Chapter 15

Early Blown Contact Lenses

Introduction

The difficulties of manufacturing ground contact lenses and the poor toleration of them discouraged potential wearers. Hydrodiascopes supplanted the first ground and blown contact lenses (1) of *Fick* and *Sulzer* for some time**.** However**,** they were never particularly successful except in the opinion of their promoters, *Lohnstein* and *Siegrist.* This was because they disfigured their wearers, in spite of reasonably good optical results. As a result, the problem of the optical correction of major anomalies of the cornea such as keratoconus remained unsolved.

It is true that certain devices resembling ocular prostheses had been used from time to time to protect ocular globes exposed to potential injury in patients with palpebral lesions that could not readily be corrected by surgery. However, these "prosthetic shells" were never intended or indeed fashioned for the purpose of optical correction. Nevertheless, after the first decade of the 20^{th} century, the concept of glass shells that would correct errors of refraction slowly advanced, step by step, leading to their commercialization by artificial eye makers. Among these were the *Müller Brothers (Friedrich Anton* and *Albert Carl Müller),* proprietors of the firm *The Sons of F. Ad Müller*, manufacturers of blown glass eyes and contact shells. Actually, such shells were already being used in various German towns where the *Müller* ocularists were accustomed to exercise their itinerant trade as glass blowers of ocular prostheses.

This chapter retraces the chronology starting with the development of prosthetic shells from the end of the 19th century and progressing towards the first blown scleral contact shells.
An analysis of technical and medical aspects of these shells and contact lenses follows with particular reference to their unique application to the correction of keratoconus.

1 - Source Documents

The documents describing evidence for the utilization of early blown scleral contact shells or lenses lead to the identification of three distinct periods in their development:
a first period (1885-1913), corresponding to the progressive evolution of "prosthetic shells" for therapeutic and cosmetic use to scleral contact shells destined for the correction of keratoconus,
a second period (1913-1916), marked by the first publications on the utilization of scleral blown contact shells for the correction of keratoconus,
a third period (1916-1917), characterized by a more scientific process, thanks to the publications of the *University Ophthalmology Clinic in Berne* (Switzerland) where the advantages and disadvantages of blown scleral contact shells were systematically assessed.

The Evolution from Ocular Prostheses to the First Scleral Contact Shells (1885-1913)

1.1.1 – Some Distant Precursors (1885-1892)

There are no documents relevant to the era prior to 1888 that could verify the use of scleral contact shells or lenses for the correction of refractive errors. Nevertheless, from this period on, certain blown glass shells, the designs of which took inspiration from ocular prostheses and which were equipped with a transparent central part, had been used for the protection of eyes unprotected from exposure to air because of palpebral injuries. (2)

Ocular Prostheses
In the 19th century, ocular prostheses were a specialty of the French ocularists. After having been introduced into Germany at the beginning of that century by glass blowers of the Lauscha region (Thuringen, Germany), they were presented to the *Heidelberg Congress of Ophthalmology* (3) in 1885. It is likely that this presentation inspired certain physicians who attended that congress and that it suggested that they use similar shells in other pathological contexts, in reply to their plea for the introduction of a transparent central part. This gives certain credibility to the priority claims of the ocularists *F.A. and A.C. Müller Brothers* of Wiesbaden that their firm had, in 1887, supplied a blown protective shell to Professor *Sämisch* of Bonn. The shell in question was provided with a transparent corneal part for the only eye of a one-eyed patient afflicted with lagophthalmos, whose eyelids had been destroyed by cancer. According to the brochure of the *Müller Brothers* and to the thesis defended in 1920 by their son and nephew *F.E. Müller,* a similar shell was also supplied for a female patient of *Dr. Fränkel* at Chemnitz by reason of entropion and trichiasis. It was on this occasion, some three or four years later and after the publications by *Fick, Kalt* and *August Müller*, that the ocularists claim to have noticed the refractive effect of the glass shells but admit that they did not immediately draw the conclusion that an optical correction might have been possible:

"We did not pay any further attention in regard to the further development of this aspect in an optical direction, taking into account that, in patients with relatively low-grade myopia, optical correction could be more conveniently achieved by conventional spectacle glasses, until that time when some cases of keratoconus came under our care."

„Wir wandten dem Ausbau dieser Sache nach der optischen Richtung hin weiter keine Aufmerksamkeit zu,

da bei nicht zu hochgradiger Myopie die optische Korrektur zweckmässiger durch eine Brille gewöhlicher Art bewirkt wird, bis uns einige Fälle von Keratoconus unter die Hände kamen." (4)

The Blown Contact Shells of Fick and Kalt (1888)

We should recall that *Fick* used blown contact shells in 1887 for his first experiments on rabbits and on himself, although he did not specify their origin. It is probable that they were made to order by a Zürich glassblower. He had, however, asked *Abbe* of *Zeiss* for ground shells for human application that he used as such, in good faith, for his most important work. In fact, *Abbe* sent him blown contact shell, and it is indeed in spite of himself that *Fick* figures among the users of blown contact shells. He carried out his experiments in total ignorance of their nature, and it was only when he sent them as a prototype for the optician *Himmler* of Berlin at a later date that he discovered that he had been the victim of a hoax (5).

Eugène Kalt had also used some blown contact shells for the presumed "treatment" of keratoconus in his first experiments on Professor *Panas's* unit at the *Hôtel-Dieu Hospital* in Paris. These consisted of "a piece of the bubble blown by the glassblower", as *Haas* put it at a later date. (6)

1.1.2 – The Early Blown Contact Shells for the Correction of Keratoconus (1908-1916) *(Appendix 15 – 1)*

In their brochure published in 1910 entitled ***"Das künstliche Auge"*** *(The Artificial Eye*), the ocularists *Friedrich A.* and *Albert C. Müller* report the use of prosthetic shells with transparent corneas for the optical correction of five patients affected by keratoconus.

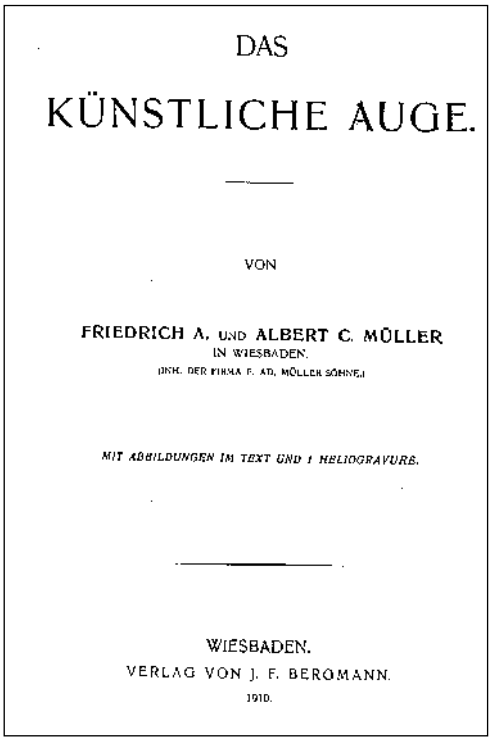
Year	***Author***
1908	*Pagenstecher (Wiesbaden)*
1908	*Axenfeld (Freiburg-im-Breisgau)*
1909	*Uthoff (Breslau)*
1909	*Schlösser & Beutnagel (Munich)*
1909	*Mayweg (Hagen)*

Table 15 - 1
In 1910, the Brothers F.A. et A.C. Müller claimed to have furnished blown scleral contact shells to various German physicians for the optical correction of keratoconus.

Pagenstecher and Axenfeld (1908)

According to the *Müller* ocularists, the first contact shells that were manufactured specifically for optical correction were fit in 1908 in two patients suffering from keratoconus, but unsuccessfully. These patients were under the care of *Pagenstecher* of Wiesbaden and *Axenfeld* in Freiburg-im-Breisgau (7). In spite of the improvement obtained in vision, the patients were not satisfied and abandoned the devices:

"A case that was referred to us from the Pagenstecher practice [...] and a second case that


DAS

KÜNSTLICHE AUGE.

VON

FRIEDRICH A. UND ALBERT C. MÜLLER
IN WIESBADEN.
INH. DER FIRMA F. AD. MÜLLER SÖHNE.

MIT ABBILDUNGEN IM TEXT UND 1 HELIOGRAVURE.

WIESBADEN.
VERLAG VON J. F. BERGMANN.
1910.

Figure 15-1
Brochure "Das Künstliche Auge" (The artificial eye) of the Brothers F.A. and A.C. Müller of Wiesbaden, 1910)
In 1910, Friedrich A. and Albert C. Müller published a brochure entitled "Das Künstliche Auge" (The Artificial Eye), of which pages 68 to 72 were devoted to "Kontakt-Adhäsionsbrillen" (Adhesion contact-spectacles). In Part 1 (pages 68 - 69), they describe the use of a "protective shell" (Schutzschale) by Sämisch in one of his patients for protection of the eye against lagophthalmos and trichiasis. Part 2 (pages 70 - 72) is devoted to specific shells for the correction of keratoconus.
(MÜLLER Friedrich A. & Albert C., Das Künstliche Auge, Wiesbaden, Bergmann, 1910.)

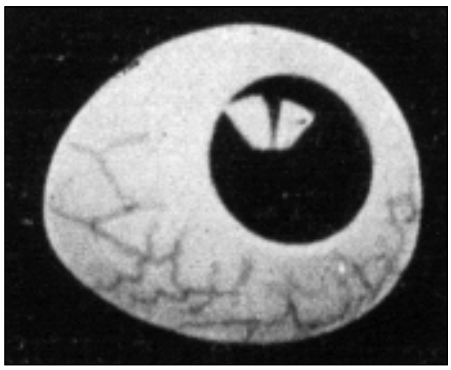


Figure 15-2
Drawing of a blown contact shell of the Brothers F.A. and A.C. Müller of Wiesbaden (1910). Drawing of an "Adhesion contact-spectacle" (Kontakt-Adhäsionsbrille) reproduced in the brochure of the Müller Brothers "Das Künstliche Auge" (The Artificial Eye) on page 69.
(MÜLLER Friedrich A. & Albert C., Das Künstliche Auge, Wiesbaden, Bergmann, 1910.- Figure page 69)

was sent by Professor Axenfeld's demonstrated that optical correction by a 'Kontaktbrille' of our manufacture could certainly be achieved. However, the patients concerned did not persevere."

"Ein Fall, der uns aus der Prof. Pagenstecherschen Praxis [...] zugeführt wurde und ein zweiter aus der des Prof. Axenfed zeigten, dass ein optischer Ausgleich durch eine Kontaktbrille nach unserer Art sehr wohl zu erzielen war. Aber die Patienten hatten keine Ausdauer." (8)

Uhthoff (1909)

In the same year, *Uhthoff* of Breslau (Germany) also fit blown shells on an eye with keratoconus. He too obtained a favorable result and noted good tolerance of the shells. *Müller* does not give details regarding the duration and the progress of these trials:

"*We are grateful to Privy Counselor R. Uthoff for his kind referral of an additional patient to us, in March 1908. She too had a good result. This same patient received a second shell in the following year to replace the one she had broken in the meantime. This lady can read the 'Nonpareille' script at the normal reading distance with the spectacle and tolerates it well."*

« Ein weiterer Fall den wir der gütigen Vermittlung des Hern Geh. R. Uhthoff verdanken, brachte gleichfalls ein gutes Ergebnis im März 1908. Die gleiche Patientin erhielt ein Jahr später einen Ersatz für die inzwischen zerbrochene Schale; sie kann mit der Brille Nonpareilleschrift in normaler Entfernung lesen und verträgt sie gut." (8)

However, *Uhthoff* did not share the optimism of the *Müller Brothers*, as shown by the following comment that he wrote later in the same year:

"In the last little while, I had the opportunity to make use of contact glasses made by Müller of Wiesbaden, which were placed directly on the ocular globe. The improvement in visual acuity was, to a degree, quite significant. However, these glass lenses were not well tolerated in the long term and were from time to time subject to displacement with movements of the globe. It is quite possible that the skilled and proven Wiesbaden glassblowers may succeed in producing a usable device."

"In letzter Zeit habe ich noch Gelegenheit gehabt, von Müller (Wiesbaden) hergestellte Kontaktgläser, welche direkt auf den Bulbus aufgesetzt wurden, zur Verwendung zu bringen. Die Verbesserung de Sehschärfe war zum Teil eine erheblich, doch wurden diese Gläser auf die Dauer nicht gut vertragen und erlitten auch zum Teil eine Verschiebung bei den Bewegungen de Augapfels. Wohl möglich, dass es hier dem bewährten Wiesbadener Techniker noch gelingt, Brauchbares zu schaffen." (9)

Mayweg (1909)

While passing through the city of Bochum, the ocularist blew a glass shell on the spot for a patient whose ophthalmologist was *Mayweg* in neighboring city Hagen. According to *Müller,* she wore the lens day and night continuously for six months (10):

"Another case from the practice of Privy Counselor R. Mayweg in Hagen was treated very successfully in Bochum April 5, 1909. The patient wore the shell continuously day and night until October 3, 1909, when it escaped him and broke while he was cleaning it under the

open sandstone water conduit. The replacement shell provides the same service."

"Ein weiterer Fall aus der Praxis von Geh. R. Mayweg, Hagen wurde mit gutem Erfolg in Bochum am 5. April 1909 behandelt. Der Patient trug die Brille bis 3. Oktober 1009 ununterbrochen Tag und Nacht, bis sie ihm beim Reinigen unter der offenen Wasserleitung auf Sandstein sprang und zerbrach. Die Ersatzschale leistet die gleichen Dienste." (8)

The Recommendations of the Ocularists F.A. and A.C. Müller (1910)

In the light of these successes, *Müller Brothers* mention the prospects that were opening up for this new practical mode of correction both for keratoconus and high myopia in their brochure:

"A vast field is opening up for the utilization of this type of spectacle, just as soon as we have the opportunity to gain more experience. Aside from keratoconus, high myopia is also an indication for these. Their manufacture demands tremendous effort on the part of the artist, for true corneal refraction can be achieved only by visual estimation and comparisons made during the blowing process. During the process, the radius of curvature of the globe must be reproduced as precisely as possible, although this too can be done only by visual estimation."

"Der Verwendung dieser Brillenart steht ein weites Feld offen, sobald uns öfter Gelegenheit geboten sein wird zu häufigen Versuchen, denn ausser der Korrektur von Keratokonus kommt auch die hochgradige Myopie in Frage. Die Herstellung erfordert ein äusserstes Mass von Anstrengung des Künstlers, da die richtige Brechkraft der Kornea nur durch Augenmass und Vergleiche während des Blasens erzielt werden kann, und dabei der Krümmungsradius des Augapfels genau getroffen werden muss, wobei auch nur das Augenmass zur Anwendung kommen kann." (11)

They also mention failures that they attribute to a lack of perseverance by patients and to poor corneal geometry:

"In other cases, results were not obtained for the time being, as patients did not have enough time and patience. Sideways displacement of the tip of the cone and periodical change in the corneal displacement in addition to irregular corneal astigmatism greatly increase the difficulty of the work. For the practical solution of these problems, it will be necessary to proceed to a study of the refraction in keratoconus."

„In anderen Fällen wurde vorläufig kein gutes Resultat erzielt, weil die Patienten zu wenig Zeit und Geduld hatten. Seitliche Lage der Kegelspitze und regelmässige Stärke der seitlichen Wandlung der Hornhaut, irregulärer Astigmatismus überhaupt, erschweren die Arbeit sehr. Es muss zur praktischen Lösung dieser Aufgabe ein Studium der Brechungsverhältnisse des Keratoconus vor sich gehen." (11)

The blown contact shells of *Müller Brothers* even appeared to have a therapeutic effect by slowing the development of keratoconus:

"*We have already observed a favorable effect when these shells are employed, taking into account that the summit of the cone is protected against further desiccation."*

"Einen günstigen Einfluss beobachteten wir schon bei Gebrauch dieser Schalen, insofern als die Spitze des Kegels gegen weitere Eintrocknung geschützt wird." (8)

Blown contact shells would be superior to the ground lenses of *Fick* and *Sulzer* because they would better resist the attack of tears:

"The value of these little glasses as compared with ground ones lies in the fact that they are melted and thus permanently resist the lacrimal liquid and mechanical irritation. For this reason they are almost not subject to wear and tear, while in the case of ground lenses (which are made out of a softer material) the pores are open and become opacified after a relatively short time."

