

# Chapter 11

Eugène Kalt's "Optical Treatment" of  
Keratoconus



## Introduction

The name of *Eugène Kalt* is associated with the first therapeutic, optical and compressive applications of contact shells and contact lenses in France (1). *Kalt* was Chief Clinical Assistant in Paris (France), at the Department of Ophthalmology of the *Hôtel Dieu Hospital*, in Professor *Photinos Panas's* Unit at the time when the latter presented, on March 20, 1888, the work of his young colleague to the *French Academy of Medicine in Paris (Académie Nationale de Médecine)*. The communication was published in the same year in the *Bulletin de l'Académie de Médecine*. An abstract appeared also, a short time later, in the *Annales d'Oculistique*, under the title of "***Traitement Optique du Kératocône***" (*Optical Treatment of Keratoconus*).

In this chapter, I propose to record and analyze the above two texts. I shall also consider and review in detail the citations of two contemporary witnesses of *Kalt*, the Parisian ophthalmologists *Sulzer* and *Haas*. Next follows a critical analysis of *Kalt's* published work, including an evaluation of his priority in the invention of contact lenses. I shall conclude the present chapter with a brief overview of the appreciation usually accorded to *Kalt's* work.

# 1 - Source Documents

<b>Late 19th century</b>	
March 20, 1888	<i>Panas's communication to the French Academy of Medicine on "Traitement Optique du Kératocône" (Optical Treatment of Keratoconus) in Bulletin de l'Académie Nationale de Médecine, 19, 1888, 400-401.</i>
1888	<i>Publication of Panas's presentation in Annales d'Oculistique (99, 1888, 233).</i>
1889	<i>Publication of Panas's presentation as reported in German literature (Centralblatt für praktische Augenheilkunde, 12, 1889, 139).</i>
1888-1893	<i>Kalt experimented with ground contact lenses without scleral zone.</i>
May 3, 1893	<i>Sulzer-Kalt-Panas controversy at the Congress of the French Society of Ophthalmology (Bulletins et Mémoires de la Société Française d'Ophtalmologie, 11, 1893, 385-392).</i>
1894	<i>Citation by Sulzer of Kalt's contact lenses in his controversy with Fick (Archiv für Augenheilkunde, 28, 1894, 236-237).</i>
<b>20th century</b>	
July 16, 1937	<i>Kalt's letter to Haas on his experiments with contact shells and with contact lenses. November 14, 1937 Presentation of Haas's report on contact lenses, together with citation of Kalt's letter's to him.</i>

Table 11 - 1  
Chronology of Eugène Kalt's presentations and of the related citations.

## 1.1. – The Communication of Panas to the French Academy of Medicine (1888)

(Appendix 11-1)

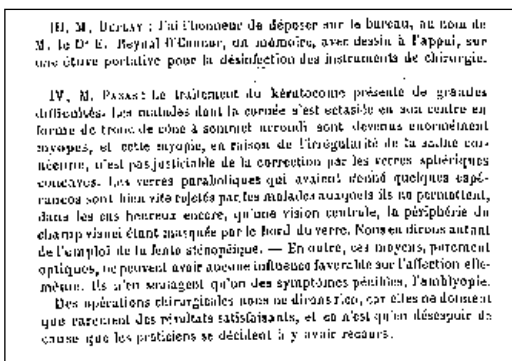


Figure 11 - 1

Communication by Photinos Panas to the French Academy of Medicine on March 20, 1888.

(PANAS Photinos, "Traitement optique du kératocône", Bulletin de l'Académie Nationale de Médecine, 19, 1888, 400-4001. - Excerpt of page 400).

*Panas's communication on March 20, 1888, to the French Academy of Medicine (Académie Nationale de Médecine) was relatively brief. It began with a review of the difficulties encountered in the treatment of keratoconus, calling to mind the procedure of compression of the cone used by Panas (1885) and the modified procedure that had been more recently perfected by Kalt, who used "glass shells" for this compression:*

*"The treatment of keratoconus presents great difficulties. The patients, whose cornea is ectatic in their central portions and which takes the shape of a conical trunk with a rounded apex typically become enormously myopic; moreover, this myopia, because of the irregularity of the corneal protrusion, is not amenable to correction by concave spherical spectacle lenses."*

*"Le traitement du kératocône présente de grandes difficultés. Les malades dont la cornée s'est ectasiée en son centre en forme de tronc de cône à sommet arrondi sont devenus énormément myopes, et cette myopie, en raison de l'irrégularité de la saillie cornéenne, n'est pas justiciable de la correction par les verres sphériques concaves." (2)*

### The Failure of Different Forms of Treatment for Keratoconus

*Panas lists the various treatments available for keratoconus patients at the time, notably the parabolic spectacle lenses, which patients were quick to reject, and the stenopaic slit,*

both of which treatment modalities were, for practical purposes, useless. Surgical treatment rarely gave good results. There remained treatment by compression with a bandage combined with simultaneous instillations of miotics. This method was recommended by *Panas* (3), who used it in Paris at the *Hôtel Dieu Hospital* and produced some positive results. However, it must be said that this method was painful and the wearing of the compression bandage made any kind of activity impossible:

*“The parabolic spectacle lenses, about which there had been some optimism, are very quickly rejected by the patients to whom they permitted, in favorable cases, moreover, only vision in the center of the visual field, the periphery of the visual field being masked by the border of the lenses. We will say the same regarding the use of the stenopaic slit. - Furthermore, these purely optical means cannot have any favorable influence on the disease itself. They only alleviate one of the troublesome symptoms, namely amblyopia. In regard to surgical operations, we shall make no comment, for they only rarely and very occasionally give satisfactory results, and it is only in despair that practitioners decide to resort to this option.*

*There remains the least hazardous method of curing patients afflicted with keratoconus that has positively given good results, namely compression with a bandage combined with the simultaneous instillation of miotics. However, the compressive bandage has the inconvenience, first, of interrupting the exercise of vision and, second, of provoking ciliary pain, which sometimes makes the use of this modality unable to be tolerated.”*

*“Les verres paraboliques qui avaient donné quelques espérances sont bien vite rejetés par les malades auxquels ils ne permettent, dans les cas heureux encore, qu’une vision centrale, la périphérie du champ visuel étant masquée par le bord du verre. Nous en dirons autant de l’emploi de la fente sténopéïque. - En outre, ces moyens purement optiques, ne peuvent avoir aucune influence favorable sur l’affection elle-même. Ils n’en soulagent qu’un des symptômes pénibles, l’amblyopie.*

*Des opérations chirurgicales nous ne dirons rien, car elles ne donnent que rarement des résultats satisfaisants, et ce n’est qu’en désespoir de cause que les praticiens se décident à y avoir recours.*

*Reste la méthode curative la moins hasardeuse, celle qui a donné positivement de bons résultats : la compression avec le bandeau, combinée avec les myotiques. Mais le bandeau compressif a l’inconvénient d’abord d’interrompre l’exercice de la vision et ensuite de provoquer des douleurs ciliaires qui rendent son usage parfois insupportable.” (2)*

### **Treatment of Keratoconus by Kalt’s Prosthetic-like Contact Shells**

The compression by glass shells invented by *Kalt* was expected to replace advantageously previous treatment modalities. *Panas* claimed many potential benefits for these contact devices. They would be analogous to “those used sometimes in the treatment of symblepharon”. They would be perfectly tolerated for many hours at a time and the slight irritation that they cause would quickly disappear. They would follow all the movements of the eye, to which they adhere strongly. They would reshape the cornea by a molding effect, which improves vision rapidly and creates a state “close to emmetropia”:

*“The means that Mr. Kalt proposes have the advantage of immediately reshaping the cornea, with resultant suppression of the cone and correction of the refractive error. The method consists of the use of glass shells analogous to those used sometimes in the treatment of symblepharon. These shells, which have the size of the enamel shells used as ocular prostheses, have a radius of curvature close of that of the cornea. They are perfectly tolerated for many a long hour and the mild conjunctival irritation that they provoke disappears quickly after their removal. Whilst following the movement of the eye, they adhere strongly to the ocular globe, due to the atmospheric pressure. The*

*cornea, much thinned, molds itself exactly inside their concavity and, as a result, is reshaped. If the curvature of the glass is well chosen, one can achieve a state close to emmetropia and, important to note, the vision is improved throughout the whole extent of the visual field. »*

*“Le moyen que M. Kalt propose a l’avantage de redresser immédiatement la cornée, d’où suppression du cône et correction de l’anomalie de réfraction. Il consiste dans l’emploi de coques de verre analogues à celles qui sont employées quelquefois dans le traitement du symlépharon. Ces coques, de la grandeur des coques d’émail qui servent à la prothèse oculaire ont un rayon de courbure voisin de celui de la cornée. Elles sont parfaitement supportées pendant de longues heures par cette membrane et la faible irritation conjonctivale qu’elles provoquent disparaît vite après leur enlèvement. Tout en suivant les mouvements de l’œil, elles adhèrent fortement au bulbe, grâce à la pression atmosphérique. La cornée très amincie, se moule exactement dans leur concavité et se trouve, par le fait, redressée. Si la courbure du verre est bien choisie, on peut réaliser un état voisin de l’emmétropie, et, fait important, la vision se trouve améliorée dans toute l’étendue du champ visuel.” (2)*

A patient in clinical practice who showed an extraordinarily rapid and quite definite favorable result furnishes the proof of the success of this treatment:

*“One of our patients, who scarcely counted fingers at a half-a-meter distance, saw his visual acuity immediately improve to the point of being able to read characters of 26 mm height at a distance of 5 meters. At near, he was able to read a newspaper.”*

