A new system of microsurgery for human and experimental corneal grafting

II. Clinical and experimental applications

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SUMMARY After preliminary testing with pig, dog, rabbit, monkey, cat, and human cadaver eyes the CLCC system has been used for penetrating and lamellar keratoplasty in human subjects. Clinical experience covers a broad range of corneal pathology. Detailed operative instructions and observations are given. In the experimental situation the CLCC is being used to achieve deep lamellar corneal dissection for a continuing study of non-penetrating keratoplasty.

The CLCC developed from an experimental programme designed to perfect deep, non-penetrating corneal grafting on to Descemet's membrane (Crock, 1977). The microsurgical system which has evolved as a by-product of this research has opened new possibilities in penetrating grafting. It is this aspect of the technology which, to date, has received most attention at a clinical level. Dissection to Descemet's membrane has become feasible, but experimental work is still moving towards a safe, rapid, and consistently reproducible surgical technique for lamellar grafting over an exposed, intact Descemet's membrane.

Operating theatre technique was outlined briefly in Paper I. The procedures will now be considered in greater detail, with specific cutting instructions, clinical features of tissue characteristics during cutting, methods of donor handling, and a synopsis of the first 25 operations using the CLCC system.

Operative routine

The importance of head and eye posture is re-emphasised. Where possible the patient's cornea should be located centrally between the open lids so that corneal pathology, optical axis of the CLCC, and the optical path of the operating microscope are aligned vertically. Placing the CLCC on the eye may for descriptive purposes be considered in three steps.

Initially the surgeon fits the lens to the cornea by tilting the instrument so that the foot plate rests on the nasal limbus while an assistant irrigates the eye from the temporal side with balanced salt solution.* The instrument is gradually brought to the vertical position with the foot plate resting over the entire limbal circumference. Most air will be excluded from the lens corneal interface during such fitting. Small remaining bubbles will bleed out through the knife race. Secondly, the CLCC is slid over the cornea until the main lesion is centrally located and completely encompassed by the outer rim of the contact lens. To achieve this it may be necessary to remove the instrument and apply a different sized cutter. The CLCC is then seated on the eye and downward pressure applied. The notched foot plate thus gains a grip of the bulbar tissues, which prevents movement of the globe during corneal cutting. Indirect ophthalmoscopy through the contact lens during this phase of operation has shown that the risk of inducing central retinal vessel closure is negligible.

Fitting difficulties may be due to inappropriate eye posture, corneal irregularity, or conjunctival entrapment by the foot plate in the case of larger grafts. In the first instance, the CLCC should be withdrawn and reintroduced after the eye position has been adjusted. A squint hook can be used to maintain a good eye posture until the foot plate is adequately seated. A rectus stay suture is almost never required.

In the presence of marked corneal irregularity it

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may be impossible to bleed all air from the lens corneal interface. Provided the air bubble is evenly distributed, preferably under the central portion of the lens, it is safe to proceed with cutting. A large eccentrically placed air bubble will result in shallow depth of cut over the corneal section adjacent to the air pocket. Altering the height of the interchangeable foot plate can play an important part in securing adequate seating of the CLCC. Having thus selected the appropriately sized cutter, the surgeon removes the instrument from the eye and loads the knife blade.

The stage is now set for the penetrating graft procedure. The loaded CLCC is repositioned, and while the knife is still retracted the surgeon rotates the contact lens carriage two or three times to confirm a stable instrument grip on the eye before cutting is begun.

The knife carriage is 'parked', with the micrometer screw coming to rest under the retractable control rod. The assistant turns this rod to lower the knife blade towards the cornea. The surgeon observes when the knife contacts the corneal surface. Often a small air bubble will develop around the cutting tip. After the assistant has retracted the depth control rod back into its sheath, the surgeon then 'drives' the blade around two or three times in rapid succession until a cut of uniform depth has been achieved. This initial cut should be into the superficial stroma only. The knife carriage mechanism is again parked while the assistant lowers the blade deeper into cornea. He is guided both by the view down the operating microscope and the rotation of the micrometer gauge. Again the control rod is retracted and the surgeon repeats the cutting sequence, driving the blade through several quick turns to produce a circular cut of uniform depth.

Wrinkling of Descemet's membrane indicates that the corneal cut is nearing full thickness. Fine gaping of the wound edges, a circular motion of the disc, sudden clearing of air or blood in the incision track or the appearance of a fluid droplet on the inner face of the contact lens around the micrometer screw region are all indications of full corneal penetration.

