ASTIGMATISM AND MYOPIA IN KERATOCONUS*

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ASTIGMATISM AND MYOPIA IN KERATOPLASTY

IT IS THE PURPOSE OF THIS PAPER TO DISCUSS THE SUCCESS OF PENETRATING keratoplasty, not in the usual terms of clarity of the graft, but rather in terms of the spherical equivalent and cylindrical power necessary to obtain the final visual result. From the literature it is obvious that, though clarity of the graft is essential for good vision, it does not necessarily guarantee it.

In 1962 Campinchi and Haye,[1] in an extensive review of keratoconus, noted that "[after surgery] a perfect visual acuity is rarely obtained, even with contact lenses, which are often indicated." Though it is variously reported that clear grafts are obtained in 65 to 95 per cent of eyes operated upon, with a corresponding improvement in visual acuity, the moderate to marked myopia and astigmatism occurring in the postoperative keratoconic eye, though sometimes documented, have been largely ignored. A thorough search of the literature fails to reveal evidence that any direct attempt has been made to control or to eliminate these often debilitating surgical residuals.[2–13]

It was in 1963,[14] when the senior author was introduced to monofilament perlon suture by Harms and Mackensen and began to use it routinely for corneal surgery,[15] that we began to have an interest in the control of corneal astigmatism and myopia in keratoplasty and in cataract surgery.[16] A significant improvement in the technical result of our corneal surgery was accompanied by a corresponding improvement in the anatomic and optical result. The prolonged, firm apposition of graft

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edges by this fine elastic suture produce a more regular scar and a more stable cornea. Up to that time we had rarely performed grafts of more than 7 mm in diameter. Encouraged by the initial technical success, we began regularly to perform 8-mm grafts so as to remove more completely the pathologic or thinned cornea. We had used the edge-to-edge continuous and interrupted virgin silk suture of J.I. Barraquer since 1957, and continued the same configuration with the monofilament suture. All surgery was done under the operating microscope.

About 1966, when we noted and described the torquing effect of the single continuous suture, we began to remove the superfluous interrupted sutures at the close of the operation and depended entirely on the single continuous suture for closure.

In 1968 we began to reinforce the single continuous suture by a second continuous suture run in the opposite direction, to compensate for the torquing effect and to produce a firmer and more secure closure. After each change in suture configuration alterations in the final postoperative refractive measurements were noted.

Concomitantly in 1966, under a grant from the John A. Hartford Foundation, a study was begun on experimental production of astigmatism in the rabbit by the co-author, Dr Meltzer, and later in the primate (baboon) eye with Dr P. deLaage deMeux. Investigation of, and development of, a new manual instrumentation and automated stereotactic instruments for the alteration and correction of experimentally induced astigmatism was also begun.

In 1969 a group of patients who had undergone penetrating keratoplasty for keratoconus from July 1963 were recalled and carefully evaluated by the co-author. Particular attention was given to corneal topography (keratometry) and to the accurate measurement of spherical and cylindrical refraction. A total of 74 eyes were examined. Thirty-one of these were obtained through the courtesy of the corneal clinic of the Manhattan Eye, Ear, and Throat Hospital, and from the practice of Dr Herbert Katzin. These latter were included since they represented eyes treated surgically, during the same period, with multiple interrupted virgin silk sutures for wound closure. In addition, all of these eyes had been operated upon using 1.5 or 2 × loupe magnification. The remaining 43 eyes had all been operated upon by the senior author, who used continuous or combined 10-0 monofilament suture for closure. All of these operations were done under the zoom operating microscope at a magnification of 10–20 ×.

In 1972 an additional 21 eyes operated upon since 1968, but where the double continuous suture closure under operating microscope mag-

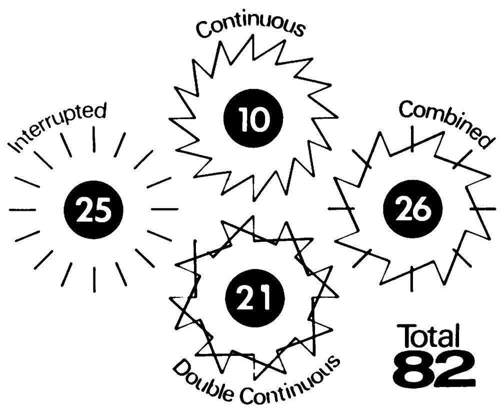

FIGURE 1

Numbers of eyes operated upon using the four suture techniques: interrupted, continuous, combined, double continuous.