*“Un de nos malades qui comptait à peine les doigts à 0,50 m voyait de suite sa vision remonter au point de pouvoir lire à 5 mètres des caractères de 26 millimètres de hauteur. De près il lisait un journal.” (2)*

Panas adds that these results were obtained in two patients (4) at the time he had knowledge of Fick’s article, whose observations and conclusions were going in the same direction as his own:

*“The optical correction was therefore achieved in a very satisfactory manner. The future will show whether the effect is truly curative.*

*The results that were obtained at the Hôtel Dieu Clinic on two patients were ready to be published, when we became aware of a paper by Dr. Fick, of Zurich, that was published in the March 1888 issue of the Archiv für Augenheilkunde. The author, who employed a method identical to ours, arrived at absolutely similar results in regard to keratoconus. We were very happy to note this agreement of results and I remain optimistic that the method will soon acquire the favor of practitioners.”*

*“La correction optique est donc réalisée d’une façon très satisfaisante. L’avenir montrera quel peut être l’effet curatif.*

*Ces résultats, obtenus à la clinique de l’Hôtel Dieu sur deux malades, étaient prêts à être publiés, quand nous avons eu connaissance d’un travail du Docteur Fick, de Zurich, paru dans les Archiv für Augenheilkunde, fascicule de mars 1888. L’auteur, qui a employé une méthode identique à la nôtre, est arrivé à des résultats absolument semblables au point de vue du kératocône.*

*Nous nous félicitons de cet accord, et nous espérons que la méthode aura bientôt acquis la faveur des praticiens.” (2)*

## 1.2. – The Article in the Annales d'Oculistique (1888)

A report of the communication of *Panas* was published in the *Annales d'Oculistique* under the title of “*Traitement Optique du Kératocône*” (*Optical Treatment of Keratoconus*). It recalls, with slight modifications, the second part of the presentation to the *French Academy of Medicine*:

“*Optical Treatment of Keratoconus. – Mr. Panas presents to the Academy, in the name of Mr. Kalt, a treatment procedure for keratoconus that has the advantage of immediately reshaping the cornea, with resultant suppression of the cone and correction of the refractive anomaly. This procedure consists essentially of the use of glass shells of the size of enamel shells, such as are used as ocular prosthesis and with a radius of curvature close to that of the cornea. These shells are perfectly tolerated for many hours by this membrane and the slight irritation that they provoke disappears quickly after their removal.*

*They follow the movements of the eye and adhere strongly to the ocular globe, because of atmospheric pressure. The cornea, much thinned, mold themselves exactly inside their concavity and are, as the result of that, reshaped. If the curvature of the glass is well chosen, one can achieve a state close to emmetropia and, important to note, the vision is improved throughout the whole extent of the visual field.*

*A patient, who scarcely counted the fingers at half a meter, saw his vision immediately improved to the point of being able to read characters of 26-mm height at 5 meters. At near, he was able to read a newspaper.*

*The optical correction was therefore achieved in a very satisfactory manner. The future will show if this is truly a curative effect.*

*These results, obtained at the Hôtel Dieu Clinic on two patients, were, according to Mr. Panas, ready to be published, when he became aware of a paper by Dr. Fick, published in the Arch. für Augenheilkunde, in the March 1888 issue. The author, who employed an identical method, arrived at absolutely similar results in regard to keratoconus.”*

“*Traitement optique du k ratoc ne. – M. Panas pr sente   l'Acad mie, au nom de M. Kalt, un proc d  de traitement du k ratoc ne, qui a l'avantage de redresser imm diatement la corn e, d'o  suppression du c ne et correction de l'anomalie de r fraction. Ce proc d  consiste dans l'emploi de coques de verres de la grandeur des coques d' mail qui servent   la proth se oculaire et d'un rayon de courbure voisin de celui de la corn e. Ces coques sont parfaitement support es pendant de longues heures par cette membrane, et la faible irritation qu'elles provoquent dispara t vite apr s leur enl vement. Elles suivent les mouvements de l' il et adh rent fortement au bulbe, gr ce   la pression atmosph rique.*

**Traitement optique du k ratoc ne.** – M. Panas pr sente   l'Acad mie, au nom de M. Kalt, un proc d  de traitement du k ratoc ne, qui a l'avantage de redresser imm diatement la corn e, d'o  suppression du c ne et correction de l'anomalie de r fraction. Ce proc d  consiste dans l'emploi de coques de verres de la grandeur des coques d' mail qui servent   la proth se oculaire et d'un rayon de courbure voisin de celui de la corn e. Ces coques sont parfaitement support es pendant de longues heures par cette membrane, et la faible irritation qu'elles provoquent dispara t vite apr s leur enl vement.  
Elles suivent les mouvements de l' il et adh rent fortement au bulbe, gr ce   la pression atmosph rique. La corn e, tr s aminciss, se moule exactement dans leur concavit  et se courbe, par le fait, redress e. Si la courbure du verre est bien choisie, on peut r aliser un  tat voisin de l'emmetropie, et, fait important, la vision se trouve am lior e dans toute l' tendue du champ visuel.  
Un malade, qui comptait   peine les doigts   0 m. 50, voyait tout de suite sa vision remonter au point de pouvoir lire   5 m tres des caract res de 26 millim tres de hauteur. De pr s, il lisait un journal.  
La correction optique est donc r alis e d'une fa on tr s satisfaisante. L'avenir montrera quel peut  tre l'effet curatif.  
Les r sultats, obtenus   la clinique de l'H tel-Dieu sur deux malades, dit M. Panas,  taient r t s    tre publi s, quand nous avons eu connaissance d'un travail du docteur Fick, paru dans les Arch. f r Augenheilkunde, fascicule de mars 1888. L'auteur, qui a employ  une m thode identique, est arriv    des r sultats absolument semblables au point de vue du k ratoc ne.

Figure 11 - 2

*Annales d'Oculistique (1888), where the report of the communication of Photinos Panas to the French Academy of Medicine was published.*

(PANAS Photinos, "Traitement optique du k ratoc ne", *Annales d'Oculistique*, 99, 1888, 233. - Excerpt of page 233).

?) Acad mie de M decine zu Paris. Mars-April 1888. (H. M.-Z.)  
Optische Behandlung des Keratoconus.  
Dr. Panas zeigt im Namen Kalt's Glinsehalen von der Gr sse der Email-  
schalen, wie sie zur Augenprothese dienen, mit einem Kr mmungsradius, der  
unabh ngig von der Cornea ist. Er wendet dieselben zur Behandlung des Ker-  
atoconus an, indem er mit ihnen sofort die Cornea redressirt. Die Schalen  
werden stundenlang auf der Cornea getragen und der geringe Reiz, den sie her-  
vorrufen, verschwindet schnell nach ihrer Entfernung. Sie folgen den Augen-  
bewegungen und adh riren fest dem Bulbus infolge der atmosph rischen Druckes.  
Die Hornhaut schmiegt sich der Concavit  der Schale an und wird dadurch  
redressirt. Wenn die Schalenkr mmung gut gew hlt wird, kann man einen der  
Emmetropie nahe kommenden Zustand herbeif hren, und die Sehsch rfe bessert  
sich im ganzen Gesichtsfeld. Ein Patient, der kaum auf 0,5 m Entfernung  
Finger z hlen konnte, erkannte sofort Buchstaben von 26 mm H he auf 5 m  
Entfernung. In dem Moment, wo diese Resultate veroffentlicht werden sollten,  
gelangte J' zur Kenntniss einer Arbeit Fick's im Archiv f r Augenheilkunde  
1888, der mit denselben Mitteln denselben Erfolge erzielte.

Figure 11 - 3

*Publication of a German summary of Photinos Panas's communication to the French Academy of Medicine.*

(PANAS Photinos, "Optische Behandlung des Keratoconus", *Centralblatt f r praktische Augenheilkunde*, 12, 1889, 139. - Excerpt of page 139).

*La cornée, très amincie, se moule exactement dans leur concavité et se trouve, par le fait, redressée. Si la courbure du verre est bien choisie, on peut réaliser un état voisin de l'emmétropie, et, fait important, la vision se trouve améliorée dans toute l'étendue du champ visuel.*

*Un malade, qui comptait à peine les doigts à 0 m 50, voyait tout de suite sa vision remonter au point de pouvoir lire à 5 mètres des caractères de 26 millimètres de hauteur. De près, il lisait un journal.*

*La correction optique est donc réalisée d'une façon très satisfaisante. L'avenir montrera quel peut être l'effet curatif.*

*Ces résultats, obtenus à la clinique de l'Hôtel-Dieu sur deux malades, dit M. Panas, étaient prêts à être publiés, quand nous avons eu connaissance d'un travail du docteur Fick, paru dans les Arch. für Augenheilkunde, fascicule de mars 1888. L'auteur, qui a employé une méthode identique, est arrivé à des résultats absolument semblables au point de vue du kératocône." (5)*

The information given by *Panas* on the nature of the glass shells used and the clinical results obtained are very succinct. He refers to “glass shells of the size of the enamel shells such as are used as ocular prosthesis and with a radius of curvature close to that of the cornea”. The communication to the Academy of Medicine indicates besides that the shells were “analogous to those used sometimes in the treatment of symblepharon”, a detail not picked up in the publication of the *Annales d'Oculistique*. A German summary of the communication by *Panas* appeared in 1889 (6).

### 1.3 - Evidence Given by Later Authors

It is necessary to complete this investigation on the utilization of contact shells and lenses by *Kalt* because of evidence from two sources: the first piece of evidence is by *Sulzer* (1893), but this must be interpreted with reservations, whereas the second, by *Haas* (1937), is much more credible.