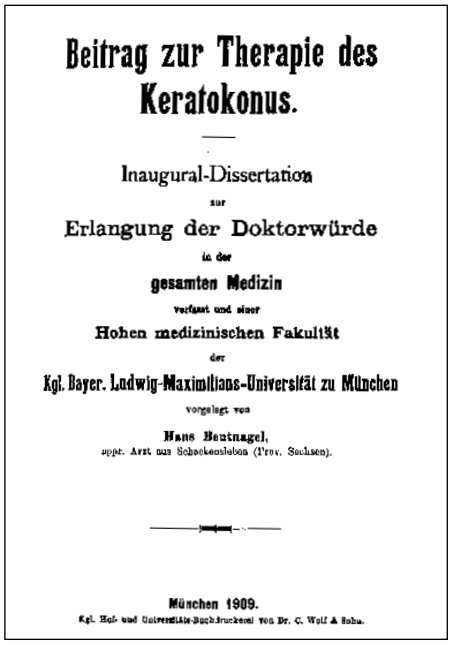
"Der Wert dieser Gläschen gegenüber den Geschliffenen liegt darin, dass sie geschmolzen sind, also der Tränenflüssigkeit, sowie der mechanischen Reizung einen dauernden Widerstand entgegensetzen, das heisst fast nicht abgenützt werden, während bei den geschliffenen Gläsern (an und für sich weicheres Material) die Poren geöffnet sind und nach verhältnismässiger kurzer Zeit blind werden." (8)

1.2 – The Early Publications (1909 - 1916)

Year	
1909	*Beutnagel (Munich): "Beitrag zur Therapie des Keratoconus" (Contribution to therapy of Keratoconus)*
1913	*Helmbold (Danzig): "Beitrag zur Sehverbesserung bei Keratokonus" (Contribution to visual Improvement in Keratoconus)*
1914	*Bielschowsky (Marbourg/Lahn): "Keratokonus" (Keratoconus)*
1916	*Weill (Strasbourg): "Ueber Korrektion des Keratokonus durch Prothesen" (Concerning Correction of keratoconus by Prostheses)*
1916	*Kraupa (Teplitz): "Kritische Beiträge zur Auffassung des Krankheitsbildes des 'Keratokonus' " (Critical Contributions to the Understanding of the Clinical Picture of Keratoconus)*

Table 15 - 2
In 1910, the Brothers F.A. et A.C. Müller claimed to have furnished blown scleral contact shells to various German physicians for the optical correction of keratoconus.

1.2.1 - Schlösser / Beutnagel (1909)



Beitrag zur Therapie des Keratokonus.

Inaugural-Dissertation

zur

Erlangung der Doktorwürde

in der

gesamten Medizin

verfaßt und einer

Hohen medizinischen Fakultät

der

Kgl. Bayer. Ludwig-Maximilians-Universität zu München

vorgelegt von

Hans Beutnagel,

appr. Arzt aus Schackensleben (Prov. Sachsen).

München 1909.

Kgl. Hof- und Universitäts-Buchdruckerei von Dr. C. Wolf & Sohn.

Figure 15-3
Front page of the doctoral thesis of Beutnagel (1909)
Hans Beutnagel's "Inaugural-Dissertation" in medicine is the first document to describe the fitting of Müller-Brothers contact shells on a patient with keratoconus.
(BEUTNAGEL Hans, Beitrag zur Therapie des Keratokonus, Inaugural-Dissertation München, Wolf, München, 1909)

In 1909, *Schlösser* hospitalized a female patient with keratoconus in his *Munich Eye Clinic* and fitted her two eyes with *Müller* ocular shells made from blown glass. This observation is quoted and itemized in detail in *Beutnagel's* "Inaugural Dissertation", submitted in Munich in 1909, entitled *"**Beitrag zur Therapie des Keratokonus**" (Contribution to the management of keratoconus):*

"The eyes of the patient are lightly cocainized and the prosthesis is inserted. The space between the cornea and the small glass shell is filled up with sterile saline solution while lightly elevating the upper border of the shell after its insertion and instilling the saline solution with a pipette."

"Die Augen der Patientin werden leicht cocainisiert und die Prothese eingesetzt. Der Zwischenraum zwischen Cornea und Schälchen wird mit steriler Kochsalzlösung ausgefüllt, derart, dass man den oberen Rand der Schälchen nach Aufsetzung derselben leicht lüftet und mittels Pipette Kochsaltzlösung einträufelt." (12)

After a second attempt with another contact shell, visual acuity in both eyes progressed to about 20/40. During the six days to follow, the shells were worn night and day without interruption. Then, the patient was lost for follow up.

"From February 8th to 14tth. The patient has been wearing the prostheses during the whole of this period, both day and night. She cleans them only twice a day. She has been having no symptoms worthy of mention apart from mild conjunctival irritation on the first day."

"8.II bis 14.II. Patientin trägt während dieser ganzen Zeit tags sowohl wie nachts die Prothesen, die nur täglich zweimal gereinigt werden. Nennenswerte Beschwerden hat Patientin nicht, abgesehen von der leichten conjunctivalen Reizung am ersten Tage." (13)

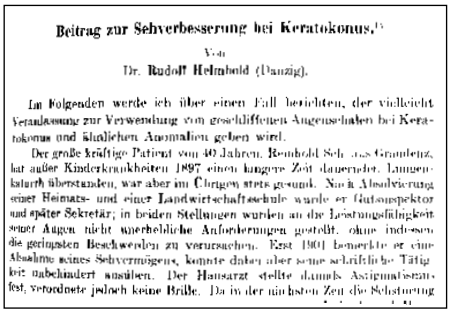
These trials were carried out in the presence of *Müller*, the ocularist. He made modifications as he went and as his observations indicated. A year later, he made the following comments:

"The correction was perfect in both eyes, in spite of the presence of a central leukoma in the left. The patient read fine print with both eyes at the normal distance and wore the shells without irritation. Her visual acuity reached the following level after the first signs of irritation disappeared:
Right Eye: 5/25, 5/10 with +2.0 +2 Cyl x 90°
Left Eye: 5/20, 5/10 with –2.00, N 1
With both eyes together, she comfortably read 5/10 N.I.
It was decided that filling the shell with liquid in order to obtain passage of the rays of light was unnecessary, taking into account that accumulated lacrimal fluid fulfilled this function."

"Auf beiden Augen gelang die Korrektur vorzüglich, obwohl linksseitig bereits ein zentrales Leukom vorhanden war. Die Patientin konnte beiderseits feine Schrift in normaler Entfernung gut lesen, und vertrug die Schalen ohne jeden Reiz. Der Visus betrug, nachdem die ersten Reizerscheinungen geschwunden:
rechts 5/25 + 2,0 Cylinder + 2,0 a + 90° 5/10 part.
links 5/20 - 2,0 5/10 part. N.I.
Binokular las die Patientin bequem 5/10 N.I.
Es wurde festgestellt, dass die Einführung von Flüssigkeit nicht nötig ist, um den ungehinderten Durchgang der Strahlen zu bewirken, da die sich ansammelnde Tränenflüssigkeit diese Aufgabe erfüllt." (8)

1.2.2 – The "Eye-shells" of Helmbold (1913)

The first communication on blown contact shells to appear in a medical journal is that of *Helmbold*, an ophthalmologist in Danzig: "***Beitrag zur Sehverbesserung bei Keratoconus"*** *(Contribution to visual improvement in keratoconus)*. The author describes how, in 1912, he had placed *Müller* contact shells on the eyes of a patient suffering from bilateral keratoconus that had been unsuccessfully treated by cauterization, tattooing, and iridectomy. The hydrodiascope alone had temporarily improved the patient's eyesight. The progression of the disease and repeat cauterizations rendered the patient



Beitrag zur Sehverbesserung bei Keratokonus.[1]

Von

Dr. **Rudolf Helmbold** (Danzig).

Im Folgenden werde ich über einen Fall berichten, der vielleicht Veranlassung zur Verwendung von geschliffenen Augenschalen bei Keratokonus und ähnlichen Anomalien geben wird.

Der große kräftige Patient von 40 Jahren, Rembold Sch. aus Graudenz, hat außer Kinderkrankheiten 1897 einen langere Zeit dauernden Lungenkatarrh überstanden, war aber im Übrigen stets gesund. Nach Absolvierung seiner Heimats- und einer Landwirtschaftsschule wurde er Gutsinspektor und später Sekretär; in beiden Stellungen wurden an die Leistungsfähigkeit seiner Augen nicht unerhebliche Anforderungen gestellt, ohne indessen die geringsten Beschwerden zu verursachen. Erst 1901 bemerkte er eine Abnahme seines Sehvermögens, konnte dabei aber seine schriftliche Tätigkeit unbehindert ausüben. Der Hausarzt stellte damals Astigmatismus fest, verordnete jedoch keine Brille. Da in der nächsten Zeit die Sehstörung

Figure 15-4
The publication of Helmbold (1913). Helmbold's article entitled "Beitrag zur Sehverbesserung bei Keratokonus" (Contribution to Visual Improvement in Keratoconus) represents the first detailed publication by an ophthalmologist concerning blown contact shells manufactured by the Müller Brothers
(HELMBOLD Rudolf, "Beitrag zur Sehverbesserung bei Keratokonus", Zeitschrift für ophthalmologische Optik 1, 77-80, 1913/14 - Excerpt of page 77).

Figure 15-5
Illustration showing patient fitted by Helmbold with contact shells blown by the Müller Brothers. Figure 1 (page 78) shows the patient wearing blown scleral contact shell of the Müller Brothers in his left eye. The contact lens is not visible in the primary position.
(HELMBOLD Rudolf, "Beitrag zur Sehverbesserung bei Keratokonus", Zeitschrift für Ophthalmologische Optik 1, 77-80, 1913/14 - Figure 1, page 78).

Figure 15-6
Illustration showing patient wearing a blown scleral contact shell of the Müller Brothers. The patient is looking maximally upwards (maximal sursumversion).
Figure 2 (page 79) shows the patient wearing a blown scleral contact lens of the Müller Brothers in his left eye. The contact lens is visible only when the patient is forced to look u
HELMBOLD Rudolf, "Beitrag zur Sehverbesserung bei Keratokonus". Zeitschrift für Ophthalmologische Optik 1, 77-80, 1913/14 - Figure 2, page 79).

incapacitated by a visual acuity reduced to 5/35 in the right eye and 5/25 in the left. (14)

In 1912, *Helmbold* ordered "glass eye shells resembling artificial eyes" from ocularist *Müller* in Wiesbaden. These shells consisted of a transparent part with the "same diameter" as the cornea in their centers and a large white peripheral border.

"In order to eliminate a very annoying oblique astigmatism and to obtain good vision in all directions of gaze, I provided myself with ocular glass shells that resemble artificial eyes from the firm Sons of F. Ad. Müller in Wiesbaden. Such a shell, with a radius of curvature of 12 mm, has a transparent part in its center with the same diameter as the cornea and is designed with concentric plane parallel surfaces; the sclera is covered by a large white edge that passes over the corneal border."

"Um den hier in Frage kommenden stark störenden Astigmatismus schiefer Büschel auszuschalten und bei beliebiger Blickrichtung ein brauchbares Sehvermögen zu erreichen, ließ ich mir von F. Ad. Müller Söhne, Wiesbaden, Augenschalen aus Glas, ähnlich den künstlichen Augen, kommen. Eine solche Schale von 12 mm Radius hat im Zentrum in Hornhautgröße eine durchsichtige Partie von konzentrischen-parallelen Flächen; der über den Cornealrand ragende breite, weiße Saum bedeckt die Sklera." (15)

The choice of the good contact shell and its correct positioning did not present any great difficulty:

"When you have rather patiently inserted and tested a well-seated shell that goes very smoothly, the space between cornea and shell is filled with tears right away and the shell follows the movements of the eyes in all directions without being displaced. You note a significant improvement in eyesight immediately or shortly afterwards. In order to achieve further improvement, I place the best-correcting lens directly on the external crown of the shell. With a -8.00 diopter, visual acuity reaches 5/15 right and left and at a distance of 30 cm medium fine print was fluently read."

"Hat man mit einiger Geduld eine gut sitzende Schale ausprobiert und eingesetzt, was sehr leicht gelingt, so füllt sich alsbald der Raum zwischen Cornea und Schale mit Tränenflüssigkeit aus, und die Schale folgt den Bewegungen des Auges nach allen Richtungen, ohne sich zu verschieben. Man bemerkt nunmehr schon eine erhebliche Sehverbesserung. Um dieselbe aber noch weiter zu steigern, setzte ich direkt auf den Außenscheitel der Schale das bestkorrigierende Glas [...]. Mit – 8 dptr erreichte die Sehschärfe rechts wie links 5/15 und in 30 cm wurde mittelfeiner Druck fließend gelesen." (15)

Since an additional spectacle lens of –8.00 produced good visual acuity in this patient, *Helmbold* reports that he had sent his contact shells to *Zeiss* to have them ground to the corresponding refractive power. *Zeiss* indicates that the *Müller* shells were difficult to grind, for their constituent material contained internal stresses that weakened them. However, "in spite of the difficulty of this grinding and its elevated cost price, Zeiss sent

him a shell of the appropriate power without charge":

"The firm Carl Zeiss, Jena, to which I made application, was very obliging and made for me several shells that I ordered from them to correspond with the refractive power of 8 diopter. They made them free of charge, even though the task took great effort and involved significant expense.
The glass employed by Müller is unfortunately not free of streaks and does not have a sufficiently high refractive index or the necessary equilibrium of internal tensions, with the result that the lenses readily burst at the time of grinding. These deficiencies will most likely be alleviated by further experiments.

"Die Firma Carl Zeiss, Iena, an die ich mich wandte, ließ mir in entgegenkommendster Weise einige der eingesandten Schalen dem Brechungszustand von 8 dptr entsprechend schleifen und stellte sie mir kostenfrei zur Verfügung, obwohl die Herstellung sehr viel Mühe und nicht geringe Kosten verursachte.
Das von Müller verwandte Glas ist leider nicht frei von Schlieren, besitzt nicht den genügenden Brechungsindex und den erforderlichen Spannungsausgleich, so dass beim Schleifen die Gläser leicht platzen. Durch weitere Versuche sollen diese Mängel möglichst behoben werden." (16)

Subsequently, the patient's other eye was also fit in the same way and, for almost a year, he wore his lenses without the least discomfort and continued to wear them for many a long year. He returned to work and has cancelled his disability pension. His lenses are "invisible", as the illustrations accompanying the text show. (17)

We learn later that *Helmbold* had interpreted *Zeiss*'s reply incorrectly. The contact lens that the latter had forwarded to him was not the result of grinding the blown shell that Helmbold had sent Zeiss but an original contact lens or shell, probably a blown shell, the method of the fabrication of which had not been detailed to him by the firm. (18)

1.2.3 - The Blown "Glass Prostheses" of Bielschowsky (1914)

In 1914, *Bielschowsky*, Professor of Ophthalmology at Marburg, reports that he had fit a young woman who was suffering from advanced keratoconus with some "blown glass prostheses" (geblasene Glasprothesen), which gave her useful vision and which she had been wearing for 18 months without any discomfort:

"Bielschowsky (Marburg) demonstrates a case of bilateral advanced keratoconus.
The patient is female and 33 years old. She counts fingers at 4 meters with –20.00 D in her right eye and with –16.00 D in the left. She has been wearing blown glass prostheses of Müller (Wiesbaden) without any discomfort for a year and a half. As a result, she sees less than 1/3 with the right eye and 1/4 with the left eye after placing a glass of -3.5 D in front. She reads Jaeger #4 at approximately 20 cms. Ground glass prostheses are not tolerated."

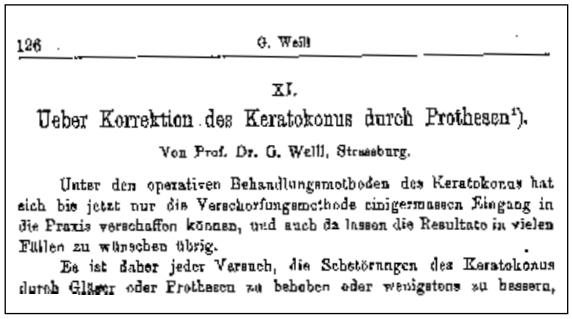
"Bielschowsky (Marburg) demonstriert einen Fall von hochgradigem beiderseitigen Keratokonus.
Die 35 jährige Frau hat rechts mit -20,0 D. und links mit - 16,0 D. S.=Fingerzählen in 4 m Entfernung. Sie trägt seit 1 ½ Jahren ohne jeglichen Beschwerden von Müller (Wiesbaden) geblasene Glasprothesen und hat damit rechts knapp 1/3 links nach Vorsetzen von - 3,5 D. ¼ Sehschärfe, liest Jaeger Nr.4 in ca. 20 cm. Geschliffene Glasprothesen sind nicht haltbar." (19)

Bielschowski refers to this idea again in his textbook "***Repertorium der Augenheilkunde"*** (Compendium of Ophthalmology), in which he specifies that it is necessary to correct residual ametropia with spectacle glasses:

"When the cornea is still unclouded, one can try placing a glass prosthesis (Müller, Wiesbaden) on the ocular globe. The tears that accumulate between the prosthesis and the cornea eliminate the irregular corneal refraction. With an appropriately chosen spectacle glass, one can get significant improvement in visual acuity."

