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INTRALAMELLAR HOMOPLASTY FOR THE PURPOSE OF RELAXATION OF REFRACTION OF THE EYE *

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The first attempt to correct myopia by means of surgery was made by Fukala (1890, 1896). His proposed operations were not successful and were discarded due to their heavy consequence. Only after more than 50 years, with the perfection of surgical technique, individual authors once again turn to the removal of transparent lens in the case of high short-sightedness (Valerio, 1953, Salgado, 1954).

Operations, having the purpose of eliminating or lessening short-sightedness, can be joined to three main groups: 1) the shortening of the eye's axial length by the resection of the sclera; 2) introduction to the anterior chamber of the eye artificial lens with diffractive action; 3) reduction of the curvature of the anterior surface of the cornea. All of these operations are now in the stage of experimental cultivation and study, operations on people are few. Surgical intervention of the cornea is less dangerous, than, the introduction of intra-cameral lens or resection of the sclera, as, basically it is not connected with the dissection of the eye. Besides which, the leading role of the cornea in the dioptric system of the eye, the availability of studying its optical properties establish wide possibilities for modifying various types of surgical intervention and, what is especially important, the degree of refractionary changes in the required limits.

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The purpose of refractionary operations of the cornea comes to the change of the curvature of its anterior surface at the same time preserving its full transparence. Such operations are lamellar auto-keratoplasty operations (Barraquer, 1958, 1961), the flattening of the cornea by incision of the posterior surface (Sato, 1953), cutting the peripheral ring of the anterior layers of the cornea (Payales, 1950; Pur, 1957; Barraquer, 1949), keratectomy (Strampelli), 1964), stromectomy (Krwawicz, 1963, 1964), keratomileusis (Barraquer, 1964, 1965) and others.

Operations of intralamellar grafts of the cornea are cultivated, mainly, for the intensification of the eye's refraction by aphakia (Barraquer, Krwawicz, Kashouk and Morkhat, 1961). Investigation of various theoretical variations of intralamellar keratoplasty with the intent of changing the refractive power of the eye, Barraquer produced up to 18 diagrams, among which is the diagram of the graft, having the form of rings, introduced to the stroma of the cornea through the anterior surface. According to Barraquer such keratoplasty should bring the flatness of the cornea, that is a negative effect. Although Barraquer himself did not use that type of keratoplasty neither in experiments nor on patients.

Engaged in refractionary keratoplasty with the aim of changing the refractive power of the eye (E. D. Blavatskaya, 1964, 1965), we had the possibility of convincing ourselves of the preservation of the transparency of the cornea after its extoliation and transplant healing of the inner- corneal graft, on the condition of isolating it and the injured bed, from the effect of tears and conjunctive detachment. Good, almost without reactionary healing of inter-lamellar homotransplants in experiments on rabbits served as a basis for explorational operations with the aim of relaxing the refractionary power of the eye. The decrease of the curvature of the anterior surface of the cornea in suggestions up to present operations have been reached by thining the cornea in its optical zone (keratectomy, stromectomy, keratomileusis). We were able to receive the same effect by another method: not changing the thickness of the cornea in its central part, lessens the refractive strength by introducing to the stroma the transplant in form of rings.

Judging by literary sources, such types of operations, up to the present have not been conducted by anyone.

Theoretically there are three possible variations for the alteration of the corneal curvature, by use of ring transplants: the surface of its central parts become: 1) less spherical, 2) flat, 3) concave (Fig. 1 a, b, c). The degree of the change of the curvature of the cornea in the optical zone depends on the thickness of the ring and size of its diametrical aperture. Consideration should

be also taken of the change of the configuration of the ring after grafting. We were convinced of the change of forms of inter-plastic grafts, when, just at the first days after the operation the peripheric parts of the ring were seen on the histologic section. The ring on the whole lost its previous from and took the