nification was used, were added. A total of 82 of 95 eyes were eventually subjected to analysis. Thirteen eyes, 8 in the virgin silk group, were screened from the study in consultation with our biostatistician. Only eyes with primary crystal clear grafts and apparently perfect incisional apposition, and without severe axial myopia unrelated to corneal topography, were included. The eyes selected were divided according to the suture material used, the suture technique or configuration used, and the size of the graft. With regard to suture configuration, there were 25 with interrupted closure, 10 with continuous, 26 with combined, and 21 with double continuous (Figure 1). Of these, 23 were closed with interrupted virgin silk suture under loupe magnification, all by Dr Katzin and associates, and 59 with all four configurations using 10-0 nylon or Perlon under operating microscope magnification, all by the senior author. The diameter of the grafts varied between 7 mm and 9 mm, with 23 grafts of 7.5 mm or less, all closed with silk sutures, and 59 grafts of 8 mm or more, all closed with nylon sutures.

RESULTS

All eyes were measured with the Javal-type keratometer to determine corneal astigmatism and axis, and by refraction to determine axial power and minus cylinder, which were combined to give the spherical equivalent power. In Figure 2 the spherical equivalent powers are grouped according to the type of suture closure and the size of graft used. There

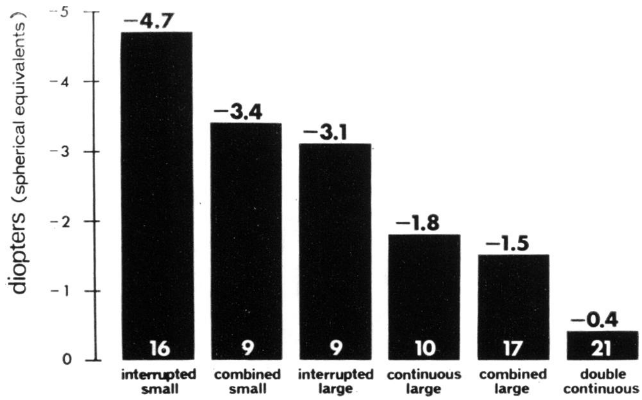

FIGURE 2
Average spherical equivalent power (diopters) according to suture configuration used, significant at $p<0.001$ (results in 82 eyes).

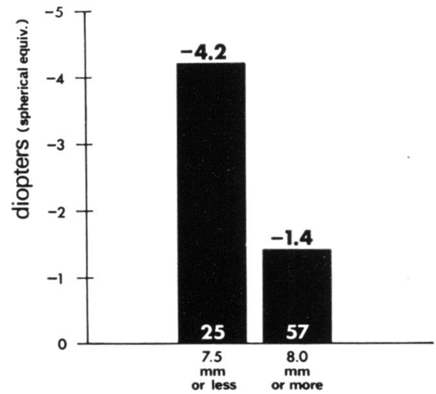

FIGURE 3
Myopia – small versus large grafts, significant at $p<0.001$.

is a large spread between the average spherical equivalent power of the interrupted small grafts, measuring −4.7 diopters, and that of the double continuous large grafts, which measured an almost emmetropic −0.4 diopters.

If we compare the spherical equivalent power of all small grafts with that of all large grafts (Figure 3), without regard to the type of fixation, we find that the significance is in the order of $p < 0.001$.

If we compare all grafts closed by interrupted sutures only with all

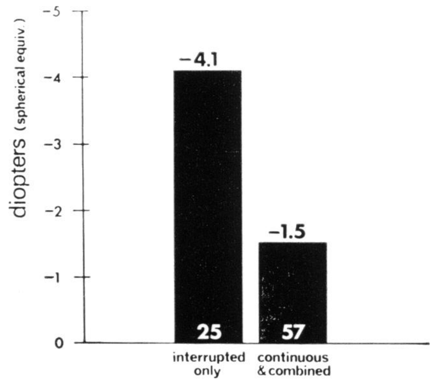

FIGURE 4

Myopia – interrupted versus continuous and combined suture closure, significant at $p<0.001$.