#### 1.3.1 – Sulzer's Evidence (1893)

The ophthalmologist *Sulzer* was himself an active contributor at this time in the development of contact lenses. His evidence came to us in the context of two controversies that he had, namely, one with *Kalt* and the other with *Fick* (7).

#### **The Kalt-Sulzer Controversy**

*(Appendix 11-2)*

At the time of a discussion on the treatment of keratoconus by *Abadie* at the *French Society of Ophthalmology (Société Française d'Ophthalmologie)* on May 3, 1893, following *Chevallereau's* communication, *Sulzer* criticized *Kalt* because his lenses were devoid of a scleral rim and did not adhere to the cornea:

*“Kalt's lenses, because of a lack of a scleral band, adhered too little to the eye to be usable.”*

*“les verres de Kalt, à défaut d'un bord scléral, adhéraient trop peu à l'œil pour pouvoir être utilisés.” (8)*

To this, *Kalt* replied that the adherence occurred by “atmospheric pressure”:

*“Mr. Sulzer said that my shells adhered insufficiently to the cornea and would not grip it. Mr. Sulzer does not appear to have taken into account that adherence occurs by atmospheric pressure such as happens when two moist plates of glass are*



*approximated.*"

"M. Sulzer dit que mes coques adhéraient insuffisamment à la cornée, ne serraient pas. M. Sulzer ne paraît pas se rendre compte que l'adhérence se fait par la pression atmosphérique, comme il arrive pour deux plaques de verre mouillées." (8)

### The Sulzer-Fick Controversy

In 1894, in the following year, and in the course of his polemic with *Fick*, *Sulzer* (9) took issue with the former regarding the priority of using contact lenses that were ground by the Paris optician *Verlin*. There is no doubt that *Sulzer* was referring to lenses ground to 11.00-, 11.50-, and 13.00-mm total diameter of a second series of *Kalt's* experiments described by *Haas*, and not to the shells presented in 1888 by *Panas*, which were of 16.00-mm total diameter, although his wording leads one to understand the contrary:

"Mr. Kalt has attempted to correct keratoconus with contact-glasses without a scleral band, which were ground by *Verlin* in Paris. His experiments were reported by *Panas* to the Academy of Medicine on March 13 [sic], 1888."

"Herr Kalt hat den Keratoconus mit von *Verlin* in Paris geschliffene Contactgläsern ohne Scleralrand zu corrigieren versucht. Seine diesbezüglichen Erfahrungen sind durch Herrn *Panas* am 13 März 1888 der Académie de médecine de Paris mitgeteilt worden." (10)

### 1.3.2 – The Evidence of Haas (1937)

(Appendix 11-3)

The report of *Haas* of the title "*Verres de contact*" (*Contact Glasses*), presented on November 14, 1937, to the *Paris Society of Ophthalmology (Société d'Ophthalmologie de Paris)*, recalls *Kalt's* studies in two instances. *Haas* effectively makes a clear distinction between, in the first place, the blown 'shell-like contact lenses' that were used for the experiments of 1888 and, secondly, the better perfected ground contact lenses used several years later.

### The Prosthetic-like blown Shells of 1888

In order to publish his report in 1937 to the *Paris Society of Ophthalmology*, *Haas* had interrogated *Kalt*. He obtained the detail that only one patient was involved in 1888 at the time of *Kalt's* first attempt: a young nun affected by bilateral keratoconus in whom the visual acuity was slightly, but immediately, improved at the time of the experiment. According to the evidence of *Haas*, who was able to examine them, two glass-blown shells of a single curvature were used with a total diameter of 16.00 mm and 22.00 mm. The shells appeared to have been cut out of a glass-blown sphere that gave them an irregular refractive power.

It is not surprising that one portion of a glass-blown sphere with the dimensions of an ocular prosthesis and introduced between the ocular globe and the eyelids was poorly

M. ABADIE. — J'ai eu l'occasion de soigner un jeune homme atteint d'une double kéraconie et j'ai employé le même moyen que M. Chevallereau c'est-à-dire la cautérisation au galvano-cautére du sommet du cône. Le résultat immédiat fut extrêmement satisfaisant, mais au bout de deux mois la vision commença à baisser et le malade revint me voir. Je constatai qu'un état glaucomeux se développait que rien n'a pu enrayer ni l'instillation d'éserine ni même l'iridectomie.

Je n'ignore pas que ces glaucomes d'origine cornéenne sont rares puisqu'à chaque instant nous cautérisons la cornée au galvano-cautére dans les ulcères infectieux et nous n'observons jamais ce genre de complication. Néanmoins elle peut survenir, même le cas auquel je viens de faire allusion.

Chez ce même malade ne sachant plus que faire pour remédier à son état je lui ai conseillé de porter sur l'autre œil les verres de contact préconisés par M. Sulzer : il s'en trouve très satisfait.

M. KALT. — Je me permettrai de rappeler à M. Abadie que le traitement optique de kéraconie a été préconisé en même temps, en Suisse, par M. Fick, en France, par moi, en 1887, dans une communication à l'Académie de médecine, et non pas par M. Sulzer.

Figure 11 - 4

Discussion of the communication by Chevallereau "Traitement du kéraconie" (Treatment of Keratoconus). Discussion by Abadie followed by Kalt's intervention on a point of information and a challenge from Sulzer.

(ABADIE Charles, "Discussion" in Chevallereau "Traitement du kéraconie", Bulletin et Mémoires de la Société Française d'Ophthalmologie, 11, 1893, 385-392, - Excerpt of page 391).

« Nous nous félicitons de cet accord, et nous espérons que la méthode aura bientôt acquis la faveur des praticiens. »

La lecture de cette présentation semblerait suggérer que la pensée principale de M. Kalt ait été le redressement orthopédique de la cornée conique par le moyen du verre de contact. Je pense qu'il faut laisser la responsabilité de ce point de vue au présentateur. Je me suis adressé à M. Kalt lui-même, qui m'a aimablement fourni, dans une lettre du 16 juillet 1937, les renseignements que je lui demandais. Le cas dont il avait eu à s'occuper était celui d'une jeune religieuse atteinte de kératocône bilatéral, et qui comptait seulement les doigts. L'application du verre de contact avait brusquement porté l'acuité visuelle à 0,3 ou 0,4.

Il s'agissait cependant d'une coque soufflée bien imparfaite, si j'en juge par les deux coques de l'époque, que M. Kalt a bien voulu me confier. Son diamètre approximatif devait être 16 à 22 mm., elle ne comportait pas les deux parties respectivement destinées à l'optique et à l'adhérence, constituée seulement par un morceau de la bulle faite par le souffleur, et d'une réfraction extrêmement irrégulière.

Un peu différemment de ce que M. Panas affirmait à l'Académie, M. Kalt m'a écrit que cette coque n'était jamais supportée plus de quelques heures.

Figure 11 - 5

Evidence of Emile Haas on the circumstances of utilization of contact shells and lenses for the optical correction of a patient with keratoconus.

(HAAS Emile, "Les Verres de contact", Bulletin de la Société d'Ophthalmologie de Paris, 1927, suppl. 1-60. - Excerpt of page 73.)

for adherence but consisted essentially of a portion of the bubble blown by the glass blower, and their refractive powers were extremely irregular.

This was somewhat different from what Mr. Panas communicated to the Academy. Mr. Kalt wrote in his letter to me that this shell was never tolerated for more than a few hours."

"Je me suis adressé à M. Kalt lui-même, qui m'a aimablement fourni, dans une lettre du 16 juillet 1937, les renseignements que je lui demandais. Le cas dont il avait eu à s'occuper était celui d'une jeune religieuse atteinte de kératocône bilatéral, et qui comptait seulement les doigts. L'application du verre de contact avait brusquement porté l'acuité visuelle à 0,3 ou 0,4.

Il s'agissait cependant d'une coque soufflée bien imparfaite, si j'en juge par les deux coques de l'époque, que M. Kalt a bien voulu me confier. Son diamètre approximatif devait être 16 à 22 mm, elle ne comportait pas les deux parties respectivement destinées à l'optique et à l'adhérence, constituée seulement par un morceau de la bulle faite par le souffleur, et d'une réfraction extrêmement irrégulière.

Un peu différemment de ce que M. Panas affirmait à L'Académie, M. Kalt m'a écrit que cette coque n'était jamais supportée plus de quelques heures." (12)

### The Ground Contact Lenses for Kalt's Second Attempt

In his report to the *Paris Society of Ophthalmology*, Haas cites also the passage of the letter in which Kalt describes his later experiments with "thin glasses of ground crystal, having a radius of curvature the same as that of a normal cornea according to the measurements taken with a Javal keratometer and verified with a mold of a cadaver eye". Haas said that he had examined the plaster mold and the three ground lenses. One can deduce from the available evidence that Kalt asked the optician to grind the contact lenses according to the keratometric measurements of a normal eye and that he compared these lenses with the impression taken from a cadaver eye.

The three contact lenses examined by Haas are single curvature lenses; they are differentiated only by their total diameters of 11.00, 11.50 and 13.00 mm. The front optic zone radius, measured by Haas, was 7.90 mm. The refractive power was +1.50 to 2.00 diopters, leading one to suppose that the back surface was flatter (i.e., of longer radius) than the front surface. Haas indicates that he did not know the name of the optician who

tolerated and could not be endured beyond the duration of the effect of the anesthesia:

"I contacted Mr. Kalt himself and he was kind enough to provide me with the information that I requested in his letter of 16 July 1937. The case with which he had been concerned was that of a young nun who suffered from bilateral keratoconus and who had visual acuity only counting fingers. The application of the contact glass in this patient's eye had suddenly improved the visual acuity to between 3/10 and 4/10 (11).