"Wenn die Hh noch nicht getrübt ist, kann versucht werden, auf dem Bulbus eine Glasprothese (Müller, Wiesbaden) zu setzen. Durch die zwischen dieser und der Hh sich sammelnden Tränenflüssigkeit wird die unregelmäßige Brechung der Hh ausgeschaltet; dann ist mit passend gewählter Brille eine wesentliche Besserung der S. zu erzielen". (20)

1.2.4 – Three Strasbourg Keratoconus Cases fit by Weill (1916)



126 G. Weill

XI.

Ueber Korrektion des Keratokonus durch Prothesen[1]).

Von Prof. Dr. G. Weill, Strassburg.

Unter den operativen Behandlungsmethoden des Keratokonus hat sich bis jetzt nur die Verschorfungsmethode einigermassen Eingang in die Praxis verschaffen können, und auch da lassen die Resultate in vielen Fällen zu wünschen übrig.

Es ist daher jeder Versuch, die Sehstörungen des Keratokonus durch Gläser oder Prothesen zu beheben oder wenigstens zu bessern,

Figure 15-7
Georges Weill's publication (1916).
In 1916, Professor Georges Weill of the Strasbourg Ophthalmology Clinic published a study on the correction of keratoconus with Müller contact shells: "Ueber Korrection des Keratoconus durch Prothesen" (Concerning Correction of Keratoconus by Prostheses)
(WEILL Georges, "Ueber Korrektion des Keratokonus durch Prothesen", Klinische Monatsblätter für Augenheilkunde, 57, 1916, 126-18. - Excerpt page.126)

In 1916, *Weill,* Professor of Ophthalmology at Strasbourg, published an interesting study on the correction of keratoconus patients at the Ophthalmology Clinic of that city using blown *Müller* contact shells: ***"Ueber Korrektion de Keratokonus durch Prosthesen"*** *(Concerning Correction of Keratoconus by Prostheses)* (21)

Weill describes how he had been using "*Müller's* prostheses" successfully for the previous three years. Moreover, these cases were of even greater interest in that the three female patients, whose histories he records, inserted and removed their contact shell themselves and wore there almost all day without problems:

"The Müller prostheses are thin eye-shells, in which the anterior segment - cornea, iris, and pupil - carry only a transparent cornea. The corneal refraction is different in different prostheses; a precisely determined curvature cannot be given to them because they are not ground but blown. What is so surprising to me is that such good results can be achieved with prostheses that are almost randomly produced. They are inserted like artificial eyes. Before insertion, they are filled with sterile physiological saline solution and, in order not to lose too much fluid, they are shoved under the lids with the patient leaning forwards. This cannot often be accomplished without fluid in this type of prosthesis, as I was soon to convince myself. If, in the course of insertion, too much fluid is lost, I fill up there and then with a dropper. A special instrument for filling keratoconus prostheses should also be readily available that I have read about somewhere, from which I conclude that these prostheses are also in use in other places; however, I have no information on that point."

"Die Müllerschen Prothesen sind dünne Schalenaugen, bei denen das vordere Segment - Kornea, Iris, Pupille - nur eine durchsichtige Kornea trägt. Die Brechung der Kornea ist in den verschiedenen Prothesen eine verschiedene; eine genaue, bestimmte Krümmung kann denselben, da sie nicht geschliffen, sondern geblasen sind, nicht gegeben werden. Um so auffalender ist es, dass mit solchen fast aufs Geratewohl angefertigten Prothesen doch so gute Erfolge erzielt werden können. Sie werden wie künstliche Augen eingeführt. Vor der Einführung werden sie mit steriler physiologischer Kochsalzlösung angefüllt, und um nicht zuviel Flüssigkeit zu verlieren, bei nach vorn gebückter Stellung des Patienten unter die Lider geschoben. Ohne Flüssigkeit ist bei dieser Art Prothesen, wie ich mich bald überzeugen konnte, nicht viel zu erreichen. Ist bei der Einführung zu viel Flüssigkeit ausgeflossen, so lässt sich dieselbe durch einen dünnen Tropfenzähler in situ nachfüllen. Ein besonderes Instrument zum Füllen der

Keratokonusprothesen soll übrigens, wie ich irgendwo gelesen habe, bereits angegeben sein, woraus zu schliessen wäre, dass die Prothesen auch sonst Anwendung gefunden haben; doch ist mir darüber nichts bekannt." (22)

The three female patients inserted their shells without anesthesia and without losing too much liquid. Trials with prototype contact lenses, ground by *Zeiss* without any scleral border, gave a superior optical result but were not well tolerated. The ideal would be a combination of blown and ground prostheses. *Weill* includes a summary of the three clinical observations.

First Observation:
"Case # I . Ms I. W., June 1915 bilateral keratoconus, more marked on the left. Right eye: visual acuity =1/10 unaided with difficulty, 1/3 with difficulty and with –4.00 Diopter Cylinder axis 100°; Left eye: visual acuity= counting fingers at 1 meter unaided, not improved by glasses.
With Müller's prostheses: Right eye visual acuity =1/3 to 1/2; Nieden 3 is read with that correction. Left Eye: visual acuity with prosthesis improves from finger counting at 1 meter to 1/3, and, at near, Nieden 4 script is read.
As the patient is unwilling to wear spectacles, Müller prostheses are inserted on both sides. She now inserts them herself without difficulty and wears them for practically the whole day. Several attempts with the Zeiss contact lenses were unsuccessful."

"Fall I. Fräulein I.W., Juni 1915. - Beiderseitz Keratokonus, besonders links. Sehschärfe rechts : schwach 1/10 ohne Glas, schwach 1/3 mit -cyl. 4,0 A. 100°. Sehschärfe links : Finger in 1 Meter ohne Glas, Gläser bessern nicht.
Mit Müllerscher Prothese ist Sehschärfe rechts 1/3 bis ½ ; in der Nähe wird damit Nieden 3 gelesen. Links steigt die Sehschärfe mit der Prothese von Fingezählen in 1 Meter auf 1/3, und in der Nähe wird Nieden vierte Schrift gelesen.
Da Patientin keine Brille tragen will, wird ihr beiderseits die Müllersche Prothese eingeführt, die sie nun seit jener Zeit ohne Beschwerden selbst einlegt und fast den ganzen Tag trägt. Mehrfache Versuche mit den Zeissschen Kontaktgläsern führten zu keinem Resultat." (22)

Second Observation:
"Case II. Deaconess Sister L.Z., September 1915.- bilateral keratoconus, worse in left eye. Visual acuity right: 1/4 with combined cylindrical glasses. Visual acuity left: 1/20 without glass, no improvement with glasses.
With Müller prosthesis, the visual acuity rises to 1/4; if I hold a +2.0 in front of her, visual acuity rises to ½ and from near the finest Nieden's print is clearly seen. With the Zeiss contact glass without saline solution, visual acuity rises likewise to 1/2, but the contact glass very quickly produces inflammatory symptoms. For that reason, Müller's prosthesis was re-inserted, and, since that time, it is worn by the patient for her duties as a nursing sister for practically the whole day."

"Fall II. Diakonissenschwester L.Z., Sept. 1915. - Beiderseits Keratokonus, besonders links. Sehschärfe rechts ¼ mit kombinierten Zylindergläsern. Sehscharfe links 1/20 ohne Glas, mit Gläsern keine Besserung. Mit Müllerscher Prothese steigt die Sehschärfe auf ¼ ; halte ich noch +2,0 davor, so steigt dieselbe auf ½ und in der Nähe wird damit Niedens feinste Schrift glatt gelesen. Mit dem Zeissschen Kontaktglase ohne Kochsazlösung steigt die Sehschärfe ebenfalls auf ½, aber das Glas ruft sehr bald Reizerscheinungen hervor. Es wird daher wieder die Müllersche Prothese eingelegt, welche seitdem fast den ganzen Tag von der Patientin in ihrem Dienst als Krankenschwester getragen wird." (22)

Third Observation:
"Case #3 (recently added) Mr. R., 43 years of age, July 1916. Bilateral keratoconus, especially left. Visual acuity both sides 1/20 without glasses.
With the Zeiss contact glass without border and without added water, visual acuity rises to

between ½ and 2/3. Patient is very happy because of the excellent vision but is able only to wear the glasses for only a short time because the eyes soon become inflamed. Müller's prostheses without water produce no significant improvement; with physiological saline, on the other hand, visual acuity rises in both eyes to a weak ½ and with placement of +3 in front, Nieden's finest print is read. Patient wears the prostheses for the whole day without difficulty."

"Fall III (neu hinzugekommen). Herr R., 43 Jahre alt, Juli 1916. - Beiderseits Keratokonus, besonders links. Sehschärfe beiderseitz 1/20 ohne Glas.
Mit dem Zeissschen Kontaktglas ohne Rand und ohne Wasserzusatz steigt die Sehschärfe auf ½ bis 2/3. Pat. ist entzückt über das grossartige Sehen, kann aber leider die Gläser nur kurze Zeit vertragen, weil die Augen bald gereizt sind. Die Müllerschen Prothesen ohne Wasser ergeben keine wesentliche Besserung ; mit physiologischer Kochsaltzlösung dagegen steigt die Sehschärfe beiderseits auf schwach ½ und bei Vorhalten von + 3, wird Niedens feinste Schrift gelesen. Patient trägt die Prothesen den ganzen Tag ohne Beschwerden." (22)

1.2.5 – Kraupa's Two Cases (1916)

In a full-length article on the etiology and pathology of keratoconus, entitled *"**Kritische Beiträge zur Auffassung des Krankheitsbildes des Keratoconus"** (Critical Contributions to the understanding of the clinical picture of keratoconus), Kraupa,* an ophthalmologist at Teplitz (Western Bohemia, now part of the Czech Republic), indicates in a footnote that he had not obtained any good results with a contact shell in the patient whose history he recounts. However, in another female patient, he obtained an improvement from perception of light to 0.3. He quotes authors who indicate good results and expresses the hope that *Zeiss* will agree to grind the optical portion of blown shells, as had been done for *Helmbold's* patient (23):

"I was not able to obtain any improvement with Müller's contact prostheses. Probably, no appropriate prosthesis was found in the sample selection forwarded by the firm. In such cases the prostheses must first be ground [Helmbold]. In favorable cases it is of course possible to obtain significant improvement of visual acuity; thus I could once improve an elderly lady from 'counting fingers' at 2 meters to a visual acuity of 0.3. Exceptionally favorable results have also been obtained by Bielschowsky, Erggelet, and recently Siegrist. To Siegrist we owe the excellent suggestion of arranging the keratoconus prostheses in lens cases according to corneal refraction. The appropriate intermediate powers can surely be manufactured by grinding, as has already been done for Helmbold by the Zeiss Company."

"Eine Besserung mit Müllerschen Kontaktprothesen konnte ich nicht erzielen. Wahrscheinlich hat sich in der mir von der Fa. überlassenen Auswahlsendung keine passende befunden. In solchen Fällen muss die Prothese eben erst zugeschliffen werden [Helmbold]. In günstigen Fällen gelingt es natürlich, eine wesentliche Besserung der Sehschärfe zu erzielen; So konnte ich einmal eine ältere Dame von Fgz. auf 2 Meter auf V. = 0,3 bringen. Aussergewöhnliche günstige Resultate haben auch Bielschowsky, Erggelet und neuerdings Siegrist erreicht. Siegrist verdanken wir den ausgezeichneten Vorschlag, die Keratokonusprothesen nach der Hornhautrefraktion in Brillenkästen anzuordnen. Die entsprechenden Zwischenstufen lassen sich durch Schliff gewiss herstellen, wie das durch die Fa. Zeiss für Helmbold bereits geschehen ist." (24)

1 3 - Siegrist and the Berne School (1916-1917)

1.3.1 – Siegrist's Publication (1916)

The interest of *Siegrist*, director of the *University Eye Clinic in Berne*, in the pathology and correction of keratoconus, as well as his interesting applications for hydrodiascopes

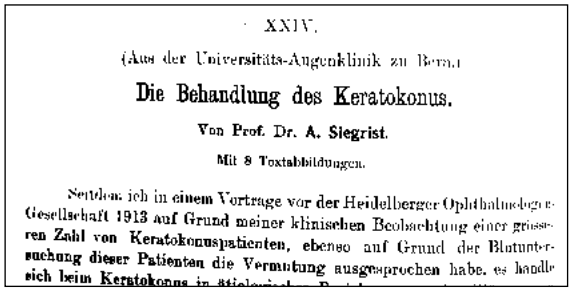
starting in 1897, have already been referred to. (25) In 1916, he published a new, important, virtually comprehensive work entitled *"**Die Behandlung des Keratokonus**" (The Treatment of Keratoconus)*.

Year	
1916	*Siegrist (Berne): "Die Behandlung des Keratokonus" (The Treatment of Keratoconus)*
1917	*Lüdemann (Berne): "Hydrodiaskop oder Kontaktglas zur Korrektur des Keratokonus" (Hydrodiascope versus Contact Glass for the Correction of Keratoconus)*
1917	*Nishimura (Berne/Kobe): "Demonstration of Contact Lens and its Value in Treatment" (in Japanese)*

Table 15 - 3
The publications of the Berne School in regard to the correction of keratoconus by Müller contact shells.

Description of the "Contact-adhesion-spectacle" (Kontaktadhäsionsbrille)

After a very detailed retrospective study on *Fick* (26), *Sulzer*, and *August Müller*, *Siegrist* describes his experience in correcting keratoconus by means of different models of hydrodiascope. He then goes on to describe the "contact-adhesion-spectacles of the *Müller Brothers* of Wiesbaden" (Kontaktadhäsionsbrillen der *Gebrüder Müller* in Wiesbaden):



XXIV.

(Aus der Universitäts-Augenklinik zu Bern.)

Die Behandlung des Keratokonus.

Von Prof. Dr. A. Siegrist.

Mit 8 Textabbildungen.

Seitdem ich in einem Vortrage vor der Heidelberger Ophthalmologischen Gesellschaft 1913 auf Grund meiner klinischen Beobachtung einer grösseren Zahl von Keratokonuspatienten, ebenso auf Grund der Blutuntersuchung dieser Patienten die Vermutung ausgesprochen habe, es handle sich beim Keratokonus in

Figure 15-8
Siegrist's publication (1916) on the use of contact shells for the correction of keratoconus.
In 1916, Siegrist published a significant article, virtually exhaustive, on the optical treatment of keratoconus: "Die Behandlung des Keratokonus" (The Treatment of Keratoconus).
(SIEGRIST August, "Die Behandlung des Keratokonus", Klinische Monatsblätter für Augenheilkunde, 56, 1916, 400-421 - Excerpt page.400).

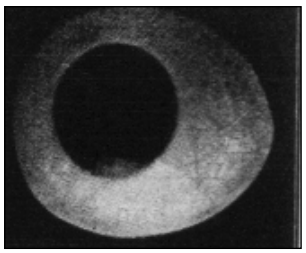


Figure 15-9
Drawing by Siegrist of blown contact shells used in 1916. Drawing of a "Muller's adhesion-contact-glass" (Müllersches Kontaktadhäsionsglas) on page 410 of Siegrist's article entitled "Die Behandlung des Keratoconus" (The Treatment of Keratoconus).
(SIEGRIST August, " Die Behandlung des Keratokonus ", Klinische Monatsblätter für Augenheilkunde, 56, 1916, 400-421 - Figure 4, p. 410).

"For some time, more and more attention has been paid to the 'contact adhesion-spectacles' of the Müller Brothers of Wiesbaden. The Müller contact glass was first manufactured in 1887 by the firm F Ad. Müller & Sons of Wiesbaden, in their artificial eye workshop, to protect the eye of a patient of Privy Counselor Sämisch from drying. Her eyelids had been almost completely destroyed by a carcinoma. The prosthesis bears a strong resemblance to a normal prosthesis, except that it is significantly thinner (1/3 mm) and has in its center, where the iris and black pupil would be, a thin and somewhat prominent transparent cornea. It is constructed like a prosthetic shell suitable for use with atrophied globes. The curvature of these shells corresponds exactly to that of the ocular globe and, unlike the contact glasses of Fick-Sulzer, they rest firmly in the lower palpebral fornix, whereas their superior portion is somewhat narrower because the globe tolerates pressure in its superior half less well. If the shell is not resting against an area in the conjunctival fornix, it risks undergoing, according to Müller, continual slippage. This movement is caused by blinking and is very irritating."