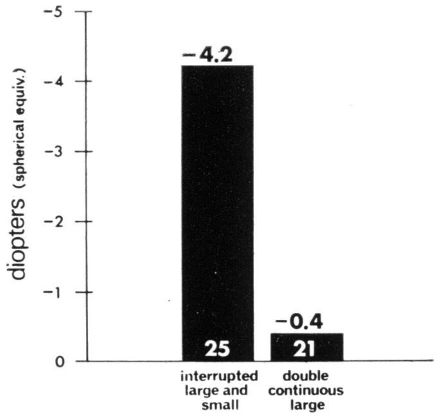

FIGURE 5

Myopia – interrupted sutures, any size of graft, versus double continuous sutures, large graft, significant at $p<0.001$.

those closed by continuous and combined sutures, both with small and with large grafts (Figure 4), a significant difference of $p < 0.001$ is also seen.

If we again combine all grafts closed with interrupted sutures (small and large grafts), and compare these to all grafts closed with double continuous sutures (all large grafts (Figure 5), we find that the difference in the spherical equivalents is even greater, and again significant at $p < 0.001$.

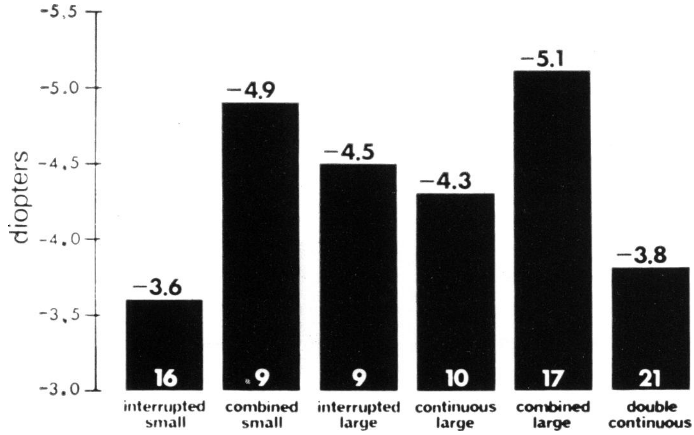

FIGURE 6

Corneal astigmatism averages for grafts of all sizes and suture configurations, not significantly different.

However, when the parameters of cylinder and acuity are examined, much less of a spread is found. For example, between the best and the worst cylinder averages, there is a difference of only −1.5 diopters (Figure 6). Surprisingly the lowest average cylinder is in the interrupted small group. This probably occurs because of the less secure closure and resultant thinner scar of the small graft closed by interrupted sutures only. This type of graft allows the donor button to retain more of its own curvature rather than being influenced by the peripheral curvature defects of the recipient eye. On the other hand, when the double continuous suture is used, a much firmer scar, more likely to be influenced by the peripheral corneal curvature defect, is created. Nevertheless the result is approximately the same and the difference is not significant. The corrected visual acuity (Figure 7) averages 20/31, and, though best in the double continuous group, is not significantly different.

Also tested and found not to be significantly different in any of the above parameters, were double continuous closure versus single continuous closure using large grafts, and continuous and combined closures using large grafts.

Large, single and double continuous, and combined closures were compared to small continuous and combined and large interrupted suture closures, and found not to be significantly different.

Finally large interrupted and small continuous and combined closures failed to show a significant difference when compared to small interrupted closures.

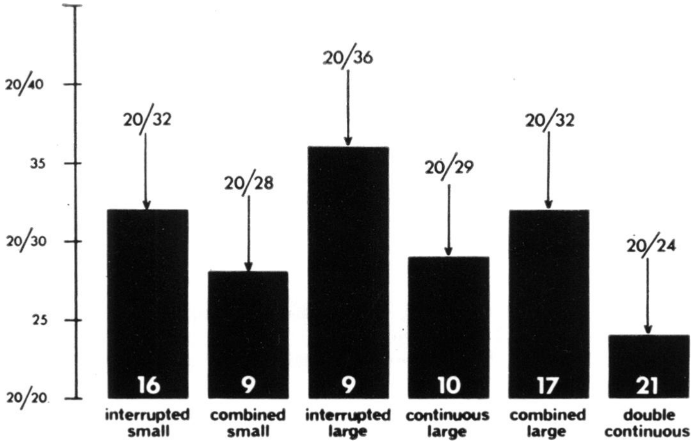

FIGURE 7
Corrected visual acuity, not significantly different.