It was in fact a really imperfectly glass-blown shell, if I can judge from the two shells from that era, that Mr. Kalt kindly entrusted to me. Their approximate diameter had to vary from 16 to 22 mm; they did not comprise the two sections destined respectively for optics and

ground these contact lenses (13):

*“After his first experiments to produce, as he put it, ‘better transparency,’ Mr. Kalt asked a manufacturer of optical glasses to construct for him thin glasses of ground crystal, having a radius of curvature the same as that of a normal cornea according to the measurements taken with a Javal keratometer and verified on a mold of a cadaver eye.*

*I have had, thanks to Mr. Kalt, the possibility of examining the plaster cast in addition to three ground glasses provided to him. These glasses consisted of only the corneal portion, which was a portion of a sphere, the diameter of which is respectively 11, 11.5 and 13 mm at the base. Examined with both surfaces in air, they have convergent effects respectively of approximately 1.5, 1.5 and 2 diopters. Their polish is satisfactory and their refraction is very regular. Examined on the Javal ophthalmometer, all three of them show a front surface free of astigmatism and a radius of curvature of 7.9 mm (14). They are obviously made from ground glass, probably with the aid of the same convex and concave grinding tools. Their difference in power can be due only to their slightly different thicknesses. Mr. Kalt does not say which optician made them.*

*It is clear to me that they must have been held in position—if they did hold—as the result of atmospheric pressure alone, for their diameter is precisely of the order of size of the palpebral slit. One can thus explain the difficulties in removing them, which Mr. Kalt has also indicated to me, as well as the difficulties of their insertion. It is probable that both the one and the other would have been greatly facilitated by the use of a pneumatic suction cup.”*

*“Après ses premiers essais et pour avoir, dit-il, une ‘transparence meilleure’, M. Kalt demanda à un fabricant de verres d’optique de lui construire des verres minces en « cristal » taillé, établis d’après le rayon de courbure de la cornée normale mesurée au Javal et vérifiées sur un moulage d’œil de cadavre. J’ai eu, grâce à M. Kalt, la possibilité d’examiner le moulage de plâtre, ainsi que trois des verres taillés qu’on lui avait fournis. Ces verres ne comportent que la partie cornéenne, calotte de sphère, dont le diamètre à la base est respectivement 11, 11,5 et 13 millimètres. Examinés avec les deux faces dans l’air, ils ont des effets convergents respectifs de 1,5 ; 1,5 ; et 2 dioptries environ. leur poli est satisfaisant, leur réfraction bien régulière. Examinés à l’ophthalmomètre de Javal, ils montrent tous les trois une face antérieure exempte d’astigmatisme, et d’un rayon de courbure de 7,9 mm. Ils sont manifestement taillés, vraisemblablement à l’aide de la même balle et du même bassin. Leur différence de pouvoir ne peut tenir qu’à leur épaisseur légèrement différente. M. Kalt ne m’a pas dit quel opticien les avait construits.*

*Il est manifeste qu’ils devaient tenir - s’ils tenaient - par suite de la pression atmosphérique seule, car leur diamètre est précisément de l’ordre de grandeur de la fente palpébrale. On s’explique ainsi les difficultés de leur enlèvement que M. Kalt m’a d’ailleurs signalé, ainsi que les difficultés de leur introduction. Il est probable que l’un et l’autre auraient été grandement facilités par l’emploi d’une ventouse pneumatique.”*

(15)

J’ai eu personnellement entre les mains un verre de contact que M. Sulzer avait autrefois donné à M. L. Duguy-Dutemps, et que celui-ci a bien voulu me confier. Il résulte de l’examen de ce verre, fait à l’Institut d’optique théorique et appliquée, qu’il est fait d’une matière dont l’indice de réfraction, pour la raie verte du mercure, est 1,499. Son diamètre total est un peu supérieur à 13 mm., dont 12,5 mm. pour la partie cornéenne. Le rayon de courbure de la face cornéenne postérieure est le même au centre qu’au bord : 7,707 mm. L’épaisseur au centre est 0,6 mm. ; au bord 0,51. Le verre examiné dans l’air est légèrement divergent, moins de 0,25 dioptrie. En ayant examiné moi-même à l’ophthalmomètre de Javal, j’ai constaté que la face antérieure était exempte d’astigmatisme. Ce verre est très probablement taillé.

Figure 11 - 6

Evidence of Emile Haas on the utilization by Eugène Kalt of ground contact lenses.

(HAAS Emile, "Les Verres de contact", Bulletin de la Société d’Ophthalmologie de Paris, 1927, suppl. 1-60. - Excerpt of page 75.)

## 2 – Discussion

### 2.1 – Terminology

*Panas* and *Kalt* use the terms “coque de verre” (glass shell) and “coque” (shell). *Abadie* used that of “cornée artificielle de *Sulzer*” (*Sulzer*'s artificial cornea) and “verre de contact de *Sulzer*” (*Sulzer*'s contact glasses). In 1894, *Sulzer* used that of “verre de contact” (contact glass).

### 2.2 – Technical Aspects: Kalt's Two Types of Contact Lenses

A crosschecking of the various documents (*Panas*, *Kalt*, *Sulzer*, *Haas*) confirms that *Kalt* performed two distinct series of experiments, for each of which he used a different model of contact lens: In 1888, he used contact shells made of blown glass, whereas, in the years that followed, he used ground and polished contact lenses.

#### Prosthetic-like blown Shells of Kalt-Panas

In his 1888 presentation to the *French Academy of Medicine*, *Panas* wrote that the contact shells used were “the same size as the enamel shells used as ocular prostheses”.

<b><i>Kalt-Panas prosthetic-like blown contact shells (1888)</i></b>	
Type	<i>Glass-blown, monocurve</i>
Front optic zone radius	<i>Irregular</i>
Back optic zone radius	<i>Irregular</i>
Power	<i>Unknown, irregular</i>
Total diameter	<i>16.00 to 22.00 mm</i>

Table 11 -2

Characteristics of the contact shells used in 1888 by Eugène Kalt.

According to the evidence of *Haas*, who had examined two of the prosthetic-like contact shells from the era, single-curvature glass-blown shells were involved with total diameters of 16.00 to 22.00 mm consisting “essentially of a portion of the bubble blown by the glass blower, having extremely irregular refractive

power” and a single back curvature. *Haas* did not indicate the radius of curvature of these scleral monocurved contact shells.

#### Ground Contact Lenses Used in Kalt's Second Attempt

<b><i>Kalt's ground contact lenses (between 1888 and 1893)</i></b>	
Type	<i>Ground, polish, monocurve</i>
Front optic zone radius	<i>7.90 mm</i>
Back optic zone radius	<i>Unknown</i>
Power	<i>+1.50 to +2.00 diopters</i>
Total diameter	<i>11.00 mm, 11.50 mm and 13.00 mm</i>

Table 11 -3

Characteristics of the contact lenses ground for Eugène Kalt and used between 1888 and 1893.

Challenged by *Fick*'s results, in the next few years *Kalt* tried to perfect his contact lenses. According to *Sulzer*, he asked the optician *Verlin* to ground contact lenses for him. *Haas* said that these were of “*thin glasses of ground crystal, having a radius of curvature*

*taken from that of a normal cornea according to measurement taken with a Javal keratometer and verified with a mold of a cadaver eye*” (16). According to *Haas*, this second generation of *Kalt*'s lenses had total diameters of 11.00, 11.50 and 13.00 mm, a radius of curvature of 7.90 mm (17), and a refractive power of one to two diopters. The front surface of these was spherical, according to the *Javal* keratometer, and their size and polish seemed perfect. We are therefore considering contact lenses with a corneal diameter, of which the curvatures had been selected according to *Javal* keratometer measurements and mold castings taken from a cadaver eye. *Haas* did not know which

optician had ground these contact lenses. *Sulzer* attributed them to Paris optician *Verlin* (18).

## 2.3 – Physiological Aspects

### **Prosthetic-like blown Shells of Large Total Diameter**

The prosthetic-like contact shells of the first generation were destined for a reshaping treatment of keratoconus, by means of a supposed molding of the deformed cornea within the concavity of the shell. For *Panas*, the observed optical improvement was secondary to the reshaping of the deformed cornea:

*“The cornea, much thinned, molds itself exactly inside their concavity and, as a result, is reshaped. If the curvature of the glass is well chosen, you can achieve a state close to emmetropia and, important to note, the vision is improved throughout the whole extent of the visual field.”* (18)

This hope of a treatment for keratoconus, “which has the advantage of immediately reshaping the cornea with resultant suppression of the cone and correction of the refractive anomaly”, was, of course, unrealistic and unachievable. At best, it was a utopian concept. It is perfectly obvious that these enormous single-curve glass shells resting in the conjunctival cul-de-sacs, like shells for the treatment of symblepharon, must have been poorly tolerated.

### **Ground Contact Lenses of Small Diameter**

The *second generation* of *Kalt* contact lenses was original, insofar as these were ground and polished glass contact lenses. Each of the three models possessed, furthermore, the radius of curvature of a normal cornea, and the total diameter of each was equal to or slightly greater than that of the cornea.

These second-generation *Kalt* contact lenses had no scleral zone and were therefore similar to corneal contact lenses of a later era. This fact did not destine them particularly for the treatment of keratoconus. It is possible that they had been intended for the correction of regular or irregular forms of astigmatism. Unfortunately, *Kalt* did not publish the results of his observations and we can rely only on evidence given by *Haas* and *Sulzer*.