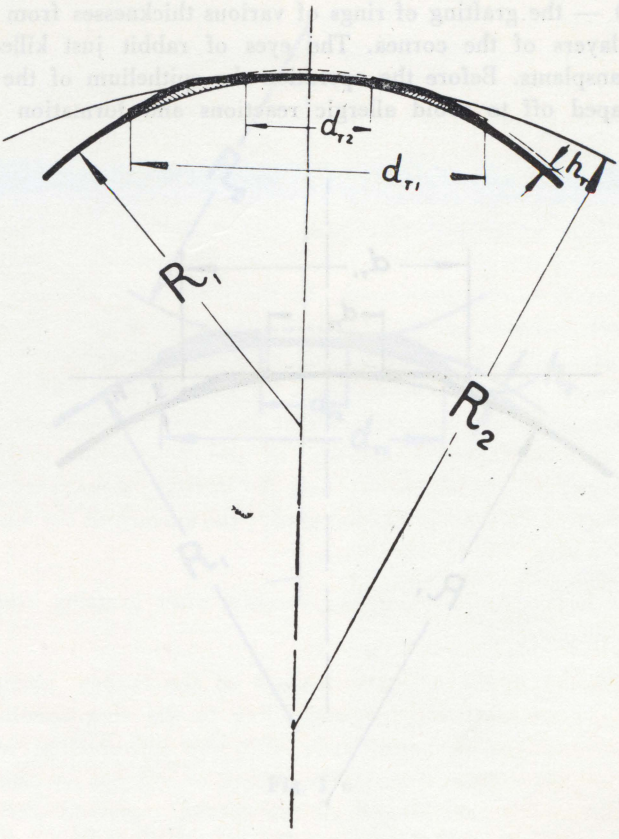

Fig. 1. A diagram of the change of the curvature of the anterior surface of the cornea after grafting rings: a- the surface of the cornea becomes less spherical; b) flat; c) corneave.

appearance of two lens. The forming power is above all the corneal plastic tension, its pressure on the transplant. Under the effect of the forming power of the cornea the smoothing of "corners" of the outer and inner border of the

ring takes place. Significance in the changes of the forms of the ring rests not only in the thickness, but in the width.

So as to acertain in experiments, what optical results may be achieved by intra-lamellar transplant rings, we undertook two basic groups of experiments: in the first group (16 operations) went the transplantation of rings of all thickness of the donar's cornea, sizes 4 x 7 mm and 5 x 8 mm; in the second (22 operations) — the grafting of rings of various thicknesses from the anterior and posterior layers of the cornea. The eyes of rabbit just killed served as material for transplants. Before the operation the epithelium of the cornea was thoroughly scraped off to avoid allergic reactions and formation of epithelial

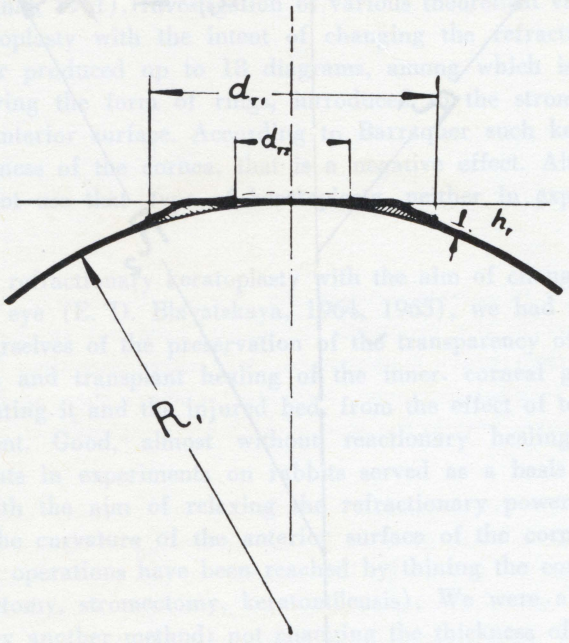

Fig. 1 b

cyst (V. V. Vojno-Yasenetcky, 1958; V. C. Bellayev, 1963) and the grafts were cut out with a trepan of suitable diameters. By taking the ring from the layer of the cornea it was preliminarily divided into layers by spatula or curved knives.

