Sinusotomy and deep sclerectomy

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ARTICLE

Abstract

Non-penetrating filtering surgery (NPFS) started in 1962 with the first sinusotomy performed by Kraznov. At that time, the author of this new technique believed that the outflow resistance in the majority of cases of primary open-angle glaucoma was located at the level of scleral aqueous drainage veins and not in the trabeculum. He therefore developed a safe NPFS technique, leaving in place the trabeculum and the inner wall of Schlemm's canal. Because of difficulties with the microsurgical technique and the small reduction in intraocular pressure (IOP) compared with trabeculectomy, sinusotomy was abandoned. In the last decade, with the widespread use of operating microscopes, NPFS has been the subject of renewed interest. IOP reduction with the new NPFS techniques is comparable to that obtained with trabeculectomy, with significantly lower pre- and post-operative complications. The new NPFS techniques such as deep sclerectomy, *ab externo* trabeculectomy and viscocanalostomy present definitively different mechanisms of filtration compared with early sinusotomy. This article will review the history of NPFS as well as describing the different new non-penetrating filtering surgeries.

Key words *Ab externo* trabeculectomy, Deep sclerectomy, Non-penetrating filtering surgery, Sinusotomy, Trabeculectomy

Historical review of non-penetrating filtering surgery

In 1962 Kraznov performed the first sinusotomy. This operation consisted in removing a lamellar band of the sclera, opening Schlemm's canal over 120° from 10 to 2 o'clock (Fig. 1).[1–4] The inner wall of Schlemm's canal was untouched and then the conjunctiva was closed. Kraznov believed that the aqueous outflow resistance in the majority of cases of primary open-angle glaucoma was situated at the level of scleral aqueous drainage veins and not in the trabeculum. He therefore developed a safe non-penetrating filtering surgery, leaving in place the trabeculum and the inner wall of Schlemm's canal. When there was no percolation of aqueous through the trabeculum and the inner wall of Schlemm's canal, Kraznov used to enter the anterior chamber and perform a peripheral iridectomy, creating a full-thickness procedure which was the standard filtering surgery at that time. Sinusotomy had almost no post-operative complications. This was certainly not the case with standard full-thickness procedures, which often led to major hypotony followed in many cases by a flat anterior chamber, choroidals and cataract formation. Kraznov also reported that the filtering blebs were more diffuse after sinusotomy and that they tended to disappear with time.

Sinusotomy never became popular because it was a difficult operation. It needed a surgical microscope, and Schlemm's canal had to be found which was not easy. Moreover the surgical results were not convincing. Kraznov reported an 83% success rate with no data regarding the success criteria, the number of patients followed or the time of follow-up. Postic *et al*.[4] have reported a 50% success rate in 12 glaucoma patients operated with sinusotomy. These 6 patients had low IOPs with filtering blebs. The other 50% presented a primary drop in IOP after the surgery, and then an IOP rise due to fibrosis of the filtering bleb.[4] To my knowledge, there is no long-term report on the outcome of sinusotomy.

In the late 1960s, and for the next three decades, trabeculectomy as described by Sugar in 1961 and Cairns in 1968 became the standard technique for filtering surgery, providing satisfactory IOP control with fewer post-operative complications than full-thickness filtering procedures.[5,6] However, even with the numerous modifications proposed to the original trabeculectomy, the lack of a reproducible post-operative IOP reduction as well as the early post-operative complications led several surgeons to reconsider Kraznov's work. Several techniques of non-penetrating filtering surgery based on sinusotomy have been described. Since the main aqueous outflow resistance may be located at the juxtacanalicular trabeculum and the inner wall of Schlemm's canal, these two anatomical structures have to be removed. *Ab externo* trabeculectomy was first proposed by de Laage de Meux in 1976, and later by Zimmermann in 1984 and Arenas in