SUMMARY

Therefore our study indicates that in keratoconus, insofar as the reduction of the minus spherical equivalent refractive power is concerned, grafts closed by combined or continuous sutures, whether large or small, show a markedly significant advantage over grafts closed with interrupted sutures in either large or small grafts.

Further analysis indicates that it is not the size of the graft alone, nor the suture technique alone, which produces the significant difference in the spherical equivalent. Rather the difference seems to depend upon a combination of the large graft together with the continuous or combined suture technique using monofilament nylon suture. These operations were performed under operating microscope magnification.

We have shown that the residual astigmatism is not influenced by either the size of the graft or by the suture technique, and must therefore depend upon other, and we believe peripheral, factors. We have already begun to work on this premise and are attempting to eliminate secondarily this residual astigmatism by a wedge-resection technique.[17] New techniques developed through surgical experimentation with animals are now being employed for primary correction of graft astigmatism at surgery. The virtual elimination of residual myopia in keratoconus by the use of 8-mm or larger grafts, in combination with double continuous or combined sutures of monofilament nylon performed with microsurgical technique, is a significant first step toward our goal of emmetropic anastigmatic penetrating keratoplasty.

ACKNOWLEDGMENTS

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DISCUSSION

Dr Ramon Castroviejo. I would like to thank Dr Troutman for having sent me his paper in time for me to read it and prepare my discussion.

I agree with him one hundred per cent that the success of modern techniques of keratoplasty, particularly in eyes with keratoconus, is the result of the combination of two factors – a graft large enough to replace the whole deformity of the cornea, and the use of the latest thin, low-reacting, monofilament sutures.

[Slide] As you can see in this illustration from one of my papers on corneal surgery, there are many different ways of suturing the corneal graft. The best way of fixing the graft illustrated in this slide is by interrupted, direct, border stitches. Dr Troutman has shown a few more ways of suturing the graft.

[Slide] Some years ago the finest suturing material available for fixation of the graft was 6-0 silk which, within a few days, gave rise to a great deal of reaction, tissue necrosis, often leading to vascularization, infiltration, and infection of the graft. Thus early removal of the stitches, between the seventh and twelfth postoperative days, was necessary, and this resulted in a high incidence of postoperative complications.

[Slide] This slide shows a pronounced protrusion of one portion of the graft, which occurred after the removal of sutures too early during the postoperative recovery. This graft had to be resutured. Such cases often resulted in high astigmatic errors of refraction and [slide] required the application of pressure bandages to push the edge of the graft back to a more normal level of cicatrization.

Nowadays, as Dr Troutman has shown, the coarser and reactive silk sutures that were used before have been replaced by a fine monofilament material that causes practically no reaction and can be left in place one, two, or more months until cicatrization of the wound is well advanced. With these new sutures postoperative complications, such as dehiscence of the incision, anterior synechia, protrusion of the edge of the graft, and the so-called graft-rejection reaction, which was nothing but a keratitis or uveitis caused by the strongly reacting suturing materials used to close the incision, have been greatly reduced or have entirely disappeared.

I have used several ways of closing the incision similar to those illustrated by Dr Troutman: [Slide] The running stitch alone. [Slide] The running stitch in combination with several interrupted stitches which may be of silk [slide] or monofilament. [Slide] Interrupted stitches alone.

The continuous stitch has the advantage that it may be left in the eye longer and causes minimal reaction. Some surgeons may consider this an advantage, while others may consider this extended period of postoperative observation a disadvantage and impractical for patients with a limited time for treatment.

Dr Troutman prefers to bury the suture knot. This complicates the procedure of suture removal as it amounts to reoperation, cutting through the epithelium and stroma to release the buried stitch. I prefer to use interrupted stitches of 10-0 monofilament, placing the knot of the suture over the host cornea, not buried. The slightly greater irritation caused by these unburied, interrupted stitches is negligible and can be neutralized by the daily topical application of a corticosteroid preparation combined with an antibiotic, which is usually well tolerated by the majority of the patients, who remained with the eye uncovered from the day following the operation.