The technique of the operation consists of the following: after hypodermic injections 0,5 ml 1% of promidol solution, then retrobulbar injections are given

of 2,0 ml 0,5% solution of novocaine; the eyeball is dislodged and a gauze napkin is fixed. At 1 — 2 mm below the limbus a horizontal or slightly arched incision of the cornea approximately at the middle of its thickness takes place. In the "pocket" the graft in the form of a ring is introduced, and it is carefully arranged so, that its opening strictly coincides with the optical zone. At the lip

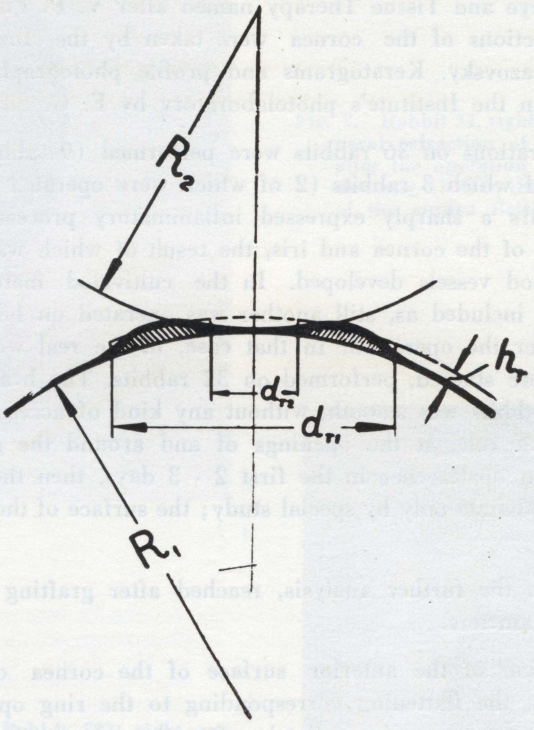

Fig. 1 c

of the wound 3 or 4 resorptive stitches are laid. Installation of 1% atropine solution and 30% albusid solution, injections of 30.000 ed. penicillin under conjunctive sclera. In the period of 5-6 days after the operation — instillation of atropine and albusid once a day.

With the use of Rodenstok's skiascopy and refractometers, the general refraction of the eye was examined before the operation; the radius of the curvature of the anterior surface of the cornea by ophthalmometer and the thickness of the cornea in the optical zone with the help of a prefix on the slit lamp, sug-

gested by I. A. Viazovsky (1960). Studies were repeated at various intervals after the operation, besides which, keratograms by the perfected method of E. G. Shaer (1962), and photographs of optical sections of the eye meridians by the method suggested by A. I. Dashevsky (1952), and Viazovsky (1956, 1961).

A great part of the experiments took place at the Odessa Institute for the Diseases of the eye and Tissue Therapy named after V. P. Filatov. Photograms of the optical sections of the cornea were taken by the Institute's Scientific worker I. A. Viazovsky. Keratograms and profile photographs of the rabbit's eye were made in the Institute's photolaboratory by E. G. Shaer.

In all, 45 operations on 36 rabbits were performed (9 rabbits were operated on both eyes), of which 3 rabbits (2 of which were operated on both eyes) in the first 24 hours a sharply expressed inflammatory process arose from the conjunctive sides of the cornea and iris, the result of which was that the cornea dimmed and blood vessels developed. In the cultivated material these three rabbits were not included as, still another was operated on both eyes and died the first day after the operation. In that case, in the real work the results of 38 operations were studied, performed on 32 rabbits. The healing of the transplants of these rabbits was smooth, without any kind of accessory inflammatory appearances; as a rule, at the openings of and around the graft and cornea, there was a slight opalescence in the first 2 - 3 days, then the detection of the graft was made possible only by special study; the surface of the cornea remained smooth.

Let us lead to the further analysis, reached after grafting rings of various thickness and diameters.

