History and advances in corneal transplantation

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Past, Present, Future
- History of corneal transplantation
- Track the progress of corneal transplant surgery.
- Recent advances

Erasmus Darwin (1731-1802)
- Suggested removal of opaque cornea in 1760.

"Could not a small piece of cornea be cut by a kind of trephine about the size of a thick bristle and would it not heal with a transparent scar. If the scar should heal without losing transparency many blind people might be made to see."

19th Century: Experimentation and Frustration
- 1813: Karl Himly first suggested replacing opaque animal corneas with transparent corneas from other animals.
- It was Franz Riesinger proposed the first corneal xenograft (animal to human).
- This idea attracted several ophthalmologists around the world to perform animal trials.

None of them were achieving any success and by 1831, they concluded that keratoplasty was simply "an audacious fantasy".

Samuel Bigger — Irish surgeon — interested in blindness from staphyloma.

In 1837, held captive by Bedouins in Africa, performed the first PK in animals — on a pet gazelle with corneal scarring.

Promise of the first decade of 19th century gave way to despair — transplanted corneas invariably became infected and opaque.

But, there was success in other branches of surgery: 1845 & 1847 ether and chloroform was introduced and 2 decades later, Lister’s principles of antiseptic surgery.

Both these improved the prospects of corneal transplantation.
• Von Hippel reported the first partially successful lamellar graft in 1886.
• Did not believe in endothelium.
• Attributed the failure of xeno transplants to edema and trauma.
• Invented the circular clock work trephine – major advancement in surgery.

• The 19th century was a century of keratoplasty failure.
• Not caused by the lack of ideas of how to replace a dysfunctional cornea but due to the lack of basic science knowledge on infection, immunology, physiology and microsurgical techniques.

Keratoplasty Success and Refinement 1900-1950

On 7th Dec 1905 Eduard Zirm in Olmutz near Prague performed the first successful PK in a human which remained clear.

Elois Glogar

45 yr old farm worker
Bilateral alkali injury
Donor: 11yr old boy
Two 5 mm donor buttons with von Hippel trephine.
Did bilateral PK’s
One PK survived
Vision of CF, J16

Filatov 1875-1956

Russian Ophthalmologist
Performed thousands of PKP’s
Used an internal spatula to protect internal contents of the eye
Conceived of cadavaric eye storage
Grandfather of eye banking.

Eye Banking

• Richard Townley Paton founded the world’s first eye bank in New York in 1944.
• Was called the Eye Bank for Sight Restoration.
**Ramon Castroviejo 1904-1987**
- Born in Spain
- Moved to the US in 1930
- Practiced in NYC
- Pioneered square PK's
- Appositional suturing
- Instrument development

**Edward Maumenee 1913-1998**
- Developed understanding of the immunobiology
- Defined graft rejection

**Current State of the Art**
- Microsurgical techniques
- Understanding of Corneal anatomy
- Ocular Pharmacology
- Ocular Immunology
- Eye Banking

**Five Ideal Goals for Corneal Transplantation**
- Smooth surface topography without significant change in astigmatism: Terrible
- Predictable corneal power: Terrible
- Tectonically strong globe: Terrible
- Healthy endothelium: Good
- Consistently optically pure stroma: Great

**PK Surgery**
- Central trephine cut made
- Smooth Surface with only endothelial disease
- Recipient tissue removed
- Donor tissue sutured into recipient
- Smooth Surface with only endothelial disease
- Full thickness block of tissue removed just to get to the endothelium
- Sutures create an irregular surface with astigmatism and blurring

**Five Ideal Goals for Corneal Transplantation**
- Smooth surface topography without significant change in astigmatism
- Predictable corneal power
- Tectonically strong globe
- Healthy endothelium
- Consistently optically pure stroma
Current Method of Replacing the Endothelium: Full Thickness PK

Clear graft, unaided vision: HM
Manifest Refraction: --8.00+8.00X70 = 6/6

Severe Complications of PK
Endophthalmitis: From retained suture fragment
Expulsive Hemorrhage: Blunt trauma 5 yrs after PK

Rebirth of Lamellar Surgery

Anterior Lamellar Surgery
Posterior Lamellar Surgery

Anterior Lamellar Keratoplasty

Superficial Anterior Lamellar Keratoplasty (SALK)
Deep Anterior Lamellar Keratoplasty (DALK)

Cornea H&E
anterior corneal epithelium
stratified squamous
keratocyte nuclei
posterior limiting lamina
posterior endothelium

Granular
Lattice
Lattice

Posterior Lamellar Keratoplasty

Gerrit Melles 1998

Developed lamellar dissection techniques

Intra corneal trephines

Succeeded in performing PLK
Indications for Post Lamellar Keratoplasty

- Fuchs endothelial dystrophy
- Any cause for endothelial failure
- Failed penetrating keratoplasty

Between 1998 and now there has been rapid and tremendous progress in both anterior and posterior lamellar surgery.

Several new terminologies have been coined.

