Intraoperative outcome of deep anterior lamellar keratoplasty using femtosecond laser versus manual trephine

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Purpose
The aim of this study was to compare the intraoperative data of femtosecond laser-assisted deep anterior lamellar keratoplasty (F-DALK) with those of manual trephine deep anterior lamellar keratoplasty (M-DALK).
Setting
The study was conducted in a single private centre (Alfat'h Eye Hospital).
Design
This is a nonrandomized comparative retrospective, single private centre clinical study.
Materials and Methods
The study was conducted between February 2013 and March 2016 on 40 eyes that underwent M-DALK and 24 eyes that underwent F-DALK, including moderate-to-advanced keratoconus (KC) intolerant to contact lenses, superficial corneal opacities or degenerations, and stromal corneal dystrophies (e.g. macular dystrophies, etc.) with best spectacle corrected visual acuity (BSCVA) less than or equal to 6/60 (0.1), and excluding those with KC (with acute hydrops or posthydrops scars), corneal opacities or corneal dystrophies involving the endothelium. The intraoperative data were retrieved and analysed.
Results
F-DALK had fewer intraoperative complications compared with M-DALK, such as the decentred cut, which was 0% in F-DALK versus 1/40 (2.5%) in M-DALK, with a statistically significant difference in the overall intraoperative complications between the two procedures (P=0.004).
Conclusion
The F-DALK technique results in fewer intraoperative complications such as the inadvertent premature entry of the anterior chamber, a better centration of the cuts in patients with KC, and more success of the big bubble formation and thereby less conversion to penetrating keratoplasty or to manual dissection, which has a lower visual outcome.

Keywords:
cornea, DALK, femtoaecond laser, keratoplasty, lamellar

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Introduction

Deep anterior lamellar keratoplasty (DALK) is considered the treatment of choice in cases of moderate-to-advanced keratoconus (KC) (without hydrops or posthydrops scar). DALK is also used in opacifying corneal diseases that do not involve the Descemet's membrane (DM)/endothelium complex. The technique involves an excision of the diseased stroma and a transplantation of the donor cornea after removing the endothelium and DM [1–6].

There are many methods of DM dissection; Anwar's big bubble (BB) technique and, to a lesser extent, Melles manual dissection technique are by far the most common techniques used for achieving baring of the DM or the pre-DM layer in DALK [7].

The introduction of the femtosecond laser (FSL) in corneal surgery created multiple advantages. In DALK, it allows for the precise identification of the tissue depth and air injection, making BB formation more feasible and with a more secure wound closure. Moreover, the sutures can be removed earlier after FSL-assisted keratoplasty. In addition, the FSL offers flexible designs of the cuts with mushroom, zigzag, or top hat configurations [8].

This study was established to evaluate femtosecond laser-assisted deep anterior lamellar keratoplasty (F-DALK) and to determine whether it has any advantages intraoperatively over the usual manual trephination procedure.

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Materials and methods

The data from 64 eyes of 61 patients were collected. A total of 40 eyes were operated on using manual trephine deep anterior lamellar keratoplasty (M-DALK) with the modified BB technique, and 24 eyes were operated on using F-DALK in the period between February 2013 and March 2016. The data were reviewed and analysed retrospectively.

The patients were selected according to the following inclusion criteria: moderate-to-advanced KC intolerant to contact lenses, superficial corneal opacities or degenerations, and stromal corneal dystrophies (e.g. macular dystrophies, etc.) with best spectacle corrected visual acuity (BSCVA) less than or equal to 6/60 (0.1). The following patients were excluded: those with KC (with acute hydrops or posthydrops scars), corneal opacities or corneal dystrophies involving the endothelium.

The selected patients were subjected to the following:

(1) Full personal and family history data collection, a complete ophthalmic examination with BSCVA, and Scheimpflug Imaging (Oculus Pentacam HR; Oculus Inc., United States). The anterior segment optical coherence tomography (anterior OCT) (the Spectralis OCT Blue Peak; Heidelberg Engineering, Heidelberg, Germany) was performed in eyes with corneal opacities to assess the depth of the opacity and the condition of the posterior part of the stroma.

This study adhered to the tenets of the Declaration of Helsinki, and ethical approval was given by the medical ethics committee of Alfat'h Eye Hospital; informed consent was obtained from all of the participants.