1. Configuration of the anterior surface of the cornea changes after the grafting of rings, the flattening corresponding to the ring openings. This flattening in most cases arose immediately after the introduction of the ring in the thickness of the cornea and at the laying of stitches on the wound. The flattening effect in the central part of the cornea remained during the whole term of study of the operated rabbits and are visible on the customary profile photographs (Fig. 2, 3). Changes of the configuration of the cornea are clearly visable on the histologic sections and photograms of the optical sections of the cornea. Studies of the histologic sections and especially photograms of the optical sections confirmed our theoretical assumptions of the three possible types of changes of the anterior surface of the cornea after introducing ring grafts to its surface. On the histologic sections received in the early days after the operations, the change of the ring forms were clearly seen: they do not have a cylindrical form by any of the sections: the sharp edges of the ring were

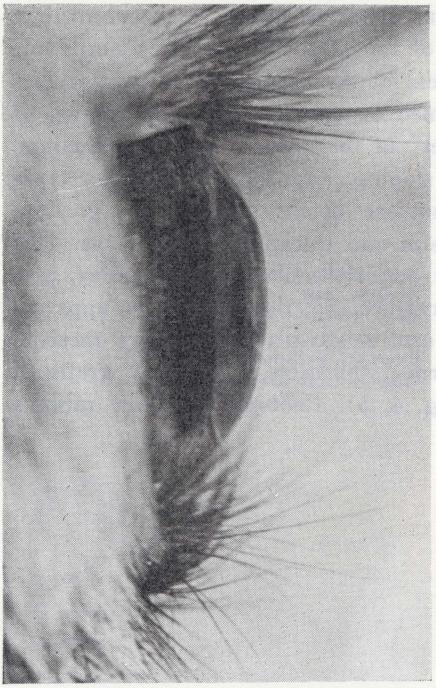

Fig. 2. Rabbit 34, right eye. General refraction of the eye after the operation - hypermetropy 11, OD, the surface of the cornea flattened.

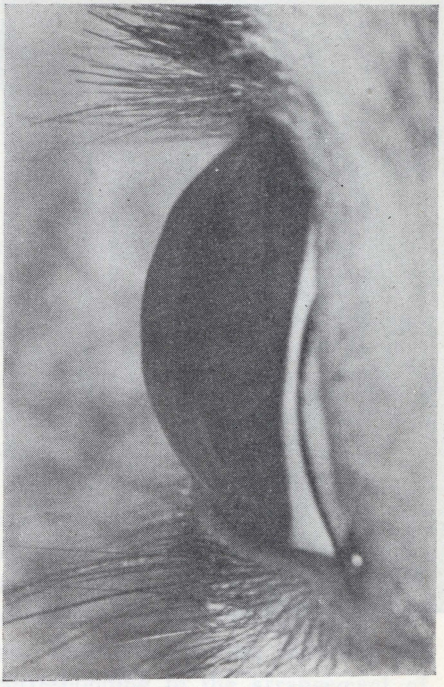

Fig. 3. Rabbit 883, right eye. General refraction of the eye after the operation - hypermetropy 7, OD. The cornea is flattened in the central parts, at the place of the ring graft-elevated.

laid the same, in the internal, as in the external limits. During the examination of the rabbits operated eye, in some cases our attention turned to rather distinct elecations, corresponding to the inner rim of the ring. Usually it is noticeable after grafting the ring from the full thickness of the cornea. On histologic section it is seen that these elevations are formed on account of the thickening of the stroma, the anterior walls of the "pocket" of the cornea and its epithelium. The edge of the rings are in these cases sloping, and thinner. Various types of configuration changes of the anterior surface of the cornea after grafting the rings, are in direct dependence of the size and thickness of the rings. This is especially clear in the photograms of the optical sections of the cornea, produced for radius studies of the corneal curvature. So, the flatness or apparent flatness of the surface of the cornea in its central parts (type II were received by grafting rings 4 x 7 mm in the full corneal thickness, that is by grafts of medium thickness, equal to 0,25 - 0,32 (Fig. 4, 5). Photograms of the rabbit's