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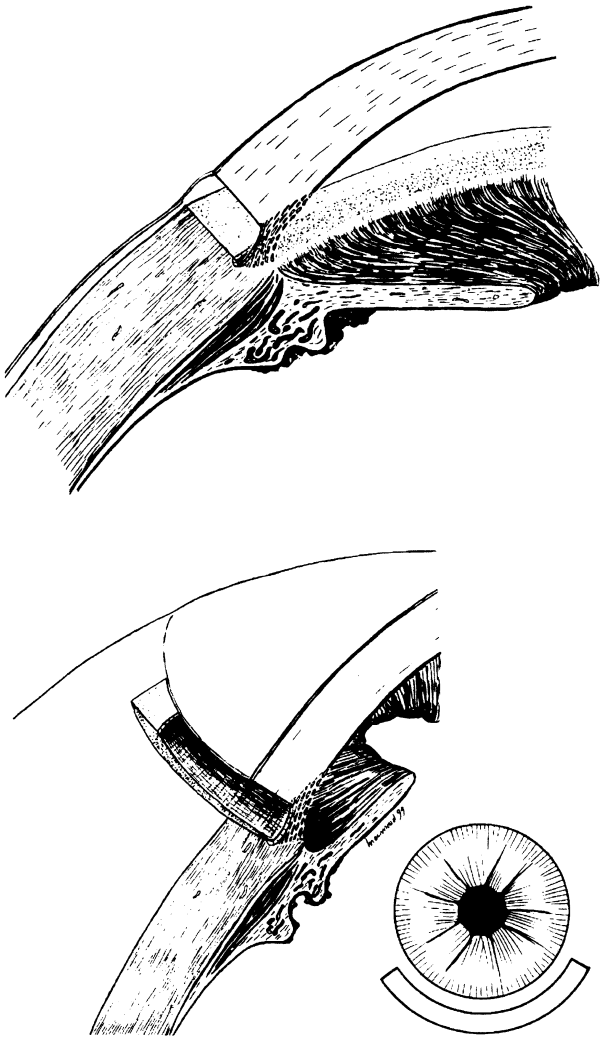

Fig. 1. *Schematic representation of sinusotomy. Schlemm's canal is unroofed. There is no superficial scleral flap to cover the sclerectomy. The inner wall of Schlemm's canal is untouched.*

1991 (Fig. 2).[7–11] Another method to improve aqueous outflow in a patient with restricted posterior trabeculum clearance is to remove the corneal stroma behind the anterior trabeculum and Descemet's membrane (Fig. 3). This was first described by Fyodorov and Kozlov[12,13] and later by Stegmann.[14]

Ab externo trabeculectomy

Ab externo trabeculectomy is very similar to sinusotomy except for the presence of a superficial scleral flap and the removal of the inner wall of Schlemm's canal and the juxtacanalicular trabeculum (Fig. 2).

Surgical technique

The conjunctiva is opened either at the fornix or at the limbus in the superior quadrant. A 4 × 4 mm superficial scleral flap is created at the 12 o'clock position. The depth of this scleral flap corresponds approximately to one-third of the full scleral thickness. A radial cut is performed on the edge of the flap at the limbus to localise Schlemm's canal. Once Schlemm's canal is found, it is unroofed in the same manner as Kraznov used in sinusotomy. At this stage, there is a 4 mm long Schlemm's river parallel to the limbus. To remove the inner wall of Schlemm's canal, different techniques have been proposed. A fine forceps ending with two small plates may be used to grab the endothelium and peel it off from one side to the other. Trabeculo-aspiration has been proposed by A. Bechetoille, who uses a fine cannula connected to a phaco infusion-aspiration system (unpublished data). E. Dahan uses a fine diamond-coated spatula which allows the endothelium to be scraped (unpublished data). All these manoeuvres have been grouped into so-called *ab externo* trabeculectomy since the juxtacanalicular trabeculum is removed and the corneo-scleral and uveo-scleral trabecula are left *in situ*. F. Valtot in an unpublished report showed that the tissues removed corresponded to the endothelium of Schlemm's canal and the juxtacanalicular trabeculum. This was later confirmed by S. Roy *et al*. who examined a large series of excised fragments using transmission electron microscopy (unpublished data). The outflow

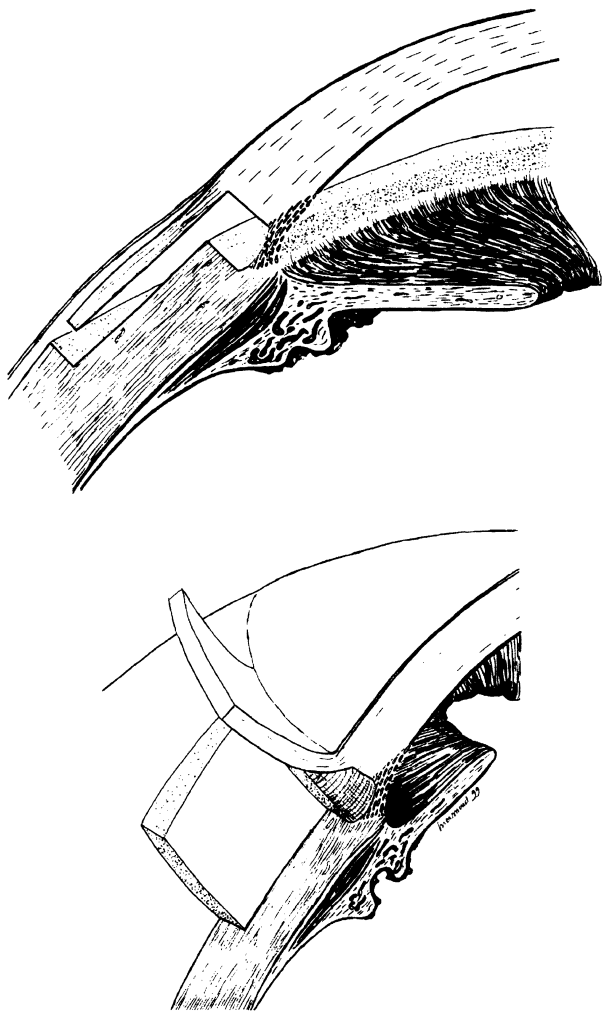

Fig. 2. *Schematic representation of* ab externo *trabeculectomy. A deep sclerectomy unroofing Schlemm's canal is covered by a superficial scleral flap. The inner wall of Schlemm's canal and the juxtacanalicular trabeculum are removed.*