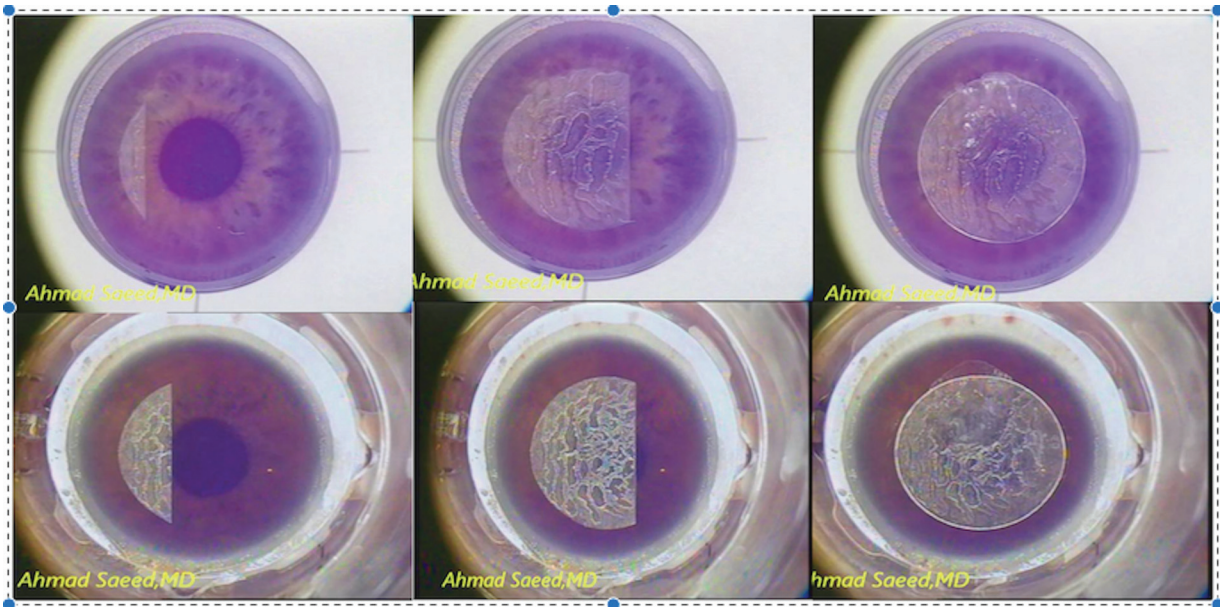
Surgical technique

Femtosecond laser-assisted deep anterior lamellar keratoplasty steps

All of the surgeries were performed by the same surgeon 'A.S.' The F-DALK eyes were operated on in two steps. First, in the FSL refractive suite the graft and patient's cornea were cut, and then a full-thickness corneoscleral donor button stored in Optisol GS (Bausch + Lomb, Rochester, New York, USA) was mounted on a disposable Barron artificial chamber and was docked with a disposable cone of the WaveLight FS200 (Alcon Laboratories Inc., Fort Worth, Texas, USA) with a repetition rate of 200 KHz FSL and a 1035 nm wavelength. The graft was cut with a full-thickness cut and a planned diameter of 0.2 larger in size than the recipient bed.

Second, the patient's cornea was cut. After instilling topical anaesthesia in the conjunctival sac, the patient's eye was stabilized. After placing a lid speculum, the suction ring with a vacuum tubing was applied to the limbus, and the vacuum was built up to 150–200 mmHg. This was followed by docking with a disposable cone of the WaveLight FS200 (Alcon Laboratories Inc.). The parameters were set to create a superior corneal cap of 200–390 μm in thickness and 7.5–8.0 mm in diameter (Fig. 1).

Figure 1



Creation of the superficial lamellal cap of depth 200–390 μm using the femtosecond laser in two different eyes.

The machine was programmed for both the graft and the recipient with a pulse energy of 1.4 μJ for the top/bed cut, 2.00 μJ for the bottom/side cut and a side cut angle of 90°.

The spot size was 5 μm with a spot separation of 6 μm for the bed cut and 4 μm for the top/bottom/side cut, and a line separation of 6.00 μm for the bed cut and 3.00 μm for the top/bottom/side cut.

Thereafter, both the graft and the patient were transferred to another operation room, and the operation was completed under general anaesthesia. General anaesthesia was preferred in all cases.

Toothed forceps only were enough to remove the superior corneal stromal cap after being cut with the FSL (Fig. 2).

A 30-G disposable needle bent at an angle of 60° at 5 mm distance from its tip with the bevel facing downward was inserted 3–4 mm into the deep stroma, starting from the FSL side cut and avoiding entry into the anterior chamber (AC) while maintaining the depth. The air was injected into the deep stroma, aiming for an air-induced separation of the DM from the stroma.