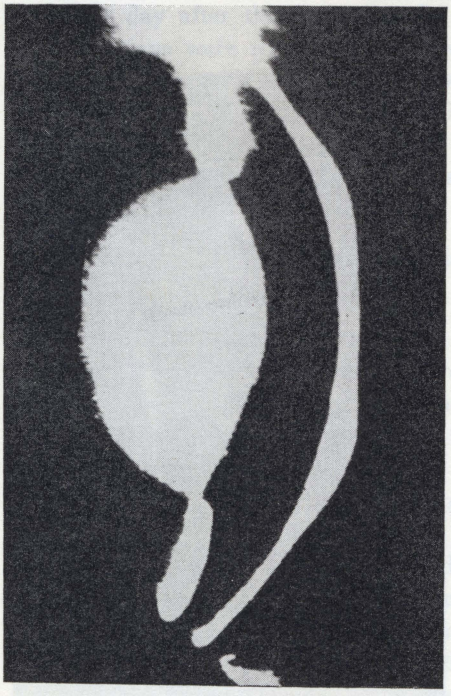

Fig. 4. Rabbit 395, right eye. Photogram of the optical section of the cornea. Corresponding aperture of the ring of the cornea is flattened. Hipermetropy 20, OD.

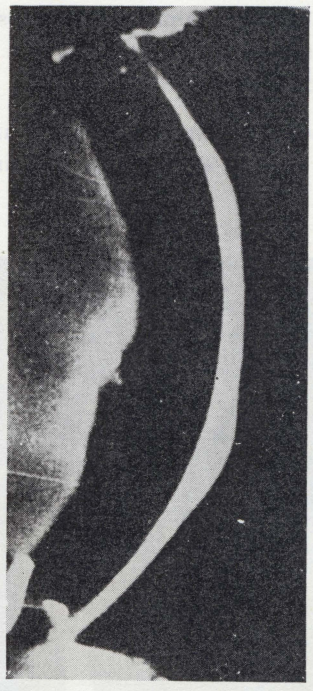

Fig. 5. Rabbit 733, right eye. Photogram of the optical section of the cornea. The anterior surface of the cornea's corresponding aperture of the ring is flat. Hypermetropy 20, OD.

cornea with transplants of rings 5 x 8 mm also ol full thickness, appear otherwise. Here, type I prevails, that is in the central part of the corneal corresponding opening of the ring, equal to 5 mm, although flat, by clearly guarding its protuding surface (Fig. 6). When grafting rings of sizes 4 x 7 mm, but two times thinner, the change of the configuration of the cornea always corresponds with type I (Fig. 7, 8).

Keratograms, received of the cornea with intralamellar ring transplants, have a special, typical form (Fig. 9, 10). The central circles of the keratograms are increased in diameter and are evidence of the relaxation of the cornea sphere, subsequently, between the rings, appearances as of ruptures, are noticeably remote; in those parts they correspond to narrow furrows on the surface of the cornea at the inner limits of the grafted rings. The rings of keratogram reflecting from flat or slightly protuding surfaces, lose their clearness, the distance between them increases by many times. Then come circles, reflecting the increase of the curvature of the cornea, corresponding to the arrangement of

the place of the grafted rings. Here the rings are condensed, narrow, smaller in diameter. Keratograms make it possible to judge not only the sphere, but and of the smoothness of the surface of the cornea and of the restoration at remote periods after the operation.

2. The radius of the corneal curvature of all of the operated rabbits increased in the field of the aperture of the ring, corresponding with the optical zone.

