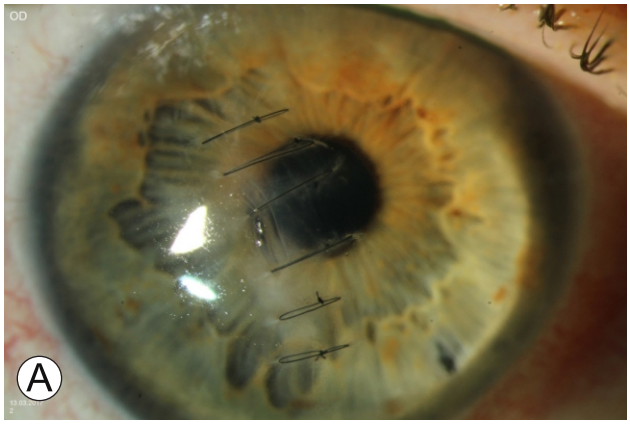
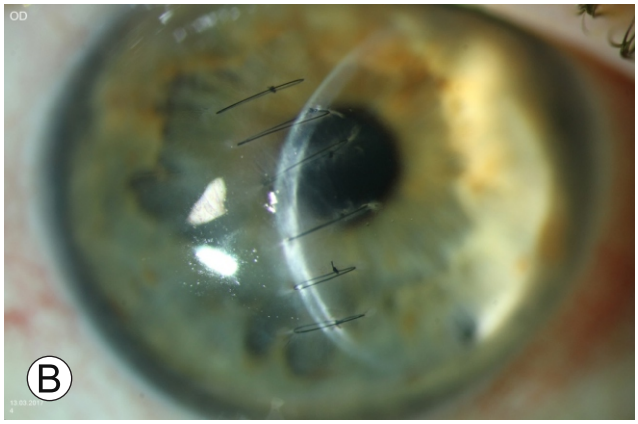
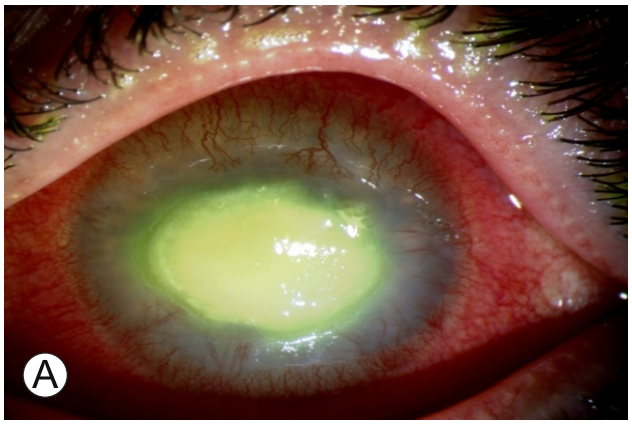




(D/E) After 6 very deep 10.0 nylon single interrupted sutures with buried nodes perpendicular to the defect (so-called 'Muraine sutures'), almost complete regression of the stromal oedema occurs within a few days.



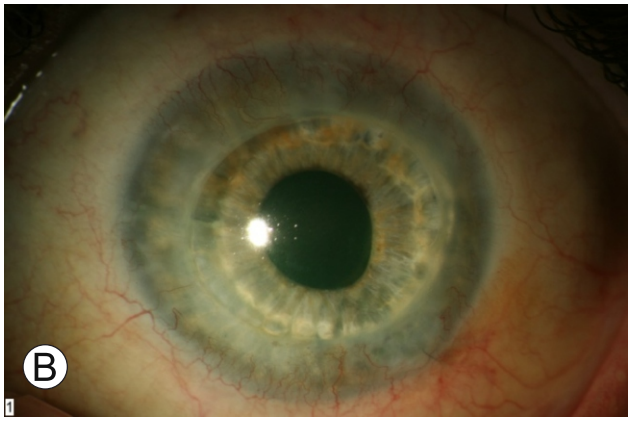


Fig. 17 (A) Most severe acanthamoeba keratitis with elliptical infiltrate that had been misdiagnosed externally for 4 months as "herpes keratitis" (visual acuity finger counting), **(B)** Status post elliptical excimer laser-assisted PK (7.5x8.5/7.6x8.6 mm) and sequential Phaco+HCL (visual acuity 0.8)