"Seit einiger Zeit schenkt man den Kontaktadhäsionsbrillen der Gebrüder Müller in Wiesbaden mehr und mehr Aufmerksamkeit. Das Müllersche Kontaktglas wurde zum ersten Male von der Firma F. Ad. Müller Söhne, Wiesbaden, Atelier für künstliche Augen im Jahre 1887 konstruirt, um das Auge eines Patienten von Geheimrat Sämisch, dessen Lider durch Karzinom fast völlig zerstört ware, gegen Austrocknung zu schützen. Es gleicht durchaus einer gewöhnlichen Prothese, nur ist es bedeutend dünner (1/3 mm) und trägt in der Mitte an Stelle der Iris und schwarzen Pupille eine dünne, etwas stärker vorgewölbte, durchsichtige Hornhaut. Es ist genau in der Weise gebildet, wie eine Schalenprothese für phtisische Bulbi. Es entspricht in seiner Wölbung genau derjenigen des Augapfels und es findet im Gegensatz zum Fick-Sulzerschen Kontaktglase einen festen sicheren Stützpunkt in der unteren Uebergangsfalte, während sein oberer Teil möglichst schmal gehalten wird, weil der Augapfel eine Belastung im oberen Teile weniger gut

verträgt. Wird die Schale nicht irgendwo in der Uebergangsfalte gestützt, so wird sie nach Müller durch den Lidschlag in fortdauernd gleitende Bewegung versetzt, was einen heftigen Reitz zur Folge hat." (27)

Figure 15-10
Drawing of a patient with keratoconus who was wearing a blown contact shell (Siegrist, 1916).
Drawing of a patient, whose right eye had been fit with a Müller contact shell. The legend states: "Keratoconus patient (female) wearing Müller contact glass in right eye." (Keratokonuspatientin mit Müllerschem Kontaktglas rechts).
(SIEGRIST August, " Die Behandlung des Keratokonus ", Klinische Monatsblätter für Augenheilkunde, 56, 1916, 400-421, - Figure 6, p. 415).

Clinical Cases

Siegrist reports experiments in a comparative trial carried out in three of his patients, whom he had wear successively ground, so-called "*Sulzer*-lenses". He had the optician *Strübin* of Basel grind these lenses for him (28) and compared them with *Müller* blown contact shells. These experiments reflect very favorably on the latter, both in relation to the objective appearance of the eye after wearing the lenses and in terms of the subjective reactions of the wearers.

Advantages of Müller Brothers Contact Shells

According to *Siegrist*, it was not necessary to fill the contact shells with liquid, as had long been believed. The space between the cornea and the corneal portion of the contact lens generally fills with tears from the moment of insertion. The shell would also be retained on the globe because of "adherence" (read: "capillary attraction"). These blown contact shells offer two great advantages: First, they are thinner and therefore cause less sensation between eye and eyelid. Secondly, their surfaces are smooth and for that reason permanently more resistant to mechanical and lacrimal injury.

Siegrist's Reservations

In his publication, *Siegrist* emphasizes that he has undergone a certain reluctance to use *Müller Brothers* contact shells because of their bad reputation resulting from patient intolerance of "*Sulzer* lenses". He was all the more pleasantly surprised by the performance of blown shells because of their ease of insertion, favorable toleration by patients, and the visual improvement generally obtained. He attributes their advantages to the thinness of these shells and relative smoothness of the actual glass:

"The Müller contact glasses are blown, not ground, lenses. They can be so much more thinly produced than by grinding, according to the statements of the manufacturers, and as thin as they have to be to allow their insertion in the space available between lids and ocular globe. Also, their fragility is absolutely minimal because of the elasticity thus obtained.
Blown shells have yet another advantage relative to ground, according to Müller, namely in the sense that they are melted and, as a result, put up continual resistance both to tears and to mechanical irritation, i.e., they are almost indestructible, whereas the pores of ground glasses are open, for which reason these lenses become opacified after a limited time."

"Die Müllerschen Kontaktgläser sind geblasen, nicht geschliffen. Sie können nach den Angaben der Fabrikanten so viel dünnwandiger hergestellt werden als durch Schliff, so dünn wie es sein müssen, um sich in den verfügbaren Raum zwischen Lider und Augapfel reizlos einzufügen ; auch die Zerbrechlichkeit wird bei grosser Dünne infolge der hierdurcherzielten Elastizität aussordentlich gering.
Die geblasenen Schalen haben noch einen weiteren Vorzug nach Müller gegenüber den geschliffenen, nämlich denjenigen, dass sie geschmolzen sind und hierdurch der Tränenflussigkeit sowie der

mechanischen Reizung einen dauernden Widerstand entgegensetzen, d. h. fast nicht abgenützt werden, während bei den geschliffenen Gläsern die Poren geöffnet sind, weshalb diese Gläser nach verhältnismässig kurzer Zeit blind werden." (29)

While admitting that blown scleral shells are not perfect, *Siegrist* was of the opinion that they would offer a new perfectible and therefore very promising mode of correction. *Müller's* contact shells had the additional advantage over the hydrodiascope of being easy to introduce under the eyelids and being tolerated by the eye for many hours. They also significantly improved vision and did not disfigure the patient:

"But when, half a year ago, we finally decided to try out the glasses in some keratoconus patients, our astonishment was not inconsiderable when we first noted that these Müller contact glasses can be very easily introduced under the lids and that, after a short period of practice, they can be worn without exception for many hours (9 to 10 hours per day). They are worn for such periods without causing any significant discomfort. Their third advantage is that they offer, at the very least, the possibility of very marked improvement of visual acuity, even if a return to normal visual acuity happens only very occasionally. A fourth advantage of the Müller contact glasses with respect to the hydrodiascope must be emphasized: that they do not disfigure the patient at all and, while being worn, can be recognized only by experienced observers. Finally, they can also be used for close work in the presbyopic age group because, in an eye that is wearing a Müller contact glass, the effectiveness of the accommodative mechanism is not greatly reduced."

"Als wir aber vor einem halben Jahre uns doch entschlossen, die Gläser bei einigen Keratokonuspatienten zu probieren, war unser Erstaunen nicht gering, als wir fürs erste festellen konnten, dass diese Müllerschen Kontaktgläser sehr leicht unter die Augenlider eingeführt werden können, dass sie vom menschlichen Auge nach kurzer Uebung fast ausnahmslos viele Stunden (9-10 Stunden pro Tag) ohne irgendwelche wesentliche Beschwerden zu verursachen, ertragen werden, und dass fürs dritte diese Kontaktgläser wenigstens die Möglichkeit besitzen, die Sehschärfe ganz merklich, wenn auch sehr selten bis zur Norm, zu verbessern. Als vierter Vorteil der Müllerschen Kontaktgläser gegenüber dem Hydrodiaslop muss hervorgehoben werden, dass sie nicht im geringsten entstellen und während des Tragens nur von geübten Beobachter gesehen werden können. Schliesslich kann man sie bis zum presbyopen Alter auch für die Nahearbeit gebrauchen, da in einem Auge, das eine Müllersches Kontaktglas trägt, der Akkommodationsapparat nicht wesentlich an Wirkung einbüsst." (29)

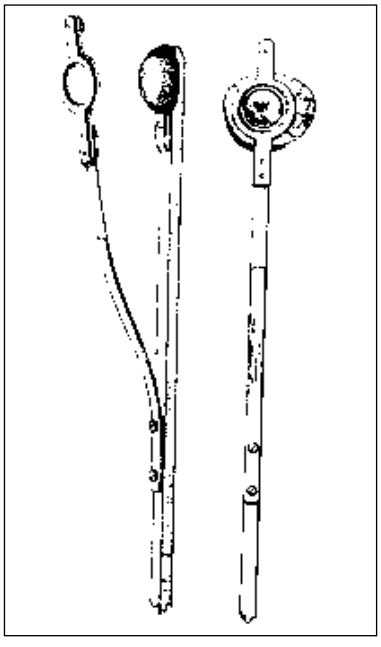


Figure 15-11
Lens holder made by Siegrist for the measurement of the radius of curvature of contact lenses.
Lens holder for Müller contact shells, invented by Siegrist for the measurement of the front optic zone radius.
(SIEGRIST August, "Die Behandlung des Keratokonus", Klinische Monatsblätter für Augenheilkunde, 56, 1916, 400-421. Figure 7, p. 417).

Siegrist then describes the disadvantages of blown contact shells. In view of the fact that the optical correction is made by the lacrimal lens positioned between the cornea and the shell, the dioptric power is displaced towards the anterior surface of the lens. Now, this would have to be perfectly spherical and possess a radius of curvature between 42.75 and 43.50 diopters. Unfortunately, the blown shells of *Müller* did not reach these standards. From an optical point of view, hydrodiascopes are far and away superior to *Müller Brothers* contact shells.

Control of the Radius of the Optic Zone

Siegrist had ordered the construction of a holder to be fixed in place of the chin-rest of the Javal keratometer with which he measured the two essential properties of

Müller Brothers contact shells, namely radius of curvature and sphericity:

"I ordered to be constructed a little device that replaces the chin rest of my Javal instrument and that fixes the contact glasses in such a way that they rest with their concave surfaces on a hemispherical support covered with velvet, where they are held with their front surface forwards by a spring provided with an opening corresponding with the transparent part of the cornea. In this way, I have tried to determine, by means of the Javal instrument, the astigmatism and the corneal power of Müller contact glasses. However, that was not so simple. The posterior surface of the glass cornea actually produced some bothersome mirror images. An exact and impeccable measurement of the contact glasses could be obtained only by painting over their posterior surfaces temporarily (exclusively for measurements) with black lacquer (enameloid lacquer). Only thus was the image of the reflections from the anterior surface of the glass cornea visible and did the precise measurement of these become a practical possibility."

"Ich habe für meinen Javalschen Apparat an Stelle der Kinnstütze einen kleinen neben abgebildeten Apparat konstruieren lassen, welche die Kontaktgläser fixiert in der Weise, dass sie mit ihrer Hohlfläche auf einen mit Samt überzogenen halbkugelförmigen Körper aufgesetzt und durch eine Feder, welche einen der durchsichtigen Hornhaut entsprechenden runden Ausschnitt trägt, von vorne angepresst werden. Auf diese Art suchte ich mit dem Javalschen Apparat sowohl den Astigmatismus wie die Brechkraft der gläsernen Hornhaut der Müllerschen Kontaktgläser zu bestimmen. Die Sache war aber nicht so einfach. Die Hinterfläche der Glashornhaut gab ebenfalls störende Spiegelbilden. Eine exakte, einwandfreie Messung der Vorderfläche der Kontaktgläser konnte erst erzielt werden, nachdem die Hinterfläche derselben vorübergehend (ausschliesslich für Messzwecke) mit einem schwarzen Lack (Enameloidlack matt) überzogen worden war. Nun kamen ausschliesslich die Spiegelbilder der Vorderfläche der Glashornhaut in Erscheinung und eine genaue Bestimmung dieser Hornhäute wurde möglich." (30)

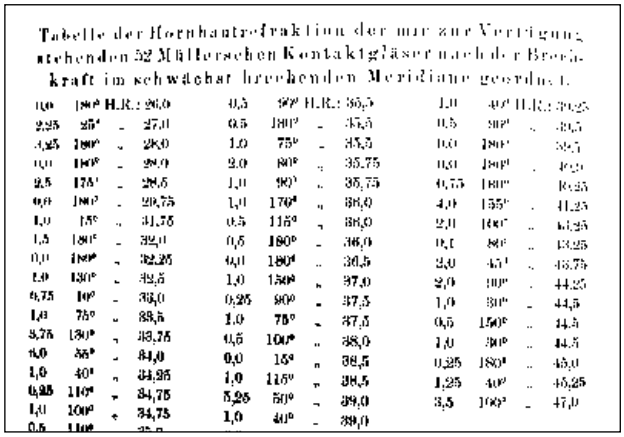


Tabelle der Hornhautrefraktion der mir zur Verfügung stehenden 52 Müllerschen Kontaktgläser nach der Brechkraft im schwächst brechenden Meridiane geordnet.

1,0	180°	H.R.	26,0	0,5	90°	H.R.	36,5	1,0	40°	H.R.	36,25
2,25	25°	„	27,0	0,5	180°	„	35,5	0,5	90°	„	36,5
4,25	180°	„	28,0	1,0	75°	„	35,5	0,0	180°		36,5
0,0	180°	„	28,0	2,0	80°	„	35,75	0,0	180°	„	36,5
2,5	175°	„	28,5	1,0	90°	„	35,75	0,75	180°		36,25
0,0	180°	„	29,75	1,0	170°	„	36,0	4,0	155°	„	41,25
1,0	15°	„	31,75	0,5	115°	„	36,0	2,0	180°	„	41,25
1,5	180°	„	32,0	0,5	180°	„	36,0	0,0	80°	„	43,25
0,0	180°	„	32,25	0,0	180°	„	36,5	3,0	45°	„	43,75
1,0	130°	„	32,5	1,0	150°	„	37,0	2,0	10°	„	44,25
0,75	10°	„	35,0	0,25	80°	„	37,5	1,0	30°	„	44,5
1,0	75°	„	35,5	1,0	75°	„	37,5	0,5	150°	„	44,5
3,75	150°	„	35,75	0,5	100°	„	38,0	1,0	30°	„	44,5
1,0	55°	„	34,0	0,0	15°	„	38,5	0,25	180°	„	45,0
1,0	40°	„	34,25	1,0	115°	„	38,5	1,25	40°	„	45,25
0,25	110°	„	34,75	5,25	50°	„	39,0	3,5	160°	„	47,0
1,0	100°	„	34,75	1,0	40°	„	39,0				
0,5	110°										

Figure 15-12
Table of measurements of the front optic zone radius of Müller contact shells.
Table describing the refraction of the front optic zone radius of 52 Müller contact shells on hand at the Eye Clinic in Berne, classified according to the meridian of the lowest power.
H.R. = "Corneal Radius" (Hornhautradius), equivalent of "front optic zone radius".
(SIEGRIST August, "Die Behandlung des Keratokonus", Klinische Monatsblätter für Augenheilkunde, 56, 1916, 400-421. - Table p. 418).

Disappointing Results

The results of these control measurements were disappointing: of 52 "*Müller* lenses" on hand in the Clinic inventory, only 22 were usable. The remaining 30 had either irregular astigmatism or astigmatism higher than 1.5 diopters, a corneal refraction of under 37 diopters, or two or more deficiencies at the same time:

"The justice of my assertions is demonstrated with a clarity evident from this table. More than half of my Müller contact glasses have a corneal refraction that is less than 37.0 diopters. These must be eliminated from the above for the sole reason that they are far too weak. Furthermore, among these, 52 shells had 39 oblique axis positions or a marked irregular astigmatism. A perverse astigmatism with position of the weakest refracting axis between 70 and 110 degrees occurred in 16 shells. An astigmatism higher than 1.5 diopters was found in 12 shells and of these 4 showed an astigmatism of between 3 and 4 diopters, one of 5.25 and even one of 6.0."

"Aus dieser Tabelle geht mit nicht misszuverstehener Klarheit die Richtigkeit meiner obigen Behauptungen hervor. Ueber die Hälfte meiner Müllerschen Kontaktgläser besitzt eine

Hornhautrefraktion die geringer ist als 37,0 Dioptrieen. Sie ist schon aus diesem Grunde als bedeutend zu schwach von vorneherein auszuschalten. Ferner haben unter diesen 52 Schalen 39 schiefe Achsenstellung oder einen direkt perversen Astigmatismus. Eine Perversen Astigmatismus mit Stellung der schwächsten brechenden Achse zwischen 70 und 110 Grad zeigen 16 Schalen. Ein Astigmatismus, der höher ist als 1,5 D. besitzen 12 Schalen unter diesen zeigen 4 einen Astigmatismus zwischen 3 und 4 D. eine von 5,25 und eine sogar von 6,0 D." (31)

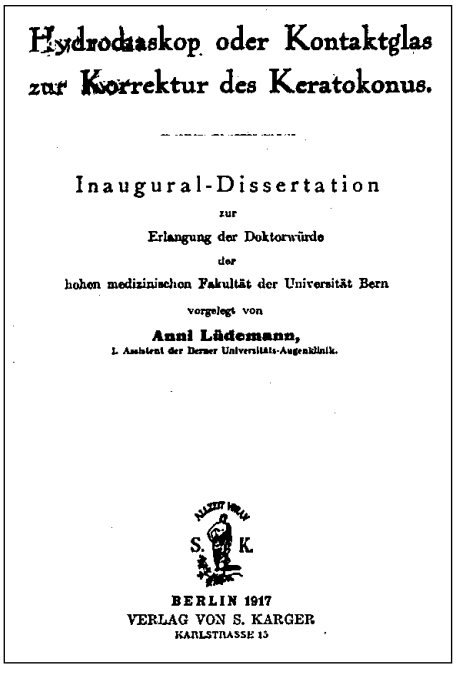
Siegrist classified the usable contact shells in terms of their radii of curvature and thus developed a rational fitting technique. For the trials, a first lens was selected from the most regular lenses, and the spectacle lens power necessary to obtain the best visual acuity was determined from this. This allowed the selection of a second contact lens of which the chosen radius produced a convex or a concave liquid film corresponding with the indicated correction.

It is an astonishing fact that, with such a limited number of contact shells, *Siegrist* was able to obtain the results he published. Furthermore, he observed that a reliable adaptation with a satisfactory optical correction could not be obtained with blown shells. Ground lenses or lenses blown in a mold had a more regular optical surface. Nevertheless, it seemed to him that the conformity of the scleral support of the blown shells was well matched with the eye and eyelids.