## 2.4 – Fitting and Tolerance

We possess little credible information concerning the fitting and tolerance of *Kalt's* contact shells and lenses. For the shells of the first type, *Panas* was unreasonably optimistic in his announcement to the Academy of Medicine that “*they are perfectly tolerated for long hours and the mild conjunctival irritation that they provoke disappears quickly after their removal.*” (20) *Haas* rectified this statement and indicated that it did not represent the true situation: “*This was somewhat different from what Mr. Panas communicated to the Academy. Mr. Kalt wrote in his letter to me that this shell was never tolerated for more than a few hours.*” (21) No evidence regarding the tolerance of contact glasses of the second type is available to us, except regarding the difficulties of their insertion and removal.

### **Adherence of the Prosthetic-like Blown Shells**

According to *Panas*, the prosthetic-like blown shells, being of large diameter, were retained by surface tension and eyelid pressure, and they “*followed the movements of the eye and adhered strongly to the ocular globe because of atmospheric pressure*”. (22) In fact, these enormous shells were stuck in the conjunctival *culs-de sac*, as were similar monocurve shells that *Fick* had inserted into the eyes of rabbits at the time of his first experiments.

### **Adherence of the Ground Corneal Lenses**

The later contact lenses, being of smaller diameter, appeared to adhere less to the ocular globe, as *Haas* described: “*It is clear to me that they must have been held in position - if they did indeed hold - as the result of atmospheric pressure alone, for their diameter is precisely of the order of size of the palpebral slit*” (23). This weak point in regard to second-generation lenses was also noted by *Sulzer* in the controversy of 1893, in which *Kalt* indicated that “adherence occurs by atmospheric pressure, as happens between two plates of wet glass”.

Neither *Panas* nor *Kalt* mentioned the role of tears and the neutralization of corneal refractive power. Furthermore, they did not seem to have used any liquid for the insertion of the contact shells and lenses.

## **2.5 – Optical Aspects**

The prosthetic-like contact shells described by *Panas* were originally conceived for the treatment of keratoconus, by virtue of their ability to compress and mold the pathological cornea. Any optical effect of the lenses was unexpected and unforeseen because it had been falsely attributed by *Panas* to reshaping of the pathological cornea.

In having contact lenses ground with corneal diameters, *Kalt* showed that he did not believe in the compressive effect and that the visual improvement was due to optical correction by neutralization of the corneal refractive power and the substitution of one surface of ground and polished glass for that of the irregular cornea. It is true that *Fick*'s publication had appeared in the meantime and that his opinion differed from that of *Panas*.

## **2.6 – The Priorities**

### **2.6.1 – Chronology**

#### **Blown Scleral Shells (1888)**

The communication of *Panas* to the *French Academy of Medicine* is practically contemporaneous with the publication of *Fick*'s paper. Certainly, the approaches of these two authors are different: *Fick* wished to substitute for the irregular cornea a ground and polished contact lens, whereas *Panas* claimed to “mold” and reduce the corneal cone by a prosthetic-like shell.

We do not know at what date *Kalt* and *Panas* commenced their experiments. In the light of the context, it is very probable that this was after September 1887, on which date *Fick*

sent his paper to *Archiv für Augenheilkunde*. Knowing that *Fick* had undertaken his trials in June 1887 (24), his priority rights regarding the discovery of the principle of contact lenses and their first application is therefore not in dispute.

### **Ground Corneal Contact Lenses (1890-1893)**

In reducing the diameter of the contact lenses to the diameter of the cornea, *Kalt* went down a hitherto untravelled path, which is another way of saying that he was the inventor of corneal contact lenses as we know them in the second half of the twentieth century. These lenses, made from ground and polished glass, were, however, too heavy to be retained by the effect of surface tension alone, an advantage not achieved until the later introduction of contact lenses made from organic materials.

#### 2.6.2 – May, an Indiscreet Translator?

There is a hypothesis (25) that *May*, the translator of *Fick's* paper, revealed to *Panas* (or possibly to *Kalt*, who was also German-speaking) the content of *Fick's* article that he was commissioned to translate and to publish in the American sister-edition of the *Archiv für Augenheilkunde*, the *Archives of Ophthalmology*. This indiscretion could have been at the origin of *Kalt's* attempts and of the somewhat premature, if not precipitous, communication by *Panas* to the *French Academy of Medicine* on March 20, 1888, almost at the same time as *Fick's* article appeared. This hypothesis depends on the fact that, in the first month of the year 1888, *May* was spending time in Paris, where he almost certainly visited the eye units and clinics (26). However plausible these suppositions of scientific plagiarism may be, they require an investigation that would be difficult to conduct satisfactorily more than a century after the facts. The hypothesis gains support from the argument that *Fick* no longer entrusted papers to the *Archiv für Augenheilkunde*, except in the form of “readers’ letters” regarding rectifications or clarifications, and that he did not cite either *Kalt* or *Panas* in his subsequent publications on contact lenses.

## 2.7 – Kalt’s Contact Lenses

One can concede several priorities to *Kalt* that would be sufficient for him to be considered an inventor of contact lenses, with the same entitlement and at the same time as both *Fick* and *Müller*. The following are true:

The prosthetic-like blown shells presented by *Panas* are acknowledged as being the first “contact lenses” intended for the correction of keratoconus by compression of the cornea.

The second generation of *Kalt's* ground lenses is recognized as being the first generation of contact lenses of corneal diameter. These already had two essential characteristics of later corneal contact lenses, namely a reduced total diameter without a scleral rim and a curvature parallel to that of the cornea.

## 3 – A short History on the Citations, Omissions and Misinterpretations

### 3.1 Citations and Omissions

*Kalt* is often forgotten in histories of contact lenses. If he is cited among the inventors of contact lenses, it is sometimes by a discreet allusion or by a citation copied from a previous author (27). Considerable confusion has resulted from these omissions. Few citations are consistent with the available facts that I have been able to assemble, both from original documents and from the rechecking of the citations in the present chapter.

### 3.2 Causes for these Confusions: the two Types of Kalt Contact Lenses

It must be admitted that the task of a historian is far from easy, because *Kalt* presented neither communication nor publication concerning contact lenses. The only clues available to the historian are the evidence of three witnesses, namely *Panas*, *Sulzer* and *Haas* along with a record of a discussion that occurred in 1893 at the Paris Society of Ophthalmology. It has to be remembered that *Kalt* used two types of contact lenses:

#### **Kalt's Prosthetic-like Blown Shells**

Initially, *Kalt* used prosthetic-like blown scleral contact lenses, these having a large diameter varying from 16.00 to 22.00 mm, cut out of a glass bubble. These glass-blown shells were the subject of the presentation by *Panas* to the *French Academy of Medicine* on March 20, 1888, and they were intended for the compression of the cone in keratoconus. They were described by *Haas* as “*imperfectly glass-blown shells. [...] Their approximate diameter had to vary from 16 to 22 mm; they did not comprise two sections destined respectively for optics and for adherence but consisted essentially of a piece of the bubble blown by the glass blower, and their refractive power was extremely irregular*” (28).

#### **Kalt's Ground Corneal Lenses**

Later, *Kalt* used ground contact lenses of optical quality, of single curvature, and of small diameter. *Sulzer* recalled these contact lenses in 1893 in his controversy with *Kalt* as follows: “the contact-glasses, because they lacked a scleral border, adhered too little to the eye to be able to be used.” These ground contact lenses were also described by *Haas*: “*These glasses consisted only of the corneal portion, a section of a sphere, the diameter of which was respectively 11, 11.5 and 13 mm at the base. [...] Examined on the Javal ophthalmometer, all three of them show an anterior surface free of astigmatism and a radius of curvature of 7.9 mm.*” (29) Due to their relatively reduced diameter, these ground and polished contact glasses of the second type have been considered “corneal contact lenses”. This attribution is acceptable only for the lens of 11.00 mm total diameter but not for that of 13.00 mm total diameter. The single curve cut with a radius of curvature close to that of the keratometric corneal radius is evidence, however, of their use with corneal support.



### 3.3 – A Historical Essay in Regard to Misinterpretations

The errors repeated in the literature come from the confusion which authors typically make between the two types of *Kalt's* contact glasses, i.e., the “shell-like” blown lenses presented in 1888 by *Panas* and the ground contact lenses to which *Sulzer* and *Haas* refer. There follows, as the result of recopying and translations, a tangle of contradictory and muddled citations.

#### **Errors of Attribution of Corneal Diameter to Kalt's Prosthetic-like Shells of 1888**

It is thus alleged, for example, with reference to the glass shells of 1888, that their radius would be close to that of the cornea : “*He [Kalt] ground some small lenses to correct keratoconus that had no scleral band and rested at the edge of the cornea. They were designed to exert some pressure on the apex of the conus in an attempt to reduce the ectasia as well as to correct the visual errors.*” (30) Or: “*Kalt's lenses, designed to replace the pressure dressing, consisted of glass shells with a radius of curvature approximately that of a normal cornea.*” (31) On the other hand, it is stated that these first shells for corneal reshaping were of corneal diameter: “*Even in the early years of their development, however, attempts had been made to reduce their overall size, making them virtually 'corneal' in dimensions (Kalt, 1888).*” (32)

However, it is generally accepted that the shells presented in 1888 by *Panas* for the compressive treatment of keratoconus were of blown glass, possessing an irregular curvature, and not provided with any refractive power.

