Bier-Lowther, 1977; Boberg-Ans, 1952, 1955, 1956; Cochet P., 1960, 1957; Cochet P., Bonnet R., 1957; Hirano J., 1959; Mishima S., 1965, 1968; Mishima S., Maurice D.M., 1961.
113. Tuohy K.H., 1960; Wesley N.K., 1988.
114. Bailey N., 1987.
115. Wesley N.K., 1988.
116. Wesley N.K., Jessen G.N., 1950, 1953, 1956, 1959a, b, 1960a, b, c, 1961; Wesley N.K., 1958a, b, 1962, 1964, 1966, 1969, 1972a, 1974.
117. Bailey N., 1987.

118. Wesley N.K., 1988.
119. Wesley, N.K., Jessen G.N., 1956.
120. Wesley N.K., 1958, 1959, 1962; DeCarles J.T., 1957, 1959a, b, 1964.
121. Cepero G.P., 1958; Plastic Lens Co., 1959; Wesley N.K., 1958a; Wesley N.K., Jessen G.N., 1959b, 1961; Townsley M.G., 1967.
122. Wesley N.K., 1988, p.123.
123. Granted by the 'General Not-for-Profit Corporation Act' of the State of Illinois.
124. There was to be much criticism of Contacto for becoming an in-house publication.
125. It was recorded that $3.00 invested was worth $15 when the company was sold in 1981 (Wesley. 1988).
126. Georg Jessen retired from the organization in 1968 and died in 1987. Newton Wesley died in July 2011 at the age of 93.
127. Becker W.F., 1962.
128. Butterfield J.H., 1968.
129. Tuohy K.M., 1960.
130. The two founders of Solex had sold their shares: Solon Braff to Kevin M. Tuohy, Xavier Villagran to Louis M. Zabener. In 1960, after the take-over of Solex by Plastic Contact Lens Company, Tuohy started his own laboratory, 6615 Wiltshire Boulevard, Los Angeles. He committed suicide in 1968. Zabener emigrated to Israel.
131. Obrig T.E., Salvatori P.L., 1957. Theo E. Obrig died 23th February 1967.
132. Stimson N.O., 1951.
133. Moss H., 1962.
134. Gordon S., 1959.
135. Feinbloom W., 1961.
136. Ewel D.G., 1959.
137. Neefe C.W., 1959, 1962.
138. Hornstein J.J., 1952.
139. Silverstein S.W., 1950.
140. Bayshore C.A., 1962, 1963, 1964a, b.
141. Boyd H.H., 1960, 1963.
142. Volk D., 1962, 1965a, b, 1967, 1977, 1984.
143. Dabezies O.H., 1965; Sampson W.G., Feldman G.L., 1970.
144. Shapero M., 1960.
145. Editorial (H.F.A.), 1961; Girard L.J., Soper J., Camp R., 1961; Cassady, J.R., 1961.
146. Advertising Conforma , Dow Corning Ophthalmics, May 1980.
147. Dallos J., 1964.
148. DeCarle J.T., 1955, 1957, 1959a, b, 1964.
149. Söhnges P.W., 1961, 1962.
150. Emmerich K., 1962.
151. Mathieur P., 1953. Presentation on the 22nd February 1953 to the Belgian Society of Ophthalmology followed by discussions by P. Daenens and L. Weekers.
152. Cochet P., Maréchal-Courtois C., Prijot E., 1967.
153. The first 'Study Day at Royaumont' was held in 1963.
154. Bronner A., Gerhard J-P., 1958; Bonnet R., Cochet P., 1960; Cochet P., Bonnet R., 1957a, b, 1961; Bonnet R., 1964; Bonnet R., Gerhard J-P., Massin M., 1966.
155. Knüsel O., 1953a, b, c, d.
156. Györffy, I.v., 1961.
157. Silva Da, 1953; Tuohy K.M., 1988: Lentes de Contacto, S.A. Super Lentes Tuohy, Av. Insurgentes No 377, Mexico D.F.
158. Mizutani Y., 1953, 1954, 1964, 1966; Jojima, A. Kaigen, 2001.
159. Thomas P.F., 1967.