Siegrist concludes that the hydrodiascope era is past and that *Müller Brothers* can take the credit for having opened a new modern contact lens era:

"These modern contact glasses will, in my opinion, render the hydrodiascope totally useless and superfluous because it represents only a step in the search for a perfect optical aid. It will remain to the lasting credit of the firm of the Sons of F. Ad. Müller in Wiesbaden, who showed the correct pathway to, or at least one direction towards, the manufacture of clinically useable contact glasses that can be tolerated by the eye.

"Diese modernen Kontaktgläser werden nach meiner Ueberzeugung das Hydrodiaskop, welches nur eine Stufe in den Vervollkommnungsbestrebungen unserer optischen Hilfsmittel gegen Keratokonus darstellt vollkommen unnötig und entbehrlich machen. Es wird ein dauerndes Verdienst der Firma F. Ad. Müller Söhne in Wiesbaden bleiben, für die Konstruktion praktische verwendbarer, d. h. vom Auge ertragbarer Kontaktgläser den richtigen Weg wenigstens nach einer Richtung hin gewiesen zu haben." (32)


Hydrodiaskop oder Kontaktglas zur Korrektur des Keratokonus.

Inaugural-Dissertation
zur
Erlangung der Doktorwürde
der
hohen medizinischen Fakultät der Universität Bern
vorgelegt von
Anni Lüdemann,
I. Assistent der Berner Universitäts-Augenklinik.

S. K.

BERLIN 1917
VERLAG VON S. KARGER
KARLSTRASSE 15

Figure 15-13
Front page of the Lüdemann's M.D. "Inaugural-Dissertation".
Anni Lüdemann's "Inaugural-Dissertation" in Medicine, entitled "Hydrodiaskop oder Kontaktglas zur Korrektur des Keratokonus" (Hydrodiascope versus contact glass for the correction of keratoconus), is a milestone in the history of contact lenses. In the University Ophthalmology Clinic in Berne, the patients preferred contact shells manufactured by the Müller Brothers rather than the hydrodiascope.
(LUDEMANN Anni, Hydrodiaskop oder Kontaktglas zur Korrektur des Keratokonus, Inaugural-Dissertation Bern, Karger, Berlin, 1917)

1.3.2 – Lüdemann's Final Touches (1917)

In 1917, a year later, *Lüdemann*, Assistant at the *University Ophthalmology Clinic in Berne*, published, on *Siegrist's* suggestion, a comparative study of the methods of treating keratoconus. Her "Inaugural Dissertation" and her publication was entitled ***"Hydrodiaskop oder Kontaktglas zur Korrektur des Keratokonus"*** *(Hydrodiascope*

versus contact glass in the correction of keratoconus). (33)

Ten patients with keratoconus were fit successively, as part of an experiment, with a hydrodiascope then with a *Müller* contact shell according to the Berne technique. The optical results favored the hydrodiascope. Nevertheless, all the patients preferred contact shells, first and foremost for cosmetic reasons and secondarily because of their ease of insertion (34). *Lüdemann* also described the discomfort that occurred when the contact shells were worn for too long a time:

"The principal advantage of the Müller contact glass lies in the almost total invisibility of the corrective device, its principal disadvantage being the improper correction of the refractive errors and the resultant defective normalization of visual acuity. Another disadvantage consists of the subjective feeling of discomfort that occasionally appears when the glass is worn too long. Relatively minor difficulties also occur that are linked to the initial learning curve for independent insertion of the contact glass by the patient as well as the need for the help of another person to assist with removal."

"Der Hauptvorteil des Müllerschen Kontaktglases beruht in der fast völligen Unsichtbarkeit des Korrekturapparates, der Hauptnachteil in der mangelhaften Korrektur des optischen Fehlers und in der infolgedessen nur mangelhaften Normalisierung der Sehkraft. Ein weiterer Nachteil beruht in den allerdings nur bisweilen auftretenden subjektiven Beschwerden bei längerem Tragen des Glases in den allerdings nur geringen Schwierigkeiten, welche anfänglich das Erlernen der selbstständigen Einführung des Kontaktglases verursacht und in der Notwendigkeit, bei der Herausnahme des Kontaktglases sich vordehand fremder Hilfe bedienen zu müssen." (35)

Lüdemann observed that the available *Müller* contact shells were of poorer quality than the ground lenses introduced by *Zeiss*. On the other hand, it was agreed that a well-fit contact shell could be tolerated by the eye for hours or even days at a time with minimal or no discomfort. If ground contact lenses in all spherical powers were available, then it would be possible to correct all refractive errors. Contact lenses and shells following the movements of the globe would be separated from the cornea by a regular tear film and would eventually replace spectacle glasses:

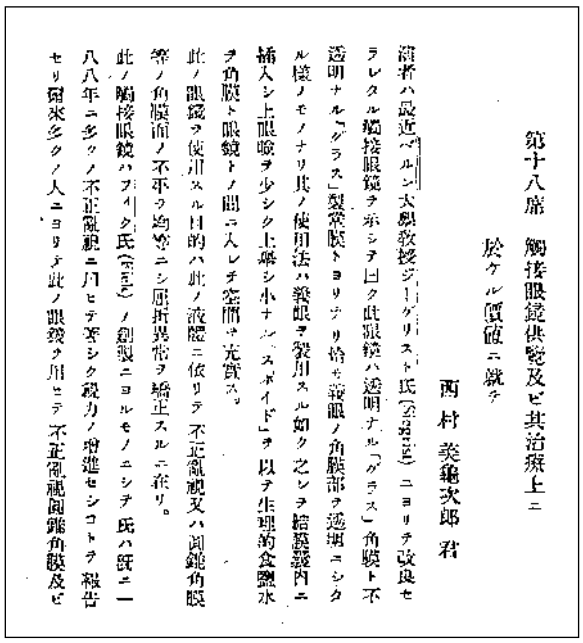
"If we have, at a future date [...], the possibility of creating well-positioned ground contact glasses of any spherical power we wish, as at least Professor Siegrist thinks we shall, then the contact glass will represent the most ideal spectacle glass for many patients, even for the correction of other refractive errors. Such a spectacle glass would eliminate all the disadvantages of normal spectacle glasses because it actually accompanies the eye in all its movements and is separated from the cornea at all times by the same distance as that tear-filled distance between cornea and lens."

"Besitzen wir einmal [...], die Möglichkeit, uns gut sitzende, geschliffene Kontaktgläser von beliebiger sphärischen Brechkraft zu verschaffen, so wird vielleicht, so glaubt wenigstens Professor Siegrist, das Kontaktglas in manchen Fällen das idealste Brillenglas darstellen zur Korrektur auch anderer Refraktionsfehler. Dieses Brillenglas würde alle fehlerhafte Eigenschaften der gewöhnlichen Brillengläser vermeiden, da es ja das Auge bei seinen Bewegungen begleitet und jederzeit durch die gleiche mit Tränenflüssigkeit ausgefüllte Distanz von der Hornhaut getrennt ist." (36)

1.3.3 –Nishimura's Evidence (1916)

After having spent some time at the *Berne Ophthalmological Clinic*, the Japanese ophthalmologist *Mikijiro Nishimura* of Kobe reports in 1916, at the first congress of the *Kinki Ophthalmological Society*, the observations that he had made with *Müller Brothers*

contact shells (37):



第十八席　觸接眼鏡供覧及ビ其治療上ニ
於ケル價値ニ就テ
西村美龜次郎君
演者ハ最近ベルン大學教授ジーグリスト氏（Siegrist）ニヨリテ改良セラレタル觸接眼鏡ヲ示シテ曰ク此眼鏡ハ透明ナル「グラス」角膜ト不透明ナル「グラス」製鞏膜トヨリナリ恰モ義眼ノ角膜部ヲ透明ニシタル樣ノモノナリ其ノ使用法ハ義眼ヲ裝用スル如ク之レヲ結膜嚢内ニ挿入シ上眼瞼ヲ少シク上擧シ小ナル「スポイド」ヲ以テ生理的食鹽水ヲ角膜ト眼鏡トノ間ニ入レテ密閉セ充實ス。
此ノ眼鏡ヲ使用スル目的ハ此ノ液體ニ依リテ不正亂視又ハ圓錐角膜等ノ角膜面ノ不平ヲ均等ニ屈折異常ヲ矯正スルニ在リ。
此ノ觸接眼鏡ハフィク氏（Fick）ノ創製ニヨルモノニシテ氏ハ既ニ一八八八年ニ多クノ不正亂視ニ用ヒテ著シク視力ノ增進セシコトヲ報告セリ爾來多クノ人ニヨリテ此ノ眼鏡ヲ用ヒテ不正亂視圓錐角膜及ビ

Figure 15-14
Nishimura's publication on contact lenses used by Siegrist at the Berne Ophthalmological Clinic.
First page of the communication of Mikijiro Nishimura at the first congress of the Kinki Ophthalmological Society in 1916. The text is read from above down from the right to the left. One recognizes the transcriptions of the names of Siegrist and Fick, whereas those of Sulzer and Dor are represented by phonetic characters.
(Nishimura Mikijiro, (in Japanese) "Demonstration of Contact Lens and its Value in Treatment", Cho Ganla Iho, 8, 1916, 804-805 - Page 804)

"Nishimura demonstrated a contact glass recently improved by Prof Siegrist of the University of Berne. This device consists of transparent glass cornea and opaque sclera made of glass; namely, it is like a prosthesis with the corneal part made transparent. One inserts the lens in the conjunctival sac, lifts up the upper lid and fills the space between the cornea and lens with physiological saline using a pipette. The purpose of this glass is to correct irregular astigmatism or keratoconus through smoothing out the irregular corneal surface.
The contact glass is an invention of Fick, who reported already in 1888 that the 'Kontakt-brille' improves vision of irregular astigmatism. Since then many ophthalmologists used this glass and reported improvement of vision.
Case of Sulzer: Visual Acuity= 3M/F [Counting fingers at 3 meters], 5/6 with 'Kontaktbrille',
Case of Dor: Visual Acuity =20/70, 20/20 with 'Kontaktbrille',
Fick's case of keratoconus: Right eye visual acuity = finger counting at 3 meters, with 'Kontaktbrille' and –1.75D = 4/6. Left eye visual acuity = 4/12, with 'Kontactbrille' and +15D = 4/4.
Improvement of vision such as in these examples can be obtained, but Fick's contact glass has not been used widely. This is because the lens causes hyperemia and corneal opacity and because long-term use is impossible.
At the Department of Ophthalmology of the University of Berne, Siegrist's improved glass and the previous glasses were tried in several keratoconus patients. With the previous glass, the patients complained of pain in about one hour, but Siegrist's lens could be tolerated for 6-7 hours, sometimes for 27 hours. Improvement of vision was of various degrees; for example, visual acuity of 0.1 was improved to 0.9.
I had the opportunity of examining a case who used the contact glass for 5-6 hours, and the patient showed no irritation. In a case of keratoconus, the patient was able to work again with this glass. In another case of secondary keratoconus, I used the contact glass. The cornea appeared conical with scattered nebulae, the apex of the cone was opaque with iris synechia, and the intraocular pressure was high. The visual acuity was only 'finger counting' at 10 cm, but with the contact glass, it was improved to 0.2. In conclusion, the contact glass improves the vision in irregular astigmatism and keratoconus. The improved contact glass of Siegrist shows less irritation than Fick's glass and is tolerated for longer periods. As in the case I explained, if the patient can regain work, it is recommended to use contact glass for patients with irregular astigmatism or keratoconus. Particularly in keratoconus cases where surgical methods cannot promise good vision, the contact glass should be tried."

This interesting document represents the only evidence regarding this epoch outside of the German-speaking countries. *Nishimura* does not state that the lenses used in Berne were blown and he attributes their paternity to *Siegrist*. At the same time, no manufacturer was found to produce equivalent contact glasses.

2 - Discussion

2.1 - Terminology

Brille (spectacle)	*Kontaktbrille (contact-spectacle), Adhäsionsbrille (adhesion-spectacle), Kontakt-adhäsionsbrille (contact adhesion-spectacle)*
Prothese (prosthesis)	*Kontaktprothese (contact-prosthesis), Keratokonusprothese (keratoconus-prosthesis),Müller'sche Kontaktprothese (Müller's contact-prosthesis)*
Schale (shell)	*Kontaktschale (contact-shell), Augenschale (eye-shell), Schalenauge (shell-eye), Müller'sche Schale (Müller's shell)*
Glas (glass)	*Kontaktglas (contact-glass), Glasprothese (glass-prosthesis),Müller'sche Kontaktglas (Müller's contact-glass)*

Table 15 - 4
Words invented, starting with the terms "Kontakt-, Augen-, Adhäsion-, and Keratokonus-", combined with the words "Brille, Prothese, Schale, Glas", to designate Müller contact shells between 1900 and 1916.

The terminology of the first blown contact shells and lenses is undecided. Authors use one or another of the following terms, alternating between them: " spectacles" (Brille), "prosthesis" (Prothese), "shell" (Schale) and "glas" (Glass), to which they add specifications as follows: "contact" (Kontakt), "blown" (Geblasene), "eye" (Augen), "adherent" (Adhäsion), "keratoconus" (Keratoconus), "Müller's" (Müllersche), etc.

Initially, in 1910, the *Müller Company* had used the term "contact-adhesion-spectacle" (Kontakt-Adhäsionsbrille), probably referring to the *Fick's* "Kontaktbrille". Users were faced with a multitude of terms and did not use them with great discrimination. They rapidly abandoned "Kontaktbrille" and "Kontaktprothese", adopting instead, depending on the era, local customs and fashion, first "contact shell" (Kontaktschale) then "contact glass" (Kontaktglas).

2.2 –Details of material and manufacture

The first contact shells made by *Müller Brothers* were derived from artificial eye prostheses in which the cornea was transparent. Following the example of ocular prostheses, the scleral portion was tinted white and displayed drawings of minute conjunctival vessels. The diameter of the transparent corneal zone was approximately 12 mm. The scleral portion extended downwards to the bottom of the inferior oculo-palpebral fornix, on which the margin of the lens rested, whereas the superior portion of the globe was less covered: "*Müller's Prostheses are thin shell eyes, in which the anterior segment—cornea, iris and pupil—carries only a transparent cornea."* (38)

Manufacture on Location
Skilled professional glassblowers used the ocular profile to blow the contact shells of *Müller Brothers*. If the patient traveled to Wiesbaden or was seen in the course of the ocularist's circuit, the ocularist manufactured the shell by estimating the ocular profile as accurately as possible depending on his judgment. In order to achieve this, he first blew a glass bubble following the curvature that seemed to him to be closest to that of the ocular scleral curvature. He then blew a second bulge in the center of this bubble, to which he tried to give a curvature corresponding approximately both to the lateral corneal profile and to the tear meniscus necessary for optical correction. Finally, he cut

off the edge, fashioned and smoothed the circumference, tinted the scleral part in white and decorated it with little drawings representing conjunctival vessels.

Forwarding Trial Lenses
In response to orders from physicians, *Müller* also made loans of trial lens sets. He referred to these as "trial consignments" (Auswahlsendungen*)*. Certain hospitals owned a large reserve of these shells, from which physicians randomly drew out samples for their trials. Depending on the participants, the irrational process of choosing the best model constituted one of the main obstacles to the wider dissemination of blown contact shells. It seems that only *Siegrist* had classified contact shells according to their specifications in order to obtain a better choice, which led him to reject two-thirds of them.

2.3 – The Physical Properties of the Corneal and Scleral Parts

Depending on the model of prosthesis, blown contact shells were of poor quality, both in relation to their corneal and scleral portions.

The Corneal Portion
The corneal portion was afocal. This means that it was deprived of any optical effect, its curvature being unpredictable and unsuitable, for it had no refractive effect. It was also aspheric and was beset with cylindrical optical aberrations, which, according to *Siegrist,* rendered two-thirds of the shells unusable. In order to pass "like a bridge" over the cornea, the *Müller Brothers* tried to produce a corneal portion that bulged forwards relative to the scleral portion. The *Müllers* did not research any specifications to match the corneal profile but used only a specific height matching the corneal height as shown by an arrow in diagrams. It was of no concern to them that the corneal curvature might be too flat or too arched, provided that the shell could pass over the cornea like a bridge. *Siegrist* had eliminated a majority of shells by reason of their corneal curvature being too flat and not suited to the optical correction because he feared that the contact lens might touch the cornea.

The Scleral Portion
Ocularists had greater experience and confidence in the manufacture of the scleral portion since they were accustomed to blow a scleral contact zone for glass eyes. The experience of the glass blowers for ocular prostheses had shown them that the lower part of the globe was less sensitive than the superior part. They therefore extended the scleral shell to the inferior portion of the lower conjunctival cul-de-sac, where the lens could rest. The superior scleral part was, on the other hand, reduced in width and kept narrower. This rule was not, however, absolute, and they fit lenses individually depending on the features of a particular case.