Corneal Soup

- DALK (Deep Anterior Lamellar Keratoplasty)
- PLK (Posterior Lamellar Keratoplasty)
- DLEK (Deep Lamellar Endothelial Keratoplasty)
- DSEK (Descemet's Stripping Endothelial Keratoplasty)
- DSAEK (Descemet's Stripping Automated Endothelial Keratoplasty)
- DMEK (Descemet's Membrane Endothelial Keratoplasty)

PLK/ DLEK Surgery

- donor tissue placed into recipient
- scleral incision, deep corneal pocket, and endothelium trephined
- posterior stromal disc and endothelium removed from pocket
- endothelium replaced with no sutures, supported by air bubble in anterior chamber.
- Surface remains smooth with no astigmatism.
During the same time, on the other side of the Atlantic, Mark Terry from Portland, Oregon, modified and popularised the Melles technique of PK as:

Deep Lamellar Endothelial Keratoplasty (DLEK)

Early visual rehabilitation with DLEK:
1 week

Early visual rehabilitation with DLEK:
1 week

Same Patient
PK RE    vs    DLEK LE
2 years s/p PK
-4.25 + 4.75 x 73 = 6/12
Same Patient
1 month s/p DLEK with Phaco
1.00 + 1.50 x 170 = 6/12
DLEK/ PLK Pitfalls
- Technically very very difficult procedure
- Very few surgeons took up
- Never “caught on”
- Disc dislocation
- Endothelial cell loss and long term survival
- Reduced BCVA from interface haze

Melles et al: A technique to excise the Descemet membrane from a recipient cornea (Descemerhexis) - Cornea 2005; 24:286-288

DSEK: Descemet’s Stripping Endothelial Keratoplasty.

DSAEEK: Descemet’s stripping automated endothelial Keratoplasty

Video of DSEK

Moria ALTK System
When things go well

Day 1

Day 1 post op – 6/60

1 week: 6/12
1 month: 6/9

Fuchs Endothelial Dystrophy with sub epithelial scarring

Day 1: 6/60

Day 7: 6/9
Where are we today

- PK is no more the gold standard.
- Selective lamellar transplantation – based on the level of pathology.
- Field of selective endothelial transplantation is rapidly becoming popular and is being constantly refined.
- Where next ...........

Top Hat PK

- Keratoplasty in two planes* by Jose Barraquer 50 years ago
- Described by Busin* from Italy in 2003
- Combines the visual outcomes of PKP with the wound-healing advantage of lamellar keratoplasty.


Top Hat Configuration

Busin, M. Arch Ophthalmol 2003;121:260-265

Results: Clinical Appearance

Table 4. Complications of Top hat Penetrating Keratoplasty (PK) versus Traditional PK following 12 months of follow up

<table>
<thead>
<tr>
<th>Complications</th>
<th>Top Hat PK (n=36)</th>
<th>Traditional PK (n=35)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rejection episodes</td>
<td>4 (11.1%)</td>
<td>7 (20%)</td>
<td>P = 0.47</td>
</tr>
<tr>
<td>Astigmatism treated with relaxing incisions/Refractive procedure</td>
<td>2 (5.6%)</td>
<td>7 (20%)</td>
<td>P = 0.28</td>
</tr>
<tr>
<td>Scleral astage</td>
<td>1 (2.7%)</td>
<td>2 (5.7%)</td>
<td>P = 0.66</td>
</tr>
<tr>
<td>Infectious Keratitis</td>
<td>1 (2.7%)</td>
<td>1 (2.9%)</td>
<td>P = 0.49</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>3 (8.3%)</td>
<td>3 (8.6%)</td>
<td>P = 0.90</td>
</tr>
<tr>
<td>Wound dehiscence</td>
<td>-</td>
<td>2 (5.9%)</td>
<td>P = 0.47</td>
</tr>
<tr>
<td>Retinal Detachment</td>
<td>1 (2.7%)</td>
<td>-</td>
<td>P = 0.90</td>
</tr>
</tbody>
</table>
Graft Rejection

The Future of corneal transplants

Femtosecond laser assisted corneal transplantation

Femtosecond laser

- 1053 nm (near infrared)
- Each pulse of focused laser light lasts approximately 10^-15 seconds (500-800 femtoseconds)
- In one second, light travels 7.5 times around the globe
- In 100 femtoseconds, light travels across a human hair
- Power = Energy/Time, extremely high power attained at relatively low energy

Endothelial Cell Loss

FS laser

- Surgical effect is achieved through "Photodisruption"
- No thermal or shock wave transmission to surrounding tissues
- Pulses focused to precise locations (± 5 microns)
- Optical delivery system place pulses next to each other creating flaps, incisions, lamellar resections, keratectomy
Optical Delivery System

- Laser is set to desired depth
  - Defined distance from bottom of glass applanation surface
- Pulses delivered in a prescribed pattern creating a horizontal or vertical cleavage plane in the cornea

Photodisruption

- A pulse of laser energy is focused to a precise location inside the cornea

  1 Micron

- A microplasma is created, vaporizing approximately 1 micron of corneal tissue

Photodisruption

- An expanding bubble of gas & water is created separating the corneal lamellae

  5 to 12 Microns

Photodisruption

- The bi-products of photodisruption (CO₂ & water) are absorbed by the mechanism of the endothelial pump, leaving a resection plane in the cornea

Photodisruption

- Thousands of laser pulses are connected together in a raster pattern to define a resection plane

Photodisruption

- A resection plane is created
Photodisruption

Laser pulses can be stacked on each other to create a vertical cleavage plane.

Allowed Cut Patterns

The IntraLase FS Laser has received FDA clearance to perform a wide variety of corneal cuts:

- Lamellar Cut
- Posterior Side Cut
- Anterior Side Cut
- Full Thickness Ring Cut
- Top Hat
- Zig Zag
- Mushroom
SALK

DALK

DSAEK

Top hat PK

2007

DLEK-2002

DSEK / DSAEK-2004

Femtosecond laser assisted PK

1944, Eye Bank

PLK -1998

1905

7th Dec

1905

7th Dec

2007