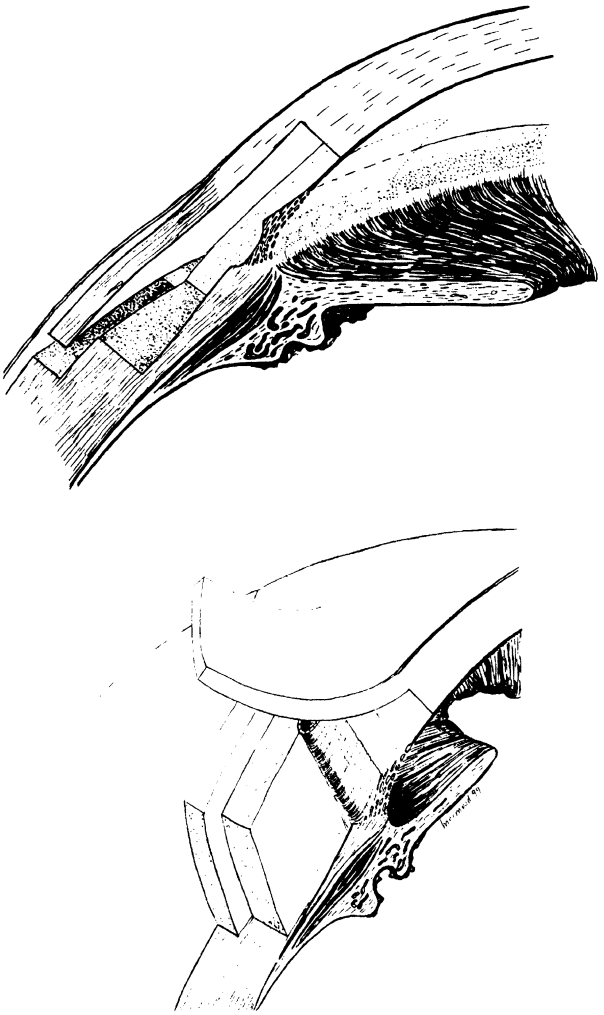

Fig. 3. *Schematic representation of deep sclerectomy. Under a superficial scleral flap, a deep corneo-sclerectomy unroofing Schlemm's canal is performed. The inner wall of Schlemm's canal and the juxtacanalicular trabeculum have to be removed. Corneal tissues behind the anterior trabeculum and Descemet's membrane are removed.*

resistance of the remaining membrane formed by the posterior trabeculum has been studied by A. Rossier *et al.* (unpublished data). They found that in enucleated human eyes, the outflow facility increased from 0.21 ± 00.6 to 2.03 ± 1.43 μl/min/mmHg after the removal of 4 mm of the inner wall of Schlemm's canal and the juxtacanalicular trabeculum.

Results

Zimmerman and colleagues[8,9] have reported good results of non-penetrating *ab externo* trabeculectomy in both phakic and aphakic patients. However, after their first two publications they abandoned the technique because of surgical difficulties. Arenas[10] is currently continuing to use *ab externo* trabeculectomy, and has reported a success rate of 88%. Other authors who have been using similar techniques have reported satisfactorily controlled IOPs in 85.8–90% of patients.[11,12] Regarding the long-term results, Arenas, Valtot and Bechetoille have all reported satisfactory IOP control over time, but no results have yet been published.

Deep sclerectomy

Deep sclerectomy was first described by Fyodorov and Kozlov.[13,14] The route of the aqueous outflow is different from that described for sinusotomy and *ab externo* trabeculectomy where post-operative drainage occurs through the posterior trabeculum. In deep sclerectomy the main outflow occurs at the level of the anterior trabeculum and Descemet's membrane. This was shown by Vaudaux and Mermoud[15] in an *ex vivo* model of deep sclerectomy. They also reported that the outflow facility increased from 0.19 ± 0.03 to 24.5 ± 12.6 μl/min/mmHg after deep sclerectomy. In comparison with the same experiment performed in *ex vivo*, *ab externo* trabeculectomy, the post-operative outflow facility increase is 10 times higher after deep sclerectomy (A. Rossier *et al.*, unpublished data). To provide an aqueous outflow through the anterior trabeculum and Descemet's membrane, the corneal stroma behind these structures has to be removed (Fig. 3).