Siegrist found an advantage for the individualized manufacture of the scleral portion. The scleral portion was therefore manufactured by glass blowing that would thus be better matched in shape and size with the ocular sclera and eyelid proportions: *"On the other hand, the nontransparent part of the contact glass is better obtained by blowing because it must be adjusted to individual variations and more or less different shapes of globe and eyelid relations."* (39)

The irregularity of the scleral geometry had the unintended advantage of favoring the passage of tears and thereby producing a better tolerance of the lens than that which a perfectly spherical surface might have produced.
The external border of blown contact shells was rounded by flame, which generated a profile considered to be appropriate. The transition between the corneal and scleral parts was derived from the blowing procedure and was more a coincidental effect than the result of a rational approach. This transition zone generally stretched in beyond the ocular limbus, thus providing a broad and deep pre- and peri-limbic space.
Notwithstanding the claim for a certain systematic approach on the part of *Müllers,* one can state that all the contact shells coming out of their workshop at this time were individualized and did not have any characteristics common to all of them.

2.4 – The Fit

Fit was random. The choice of a contact shell with undefined characteristics for the optical correction of an eye affected with a deformation as serious as that of keratoconus was a daunting challenge. The physician prided himself in his skill and good luck as he searched out a shell which corresponded to the two recommended criteria: these were, objectively speaking, the absence of air bubbles and an acceptable tolerance:
"If you wish to correct keratoconus with a Müller contact glass, choose a medium-power lens with an approximately spherical curvature from the collection. You measure the visual acuity, then place weak plus or minus lenses (+1.0 or 1.0) in front of the contact shell and check whether the visual acuity is improved by any of these. The findings that you obtain thus provide a finger pointer to indicate if you should search out and try a contact lens with a stronger or weaker corneal refractive power from our collection. The new contact glass is now tried in the same manner for correctness and, if required, changed a second or a third time until you have found the precise contact glass with the necessary refractive power. By using this procedure and notwithstanding the very limited number of Müller contact glasses that were actually usable, we succeeded in reaching visual acuities in patients with keratoconus as high as 0.9 with the help of Müller glasses." (39)

2.5 – The Optical Choice

Optical correction by blown contact shells was the result of three factors:
the neutralization of the front surface of the corneal dioptric power by liquid lens,
the thickness and the geometry of the liquid layer between the eye and the shell, in the pre-corneal space,
the geometry of the front surface of the contact shell.

Only the first aim was actually achieved. Taking into account the random nature of the two other factors, this aspect caused the correction to be nearly always imperfect. This meant that additional spectacles were necessary: *"The refraction of the corneal portion varies depending on the prosthesis; if you take into account that these are not ground but blown, an exact specific curvature cannot be given to them."* (40)
In practice, the appropriate subjective visual correction was made once the contact shell was in place by using trial spectacle lenses. The result could be disappointing when it was confirmed that optical imperfections did not permit an accurate correction after the choice of a reasonably well-tolerated contact lens.

Siegrist had described the optical deficiencies of the optical zone of blown contact shells. The pious hope of contact lenses with a ground optical zone was expressed by *Helmbold* starting in 1913 and was to return as a recurring theme throughout the following years. In favorable cases, one succeeded in obtaining a significant improvement in visual acuity but always less than that obtained with either the hydrodiascope or *Fick-Sulzer* ground contact lenses*: "In favorable cases, you do, of course, succeed in achieving a significant improvement in visual acuity."* (41)
The decision of *Müller Brothers* to favor a precorneal space that was deliberately spacious in order to pass like a bridge above the cornea had the inevitable disadvantage of attracting air bubbles between contact shell and cornea. It is instructive to remember that *Siegrist's* hydrodiascope gave his patients a superior optical correction than was obtained with *Müller's* blown shells.

2.6 - Tolerance

The favorable tolerance for blown contact shells was an indirect consequence of their deficiencies. Such devices passed generously above the cornea like a bridge, separated by a large tear film. The exchange of tears was favored by the irregular scleral curvature and the lax adherence of the scleral portion. The scleral zone reached down to the inferior conjunctival fold, where it settled, whereas the superior part, being less thick, remained somewhat unstable and had a pumping effect during blinking: *"Its curvature corresponds exactly to that of the ocular globe and, unlike the Fick-Sulzer contact glass, it finds a resting point on the inferior conjunctival fold, whilst the superior part is kept as narrow as possible because the ocular globe is less tolerant of any irritation in its upper portion."* (42)

Around 1917, the *Berne School* was convinced of the future of contact lenses, thanks to their "incredibly good tolerance": *"The most important fact demonstrated by our research and that is in agreement with various recent communications is the extraordinary, almost unbelievable fact that a more or less well-fit contact glass can be worn for hours or even days at a time by the human eye without or with only minimal disturbances."* (43)

2.7 – The Intermediary Liquid

Weill recommended that the contact shells and lenses should be filled with sterile physiological saline solution before inserting them. In order not to lose too much liquid, the subject was required to lean his or her head forwards while slipping the lens under the eyelids. Often it was necessary to top up the liquid in situ with a dropper. For other authors, such as *Siegrist, Helmbold*, and *Clausen*, it was not necessary to top up the shell with any specific liquid because the space between the cornea and the back surface of the lens would fill itself spontaneously with tears: "*The shell does not require to be filled up with any particular liquid before it is inserted onto the cornea, as was believed initially and as Fick and Sulzer have also recommended for their contact glasses. The space between the cornea and the corneal shell of the contact glass fills most of the time on its own with tears that are less irritating than fluid as soon as the lens is inserted. The glass is then held in position by adherence to the ocular globe."* (44)
Lüdemann, who was still an assistant to *Siegrist* in Berne, also recalls the formation of

air bubbles and the method used by the physicians of the *Berne Ophthalmological Clinic*, who dealt with that problem by instilling warm physiological saline solution with a glass pipette: *"Taking into account that the glasses did not join as tightly to the globe as we would wish, a relatively large air bubble came into existence between the cornea and the glass. In some cases, it disappeared by tearing. In other cases, it remained and caused visual acuity to diminish significantly as a result, which was very upsetting to the patient. This was probably because of the defective wetting of the cornea. In order to remove this air bubble, I had the patient look down and separated the superior border of the contact glass by means of an ordinary glass pipette (eye-dropper) filled with warm physiological saline. At the same time, I caused the liquid to flow in between the glass and the cornea. In this way I succeeded in quickly removing the air bubbles in all instances without harming the patient. The immediate resulting improvement in vision was also enormously reassuring to the patient."* (45)

2.8 – Difficulties in Insertion and Removal of Contact Shells

The manipulations of insertion and removal were not straightforward and created more than a little trepidation among both physicians and their patients. *Weill* notes that the three patients cited had learned insertion after three tries, without anesthesia or losing too much liquid.

The insertion of a relatively very large scleral glass contact shell into the eye was rejected by patients and physicians in some cases. Respect for the visual organ and the justified fear of a manipulation mishap limited the carrying out of this maneuver by some professionals. For trials of lenses, prior instillation of anesthesia was recommended and some patients continued with this habit for the insertion of the prescribed lens. This was something certainly not without disadvantages and caused iatrogenic complications.

Lüdemann describes her experience at the *Berne Ophthalmology Clinic* as follows: "*Except at the time of the first two trials, the glass was inserted without cocaine anesthesia; to achieve this, I had the patient look down strongly, slipped the lens under the upper eyelid, raising this gently with the thumb of my left hand. Then, I firmly held the glass and the upper eyelid with my thumb, while the index of my right hand drew the lower eyelid downwards, which allowed the glass to slip into the conjunctival sac painlessly and without any difficulty whatsoever.*

In order to remove the glass, the patient looked up strongly while I gently separated the lower lid and slipped a strabismus hook under the lower border of the contact glass, which I gently pulled outwards. At the same time, I exerted light pressure on the upper lid and, at the same moment, the glass popped out of the eye.

In this way, I was able to insert and remove the glass painlessly, and this has allowed me frequently to try several glasses in the same eye without irritating it or causing the patient to complain." (45)

The removal of the contact shell still necessitated the assistance of someone in the entourage at this period of time, as *Lüdemann* describes in one patient: *"He is capable of inserting his contact glass himself, but, in order to remove it, he has his wife assist him*." (46) *Siegrist,* however, envisaged the use of plungers: *"Professor Siegrist is at the present time carrying out experiments with the aim of removing contact glasses with Braun's little aspirating plungers. These are not yet completed but leave us at the present time with every prospect of a favorable result."* (47)

2.9 – Wearing Time

The authors emphasize the excellent tolerance of *Müller's* contact shells. However, few of them give details on the duration of wear that their patients actually achieved. *Weill* indicates that in two cases the contact shell was worn "for almost the whole day" and in one case "the whole day", in one eye at least. (48) In contrast, *Lüdemann's* publication does give indications of the duration of wear achieved: *"The patient generally wears the contact glass in the left eye for 7 to 8 hours without the least ocular irritation. He has been able to wear it for 8 to 9 days. Then the eye becomes sensitive and he leaves it out for 3 to 4 days (Case # 1)."* and later *"She reported that she wore the glass several hours each day without difficulty. One time she forgot to take it out in the evening (in any event the proof that she was not having any trouble), and so she wore it without inconvenience for 24 hours. The next morning, however, the eye was slightly red and also showed tearing, but it became normal again 3 to 4 hours after the glass had been removed. (Case # 3)"* (49)

2.10 – Indications and Alternatives

The indications for the first blown contact shells of *Müller* remained limited to keratoconus only. This was because no valid alternative treatment existed for keratoconus except for the only two other modalities for correction of the condition by a contact method, namely a *Fick-Sulzer* ground contact lens or hydrodiascope.

Comparison with the Ground Contact Lenses of Fick-Sulzer
In 1916, *Siegrist* published a study comparing *Müller's* blown contact shells with the ground so-called *Fick-Sulzer* contact lenses. As *Siegrist* was aware of the disadvantages of these *Fick-Sulzer* lenses, he had fit successfully blown contact shells of *Müller* in three of his patients some time previously*: "In the first patient, really painful crises occurred after two hours that lasted several minutes each time and worsened particularly when the patient looked upwards. When we took the glass out after 6 hours, the contact glass and the cornea were diffusely cloudy as in acute glaucoma.*
The second patient complained immediately after insertion of the glass that its inferior edge was pressing and that eye movements were difficult. Wearing this glass was, in any event, more uncomfortable than wearing a Müller glass.
The third patient […] complained that she was very uncomfortable immediately after the insertion of the Sulzer's glass and that she was particularly sensitive to the lower edge of the glass. After only half an hour of wearing it, the patient requested that the glass be removed because the painful symptoms were too severe." (50)

He summarized the disadvantages of the *Sulzer* contact lenses as compared with the *Müller* lenses under four headings:

Insertion of "*Sulzer* lenses" is more difficult; there is always an air bubble that does not remove itself except by complicated maneuvers consisting of lifting the upper border with a strabismus hook and filling the space between the shell and the eye with physiological saline solution using a pipette. The blown shells are, in contrast, easy to insert under the lids compared with "*Sulzer* lenses".
The "*Sulzer* lens" produces a very marked sensation of a foreign body and pain where its edge is. These pains become progressively more marked and prevent the possibility

of wearing the lens for longer than one or two hours. The "*Müller* lenses", on the other hand, can be worn without symptoms for as long as ten hours a day but do not improve vision as much.
Movement of the ocular globe is greatly limited by the "*Sulzer* lenses" and less so with blown scleral shells.
Removal of the "*Sulzer* lenses" is difficult because of the strong adherence of the lens to the globe, which often requires that cocaine be instilled. Removal of blown shells is much easier.

In spite of these stated advantages, *Siegrist* emphasized that the *Müller* contact shells were primitive and imperfect and did not satisfy the demands required of an ideal contact lens, i.e., transparency, sphericity, and appropriate dioptric power.
Certainly, these *Müller* contact shells were transparent, but, by reason of their blown nature, they possessed neither sphericity nor dioptric power. Theirs was a stopgap solution, an intermediate step and an advance as compared with *Sulzer* lenses, which were only an instrument for scientific use and could not be used for the routine correction of visual anomalies. The empirical and unpredictable procedure for fitting blown contact shells still, however, represented an obstacle to their widespread or more generalized use.

Comparison with the Hydrodiascopes
Just as *Siegrist* and *Lüdemann* had demonstrated, blown contact shells had an advantage over hydrodiascopes: their good and highly acceptable esthetic appearance. This largely compensated for the wretched optical correction obtained with them and the interminable and random trials needed for fitting: *"If you compare the advantages and disadvantages of the contact glass with those of the hydrodiascope, you will immediately give priority to the contact glass. This is the reality that was gained by practical experience in patients who had previously worn hydrodiascopes and who passed, almost without being aware of it, to the contact glass. Generally speaking, you accept a visual acuity that is somewhat less good, provided that it is adequate for the demands of daily life. This is in contradistinction to the disfigurement produced by wearing the hydrodiascope. You accept certain disadvantages as well, as described. You do this because of the significant disfiguration and because of the complicated filling of the instrument with saline solution, and you reject the hydrodiascope without any regrets, notwithstanding its outstanding optical performance."* (51)

Lüdemann lists the advantages of *Müller Brothers* contact shells over hydrodiascopes:
easier insertion,
superior tolerance as compared with hydrodiascopes,
visual improvement, perhaps less than that obtained with the hydrodiascope but adequate for ordinary daily living,
undeniable esthetic advantage, causing patients to prefer contact glasses for correction of their refractive errors,
absence of disturbance of accommodation.

2.11 – Müller Brother's Priority Rights

In order to determine whether the first prosthetic shells blown by the *Müller Brothers* would have the right to a priority in the history of contact lenses, the following analysis

will address two groups of questions that seem to be fundamental:
Should the ocular prostheses used in 1887 by *Sämisch* for the protection of lagophthalmic globes against desiccation be considered contact lenses?
Were contact shells invented by *Müller Brothers*? Should the precedence of *Fick*, *Kalt* and *August Müller* be challenged?

Are "Protective shells" (Schutzschalen) a form of Contact Lenses?
Textual analysis shows that in 1887 *Sämisch* did not order the manufacture of a contact lens or a contact shell but rather of a "capsule*"* (Kapsel) in order to cover the orbit and protect an eye exposed to desiccation.
Müller took the initiative of placing a "protective shell" (Schutzschale) inspired by the ocular prostheses. Such prostheses had been used for decades both in France and the British Isles (52).

The Müller Brothers did not claim Priority in the Utilization of Contact Lenses
We should remember that the brothers *F.A.* and *A.C. Müller* (in their 1910 publication) did not claim the characteristics of a contact lens for the protective shell placed on the eye of *Sämisch's* patient in 1887: *"We wished to protect the ocular globe from the air by the insertion of a transparent capsule and thus prevent additional drying of the cornea, the epithelium of which already showed necrotic desiccation."* (53)

Their description distinguishes precisely and without ambiguity, firstly, the *"*protective-shell" (Schutzschale), to which are dedicated pages 68 and 69 of their brochure, and, secondly, the "contact-spectacle" (Kontaktbrille), used after 1908 for the correction of keratoconus, as described in pages 70 to 72 of the brochure. (54) Indeed, they describe what they observed afterwards, namely that it was possible to give dioptric power to the "glass cornea", but they add that they "had not given special emphasis to these optical considerations": *"We also immediately observed that it was possible to give, by means of glass-blowing, some dioptric power to the glass cornea and thus make a spectacle that was totally in contact with the globe and followed each movement of it, allowing regular vision in all directions of gaze. […] At that time, we did not pay any special attention to this optical consideration since, in the case of high myopia, optical correction is easily made with normal spectacles until some keratoconus cases came under our care."* (55)

Müller Brothers recognized Fick's Priority
The *Müller Brothers* claim that they had observed the focusing by blown shells in 1908, the corneas of which possessed an optical effect. They state that at this time they did conduct his work "without having had any knowledge of that of Dr. *Fick*", to whom they also attributed (erroneously) the use of single-curvature lenses of corneal diameter. They "recognize the priority of his work" but are convinced of the superiority of blown shells with respect to ground contact lenses: *"We note that our fundamental works have been conducted* ***without our having had any knowledge*** *of those of Dr. Fick. While we do indeed* ***recognize the priority of his work*** *for the solution of the question of the 'Kontaktbrille,' we are at the same time convinced that a practical development of this type of correction cannot be brought about except on the basis that we have just described."* (56)

The following therefore becomes evident:
The "protective shells" (Schutzschalen) blown in 1887 are not contact lenses or contact shells. *Müller Brothers* did not claim and did not produce the neutralization of corneal

dioptric power and the substitution of a new optical surface for the neutralized cornea with these shells (57).

Müller Brothers recognized *Fick's* priority. They recognized that it was only twenty years after *Fick's* use of the first contact lens that they had blown their first shells for the optical correction of keratoconus in 1908. They actually adopted the term "Kontaktbrille", as recommended by *Fick*, at this point in history.

3 - A short History of the Citations, Omissions and the Misinterpretations

Historians have never researched the historical background of the first blown contact shells in its totality starting with the data contained in the literature. That background has been assembled for the first time in this chapter. Certain people have concealed this episode or adopt a sibylline expression for it. This serves as proof of the confusion of authors when they confront this intermediate period between the epoch of the inventions of 1888 and that of the first ground lenses or shells to be marketed in 1920.
Others attributed to *Müller Brothers* a role and a priority that they do not have and that they never claimed, especially that of having, since 1887, invented, fabricated, sold, and used contact lenses.