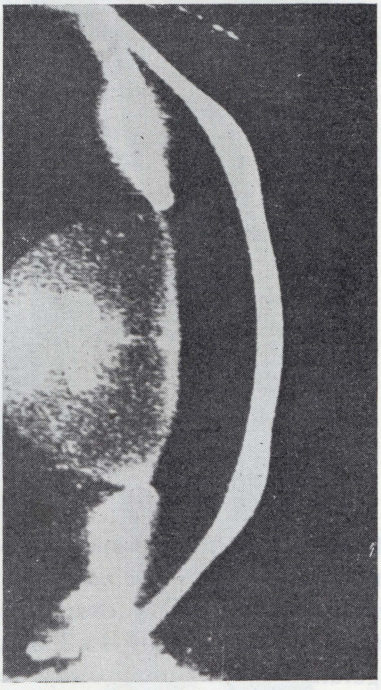

Fig. 6. Rabbit 403, right eye. Photogram of the optical section of the cornea. Corresponding aperture of the ring in the anterior surface of the cornea is flattened. Hypermetropy 16, OD.

Studies of the radius of the corneal curvature were made by using ophthalmometry and demanded special skill, as it was important to center the apparatus on the aperture of the ring. That was possible thanks to the correspondance of the diameters of the optical zones, the operature of the transplanted rings and the technical data of the apparatus, intented for studies of the spherical surface on parts of 3 mm. in diameter. The normal size of the radius of the rabbit's corneal curvature for the given groups of experimental animals were within the limits of 6,13 to 7,05, with the predominant curvature of 6,57 - 6,64.

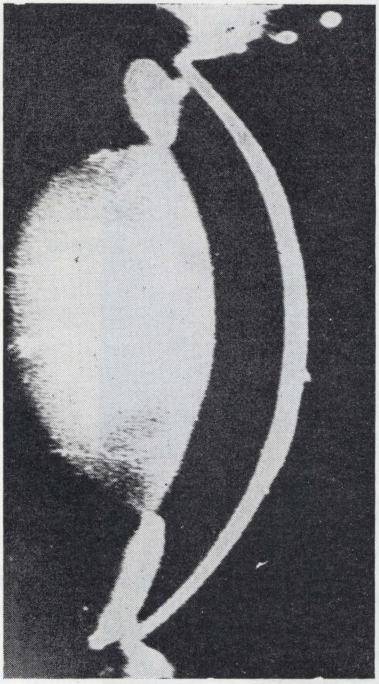

Fig. 7. Rabbit 833, right eye. Photogram of the optical section of the cornea. The cornea flattened, the general configuration is spherical. Hypermetropy 7, OD.

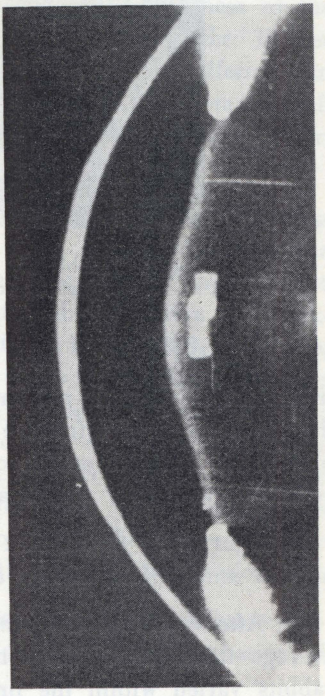

Fig. 8. Rabbit 364, right eye. Photogram of the optical section of the cornea. The cornea is flattened, the general configuration is spherical. Hypermetropy 10, OD.

Among the operated rabbits the maximum increase of the radius of the corneal curvature of the anterior surface of three rabbits after the transplants of rings 4 x 7 and equaled to 10,05. The grafted rings had 0,29 and 0,30 mm thickness. By grafting rings of the same thickness, but of 5 x 8 diameters, the radius of the corneal curvature increased from 8,3 to 9,35 in 5 eyes. The same figures were reached by grafting rings of 4 x 7 mm thickness fo 0,13 — 0,16 mm. The radius of the corneal curvatures by transplanting rings of 6 x 8, thickness of 0,12 — 0,14, were practically uncharged. Apparently, not only the theoretical but and the practical possible variations, when the curvature of the cornea after