The more noticeable irritation of interrupted, unburied stitches placed over the host cornea is an advantage over the continuous, less reactive suture, because it enhances cicatrization of the wound, accelerating the recovery, and permits the removal of the last few stitches usually no later than two months after the operation.

One of the reasons why I stopped using the continuous suture is because sometimes, if a loop is lost or several loops loosen up, there may be a protrusion of the edge of the graft in one or more than one quadrant. Dr Troutman's addition of a second continuous suture, crisscrossing the first one, adds safety to the closing of the wounds with continuous sutures, but is nothing but a multiplication of stitches; it is simpler to apply as many interrupted stitches as may be necessary to close the incision accurately.

With the interrupted stitches, half are removed one month after the operation, and the other half four or five weeks later. I have not seen, in several hundred patients, a single one that has shown a reopening of the incision or collapse of the anterior chamber with this management of suture removal.

To emphasize a few points mentioned by Dr Troutman regarding the size of the graft, I would like to project a few slides:

[Slide] This is an eye affected with keratoconus, operated on over 30 years ago with a graft of 6 mm. As you see, the graft cicatrized well, even in those days, and remained crystal clear, but it was too small to replace the whole corneal deformity of the keratoconus, thus resulting [slide] in a protruding cornea with a clear graft but high myopia and astigmatism.

[Slide] A second operation with a larger graft of 7.5 mm rendered a more normal curvature to the cornea, lower refractive error, and better vision.

[Slide] To be able to know how much of the protruding cornea should be excised in eyes with keratoconus I designed some years ago the technique of flattening the protruding conus by electrodessication to an approximately normal corneal curvature, excising afterwards the electrodessicated area with an incision placed outside the area thus treated.

[Slide] This is an eye with a penetrating 8.5-mm graft, the size mentioned by Dr Troutman, that should give, when adequately sutured, a good corneal curvature and excellent visual results.

With the monofilament materials presently in use even larger grafts [slide] of 9 mm, [slide] 10 mm, or [slide] 11 mm may be successfully obtained. In the largest graft, as the incision approaches the root of the iris, it is advisable to perform several large peripheral iridectomies, usually one per quadrant, to minimize the incidence of peripheral synechiae.

[Slide] I would like to mention the use of the square graft in keratoconus because, with a relatively small graft of 7.5 mm from border to border, the square graft measures from corner to corner about 10.5 mm, improving the cornea structurally and peripherally as a result of the scarring of the corners of the graft extending close to the limbus [slide]. In addition, if the apex of the conus is excentric, usually deflected downwards, it is possible to orient the square graft, using one of the corners to include the excentric conus while still maintaining the rest of the graft in a central position in front of the pupil.

I agree with Dr Troutman that the modern approach to treat keratoconus by surgery is a partial penetrating keratoplasty which I first advocated in 1937. The graft should be large enough, as he has mentioned, to remove the whole deformity caused by the keratoconus, rarely smaller than 8 mm. The incision should be closed accurately with 10-0 monofilament sutures.

In his paper Dr Troutman comments on a 1962 article by Campinchi and Hayes which states that in an extensive review of keratoconus it was noted that (after surgery) a perfect visual acuity is rarely obtained. In my experience, based on several thousand keratoplasties in keratoconus, the contrary is true. In these cases great improvement of visual acuity is generally the rule, often sufficient to satisfy the patients' needs without the use of glasses, but almost always, in over 90 per cent of the cases, able to be corrected to between 20/30 and 20/20 with glasses of not too high refractive power.

Dr Troutman prefers the use of an esoteric, double continuous suture and concludes, after careful observation of a series of cases, that the combination of a large graft and his double continuous suture should give better results, with low refractive errors and, particularly, less astigmatism.

I agree with him regarding the need for relatively large grafts, usually not smaller than 8 mm. I do not feel, however, that Dr Troutman's double continuous suture offers any advantage over an accurately closed incision with interrupted stitches; on the contrary, I feel that the interrupted stitches offer over the continuous suture the advantages that have been enumerated above. The selection of the best way of fixing the corneal graft cannot be approached by theoretical discussion but has to be decided by the individual surgeon after he gets acquainted in actual performance of operations with the different ways of closing the corneal wound.