The chronology of the first blown scleral contact shells is, however, clearly described in the brochure of *F.A. and A.C. Müller* of Wiesbaden (1910):
in 1887, they produced a "protective-shell" (Schutzschale) for *Sämisch* for one of his patients with lagophthalmos,
starting in 1908**,** they supplied blown scleral contact shells, designated as "*Kontaktbrillen"*, for the optical correction of keratoconus.

It is therefore unacceptable to amalgamate the two periods and to attribute the characteristics of contact lenses/shells to protective shells. This confusion could explain the omissions, amalgamations, obscurations, or reservations of certain historians. As one author recalls, numerous authorities are led astray: *"The first of these contact lens investigators is mentioned by several authorities, notably F. A and A.C. Muller, Duke-Elder, Obrig, Jenkins, and Pascal. All report that in 1887, Professor E.T. Saemisch of Bonn utilized the first true contact lens as a protective device. […] A patient with similar conditions was fitted by Dr. Saemisch in the following years." (*58)

One author recalls that protective shells were used prior to 1887: *"Apart from the suggestion of William White Cooper (1859), […] there is no record until more than 60 years had passed, when in 1887, Saemisch suggested to A.C. Müller, one of the famous family of glass-blowers and artificial eye makers of Wiesbaden, that he make a protective shell for a patient who had complete lagophthalmos after operative removal of the lid for malignant disease."* (59)
However, the same author attributes a disproportionate importance to *A.C. Müller* by reproducing his portrait on an entire page of his treatise. This error is repeated regularly, just as happened again recently when as reputed historian omitted to indicate that "the first scleral contact lens" of 1887 was a protective shell: *"It was not until 1887 that the first scleral contact lens was made: F.E Müller, an artificial eye maker in Wiesbaden, was requested to construct a contact lens by Theodor Saemisch. […] Numerous subsequent patients were referred to and fitted by the artificial eye maker."* (60) In a reputed treatise, an illustration representing two blown lenses of *Müller* carries the legend: *"Blown glass contact lenses made by Müller of Wiesbaden (about 1900)"* (61).
However, the *Müller Brothers* state very clearly in their publication that they only supplied their first contact shells for keratoconus starting in 1908. Similar errors are unfortunately common.

Conclusion

In conclusion, one can say that the first blown scleral contact shells of the *Müller Brothers* of Wiesbaden, by replacing *Lohnstein*'s and *Siegrist*'s hydrodiascopes, stimulated both the curiosity and interest of professional circles in refractive correction by corneal contact. They also allowed several patients to be comforted, at least for a short while, and gave these patients the hope of an alternative to surgical treatment, the results of which were unpredictable.
The monopoly of the blown contact shells of *Müller Brothers* of Wiesbaden was to last for another ten years or so, in the course of which these devices had some success in spite of their limited production and empirical method of fitting. (62)

Notes

1 In this chapter, we use often the generic term "contact lens" (*ISO 8320: Contact lens: a generic term including any lens designed to be worn on the front surface of the eyeball). A scleral contact lens is worn on the cornea and the sclera. A contact shell [is an] appliance similar in form to a contact lens but not designed to correct vision*.) (See Appendix 10-1).
The essential difference between a contact lens and a contact shell is that the former has a specified front or back vertex power. Although a rigid contact shell has no specified power, it does allow the formation of a *liquid lens* that will correct regular or irregular astigmatism and may also correct part of the spherical component of a refractive error. Thus, an afocal contact shell is capable of providing reasonable visual acuity, especially in a condition such as keratoconus.
2 See chapter XIX: *Early Therapeutic and Diagnostic Contact Lenses*. The history of ocular prostheses, also called "artificial eyes", is outside the scope of this work, except when these prostheses are provided with a transparent central part against the cornea that could contribute to the neutralization of the cornea and to the correction of a refractive error.
3 *Becker* 1885, page 400: Presentation to the *17th Congress of the Ophthalmology Society of Heidelberg (Ophthalmologische Gesellschaft in Heidelberg*).
4 *Müller F.A. & A.C.* 1910, p. 70. The chapter "*Kontakt-Adhäsionsbrillen*" (contact adhesion spectacles) p. 68-72 of the brochure "*Das Künstliche Auge*" of *F.A and A.C. Müller* is reproduced in *Appendix 15-1*.
5 See chapter X: *Adolf Eugen Fick's Contactbrille,* and chapter XIII*: The Decades after the Invention.*
6 "*par un morceau de la bulle faite par le souffleur de verres." See details in chapter XI: Eugène Kalt's "Optical Treatment" of Keratoconus*.
7 The observations of *Pagenstecher* and *Axenfeld* are taken from the brochure published in *1910* by the brothers *F. A. & A. C. Müller* "*Das künstliche Auge" (The Artificial Eye).* The observations were copied textually almost word for word ten years later in the Inaugural Dissertation" of *F. E. Müller* (1920). They were not published in any medical journals.
8 *Müller F.A. & A.C.* 1910, p.70.
9 *Uhthoff* 1909, p. 48. The *Müller Brothers* appeared to be unaware of this text at the time of publication of their brochure.
10 I have not found any evidence from *Mayweg* that could confirm *Müller's* report.
11 *Müller F;A; & A;C;* 1910, p. 71.
12 *Beutnagel* 1909, p. 22.
13 *Beutnagel* 1909, p. 23.
14 *Helmbold* 1913/14. *Helmbold's* communication was presented in Danzig on the 1st June 1913 to the Meeting of the *Ophthalmologists of East and West Prussia (Versammlung der Augenärzte Ost- und Westpreusens*) and was published in the following year.
15 *Helmbold* 1913, p. 79-80.
16 *Helmbold* 1913/14, p. 80.
17 This patient had been fit with contact lenses in May 1912. In June 1913, at the time of *Helmbold*'s communication, he was wearing contact lenses "*without the least discomfort" (ohne die geringste Unbequemlichkeit- Helmbold 1913/14, p. 80)*. *Helmbold* is to describe the same case once again in 1920, at which date the patient had been wearing his blown contact lenses for eight consecutive years. (*Müller 1920*). See chapter XVII: *The Era of Blown Contact Lenses*.
18 These corrections would be made in 1918 by *von Hippel* and in 1920 by *F.E. Müller*. Note that, in 1888, *Fick* also believed that the shells delivered by *Zeiss* were ground, and it was only in the following year that he learned that they were in fact blown. According to *von Hippel* (1918) and *F.E. Müller* (1920), the ocularist *Müller* subsequently sent 200 blown shells to *Zeiss* for grinding experiments in their optical portions. These shells did not stand up to refinishing, and all of them broke, without exception. The procurement of blown contact shells equipped with a ground optical portion remained a wished-for but unrealizable goal that all authors were to express in the course of the following years.
19 *Bielschowsky* 1914/a, p. 220: Communication presented at the *3rd Meeting of the Hesse and Hesse-Nassau Ophthalmologists (3.Versammlung der hessischen und hessisch-nassauischen Augenärzte)* held in Marburg on May 3, 1914. The case of this female patient is to be described again in 1920 by *F.E. Müller,* on which date she was still wearing her contact lenses.
20 *Bielschowsky* 1914/b, p. 37.
21 The publication appeared in German language, Strasbourg being a German "Reichsland" ("Empire-State territory" of the German Empire) between 1870 and 1918. The ocularists *Müller* traveled every year for a few days to Strasbourg where they visited the *University Eye Clinic* and blew ocular prostheses on location. Starting in 1915, they blew contact lenses for patients suffering from keratoconus who were referred to them.
22 *Weill* 1916, p. 128 & 129.
23 This has to do with repetition of erroneous information reported by *Helmbold* (1913/14), which was rectified later by *Hippel* (1918) and *Müller* (1920).
24 *Kraupa* 1916, note on p. 113.
25 See chapter XIV: *The Era of Hydrodiascopes.*
26 *Siegrist* attributes the invention of the term "Kontaktglass" (contact-glass) incorrectly to *Fick*: *"Fick names this spectacle-glass Kontaktglass."* (*Fick nennt dieses Brillenglas Kontaktglas*) (*Siegrist* 1916, p. 406)
27 *Siegrist* 1916, p. 410-411.
28 See chapter XVIII: *Early Ground Contact Lenses*

29 *Siegrist* 1914, p. 413.
30 *Siegrist* 1916, p. 417.
31 *Siegrist* 1916, p. 418.
32 *Siegrist* 1916, p. 429.
33 The research of *Anni Lüdemann* was published in an article in *Klinische Monatsblätter* (1917/a) and simultaneously with the same title and text as an M.D. "Inaugural Dissertation" (1917/b) that she successfully defended on January 17, 1917.
34 *Lüdemann* recommends insertion without anesthesia.
35 *Lüdemann* 1917/a, p. 285 & 1917/b p. 21.
36 *Lüdemann* 1917/a, p. 288-289 & 1917/b p. 24-25.
37 *Nishimura* 1916, presentation to the first congress of the *Kinki Ophthalmological Society* (The region of *Kinki* includes the cities of *Osaka, Kyoto*, and *Kobe*). The summary of the congress was published in *Chuo Ganka Iho* in 1916 (sometimes cited erroneously in 1917). I am indebted to Professor *Saiichi Mishima* for the verification of this document and its translation, for which I extend my sincere appreciation.
38 *"Die Müllerschen Prothesen sind dünne Schalenaugen, bei denen das vordere Segment - Kornea, Iris, Pupille - nur eine durchsichtige Kornea trägt."* (*Weill* 1916, p. 127).
39 "Auf der anderen Seite wird der undurchsichtige Teil des Kontaktglases, der den individuell mehr oder weniger verschiedenen Bulbusformen und Lidverhältnissen angepasst sein muss, vorderhand am besten durch Blasen erreicht."
"Will man einen Keratokonus mit einem Müllerschen Kontaktglas korrigieren, so nimmt man ein mittelstarkes Glas aus der Sammlung, welches annährend sphärische Krümmung aufweist und bestimmt mit ihm die Fernesehschärfe; dann setzt man vor

dasselbe schwache Plus- oder Minusgläser (+ 1,0 D. oder – 1,0 D.) und sieht nach, ob durch dieselben die Sehschärfe verbessert werden kann. Die so gewonnenen Angaben geben uns einen Fingerzeig, ob wir aus unserer Sammlung ein Kontaktglas mit stärkerer oder schwächerer Hornhautrefraktion aussuchen und probieren sollen. Das neue Kontaktglas wird nun abermals auf die gleiche Methode auf seine Richtigkeit geprüft und nötigenfalls zum zweiten- oder drittenmal gewechselt, bis man exact die nötige Brechkraft des Kontaktglases gefunden hat. Auf diese Weise ist es uns gelungen, trotz der sehr beschränkten Zahl der uns zur Verfügung stehenden überhaupt brauchbaren Müllerschen Kontaktgläser bei einer Anzahl von Keratokonuspatienten bereits Sehschärfen bis zu 0,9 mit Hilfe dieser Müllerschen Gläser zu erzielen." (*Siegrist 1*916, p. 419*)*.

40 *"Die Brechung der Kornea ist in den verschiedenen Prothesen eine verschiedene; eine genaue, bestimmte Krümmung kann denselben, da sie nicht geschliffen, sondern geblasen sind, nicht gegeben werden."* (*Weill* 1916, p. 128-129).

41 *"In günstigen Fällen gelingt es natürlich, eine wesentliche Besserung der Sehschärfe zu erzielen."* (*Kraupa* 1916, p. 113 note).

42 *"Es entspricht in seiner Wölbung genau derjenigen des Augapfels und es findet im Gegensatz zum Fick-Sulzerschen Kontaktglase einen festen sicheren Stützpunkt in der unteren Uebergangsfalte, während sein oberer Teil möglichst schmal gehalten wird, weil der Augapfel eine Belästigung im oberen Teile weniger gut verträgt."* (*Siegrist* 1916, p. 410).

43 *"Das Wichtigste, was auch unsere Untersuchungen in Übereinstimmung mit verschiedenen in der letzten Zeit gemachten Mitteilungen konstatierten, ist die merkwürdige, von vornherein kaum glaubwürdige Tatsache, dass ein irgendwie gut passende Kontaktglas vom menschlichen Auge stunden-, ja tagelang ohne oder nur mit ganz geringen Störungen getragen werden konnte."* (*Lüdemann* 1917/a, p. 288 & 1917/b, p. 24).

44 *"Die Schale braucht nicht, wie man das anfangs für nötig hielt, und wie dies auch Fick und Sulzer für ihre Kontaktgläser angaben, vor dem Aufsetzen auf die Hornhaut mit Flüssigkeit gefüllt zu werden. Der Raum zwischen Hornhaut und Hornhautschale des Kontaktglases füllt sich meist von selbst nach der Einführung des Glases mit der am wenigsten reizenden Tränenflüssigkeit. Das Glas wird dann durch Adhäsion an dem Augapfel festgehalten."* (*Siegrist* 1916, p. 411).

45 *"Da die Gläser sich dem Bulbus nicht so tadellos anschlossen wie wir es verlangen müssen, entstand oft eine relativ große Luftblase zwischen Hornhaut und Glas, die in einigen Fällen durch Tränenabsonderung vertrieben wurde, in anderen fällen aber resistiere und dadurch die Sehschärfe bedeutend herabsetzte, auch direkt unangenehm von den Patienten empfunden wurde, wohl infolge der mangelhaft befeuchteten Hornhaut. Zur Entfernung dieser Luftblase ließ ich den Patient stark abwärts sehen und hob nun mit einer gewöhnlichen Glaspipette (Tropfenzähler), die mit lauwarmen physiologischer Kochsalzlösung gefüllt war, den oberen Rand des Kontaktglases etwas vom Bulbus ab und ließ zu gleicher Zeit Flüssigkeit zwischen Glas und Hornhaut einfließen. So gelang es mir in allen Fällen, die Luftblasen rasch zu entfernen, ohne dem Patienten wehzutun. Die sofort steigende Sehschärfe beruhigte die Patienten auch in hohem Grade."*

and

"Außer den ersten zwei Versuchen wurde das Glas ohne Kokainanästhesie eingesetzt, und zwar ließ ich der Patienten stark abwärts blicken, schob dann das Glas unter das obere Augenlid, das ich leicht mit dem Daumen der linken Hand emporhob. Dann hielt ich Glas und Oberlid mit dem Daumen fest, während der Zeigefinger der rechten Hand das Unterlid abzog, worauf das Glas schmerzlos ohne die geringste Schwierigkeit in den Konjunktivalsack glitt.

Bei der Entfernung des Glases blickte der Patient stark aufwärts, ich zog das Unterlid etwas ab und schob nun einen Schielhaken unter den unteren Rand des Kontaktglases, das ich etwas nach außen zog. Zur gleichen Zeit wurde auf das Oberlid ein leichter Druck ausgeübt, und im selben Moment sprang das Glas heraus.

Auf diese Weise konnte ich völlig schmerzlos das Glas einsetzen und entfernen, so dass ich oftmals mehrere Gläser an ein und demselben Auge probierte, ohne dass dieses gereizt wurde oder die Patienten geklagt hätten."

(*Lüdemann* 1917/a, p. 269 & 1917/b, p. 5).

46 *"Er kann sich seine Kontaktgläser selber einsetzen, nur beim Herausnehmen derselben hilft ihm sein Frau."* (*Lüdemann* 1917/a, p. 270 & 1917/b, p. 5).

47 *"Prof Siegrist macht gegenwärtig Versuche, die Entfernung der Kontaktgläser durch kleine Braunsche Saugnäpfe zu bewerkstelligen. Die Versuche sind noch nicht abgeschlossen, lassen aber jetzt schon die Hoffnung auf ein günstiges Resultat berechtigt erscheinen."* (*Lüdemann* 1917/a, p. 288 & 1917/b, p. 24.)

48 *Weill* 1916, p. 128-129.

49 *"Der Patient trägt besonders das Kontaktglas des linken Auges oft 7-8 Stunden ohne die geringste Reizung des Auges. Dies konnte er 8-9 Tage durchführen. Dann wurde das Auge etwas empfindlich, so dass er eine Pause von 3-4 Tage eintreten ließ. (1.Fall)"*

*"Sie erzählte, sie trage das Glas fast jeden Tag ein paar Stunden lang beschwerdenfrei. Einmal vergaß sie es abends herauszunehmen (jedenfalls ein Beweis, wie wenig Beschwerden es macht) und trug es auf diese Weise 24 Stunden lang beschwerdenfrei. Am anderen Morgen sei das rechte Auge dann allerdings etwas rot gewesen, habe auch geträn*t, *sei aber schon 3-4 Stunden nach Entfernung des Glases wieder normal geworden. (3.Fall)."*

(Lüdemann 1917/a, p. 270 & 271-272 & 1917/b p. 6 & 9).