#### **Errors Relating to the May 3, 1893 Controversy between Sulzer and Kalt**

It is not easy to determine the correct sequence of texts connected with the controversy of May 3, 1893, between *Kalt* and *Sulzer* at the *Paris Society of Ophthalmology*. This occurred after the discussion of *Abadie* following a communication by *Chevallereau*. Therefore, the citation of this controversy is usually secondhand and therefore rendered ambiguous and inaccurate by successive copying. It is attributed sometimes to *Chevallereau*, sometimes to *Abadie*, and one reads also: “*Charles Abadie (1842-1932), a Parisian ophthalmologist, presented Kalt's work in 1893.*” (33)

### 3.4 – The Origin of the Errors

*Sabell* summarizes in judicious fashion the confusion of the Anglo-Saxon authors: “*According to Graham (1959), one of the first to draw attention to earlier usage of corneal lenses was Emerich Rakoss, who published a paper entitled “How New is the Corneal Lens?” in May 1950. Both authors refer to the lenses by Kalt of Paris as being of corneal lens design. Obrig and several other authors have described M. Kalt as an optician. This seems unlikely in view of his participation in meetings of the Société Française d'Ophtalmologie, as reported (in the discussion following a paper) by Chevallereau (1893). It would seem likely that this was Eugène Kalt of Paris, whose photograph is published by Duke-Elder (1969).*” (34)

### 3.5 – Other Erroneous Citations

One must also mention other fanciful citations, which supported me in the task of

documenting my essay by means of original documents: “*This was an optician, E. Kalt, who ground some small contact lenses for keratoconus. His lenses just covered the cornea [and] apparently had no scleral flange.*” (35)

This erroneous statement was repeated on numerous occasions and, in particular, by *Obrig* (36) and by *Graham*, who ensured its wide dissemination (37). Thus, by accumulation of the errors, we read: “*Kalt, a glassblower in Wiesbaden, Germany described [the following:] These shells had a radius of curvature similar to that of the cornea. They were well tolerated for several hours with little irritation, good vision, and few problems of decentering.*” (38)

Recently, *Heitz* (39) and *Pearson* advanced arguments for the correction of this error: “*It is doubtless because Panas identified his junior colleague as ‘M. Kalt’ [M. is the abbreviation of monsieur, i.e., Mr.] that Obrig incorrectly assumed that he was an optician. At this time a fuller title for a doctor would have been ‘M. le Dr.’ Obrig’s error has been perpetuated by other authors, and it has been noted that an even greater mistake was made by Hales when he referred to ‘Kalt, a glass blower in Wiesbaden, Germany’.*” (40)

Another tenacious legend claims that the *Kalt* lenses were made with the bottom of a test tube: “*Kalt makes use of the bottoms of test tubes for the correction of a keratoconus case.*” (41) A recent article alleges that these test tube bottoms have a dioptric power, a concept that is technically improbable: “*Kalt’s lenses, cut from the bottom of test tubes incorporated plus power (1.5 - 2.0 diopter) and were likely the first powered contact lenses.*” (42) Another error consists of misspelling *Kalt*’s family name: “*Galt [sic] was designing contact lenses.*” (43)

I would like to conclude this chapter by reiterating that *Kalt*:  
in 1888, placed a prosthetic-like blown contact shell in an eye affected by keratoconus and obtained visual improvement, attributed by *Panas* to an effect of corneal reshaping, and  
tried to fit, between 1888 and 1894, ground monocular contact lenses of 11.00-mm, 11.50-mm and 13.00-mm total diameter, the radius of curvature of which was close to that of the cornea.

It is a mistake to attribute to *Kalt* the use of ground lenses of *corneal* diameter for the optical correction of or the treatment by compression of keratoconus. It is also useful to recall that *Kalt* was an ophthalmologist: from 1886 to 1889, he was Chief Clinical Assistant at the *Hôtel Dieu Hospital* in Paris, then, from 1889 to 1941, he was Unit Chief at the *Centre National d’Ophthalmologie of the Quinze-Vingts Hospital* in Paris (44).

## Notes

- 1 In this chapter, I often use 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 corneal contact lens is worn in its entirety on the cornea. - A scleral contact lens is worn on the cornea and the sclera*). (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 a reasonable visual acuity, especially in a condition such as keratoconus.
- 2 *Panas* 1888/a, p. 100–101.
- 3 *Panas* 1885. See details of the compressive "treatment" of keratoconus in chapter XIX: *Early Therapeutic and Diagnostic Contact Devices*.
- 4 *Panas* cited two cases, but in 1937 *Kalt* is to confide to *Haas* that he had treated, in fact, only one patient, whom he described as, "a young nun with bilateral keratoconus" (*Haas* 1937, p. 73).
- 5 *Panas* 1888/a, p. 100-101.
- 6 *Panas*, 1888/b, p. 293.
- 7 *Panas* 1889, p. 139, see Appendix 11-1.
- 8 For a detailed account of the *Kalt-Sulzer* controversies, refer to chapter XIII: *The Decades after the Invention*.
- 9 *Sulzer* 1893/a, p. 392.
- 10 For a detailed account of the *Sulzer-Fick* controversy, see chapter XIII: *The Decades after the Invention*.
- 11 *Sulzer* 1894, p. 237. Later author was unaware of *Sulzer's* citation of *Verlin's* work and repeated that the origin of *Kalt's* ground lenses was unknown. The second sentence of *Sulzer* is incorrect: the presentation by *Panas* to the Academy of Medicine of March 20, 1888, (and not March 13, 1888) did describe blown shells with a prosthetic-like shape and a diameter of 16.00 and 22.00 mm, and not a ground contact lens without a scleral zone.
- 12 Equivalent to 20/67 (or 6/20) and 20/50 (or 6/15), respectively (*Pearson*, 1989).
- 13 *Haas* 1937, p. 73. This description, that the early *Kalt's* contact shell was a portion of a sphere cut about a glass sphere, contradicts the statements made by certain historians who repeated incorrectly that he was taken from the bottom of a test-tube.
- 14 *Haas* was unaware of *Sulzer's* (1894, p. 237) citation that *Kalt's* second attempt at contact lenses was ground by the Paris optician *Verlin*.
- 15 Presumably the front optic zone radius (*Pearson*, 1989).
- 16 *Haas* 1937, p. 75-76.
- 17 "des verres minces en cristal taillé, établis d'après le rayon de courbure de la cornée normale mesurée au Javal et vérifiées sur un moulage d'œil de cadavre." (*Haas* 1937, p. 75).
- 18 *Haas* does not indicate whether he refers to the front or to the back optic zone radius.
- 19 *Sulzer* 1894, p. 237. Later author was unaware of *Sulzer's* citation.
- 20 "La cornée très amincie, se moule exactement dans leur concavité et se trouve, par le fait, redressée. Si la courbure du verre est bien choisie, on peut réaliser un état voisin de l'emmétropie, et, fait important, la vision se trouve améliorée dans toute l'étendue du champ visuel." (*Panas* 1888/a, p. 101).
- 21 "Elles sont parfaitement supportées pendant de longues heures par cette membrane et la faible irritation conjonctivale qu'elles provoquent disparaît vite après leur enlèvement." (*Panas* 1888/a, p. 101).
- 22 "Un peu différemment de ce que M. *Panas* affirmait à L'Académie, M. *Kalt* m'a écrit que cette coque n'était jamais supportée plus de quelques heures." (*Haas* 1937, p. 75).
- 23 "Elles suivent les mouvements de l'œil et adhèrent fortement au bulbe, grâce à la pression atmosphérique." (*Panas* 1888/b, p. 293).
- 24 "Il est manifeste qu'ils devaient tenir - s'ils tenaient - par suite de la pression atmosphérique seule, car leur diamètre est précisément de l'ordre de grandeur de la fente palpébrale." (*Haas* 1937, p. 75).
- 25 See *Fick's* letters to *Zeiss* of June 1887 (chapter X: *Adolf Eugen Fick's "Contactbrille"*).
- 26 *Knöll*, 1980, personal communication.
- 27 According to *May's* biography by *Perera*, 1944.
- 28 Especially from *Pascal's* erroneous citation: "There was one other worker who is sometimes mentioned as having pioneered independently in contact lens work at about the same time. This was an optician, E. Kalt, who ground some small contact lenses for keratoconus. His lenses just covered the cornea, apparently had no scleral flange, and were designed not only to improve vision, but also to exert pressure against the eye, and thus reduce the cornea protrusion. Some of his work was reported by Dr. *Abadie* in 1893" (*Pascal* 1941, p. 59).
- 29 "Il s'agissait cependant d'une coque soufflée bien imparfaite, [...]. Son diamètre approximatif devait être 16 à 22 mm, elle ne comportait pas les deux parties respectivement destinées à l'optique et à l'adhérence, constituée seulement par un morceau de la bulle faite par le souffleur, et d'une réfraction extrêmement irrégulière." (*Haas* 1937, p. 73).
- 30 "Ces verres ne comportent que la partie cornéenne, calotte de sphère, dont le diamètre à la base est respectivement 11, 11,5 et 13 millimètres. [...] Examinés à l'ophthalmomètre de Javal, ils montrent tous les trois une face antérieure exempte d'astigmatisme, et d'un rayon de courbure de 7,9 mm." (*Haas* 1937, p. 75).
- 31 *Obrig* 1942, p.129-130.
- 32 *Mandell* 1988, p. 9.
- 33 *Mackie* in *Duke-Elder* 1970, p. 735.
- 34 *Albert & Edwards* 1996, p. 121. It is possible that the error comes from *Pascal* 1941, p. 59, to be later cited by *Obrig* and repeated by *Graham* 1959, p. 62: "some of his work was reported by Dr. *Abadie* in 1893."
- 35 *Sabell* 1972, p. 22 – The portrait of *Kalt* to which *Sabell* refers appears in the chapter "Diseases of the lens", on page 260 of Volume XI of *Duke-Elder's System of Ophthalmology*. It is unfortunate that *Mackie* did not take this into account at the time of the publication of his history of contact lenses in Volume V of *Duke-Elder's System*. One should also give more emphasis to *Pearson's* excellent clarification regarding the contribution made by *Kalt*, unfortunately rarely consulted (*Pearson*, 1989).
- 36 *Pascal* 1941, p. 59.
- 37 "an optician, E. Kalt, independently carried on an investigation of his own. He ground some small lenses to correct keratoconus that had no scleral band and rested at the edge of the cornea. They were designed to exert some pressure on the apex of the conus in an attempt to reduce the ectasia as well as to correct the visual error. As might be expected, they were unsuccessful." (*Obrig*, 1942 p.129-130).
- 38 *Graham* 1959, p. 62. We should recall that *Graham* was accused by the manufacturers of contact lenses of having violated their patents on contact lenses of corneal diameter. In his defense that the patents taken out on contact lenses and especially those of corneal diameter, which came onto the market after World War II, no longer applied, he invoked historical priorities, notably those relating to *Descartes*, *La Hire*, *Fick*, *August Müller* and *Kalt*. *Graham* thus took stock in 1959 of the totality of the contact lens field and attributed to *Kalt* the priority of the invention and of the utilization of corneal contact lenses. This author, however, made no distinction between glass-blown shells, which were described in the communication of *Panas*, and the second-generation

ground contact lenses of Kalt. Graham pursued a very wide distribution of his arguments by using publications in professional reviews and reprints.