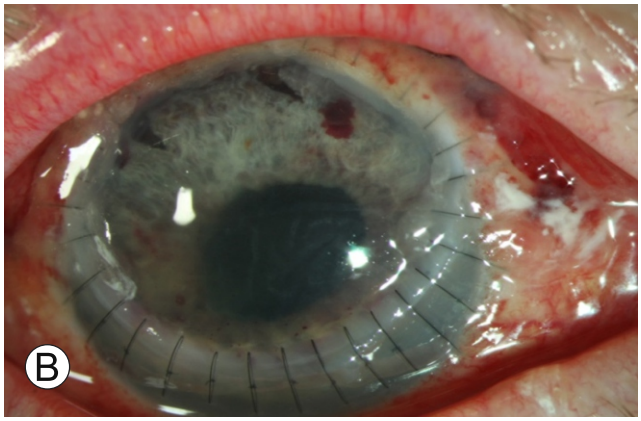


Fig. 18 (A) 65-year-old female patient 5 weeks after small eccentric PK due to severe keratitis with the mould Pseudallescheria boydii (Scedosporium apiospermum), (**B)** 1st day after large eccentric repeat PK (10.0/10.5 mm, manual trephination) with ECCE without IOL.

Table 2: Suggestions for dealing with aggressive fungal keratitis (e.g. Fusarium solani)

- Rapid PK (within days and weeks) – before infestation of the anterior chamber!
- Very large PK (e.g. 10.0/10.5 mm)
- Many single interrupted sutures to avoid steps (e.g. 32)
- Thoroughly rinse the anterior chamber with antifungal medication intraoperatively
- Intrastromal injection of antifungal medication (e.g. voriconazole)
- Repeat injections of antifungal medication into the anterior chamber postoperatively (e.g. every 2 days)
- Close cooperation with the vitreoretinal surgeon

Non-mechanical laser trephination for keratoplasty.

Since 01/07/1989 more than 4,000 PKs have been successfully carried out with this technique in Erlangen and later in Homburg/Saar. Currently, the Schwind AMARIS excimer laser is well suitable for this procedure in the so-called 'modified PALK mode with pseudo-ring profile'. The development of laser keratoplasty began more than 20 years before the introduction of the femtosecond laser (FSL). Under the hypothesis that the wound bed was of significant importance to the optical quality of the corneal transplant after suture removal, GOH Naumann and GK Lang (now in Ulm) have developed the technique of non-mechanical corneal trephination since 1986 using the 193 nm excimer laser (EXL) along metal masks for penetrating keratoplasty (PK) [Naumann 1995]. It was initiated with an elliptical configuration (**Figure 17**).

However, the breakthrough came with the introduction of 8 'orientation teeth/notches' on circular masks to minimise horizontal torsion. For non-contact donor trephination from the epithelial side an artificial anterior chamber was used.

Prospective clinical trials have shown that the non-contact EXL-PK technique improves donor and recipient centration, reduces vertical tilt and horizontal torsion of the transplant in the recipient bed. This results in significantly lower corneal astigmatism without sutures, higher regularity of the topography and thus better spectacle-corrected visual acuity [Seitz 1999, 2018, Szentmàry 2006]. Moreover, the EXL allows for trephination in unstable corneas, such as advanced keratoconus, penetrated corneal ulcer or radial keratotomy or LASIK.

The major disadvantage of lamellar and penetrating keratoplasty using FSL, which has been in clinical use since 2006, is the need for aspiration and applanation, even with a curved interface, which results in distortion of the corneal tissue. In advanced keratoconus in