Complete separation of the DM was noted as a large air bubble reaching the trephination or the FSL side cut. Once the BB was achieved, a peripheral paracentesis was performed to lower intraocular pressure. A sharp-tipped or MVR blade was inserted into the BB to collapse it. Blunt corneal scissors were used to divide the remnant stromal tissue into four quadrants that were excised for baring of the DM at the edge of the FSL laser side cut.

The endothelium of the donor corneal buttons was peeled using a dry sponge or toothed forceps after staining with 0.06% trypan blue dye. The button was secured in place using 10/0 nylon sutures with 16 interrupted bites. Keratoscopy was performed intraoperatively to adjust the suture tension.

Manual trephine deep anterior lamellar keratoplasty

M-DALK was performed under general anaesthesia using the modified BB technique.

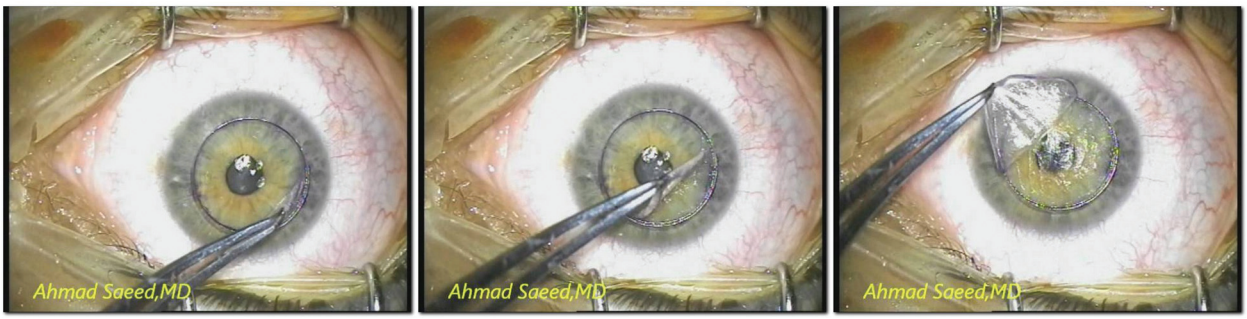
A Barron suction trephine (range: 7.5–8 mm) was used for partial thickness trephination of up to 60–70% of the corneal depth. A crescent knife was used for a superficial corneal keratectomy, leaving a thin layer of corneal stroma in place. The blade was used carefully from edge to edge to remove the superficially trephined corneal tissue (Fig. 3).

Thereafter, the same steps used for the DALK were followed to complete the procedure. Full-thickness corneoscleral donor buttons were punched with Barron trephine punch blades with diameters ranging from 7.75 to 8.25 mm. The donor buttons were 0.25 mm larger than the recipient bed. The DM was removed in the same manner as explained before.

Postoperative

After the surgery, all of the patients received a 0.5% moxifloxacin HCl ophthalmic solution, a 1% prednisolone acetate solution and preservative-free artificial eye drops six times per day for 1 month. Artificial tears and the 1% prednisolone acetate eye drops were tapered off over 3–6 months. The postherpetic scar was operated on after ensuring that it was clinically inactive and received a special regime of treatment of 800 mg three times per day in the first month postoperatively and was tapered off slowly to 400 mg twice daily during the following 2 months to avoid recurrence in the form of systemic acyclovir.

Figure 2



Removal of the superior corneal stromal cap after being cut with the femtosecond laser with toothed forceps without resistance.

Statistical analysis

All of the data were analysed using statistical package for the social sciences for Windows version 18.0 (SPSS Inc., Chicago, Illinois, USA) and MedCalc for Windows version 13 (MedCalc Software bvba, Ostend, Belgium). The categorical variables were expressed as numbers (percentage). The per cent of categorical variables was compared using Pearson's χ^2-test. All of the tests were two-sided, and P less than 0.05 was considered statistically significant.

Results

Analysis of the indication for DALK of both M-DALK and F-DALK is shown in Table 1.