38 Hales 1978, p. 4.

39 Heitz 1979, 1984.

40 Pearson 1989, p. 644.

41 "Kalt utilise des fonds de tubes d'essai pour la correction d'un k eratoc one." (Lumbroso 1977, p. 17).

42 Rubin 1996, p. S103.

43 "At the same time, Galt [sic] developed contact lenses in France" (Ruben 1975, p. 3) and also in Ruben translated into German: "Zur gleichen Zeit entwickelte Galt in Frankreich Kontaktlinsen." (Roth 1978, p. 2).

44 See biographical section.

## Appendix XI -1

Transcription of  
Photonos Panas's Presentation of the Early "Kalt Contact Lens"

### A – *Panas' communication to the French Academy of Medicine at the March 20, 1888 session.*

*(Bulletin de l'Académie Nationale de Médecine, 19, 400-401, 1888)*

IV. M. PANAS : Le traitement du k ratoc ne pr sente de grandes difficult s. Les malades dont la corn e s'est ectasi e en son centre en forme de tronc de c ne   sommet arrondi sont devenus  norm ment myopes, et cette myopie, en raison de l'irr gularit  de la saillie corn enne, n'est pas justiciable de la correction par les verres sph riques concaves. Les verres paraboliques qui avaient donn  quelques esp rances sont bien vite rejet s par les malades auxquels ils ne permettent, dans les cas heureux encore, qu'une vision centrale, la p riph rie du champ visuel  tant masqu e par le bord du verre. Nous en dirons autant de l'emploi de la fente st nop ique. - En outre, ces moyens purement optiques, ne peuvent avoir aucune influence favorable sur l'affection elle-m me. Ils n'en soulagent qu'un des sympt mes p nibles, l'amblyopie.

Des op rations chirurgicales nous ne dirons rien, car elles ne donnent que rarement des r sultats satisfaisants, et ce n'est qu'en d sespoir de cause que les praticiens se d cident   y avoir recours.

Reste la m thode curative la moins hasardeuse, celle qui a donn  positivement de bons r sultats : la compression avec le bandeau, combin e avec les myotiques. Mais le bandeau compressif a l'inconv nient d'abord d'interrompre l'exercice de la vision et ensuite de provoquer des douleurs ciliaires qui rendent son usage parfois insupportable. Le moyen que M. Kalt propose a l'avantage de redresser imm diatement la corn e, d'o  suppression du c ne et correction de l'anomalie de r fraction. Il consiste dans l'emploi de coques de verre analogues   celles qui sont employ es quelquefois dans le traitement du syml pharon. Ces coques, de la grandeur des coques d' mail qui servent   la proth se oculaire ont un rayon de courbure voisin de celui de la corn e. Elles sont parfaitement support es pendant de longues heures par cette membrane et la faible irritation conjonctivale qu'elles provoquent dispara t vite apr s leur enl vement. Tout en suivant les mouvements de l' il, elles adh rent fortement au bulbe, gr ce   la pression atmosph rique. La corn e tr s amincie, se moule exactement dans leur concavit  et se trouve, par le fait, redress e. Si la courbure du verre est bien choisie, on peut r aliser un  tat voisin de l'emmetropie, et, fait important, la vision se trouve am lior e dans toute l' tendue du champ visuel. Un de nos malades qui comptait   peine les doigts   0,50 m voyait de suite sa vision remonter au point de pouvoir lire   5 m tres des caract res de 26 millim tres de hauteur. De pr s il lisait un journal. La correction optique est donc r alis e d'une fa on tr s satisfaisante. L'avenir montrera quel peut  tre l'effet curatif.

Ces r sultats, obtenus   la clinique de l'H tel Dieu sur deux malades,  taient pr ts    tre publi s, quand nous avons eu connaissance d'un travail du Dr Fick, de Zurich, paru dans les *Archiv f r Augenheilkunde*, fascicule de mars 1888. L'auteur, qui a employ  une m thode identique   la n tre, est arriv    des r sultats absolument semblables au point de vue du k ratoc ne.

Nous nous f licitons de cet accord, et nous esp rons que la m thode aura bient t acquis la faveur des praticiens.

### B – *Report of Panas' communication to the French Academy of Medicine.*

*(Annales d'Oculistiques, 49, 293, 1888)*

**Traitement optique du k ratoc ne.** - M. Panas pr sente   l'Acad mie, au nom de M. Kalt, un proc d  de traitement du k ratoc ne, qui a l'avantage de redresser imm diatement la corn e, d'o  suppression du c ne et correction de l'anomalie de r fraction. Ce proc d  consiste dans l'emploi de coques de verres de la grandeur des coques d' mail qui servent   la proth se oculaire et d'un rayon de courbure voisin de celui de la corn e. Ces coques sont parfaitement support es pendant de longues heures par cette membrane, et la faible irritation qu'elles provoquent dispara t vite apr s leur enl vement.

Elles suivent les mouvements de l' il et adh rent fortement au bulbe, gr ce   la pression atmosph rique. La corn e, tr s amincie, se moule exactement dans leur concavit  et se trouve, par le fait, redress e. Si la courbure du verre est bien choisie, on peut r aliser un  tat voisin de l'emmetropie, et, fait important, la vision se trouve am lior e dans toute l' tendue du champ visuel.

Un malade, qui comptait   peine les doigts   0 m 50, voyait tout de suite sa vision remonter au point de pouvoir lire   5 m tres des caract res de 26 millim tres de hauteur. De pr s, il lisait un journal.

La correction optique est donc r alis e d'une fa on tr s satisfaisante. L'avenir montrera quel peut  tre l'effet curatif.

« Ces r sultats, obtenus   la clinique de l'H tel-Dieu sur deux malades, dit M. Panas,  taient pr ts    tre publi s, quand nous avons eu connaissance d'un travail du docteur Fick, paru dans les *Arch. f r Augenheilkunde*, fascicule de mars 1888. L'auteur, qui a employ  une m thode identique, est arriv    des r sultats absolument semblables au point de vue du k ratoc ne ».

**C – Report of Panas' communication to the French Academy of Medicine in a German journal.**  
(*Centralblatt für praktische Augenheilkunde*, 12, 139, 1889)

**Académie de Médecine zu Paris.** März-April 1888 (D. M.-Z.)

Optische Behandlung des Keratoconus

Hr. Panas zeigt im Nahmen Kalt's Glasschalen von der Grösse der Emailschalen, wie sie zur Augenprothese dienen, mit einem Krümmungsradius, der annähernd der der Cornea ist. Er wendet dieselben zur Behandlung des Keratoconus an, indem er mit ihnen sofort die Cornea redressirt. Die Schalen werden stundenlang auf der Cornea ertragen und der geringe Reiz, den sie hervorrufen, verschwindet schnell nach ihrer Entfernung. Sie folgen den Augenbewegungen und adhären fest dem Bulbus infolge der atmosphärischen Druckes. Die Hornhaut schmiegt sich der Concavität der Schale an und wird dadurch redressirt. Wenn die Schalenkrümmung gut gewählt wird, kann man einen der Emmetropie nahe kommenden Zustand herbeiführen, und die Sehschärfe bessert sich im ganzen Gesichtsfeld. Ein Patient, der kaum auf 0,5 m Entfernung Finger zählen konnte, erkannte sofort Buchstaben von 26 mm Höhe auf 5 m Entfernung. In dem Moment, wo diese Resultate veröffentlicht werden sollten, gelangte P. zur Kenntnis einer Arbeit Fick's im Archiv für Augenheilkunde 1888, der mit denselben Mitteln dieselben Erfolge erzielte.

## Appendix XI – 2

### *Transcription of*

#### **Discussions held on May 3, 1893, at the Congress of the French Society of Ophthalmology on the Contact Shells and Contact Lenses used by Kalt**

Following *Chevallereau's* communication entitled “*Traitement du k ratoc ne*” (*Treatment of Keratoconus*), on May 3, 1893 a discussion took place at the congress of the *French Society of Ophthalmology (Soci t  Fran aise d’Ophtalmologie)*, in which *Mortais, Despargnet, Coppez* and *Abadie* took part. The last-named made reference to “contact lenses or artificial corneas of *Sulzer*”, provoking a request for clarification by *Kalt*. This “Kalt-Sulzer Controversy” is reported with nuances that vary according to the journals.