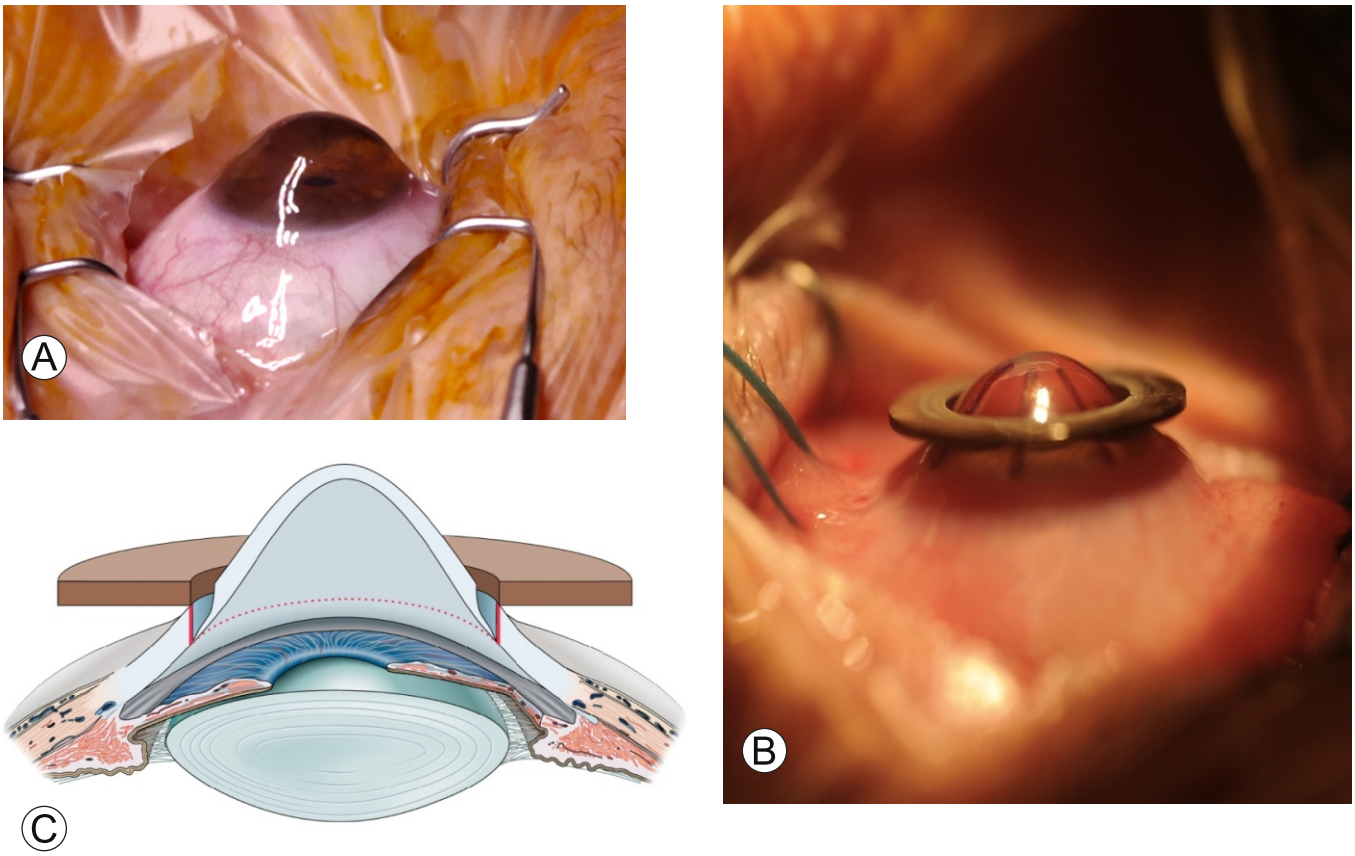


Fig. 19: Advanced keratoconus: (A) Side view, preoperatively, **(B)** Recipient mask in the excimer laser keratoplasty sits without deformation 'saturn-like' over the cone like a "neck brace". **(C)** SCHEMATIC: Recipient mask in excimer laser keratoplasty results in round excisions with perpendicular cut edges without deformation.