Surgical technique

The conjunctiva may be opened either at the fornix or at the limbus. A 5×5 mm superficial scleral flap is performed including one-third of the scleral thickness (300 μm). To be able to reach Descemet's membrane later in the dissection, the superficial scleral flap has to be cut 1–1.5 mm anteriorly into the clear cornea. A second deep scleral flap measuring 4×4 mm and leaving about 10% of the sclera over the choroid and the ciliary body is dissected. The second flap is usually started in its posterior part. The horizontal dissection is performed starting posteriorly and moving anteriorly using a crescent blade. Near the limbus Schlemm's canal is automatically unroofed. The dissection is continued anteriorly using a blunt spatula or sponge to find the natural cleavage plane between Descemet's membrane and the corneal stroma. When Descemet's membrane has been exposed for 1 mm, the second scleral flap is excised. At this stage, the aqueous is seen percolating through the anterior trabeculum and Descemet's membrane. To enhance the filtration, an *ab externo* trabeculectomy can be performed as well at this stage. To keep the intrascleral space created patent, an implant may be used. Kozlov[14,16] has proposed a collagen implant which resorbs itself within 6–9 months.[17,18] Stegmann uses high-viscosity hyaluronic acid,[19] and P. Sourdille and E. Dahan are using reticulated hyaluronic acid and Hema implants respectively (unpublished data).

Results

Kozlov *et al.*[14] have reported an 85% success rate, but no information regarding success criteria or follow-up is available. Demailly *et al.*[20] reported a mean decrease in

IOP of 9.1 ± 7.1 mmHg after 219 deep sclerotomy procedures with collagen implant. Using Kaplan–Meier survival analysis, they reported a success rate without glaucoma medication of 89% at 6 months and 75.6% at 16 months; with glaucoma medication, their success rate increased to 97% at 6 months and 79% at 16 months.

Karlen *et al*.[21] have reported the medium-term success rate (36 months) of 100 patients who underwent deep sclerectomy with collagen implant. The mean pre-operative IOP was 27.8 ± 8.6 mmHg, which dropped to 5.7 ± 4 mmHg on the first post-operative day and remained stable at 13 ± 3.5 mmHg during the entire follow-up period. Complete success, defined as an IOP lower than 21 mmHg without medication, was 44.6% at 36 months; qualified success, defined as an IOP lower than 21 mmHg with medication, was 97.7% at 36 months. Goniopuncture had to be performed on 41 of the patients, and 5-fluorouracil injections were made in 23 patients; cataract progression occurred in 7 patients. When comparing the different types of open-angle glaucoma, no difference was found in terms of reduction in IOP, number of patients requiring antiglaucoma medications or success rate. There was, however, a tendency for a lower success rate in patients with pseudoexfoliative or pseudophakic glaucomas. In comparison with the standard filtering procedure of trabeculectomy, deep sclerectomy offers a similar IOP drop with a significantly lower rate of post-operative complications and a quicker recovery of visual acuity.[22,23]

Viscocanalostomy

The assumed mechanism of filtration in viscocanalostomy is different from the one described in other non-penetrating filtering surgeries. R. Stegmann thinks that the aqueous filters through the trabeculo-Descemetic membrane to the scleral space, as in deep sclerectomy, but that it does not form a subconjunctival filtering bleb since the superficial scleral flap is tightly closed with numerous Nylon 10/0 sutures. From the scleral space, the aqueous is supposed to reach Schlemm's canal, which is open on either side of the deep sclerectomy, and then to flow into the aqueous episcleral veins. No scientific study has yet been able to confirm this hypothesis and, in our hands, 50% of patients who underwent a viscocanalostomy had a subconjunctival filtering bleb. Long-term follow-up of viscocanalostomy is reported to be satisfactory. In a prospective study involving 214 eyes of 157 patients, a post-operative IOP less of than 22 mmHg was observed in 82.7%.[19]

Conclusions

In comparison with full-thickness filtering procedures, sinusotomy showed an important improvement in terms of post-operative complications. Unfortunately, the long-term IOP drop did not come up to expectations and trabeculectomy became the standard filtering surgery for the next three decades. Since sinusotomy has been modified over recent years, there has been renewed interest in non-penetrating filtering surgery, mainly because it provides a more reproducible early drop in IOP with fewer post-operative complications. The main changes made from sinusotomy in the new non-penetrating filtering surgery techniques are: the peeling of the inner wall of Schlemm's canal (*ab externo* trabeculectomy) and the excision of the corneal stroma behind the anterior trabeculum and Descemet's membrane (deep sclerectomy). These new techniques compare favourably with trabeculectomy in terms of the IOP drop. However, long-term follow-up is still needed to tell us whether this IOP control will persist or not.

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