DR FREDERICK W. STOCKER. As another veteran, with Dr Castroviejo, in the field of corneal grafting, I may be allowed a few words. Dr Troutman's excellent presentation has clearly demonstrated how far we have come from the time when we used an egg membrane or a reversed conjunctival flap to hold the graft in place. I can wholeheartedly agree with him that the last step – the continuous monofilament suture – constitutes a tremendous improvement. Indeed since we have used it we have had several cases of keratoconus in which the graft provided 20/25 vision without any correction whatsoever.

I also would like to emphasize the value of larger grafts. I have always supported Dr Castroviejo in the belief that for keratoconus we need a fairly large graft because the cornea sometimes is thin quite a way out toward the periphery, and the farther out the graft extends, the more normal the recipient's cornea becomes, and the better approximation we will get.

We have been at odds, in this respect, with some ophthalmic surgeons for years. It was said that large grafts would enhance immune reaction: the bigger the piece of cornea implanted, the more antigens introduced to cause immune reaction. Such simplistic reasoning must be termed almost naive. Why would grafts for keratoconus be successful in such a comparatively high percentage of cases, although relatively large grafts are generally used, if there were anything to that theory? While I do not deny that there is such a thing as an immune reaction, it is very rare. Most failures in corneal grafts are due to technical inadequacies and their sequels.

I want to congratulate Dr Troutman on his excellent presentation.

DR JOHN WOODWORTH HENDERSON. I would like to congratulate Dr Troutman on a very well documented paper. I would like to ask one question. I think there is one gap in your information that might be of interest, and that is: Do you know, in your final results on astigmatism, how much of the astigmatism has been transplanted in with the graft itself, and whether this should be measured in your future studies?

DR TROUTMAN. I would like to thank the discussers, particularly Dr Castroviejo, who has really inspired me for years in this subject, and probably is one of the major reasons (besides Dr Townley Paton, who was my teacher, as was Dr John McLean) that I have stayed with this field.

I would like to begin by answering Dr Henderson's question. Yes, we have measured corneal K in donor eyes. For a time in our studies we did measure, or attempted to measure, keratometry in our eye-bank eyes. Dr deLaage molded these eyes, and we molded also the eye of the recipient, and tried to match the recipient with the donor eye. We found this a very difficult thing to do, and we did not feel our information was valuable enough (at least at our present level of development) to report this in the present series. However we are continuing to work on this in our stereotactic program.

I would like to come back to Dr Castroviejo's comments about the use of the interrupted suture. As we showed, the interrupted suture is not nearly as effective as the continuous suture in reducing the myopia, although it is just as effective in the amount of astigmatism it produces – or does not produce, shall we say.

Dr Castroviejo's demonstration of the use of both the interrupted and the continuous suture, in my opinion, is incorrect. The interrupted sutures must be cut short, at the knot. The knot must be buried, not in the recipient cornea where, as you saw in one of his slides, considerable vascularization was produced by this irritating knot. This is sometimes followed by graft reaction, or whatever we wish to call it (as Dr Stocker said, maybe "defective technique" is a phrase for it too). I believe this is not good technique with monofilament nylon sutures. These sutures have to be cut short and buried in the donor cornea.

Also it is important with the continuous suture that the suture knot be buried, because these sutures must stay in place, particularly in keratoconus if one wants to obtain the desired result, for at least 5 or 6 months. You cannot take them out at 1 or 2 months, or you will not reduce the axial or corneal-induced myopia, as we have shown to be possible when they are left for longer periods. Otherwise you will continue to get myopic eyes.

The square grafts that I have seen, though they were a very ingenious answer to the problem in the days when one could not use large grafts, have shown both high myopic and high astigmatic changes. The two cases shown by Dr Castroviejo both had a very wide horizontal meridian of the cornea. This is a tip-off to the optical pathology of keratoconus, which has a narrow, steep, vertical corneal meridian and a flat, wide horizontal meridian (between the lids).

If one does not alter this configuration in the surgical management, the astigmatism is either maintained or made worse. Our next presentation, which will be at the Academy meeting this fall, will document our studies in the surgical management of the astigmatism.

Thank you.