50 *"Bei dem ersten Patienten stellten sich nach 2 Stunden wahre Schmerzanfälle eine, die jeweilen einige Minuten dauerten und besonders beim Blick nach oben heftiger wurden. Als wir nach 6 Stunden das Glas entfernten, waren Kontaktglas und Hornhaut diffus getrübt wie bei akutem Glaukom.*

Der zweite Patient gab sofort nach dem Einlegen des Glases an, dass der untere Rand desselben drücke und dass die Bulbusbewegungen schwieriger auszuführen seien, das Tragen dieses Glases überhaupt unangenehmer sei als das des Müllerschen. Bei einem dritten Patient [...]. Die Patientin gab sofort nach dem Einführen des Sulzerschen Glases an, dass es ihr äusserst unangenehm sei und dass vor allem der untere Rand des Glases drücke. Schon eine halbe Stunde später ersuchte die Patientin um Herausnahme des Glases, da die Schmerzen zu heftig seien."

(Siegrist 1916, p. 411-412**).**

51 *"Wenn man die Nachteile und Vorteile des Kontaktglases mit denen des Hydrodiaskopes vergleicht, wird man schon heute dem Kontaktglase den Vorzug einräumen müssen, eine Tatsache, welche durch die praktische Erfahrung bei Patienten gewonnen wurde, welche früher Hydrodiaskope trugen und jetzt ohne großes Besinnen zum Kontaktglas übergingen. Man will in der Regel eben lieber etwas weniger gute Sehschärfe, falls sie für die Erfordernisse des gewöhnlichen praktischen Lebens genügt, wenn nur die Entstellung, welche das Hydrodiaskop mit sich bringt, wegfällt. Man nimmt dabei auch gewisse Unannehmlichkeiten, wie sie angedeutet wurden, mit in den Kauf. Wegen der großen Entstellung und wegen des etwas umständliche, jeweiligen Füllens des Apparates mit physiologischer Kochsalzlösung verzichtet man lieber trotz der glänzenden optischen Resultate auf das Hydrodiaskop."*

(Lüdemann 1917/a, p. 285 & 1917/b, p. 21.

52 See chapter XIX: *Early Therapeutic and Diagnostic Contact Lenses*.

53 *"Es sollte durch Vorlegung einer durchsichtigen Kapsel der Augapfel gegen die Luft geschützt und weitere Austrocknung der Kornea, deren Epithel bereits in nekrotischem Zerfall begriffen war, vorgebeugt werden."* (*Müller F.A. & A.C.* 1920, p. 68).

54 See text in Appendix 15 - 1.

55 *"Wir sahen aber auch sofort, daß man durch Blasen imstande ist, der Glaskornea einen beliebigen Fokus zu geben und damit eine Brille zu schaffen, die den Augapfel in allen Teilen anliegend jede Bewegung mitmacht und daher ein gleichmäßiges Sehen nach allen Richtungen ermöglichten. [...] Wie wandten dem Ausbau dieser Sache nach der optischen Richtung hin weiter keine Aufmerksamkeit zu, da bei nicht zu hochgradiger Myopie die optische Korrektur zweckmäßiger durch eine Brille gewöhnlicher Art bewirkt wird, bis uns einige Fälle von Keratokonus unter die Hände kamen."*

(Müller F.A. & A.C., 1910, p. 70).
56 *"Wir bemerken, daß unsere einschlägigen Arbeiten ohne Kenntnis derjenigen des Herrn Dr. Fick vor sich gingen. Unter Anerkennung der Priorität seiner Arbeit zur Lösung der Frage der Kontaktbrille geben wir aber der Überzeugung Ausdruck, daß eine praktische Entwicklung nur auf der von uns gekennzeichneten Grundlage vor sich gehen kann."*
Details given in 1920 in the "Inaugural-Disserttion" for M.D. of *Friedrich E. Müller* (*Müller* 1920, p. 11).
57 In fact, the protective shells blown in 1887 by *Müller* for the patient of *Sämisch* did not have the character of priority of protective shells (see chapter XIX: *Early Therapeutic and Diagnostic Contact Lenses*).
58 *Rosenthal* 1996, p. 370.
59 *Duke-Elder* 1970, vol V, p. 713-715. The figure at page 714 represent "*Albert Carl Müller [1864-1923]",* one of the two *Müller Brothers*.
60 *Albert & Edwards* 1996, p.121. These authors attribute the manufacture in 1887 of the "first scleral contact lens" to "*F.E. Müller"* [sic]. In fact, this "*F.E. Müller"* was born in 1891! The founder of the *Müller* generation was *Friedrich Adolf Müller* (1838-1879), who had two sons, *Albert Carl* (1864-1923) and *Friedrich Anton* (1862-1939). The latter's son was *Friedrich E. (F.E.)*, born in 1891, who in 1920 was the author of an "Inaugural Dissertation" for M.D. on *Müller's* contact lenses/shells for keratoconus.
61 *Sabel* 1988, p. 8 fig.14 & *Sabel* 1997 p. 5 fig. 13.
62 See chapter XVII: *The Era of Blown Contact Lenses*.

Annexe 15-1

Transcription of
Friedrich A. Müller und Albert C. Müller
DAS KÜNSTLICHE AUGE
Wiesbaden, Bergmann 1910
(pages 68 – 72)

Kontakt-Adhäsionsbrillen

In das Gebiet des Augenkünstlers fallen noch einige Arten von Schutzschalen und Brillen.
Im Jahre 1887 sandte uns Geh. Rat Sämisch einen Patienten dessen rechtes Auge nach unten völlig frei lag, weil das untere Lid durch Karzinom völlig zerstört und bis auf den Orbitalrand geschwunden war. Am oberen Lid fehlte der temporale Teil, während der Rest knotig verdickt war mit Einwärtswendung der Wimpern. Es sollte durch Vorlegung einer durchsichtigen Kapsel der Augapfel gegen die Luft geschützt und weitere Austrocknung der Kornea, deren Epithel bereits in nekrotischem Zerfall begriffen war, vorgebeugt werden. Die Erhaltung des Auges war für den Patienten deshalb besonders wichtig, weil es grössere Sehtüchtigkeit besass als das linke Auge; dieses war bei hochgradiger Myopie mit Kernstar behaftet und infolgedessen fast untauglich.
Da sich erwies, dass die einwärtsgekehrten Wimpern einen dauernden Reiz ausüben würden, auch wenn die Kapsel die ganze Partie überdeckte, so entschlossen wir uns, eine Schale mit durchsichtiger Kornea herzustellen, welche nach Art einer dünnen Prothese den Augapfel bekleidete und so den Reiz der Wimpern ausschaltete, während der Augapfel zugleich von der freien Luft abgeschlossen war.

Entgegen der landläufigen Anschauung, dass bei Einlegung eines Ersatzauges über den Bulbus die Kornea nicht berührt werden dürfe, da sie keinerlei Belastung vertrage, hatten wir in vielen Fällen festgestellt, dass gerade dann die Prothese am besten vertragen wird, wenn sie dem Bulbus überall gleichmässig anliegt einschliesslich der Kornea. Sie darf nur nirgends zu fest anliegen, klemmen. Ja gerade da, wo wir die Kornea durch eine stärkere Konkavität der Schale freilegten, entstand eine leichte Einschnürung der kornea-skleralen Grenzzone, die heftige Schmerzreflexe, verbunden mit Quellungen des zentralen Teils der Hornhaut, hervorrief.

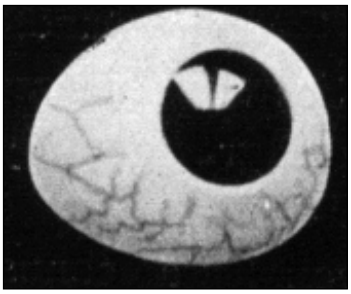


Figure 15-2
Drawing of a blown contact shell of the Brothers F.A. and A.C. Müller of Wiesbaden (1910).
Drawing of an "Adhesion contact-spectacle" (Kontakt-Adhäsionsbrille) reproduced in the brochure of the Müller Brothers "Das Künstliche Auge" (The Artificial Eye) on page 69.
(MÜLLER Friedrich A. & Albert C., Das Künstliche Auge, Wiesbaden, Bergmann, 1910.- Figure page 69)

Wir geben der Prothese eine solche Form, dass sie einen sicheren Stützpunkt in der unteren Übergangsfalte findet, während der obere Teil möglichst schmal gehalten wird, weil der Augapfel eine Belastung im oberen Teil weniger gut verträgt. – Wird die Schale nicht irgendwo in der Übergangsfalte gestützt, so wird sie durch den Lichtschlag in fortdauernde gleitende Bewegung versetzt, was einen heftigen Reiz zur Folge hat.
Diese Feststellung ist am eigenen, gesunden Auge erfolgt; es geschieht dies oft, um den Krümmungsradius einer Schale auf Richtigkeit zu prüfen, manchmal auch, um ängstlichen Patienten Mut einzuflössen. Wir bildeten also demgemäss die Schale. Der Patient trug sie fortan ununterbrochen Tag und Nacht. Er schrieb am 17. Dezember 1908:
“Unserer letzten mündlichen Unterredung gedenkend, bestätige ich Ihnen gerne, dass ich seit dem Jahre 1887 die von Ihnen gefertigten Gläser ununterbrochen Tag und Nacht getragen habe und mein Auge sich stets sehr wohl dabei befunden hat.
Die gelieferten Gläser konnte ich I½ - 2 Jahre ohne Schaden für mein Auge gebrauchen.”
Der betreffende Patient ist heute 82 Jahre alt.
Geh. R. Sämisch war über das Resultat sehr erfreut. In der Folge haben wir derartige Gläser dann mehrmals als Schutzschalen bei inkurablem Entropium verwendet.
Wir sahen aber auch sofort, dass man durch Blasen imstande ist, der Glaskornea einen beliebigen Fokus zu geben und damit eine Brille zu schaffen, die den Augapfel in allen seinen Teilen anliegend jede Bewegung mitmacht und daher ein gleichmässiges Sehen nach allen Richtungen ermöglichten.
Die Schalen können durch Blasen viel dünnwandiger hergestellt werden als durch Schliff, und die Zerbrechlichkeit ist durch ihre Elastizität ausserordentlich gering.
Zentriert man die Glaskornea genau, so ist die Schale nicht als Fremdkörper erkennbar.
Wir wandten dem Ausbau dieser Sache nach der optischen Richtung hin weiter keine Aufmerksamkeit zu, da bei nicht zu hochgradiger Myopie die optische Korrektur zweckmässiger durch eine Brille gewöhnlicher Art bewirkt wird, bis uns einige Fälle von Keratoconus unter die Hände kamen.
Ein Fall, der uns aus der Prof. Pagenstecherschen Praxis von Dr. Krumm zugeführt wurde und ein zweiter aus der des Prof. Axenfeld zeigten, dass ein optischer Ausgleich durch eine Kontaktbrille nach unserer Art sehr wohl zu erzielen war.

Aber die Patienten hatten keine Ausdauer, bis uns ebenfalls von Dr. Krumm ein Mädchen mit beiderseitigem Keratoconus aus der Klinik der Prof. Schlösser in München vorgestellt wurde. Auf beiden Augen gelang die Korrektur vorzüglich, obwohl linksseitig bereits ein zentrales Leukom vorhanden war. Die Patientin konnte beiderseits feine Schrift in normaler Entfernung gut lesen, und vertrug die Schalen ohne jeden Reiz. Der Visus betrug, nachdem die ersten Reizerscheinungen geschwunden:
rechts 5/25 + 2,0 Cylinder + 2,0 a + 90° 5/10 part.
links 5/20 – 2,0 5/10 part. N.1.
Binokular las die Patientin bequem 5/10 N.I
Es wurde festgestellt, dass die Einfüllung von Flüssigkeit nicht nötig ist, um den ungehinderten Durchgang der Strahlen zu bewirken, da die sich ansammelnde Tränenflüssigkeit diese Aufgabe erfüllt.
Ein weiterer Fall, den wir der gütigen Vermittlung des Herrn Geh. R. Uthoff verdanken, brachte gleichfalls ein gutes Ergebnis März 1908. Die gleiche Patientin erhielt ein Jahr später einen Ersatz für die inzwischen zerbrochene Schale; sie kann mit der Brille Nonpareilleschrift in normaler Entfernung lesen und verträgt sie gut.
Ein weiterer Fall aus der Praxis von Geh. R. Mayweg, Hagen wurde mit gutem Erfolg in Bochum am 5. April 1909 behandelt. Der Patient trug die Brille bis 3. Oktober 1909 ununterbrochen Tag und Nacht, bis sie ihm beim Reinigen unter der offenen Wasserleitung auf Sandstein sprang und zerbrach. Die Ersatzschale leistet die gleichen Dienste.
Der Verwendung dieser Brillenart steht ein weites Feld offen, sobald uns öfter Gelegenheit geboten sein wird zu häufigen Versuchen, denn ausser der Korrektur von Keratoconus kommt auch die hochgradige Myopie in Frage. Die Herstellung erfordert ein äusserstes Mass von Anstrengung der Künstlers, da die richtige Brechkraft der Kornea nur durch Augenmass und Vergleiche während des Blasens erzielt werden kann, und dabei der Krümmungsradius des Augapfels genau getroffen werden muss, wobei auch nur das Augenmass zur Anwendung kommen kann.
In anderen Fällen wurde vorläufig kein gutes Resultat erzielt, weil die Patienten zu wenig Zeit und Geduld hatten.
Seitliche Lage der Kegelspitze und unregelmässige Stärke der seitlichen Wandung der Hornhaut, irregulärer Astigmatismus überhaupt, erschweren die Arbeit sehr.
Es muss zur praktischen Lösung dieser Aufgabe ein Studium der Brechungsverhältnisse des Keratoconus vor sich gehen.
Einen günstigen Einfluss beobachteten wir schon bei Gebrauch dieser Schalen, insofern als die Spitze des Kegels gegen weitere Eintrocknung geschützt wird. (Siehe die Bemerkung über günstige Einwirkung auf Erhaltung des Sehvermögens bei starkem Leucoma corneae durch den Gebrauch der Prothese.)
Gegenüber den hyperbolischen Gläsern, bei denen ein scharfes Sehen nur durch den zentralen Teil, der Spitze der stenopäischen Brille, also nach einer Richtung mögliche ist, kann der Träger der Adhäsionsbrille sich nach allen Richtungen gleich gut orientieren.
Der Wert dieser Gläschen gegenüber den geschliffenen liegt darin, dass sie geschmolzen sind, also der Tränenflüssigkeit, sowie der mechanischen Reizung einen dauernden Widerstand entgegensetzen, das heisst fast nicht abgenützt werden, während bei den geschliffenen Gläsern (an und für sich weicheres Material) bei Poren geöffnet sind und nach verhältnismässig kurzer Zeit blind werden.
Wir bemerken, dass unsere einschlägigen Arbeiten ohne Kenntnis derjenigen des Herrn Dr. Fick vor sich gingen.
Unter Anerkennung der Priorität seiner Arbeit zur Lösung der Frage der Kontaktbrille geben wir aber der Überzeugung Ausdruck, dass eine praktische Entwicklung nur auf der von uns gekennzeichneten Grundlagen vor sich gehen kann.
Die Schale darf nicht nur ein kleines Kugelsegment sein, weil sie als solches durch den Lidschlag leicht mitgenommen und in gleitende Bewegung versetzt wird. Auf diese Weise kommt ein Reiz zustande, welcher nur stundenweisen Gebrauch zulässt.
Die Schale muss vielmehr genau in der Weise gebildet werden, wie eine Schalenprothese für phthisischen Bulbus, in ihrer Wölbung genau derjenigen des Augapfels entsprechen und ihren festen Stützpunkt in der unteren Übergangsfalte finden. Nur so wird jeder Reiz vermieden und eine vollkommen ruhige, sichere Lage erzielt.
Die ganze Schale durchsichtig zu halten oder die durchsichtige Kornea in eine mit Blutgefässen versehene Sklera einzufügen, ist von untergeordneter Bedeutung, aber letztere Art halten wir aus technischen wie ästhetischen Gründen für geeigneter.
Durch Blasen allein kann man eine Schale herstellen, die sich der verschiedenartigen Wölbung des Augapfels genau anpasst. Der gewünschte Fokus ist durch Blasen leichter und weniger umständlich zu erzielen als durch Schliff.
Durch Schliff erhält man die Gläser nicht so dünn, als sie nötig sind, um sich in den verfügbaren Raum zwischen Lider und Augapfel reizlos einzufügen. Denn bei Keratoconus oder stark myopischen Augen sind die Lider bereits ungewöhnlich stark angespannt, so dass sie eine weitere Belastung durch eine eingefügte Schale von mehr als einem Drittelmillimeter kaum vertragen. Die Einsetzung dieser Schälchen erfordert naturgemäss grosse Geschicklichkeit, es zeigt sich in allen Fällen anfänglich ein Konjunktivalreiz, der erst durch die Gewöhnung verschwindet; man lässt die Schale nur stundenweise tragen, steigend mit fortschreitender Gewöhnung.