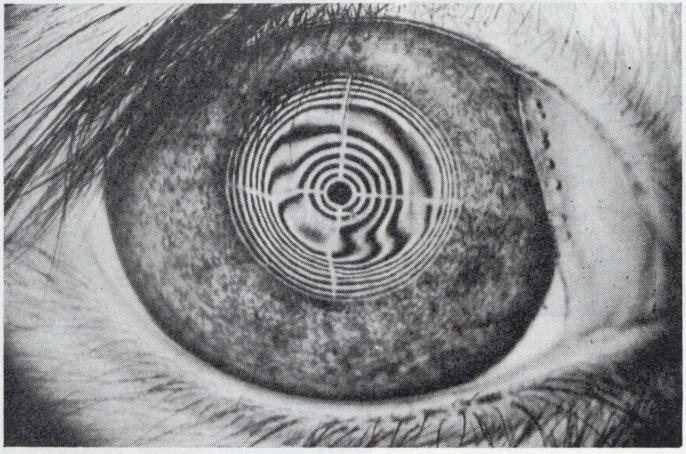

Fig. 9. Rabbit 34, right eye. Keratogram. The circles disperse according to the aperture of the ring. Hypermetropy 11, OD.

transplant of rings do not change. Then as the table of corresponding radius of the curvatures and refractive powers of the anterior surface of the cornea complid in the estimate on the co-effecient of the refractive man's cornea, we were contented with only the data of the radius of the curvatures.

It ought to be noted, that astigmatism when studied by ophthalmometer was noticed among few rabbits and was insignificant.

3. After grafting the rings, the thickness of the cornea was altered. The average thickness of the central zone of the cornea for the given groups of rabbits varied within the limits of 0,30 to 0,38. After grafting the thickness

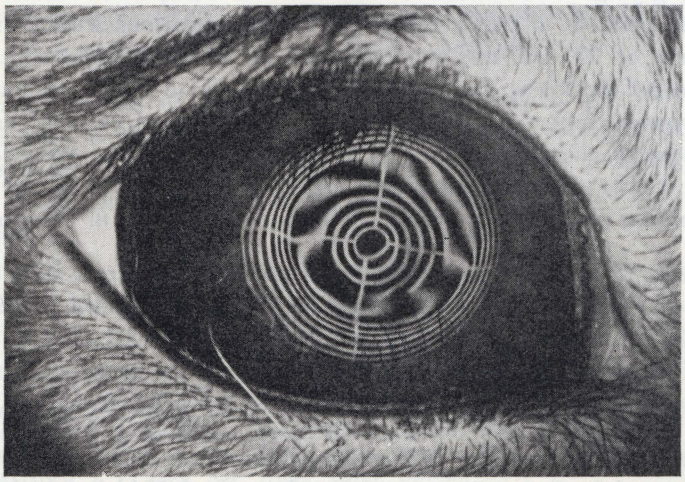

Fig. 10. Rabbit 696, right eye. Keratogram. Hypermetropy 9, OD.

of the center of the cornea did not change (difference of ± 0,01 — 0,02 were within the limits allowed for mistakes). On the contrary, the thickness of the cornea on the rings without large diviations corresponded with the figures of the graft's thickness and the owner's cornea. With noticeable difference in the thickness of the cornea in comparison with the outcome, it was usuall possible to discover the cause of differences: crevices in the cornea layer, oedama of the stoma of the cornea or transplant.

We bring in the form of examples data on the measurements of the thickness of the cornea of several rabbits: rabbit 450, right eye, thickness of the corneal center 0,33; the grafted ring 4 x 7 mm from the anterior layer of the cornea, thickness of 0,1 — 0,12 mm. Two weeks after the operation the thickness of the cornea in the center 0,34, on the ring 0,46. Rabbit 403, right eye, thickness of the cornea in the centre 0,38, grafted rings 5 x 8, thickness 0,37; two weeks after the operation — thickness of the cornea in the center 0,38; on the ring 0,70. Rabbit 395, left eye, thickness of the cornea in the center 0,35; grafted ring 4 x 7, thickness 0,30; two weeks after the operation the thickness of the cornea in the center 0,55, on the ring 0,90. In the light of the spalt-lamp a slight diffused lees of the graft and cornea in the aperture of the ring and surroundings, apparently, on account of the oedema was noticed.