particular, this results in 'non-circular' excisions in the patient's cornea and therefore horizontal torsion as the main intraoperative determinant of high/irregular astigmatism after PK. Especially in the case of keratoconus and keratotorus (= pellucid marginal degeneration), the use of an extremely light metal mask, which is placed 'saturn-like' like a neck brace without distortion of the corneal protrusion, in EXL trephination allows excision of an ideally round opening with circular perpendicular edges (**Figure 19**).A prospective randomised study comparing excimer vs. femtosecond laser PK in Homburg yielded the following **results (Table 3)**: In particular for keratoconus, the FSL group showed more decentration, more vis à tergo (so-called "vitreous pressure") and more often single interrupted sutures were required in order to ensure donor-recipient apposition without steps and gaps [El-Husseiny 2015]. At least 2 months after removal of all sutures, the topographic astigmatism in keratoconus after FSL trephination (8.1 ± 3.0 dpt) was significantly higher than with EXL trephination (3.2 ± 1.7

dpt). Also, the Surface Regularity Index of the TMS-5 system was significantly more favourable after EXL trephination (0.5 ± 0.4) than after FSL trephination (1.2 ± 0.5) [Seitz 2017]. However, there was no difference in endothelial cell density after EXL vs. FSL PK [Tóth 2019].

Table 3: Minimal requirements for comparative studies on various trephination techniques

- Visual acuity with spectacle correction (not contact lens acuity!) and central refractive power,
- Keratometric or topographic astigmatism (not only refractive cylinder!)
- Dimensions for topographic regularity (e.g. SRI/SAI of the TMS system)
- endothelium
- Immune reactions

.... in each case before and after suture removal. Papers which do not cover this subject should not be used to assess different trephination methods.

The Freiburg research group also showed an astigmatism of 6.4 ± 3.0 D after removal of the sutures from mushroom keratoplasty, and 5.8 ± 4.6 D from top hat keratoplasty [Birnbaum 2013]. These values are within a range that used to be achievable with the motor trephination by Geuder, which had long been taken off the market. Otherwise, the rate of immune reactions after FSL PK is significantly higher – especially in the mushroom profile [Szentmàry 2013].

Excimer laser-assisted deep lamellar keratoplasty ('Excimer DALK')

If there is a penetration of the Descemet membrane, it is usually necessary to 'convert' to a PK during a planned DALK. To avoid any disadvantage to the typically young keratoconus patients by the planned DALK, the recipient can typically be trephined with the Schwind AMARIS excimer laser up to 80% depth of the minimum thickness in the AS-OCT in the 7-8 mm zone. If the 'big bubble' is successful and we can achieve a bare Descemet membrane - without perforation - we terminate the operation as DALK. If this does not succeed to the operator's satisfaction, the operation can be completed as excimer laser PK with all of the advantages described above without any disadvantage for the typically young patient [Seitz 1999].

Summary and Conclusions

In addition to methodological problems with the lamellar techniques, there are a number of indications that generally require penetrating keratoplasty (PK). These indications can be classified into elective (optical vs. tectonic) and curative emergency interventions (PK à chaud). In order to avoid refractive surprises after PK,

we carry out sterile donor tomography in the corneal bank at the University Eye Hospital of Saarland for the detection of keratoconus or previous keratorefractive surgery on the planned transplant. In order to avoid high astigmatism after suture removal, a trephine system should be used for penetrating keratoplasty which ensures symmetrical, tension-free fitting of a circular donor disc in a circular recipient bed with congruent and easily waterproof-adapting cutting edges. These demands for optimal trephination are best fulfilled at this time with a non-mechanical excimer laser trephination procedure, which has been conducted for 30 years on more than 4,000 patients, and shows proven benefits in regards to keratometric astigmatism, regularity of the topography and vision after suture removal. Non-mechanical excimer laser assisted trephination is particularly advisable in (1) young patients with advanced keratoconus (in each case after acute keratoconus = corneal hydrops with rupture of the Descemet membrane), (2) dystrophies affecting all layers of the cornea (e.g. macular dystrophy, congenital stromal dystrophy), (3) repeat keratoplasty due to high and/or irregular astigmatism (with/without endothelial decompensation), (4) paediatric keratoplasty [Seitz 2013] (5) unstable cornea (e.g. after radial keratotomies, iatrogenic keratectasia after LASIK, descemetocele, perforated ulcer), (5) aphakia with simultaneous IOL implantation, and (6) acanthamoeba keratitis.

Femtosecond laser keratoplasty is significantly more expensive and superiority has not been demonstrated in the last 10 years. Although DMEK, as the most sophisticated form of posterior lamellar keratoplasty, has rightly become the method of choice for purely endothelial corneal pathologies in Germany, still a large number routine PKs will be indispensable and also applications “beyond routine”.

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