Direct sighting of the cutting tip in the anterior chamber, movement of iris stroma, iris pigment dispersal, and iris prolapse are all signs of 'over-shooting', which should be avoided.

An experienced surgeon can cut full-thickness donor buttons over 350° of arc with unerring consistency and not infrequently can achieve 360° cuts in the cadaver (Fig. 1). As the blade nears Descemet's membrane it should be advanced by small increments between cutting sequences. When necessary, corneal sectioning may be completed by

corneal scissors or, under operating room conditions, with the oscillating knife.

If the cornea is heavily vascularised the CLCC acts as a tamponade which reduces bleeding during cutting. Any blood entering the circle of incision serves as a good indicator of depth of cut, especially in opaque stroma. The sloping edge, coupled with the light pressure of the instrument, seals the anterior chamber during penetration, obviating the need for precautionary air injection into the anterior chamber.

Fig. 1 The CLCC has completed a 360° corneal cut in a cadaver eye

Fig. 2 Insertion of sutures into the corneal disc at the 6 o'clock position on the chuck

Handling procedure for corneal discs

The DDC and frame were designed to allow virtually atraumatic placement of 4 accurately aligned sutures in the donor disc without the use of holding forceps. Sutures should be inserted to the level of Descemet's membrane. Double armed 10/0 nylon suture material has been used, but 8/0 virgin silk is preferred for ease and speed of handling.

Double armed sutures are inserted into the cornea

Fig. 3 The chuck has been opened to release the corneal disc, which is now supported by its 4 sutures

Fig. 4 The frame has been turned over so that the suspended donor corneal disc now has the endothelial side facing downwards

from the 6 o'clock position on the chuck (Fig. 2). The chuck is rotated between placement of each of the 4 sutures. Tangling of the threads can be avoided by fixing them to the corneal frame in the sequence: 12, 3, 9, and 6 o'clock. The 'leading needles' are cut off as their respective thread is anchored to the corneal frame. This is an essential step, as only the 'trailing needle' can be used for suturing the donor disc into the recipient eye. With the 4 sutures in place and under proper tension the disc chuck is opened and the corneal disc gently released (Fig. 3).

In the operating theatre a small volume of storage medium may be dropped on to the endothelial surface of the disc while attention is redirected to final preparation of the recipient eye. When the recipient is ready, the corneal frame is released from its holding bracket and turned over, so that the endothelium of the donor button is downmost (Fig. 4). The frame with its centrally held donor disc is then placed over the patient's eye, and the disc is sewn in while the assistant steadies the corneal frame. The 4 primary sutures usually provide an airtight wound, so that fluid or air can be readily introduced by Rycroft cannula into the anterior chamber between the wound edges.

Clinical and experimental applications

From the clinical cases treated with the CLCC features of 25 are summarised in Table 1. This illustrates a broad scatter of anterior segment pathology, and serves to emphasise the versatility of this new microsurgical system. The optical and technical advantages of the cutter are perhaps best appreciated in vascularised corneae, in keratoconus, and in corneal opacities associated with anterior chamber pathology.

For the first time the corneal surgeon can see the outer limits of a cone during cutting. Under the CLCC the cone collapses into a series of concentric rings. The diseased tissue has a plasticity which imparts a unique appearance during cutting. The stroma meanders around under the contact lens like clay on a potter's wheel.

Deep lamellar dissection using the CLCC and SEH has exposed intact Descemet's membrane in both human cadaver eyes and in rabbit experiments (Crock, 1977). This work is continuing and will be the subject of a separate communication. The technical difficulties of a lamellar dissection by established methods can be appreciated in the illustration from Rosenthal's experiment with sutureless lamellar keratoplasty in the rabbit (Rosenthal *et al.*, 1975).