4. The general refraction of the eye of all the rabbits relaxed, definate connection between the sizes of the grafted rings and degrees of the relaxation of the general refraction were noticed.

By grafting rings with diameters from 4 x 7 to 6 x 8, in thickness from 0,31 to 0,1 it was possible to obtain the relaxation of refractions within wide limits: the maximum of 21, Od. and the minimum of 1,5 d. Rabbits with grafts of 4 x 7 in the full thickness of the cornea (from 0,27 to 0,30 - without the epithelium) hypermetropia arose from 23,0 to 14,0 d., or of calculations made of the hypermetropy place before the operation, refraction of the eye relaxed from 21,0 - 12.0 d. The refractive relaxation of 12,0 d. was noticed in one case only in the remaining seven it was from 21,0 (both eyes) to 18,5 d. (also both eyes).

The grafting of ring the sizes of 4 x 7 mm and thickness from 0,24 to 0,1 was performed on 11 eyes. The general refraction of the eye relaxed to 16,5 d. with rings of 0,24 thickness; those of 0,15 - 0,17 thicknses to 12,0 - 9,0 d. The transplanting of rings of 0,1 - 0,12 mm thickness gave the most uniform results: the refractive relaxation was within the limits of 8,5 - 7,5 d.

A markedly greater wavering in the change the refraction of the eye in further grafts of rings of 5 x 8 mm. diameters taken from the full thickness of the cornea was seen: relaxation of refraction was noticed within the limits of 14,0 to 5,0 d. Upon analysis of the data received, the knowledge of the thickness of the transplanted cornea served a great help, measured as a rule, before the donar's death. It appeared, that a great range in the results by grafting rings 5 x 8 mm have a certain tie with various thickness of the donar's cornea. So, relaxed refractions of 14,0 - 12,0 and 11,5 d. were noticed after ring transplants of 0,31 mm thickness. On the contrary, rings 5 x with the thickness of 0,28, 0,25 and 0,23 mm gave relaxed refractions of 8,0 and 7,0 d.

For the general results of the changes of the refraction of the rabbit's eye by interplasty of ringed grafts, it is eseential to note the following: transplants in the form of ring cause the flattening of the anterior surface of the cornea, increasing the radius of its curvatures, and relaxation of the general refraction of the eyes. There exist certain rules of the degrees of relaxation of refraction, depending on the geometric sizes of the transplants: rings or large diameters cause less relaxation of the eye refraction; thinning of transplants of the same diameters cause less relaxation of refraction.

Optimum sizes of the grafted ring, apparently, are rings 4 x 7 mm, rings with smaller inner diameters occupy a field smaller than the optical zone. Rings of greater diameters are placed in the pocket of the split cornea with noticeable greater difficulty and are especially placed 50, as to defend the correct form of the circle. Taken as optimum sizes of the ring graft, the diameter 4 x 7 mm and changing its thickness, it is possible to relax the refraction of the eye from 21,0 to 6,0 - 7,0 d., Conditionally we may accept, that the relaxation of the

refraction of the rabbit's eye from 18,0 - 21,0 if the thickness of the ring is 0,29 - 0,31; from 9,0 - 12,0 d. if the thickness of the ring is 0,15 - 0,17; from 6,0 - 8,0 d., if the thickness of the ring is 0,1 - 0,12 mm.

Refractionary effects of the proposed operations depend not only upon the geometrical sizes of the grafted rings, but from many other factors (thickness and the curvature of the cornea receiptant depth of transplant position, the degree of tension of the cornea layers over the graft), which should also be taken into consideration.

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