#### **A - Bulletin et M moires de la Soci t  Fran aise d’Ophtalmologie, 11, 391-392, 1893**

M.ABADIE. – J’ai eu l’occasion de soigner un jeune homme atteint d’une double k ratomie et j’ai employ  le m me moyen que M. Chevalleraud c’est- -dire la caut risation au galvano-caut re du sommet du c ne. Le r sultat imm diat fut extr mement satisfaisant, mais au bout de deux mois la vision commen a   baisser et le malade revint me voir. Je constatai qu’un  tat glaucomeux se d veloppait que rien n’a pu enrayer ni l’instillation d’ s rine ni m me l’iridectomie.

Je n’ignore pas que ces glaucomes d’origine corn ennes sont rares puisqu’  chaque instant nous caut risons la corn e au galvano-caut re dans les ulc res infectieux et nous n’observons jamais ce genre de complication. N anmoins elle peut survenir, t moin le cas auquel je viens de faire allusion.

Chez ce m me malade ne sachant plus que faire pour rem dier   son  tat je lui ai conseill  de porter sur l’autre  il les verres de contact pr conis s par M. Sulzer : il s’en trouve tr s satisfait.

M. KALT - Je me permettrai de rappeler   M. Abadie que le traitement de k ratoc ne a  t  pr conis  en m me temps, en Suisse par M. Fick, en France, par moi en 1887, dans une communication   l’Acad mie de m decine, et non par M. Sulzer.

M. SULZER - L’id e d’appliquer des verres sur la corn e est bien plus ancienne que ne le pense M. Kalt. Elle remonte au si cle dernier. Mais la r alisation de cette id e a rencontr  de grandes difficult s. Les verres employ s par M. Fick donnaient des r sultats optiques insuffisants   cause de l’irr gularit  de leurs surfaces et les verres de M. Kalt,   d faut d’un bord scl ral, adh raient trop peu   l’ il pour pouvoir  tre utilis s.

M. KALT – M.Sulzer dit que mes coques adh raient insuffisamment   la corn e, ne serraient pas. M.Sulzer ne para t pas se rendre compte que l’adh rence se fait par la pression atmosph rique, comme il arrive pour deux plaques de verre mouill es.

#### **B - Annales d’Oculistique, 59, 462, 1893**

M.Abadie. – Je n’incriminera pas le proc d  de M. Chevallereau, mais je dois dire que, l’ayant appliqu  chez un malade, j’ai vu survenir des acc s glaucomeux ; je ne m’explique d’ailleurs pas le fait. Sur l’autre  il, j’ai conseill  l’application des corn es artificielles du docteur Sulzer.

M.Kalt (de Paris). – Je rappellerai,   ce propos, que M.Sulzer n’a propos  l’application des coques intra-oculaires que l’ann e derni re, alors qu’en 1887, Fick de Zurich, et mi-m me quinze jours apr s, nous publions un travail sur le m me sujet ; nous avions eu la m me id e sans nous en douter.

M.Sulzer.- L’id e d’appliquer des verres sur la corn e est bien plus ancienne que ne le pense M.Kalt. Elle remonte au si cle dernier. Mais la r alisation de cette id e a rencontr  de grandes difficult s. Les verres employ s par M.Fick donnaient des r sultats optiques insuffisants,   cause de l’irr gularit  de leurs surfaces, et les verres de M.Kalt,   d faut d’un bord scl ral, adh raient trop peu   l’ il pour pouvoir  tre utilis s.

M.Panas. – L’astronome Herschel, en effet, avait eu l’id e d’appliquer   la surface de l’ il des coques de verres destin es   corriger la courbure irr guli re de la corn e.

#### **C - Revue G n rale d’Ophtalmologie, 12, 306-307, 1893**

M.ABADIE – Je n’incriminera pas le proc d  de M. Chevallereau, mais je dois dire que, l’ayant appliqu  chez un malade, j’ai vu survenir des acc s glaucomeux ; je ne m’explique d’ailleurs pas ce fait.

Sur l’autre  il, j’ai conseill  l’application des corn es artificielles de M.Sulzer.

M.KALT – Je rappellerai,   ce propos, que M.Sulzer n’a propos  l’application des coques intr -oculaires que l’ann e derni re, alors qu’en 1887, Fick (de Zurich) et moi-m me, quinze jours apr s, nous publions un travail sur le m me sujet ; nous avions eu la m me id e sans en douter.

M.SULZER - L’id e d’appliquer des verres sur la corn e est bien plus ancienne que ne le pense M.Kalt. - Elle remonte au si cle dernier. Mais la r alisation de cette id e a rencontr  de grandes difficult s. Les verres employ s par M. Fick donnaient des r sultats optiques insuffisants,   cause de l’irr gularit  de leurs surfaces et les verres de M. Kalt,   d faut d’un bord scl ral, adh raient trop peu   l’ il pour pouvoir  tre

utilisés.

M. PANAS – L'astronome Herschel, en effet, avait eu l'idée d'appliquer à la surface de l'œil des coques de verre destinées à corriger la courbure irrégulière de la cornée.

**D - Centralblatt für Augenheilkunde, 17, 405, 1893**

Herr Abadie: Ich habe bei einem Auge nach Anwendung der Methode von Chevallerau glaucomatöse Zustände gesehen. Ich habe in Folge dessen bei dem anderen Auge dieses Patienten nur das Tragen der Cornea artificialis von Sulzer empfohlen.

Herr Kalt: Ich habe schon im Jahre 1887, gleichzeitig mit Fick, von dessen Arbeit ich aber nichts wusste, die künstliche Hornhaut empfohlen.

Herr Sulzer: Die Idee ist viel älter, als Kalt meint, und reicht bis in das vergangene Jahrhundert zurück. Die Ausführung hat aber grosse Schwierigkeiten, die Schalen von Fick waren optische ungenügend und die von Kalt blieben nicht am Platz, weil ihnen ein Skleralrand fehlte.

Herr Panas: Die erste Idee, Gläser auf die Hornhaut aufzusetzen, hatte der Astronom Herchel.



## Annexe XI – 3

*Transcription of:*

### **Haas's Evidence in Regard to the Two Types of Contact Lenses Used by Kalt**

#### **A/ Haas's Evidence on the Prosthetic-like Blown Shells of 1888**

*"Les verres de contact". Bulletin de la Société d'Ophtalmologie de Paris et des Sociétés d'Ophtalmologie de l'Est et de Lyon 1937 Supplément, page LXXIII (Rapport présenté à la Séance plénière du 14 novembre 1937 à la Société d'Ophtalmologie de Paris)*

La lecture de cette présentation semblerait suggérer que la pensée principale de M. Kalt ait été le redressement orthopédique de la cornée conique par le moyen du verre de contact. Je pense qu'il faut laisser la responsabilité de ce point de vue au présentateur. Je me suis adressé à M. Kalt lui-même, qui m'a aimablement fourni, dans une lettre du 16 juillet 1937, les renseignements que je lui demandais. Le cas dont il avait eu à s'occuper était celui d'une jeune religieuse atteinte de kératocône bilatéral, et qui comptait seulement les doigts. L'application du verre de contact avait brusquement porté l'acuité visuelle à 0,3 ou 0,4.

Il s'agissait cependant d'une coque soufflée bien imparfaite, si j'en juge par les deux coques de l'époque, que M. Kalt a bien voulu me confier. Son diamètre approximatif devait être 16 à 22 mm, elle ne comportait pas les deux parties respectivement destinées à l'optique et à l'adhérence, constituée seulement par un morceau de la bulle faite par le souffleur, et d'une réfraction extrêmement irrégulière.

Un peu différemment de ce que M. Panas affirmait à L'Académie, M. Kalt m'a écrit que cette coque n'était jamais supportée plus de quelques heures.

#### **B/ – Haas's Evidence on the Ground Contact Lenses used by Kalt at the Time of his Second Attempt**

*"Les verres de contact" Bulletin de la Société d'Ophtalmologie de Paris et des Sociétés d'Ophtalmologie de l'Est et de Lyon 1937 Supplément, pages LXXV-LXXXVI. (Rapport sur présenté à la Séance plénière du 14 novembre 1937 à la Société d'Ophtalmologie de Paris.*

Après ses premiers essais, et pour avoir, dit-il une « transparence meilleure », M. Kalt demanda à un fabricant de verres d'optique de lui construire des verres minces en « cristal taillé établis d'après le rayon de courbure de la cornée normale mesurée au Javal et vérifié sur un moulage d'œil de cadavre. » J'ai eu grâce à M. Kalt, la possibilité d'examiner le moulage de plâtre ainsi que trois verres taillés qu'on lui avait fournis. Ces verres ne comportent que la partie cornéenne, calotte de sphère, dont le diamètre à la base est respectivement 11, 11.5 et 13 millimètres. Examinés avec les deux faces dans l'air, ils ont des effets convergents respectifs de 1.5 ; 1.5 ; et 2 dioptries environ. Leur poli est satisfaisant, leur réfraction bien régulière. Examinés à l'ophtalmomètre de Javal, ils montrent tous les trois une face antérieure exempte d'astigmatisme, et d'un rayon de courbure de 7,9 mm. Ils sont manifestement taillés, vraisemblablement à l'aide de la même balle et du même bassin. Leur différence de pouvoir ne peut tenir qu'à leur épaisseur légèrement différente. M. Kalt ne m'a pas dit quel opticien les avait construits.

Il est manifeste qu'ils devaient tenir – quand ils tenaient – par suite de la pression atmosphérique seule, car leur diamètre est précisément de l'ordre de grandeur de la fente palpébrale. On s'explique ainsi les difficultés de leur enlèvement que M. Kalt m'a d'ailleurs signalé, ainsi que les difficultés de leur introduction. Il est probable que l'un et l'autre auraient été grandement facilités par l'emploi d'une ventouse pneumatique.