Experience with corneal cutting in animals

Table 1 Summary of first 25 cases

Case No.	Sex	Age	Ocular pathology	Visual acuity		Operation
				Preop	Postop	
1	M	58	Bullous keratopathy aphakia, chronic uveitis, fibrous ingrowth	CF 2M	6/36	8 mm Penetrating graft
2	M	50	Interstitial keratitis	6/60	6/9	7 mm Penetrating graft
3	M	43	Keratoconus regrant	6/60	6/9	8 mm Penetrating graft
4	F	81	Fuchs's dystrophy	P/L	6/9	8 mm Penetrating graft plus cataract extraction
5	M	26	Keratoconus	6/60	6/6	9 mm Penetrating graft
6	F	71	Herpetic keratitis	HM	6/9	8 mm Penetrating graft
7	F	17	Penetrating injury, corneal scar, lens, iris, vitreous incarceration	HM	6/12	9 mm Autograft rotation
8	F	34	Graft rejection (herpetic keratitis)	6/60	6/6	9 mm Penetrating graft plus cataract extraction
9	M	62	Ammonia burns	P/L	6/6	7 mm Penetrating graft
10	M	55	Herpetic keratitis	HM	6/6	9 mm Penetrating graft
11	F	22	Ruptured descemetocoele (herpetic keratitis)	HM	6/6	9 mm Penetrating graft
12	F	20	Herpetic keratitis	P/L	6/6	9 mm Penetrating graft
13	F	62	Recurrent malignant melanoma conjunctiva and cornea	6/18	6/12	9 mm Corneo-scleral lamellar graft. 180°
14	F	53	Herpetic keratitis, secondary glaucoma, Gunderson flap	6/60	6/9	9 mm Penetrating graft
15	F	47	Adherent leucoma, cataract microphthalmia	HM	6/6	7 mm Penetrating graft plus cataract extraction
16	F	33	Keratoconus	6/36	6/6	9 mm Penetrating graft
17	F	63	Corneal dystrophy and cataract	6/60	6/6	7 mm Penetrating graft plus cataract extraction
18	M	68	Graft rejection, aphakia pathological myopia	HM	6/24	7 mm Penetrating graft
19	M	31	Corneal leucoma, anterior segment necrosis, after retinal surgery	P/L	HM	7 mm Autograft from blind fellow eye
20	M	55	Herpetic keratitis	HM	6/6	8 mm Penetrating graft
21	M	51	Traumatic leucoma	P/L	6/9p	9 mm Penetrating graft
22	F	76	Interstitial keratitis and cataract	HM	6/24	8 mm Penetrating graft plus cataract extraction
23	M	59	Bullous keratopathy	HM	6/36	7 mm Penetrating graft
24	F	51	Keratoconus	CF 2M	6/12	9 mm Penetrating graft
25	F	58	Fuchs's dystrophy and cataract	CF 4M	6/18	9 mm Penetrating graft plus cataract extraction

includes the corneae of dog, pig, rabbit, and cynomolgus and stub-tail monkeys. Eye holders and cutter foot plates were designed specially for them. The differences in behaviour of the various animal corneae are such that the authors found no value in comparing these results with those from human corneae. van Horn and associates found the cat to be a promising experimental animal, and

our latest trials using cat corneae corroborate their findings (van Horn *et al.*, 1977).

Discussion

The history of scientific thought is sign-posted by examples of independent discovery and invention (Ogburn and Thomas, 1922). Within the past 5

years new methods for cutting and holding the eye have emerged as the centennial of von Hippell's corneal trephine has come and gone. These methods may well displace the circular blade; they have developed from independent technical efforts on opposite shores of the Pacific and on either side of the Equator. Primacy for disclosure of the single-point cutter belongs to the Lieberman trephine (Lieberman, 1976).

What makes the CLCC unique are its optical and mechanical design features permitting uninterrupted viewing of the cornea throughout microsurgical sectioning while at the same time preserving corneal curvature and maintaining an anterior chamber until total penetration is achieved. The consistent precision of the CLCC and the holding characteristics of the accessories have important clinical and experimental implications and supersede other techniques with the impelling force of simplicity.

These inventions come also at a time when laws governing human tissue transplantation are being reviewed by many nations (Kirby, 1977). In this regard the CLCC system has sociological significance. It is no longer necessary to enucleate donor eyes. Next of kin need not be harassed at the time of bereavement. Permission for corneal collection can be sought on less emotive terms without the need for far-reaching legal reforms (Gobbo, 1977). The psychological burdens of corneal transplantation will be eased as the professions and community are gradually educated. In countries where 'the contracting out principle' is in force, as in the State of Maryland (Scholz, 1976), the tasks of donor collection for the eye bank would be simplified and expedited by the CLCC system.

This new system has shown the cat cornea to have cutting characteristics which, of all the experimental animals tested, most closely approach those of the human tissue. The same animal provides 'a practical model for stressed or old human corneal endothelium' (van Horn *et al.*, 1977).

Penetrating graft surgery now has a new dimension, broader horizons are opening in lamellar grafting, and experimentalists will be assisted in their burgeoning studies of endothelium and the nature of graft-host interactions.

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