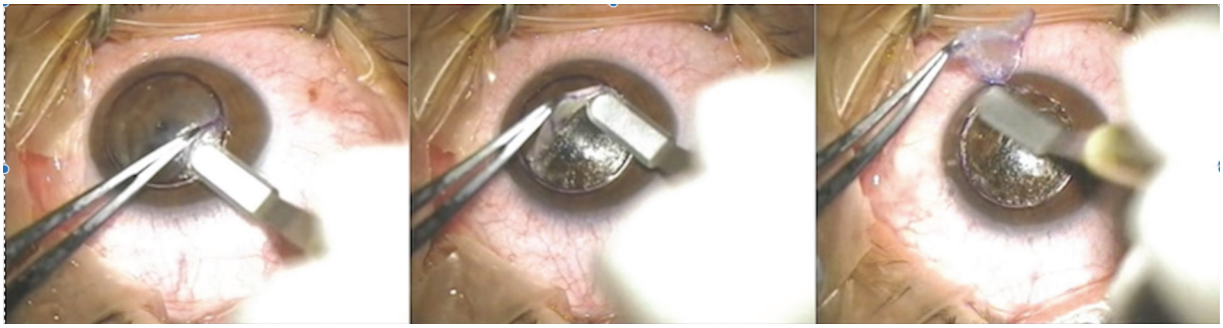
The study revealed differences in the intraoperative complications between the two techniques, such as the repeated application of trephine, a decentred cut, multiple air injection, failure in gaining BB, the inadvertent entry into the AC and DM microperforation, with a statistically significant difference in the overall intraoperative complications between the two procedures (P=0.004), as shown in Table 2.

Discussion

DALK is a partial thickness corneal transplantation used in cases of corneal diseases limited to the stroma. The aim of DALK is to replace a diseased corneal stroma with a healthy donor cornea, leaving an intact recipient corneal endothelium [9].

The FSL is involved in keratoplasty to create accurate corneal incisions with different edge shapes and lamellar planes of the corneal button that provide a better apposition of the donor and recipient corneas

Figure 3



Careful dissection with a crescent blade from the trephination edge to the other to remove the superficially trephined corneal tissue.

Table 1 Indications of femtosecond laser-assisted deep anterior lamellar keratoplasty and manual trephine deep anterior lamellar keratoplasty

	M-DALK (N=40) [n (%)]	F-DALK (N=24) [n (%)]
Keratoconus	26 (65)	20 (83.3)
Postlasik ectasia	0 (0)	1 (4.2)
Postkeratitis scar	6 (15)	1 (4.2)
Post-traumatic	2 (5)	0 (0)
Macular dystrophy	6 (15)	2 (8.3)

F-DALK, femtosecond laser-assisted deep anterior lamellar keratoplasty; M-DALK, manual trephine deep anterior lamellar keratoplasty.

Table 2 Summary of the intraoperative data

	M-DALK (N=40) [n (%)]	F-DALK (N=24) [n (%)]	P-value
Repeated application of the trephine or the interface cone for proper depth	6 (15)	0 (0)	0.046
Decentred cut (due to slide of the trephine)	1 (2.5)	0 (0)	0.435
Multiple air injection before successful single big air bubble	5 (12.5)	2 (8.3)	0.605
Failure to gain a single BB formation	4 (10)	1 (4.2)	0.110
Inadvertent entry into the AC by the trephine (and conversion to PKP)	2 (5)	0 (0)	0.266
Descemet's membrane microperforation	1 (2.5)	0 (0)	0.435
Overall complications	19 (47.5)	3 (12.5)	0.004

AC, anterior chamber; BB, big bubble; F-DALK, femtosecond laser-assisted deep anterior lamellar keratoplasty; M-DALK, manual trephine deep anterior lamellar keratoplasty; PKP, penetrating keratoplasty. ‡χ^2-test. P<0.05, significant.

with a large surface area of contact, leading to rapid wound healing and an earlier removal of sutures [10].

In this study, the intraoperative outcomes of F-DALK and conventional DALK with the manual trephine were compared. To my knowledge, this is by far the first study to compare the intraoperative data or outcomes, including the complications between the F-DALK and M-DALK techniques.

The data from 64 eyes of 61 patients were collected. A total of 40 eyes were operated on using manual trephine deep anterior lamellar keratoplasty (M-DALK) with the modified BB technique, and 24 eyes were operated on using F-DALK. The indications of the DALK are shown in Table 1. The choice of corneal transplantation (F-DALK or M-DALK) was based on the availability of the FSL system at our centre (i.e. all of the patients had undergone M-DALK before the newer system was available, and after the FSL system was installed, the patients were offered to undergo F-DALK if it was affordable).

A WaveLight FS200 femtosecond laser machine (Alcon Laboratories Inc.) was used. Its platform provides only vertical cuts in the lamellar keratoplasty and supports other shapes in the penetrating one, such as a mushroom shape, zigzag or tophat-shaped configuration.

The M-DALK procedure took place in one room, whereas the F-DALK procedure was performed in two rooms. The first step was performed in the FSL refractive suite, where the graft and patient's cornea were cut. Thereafter, both the patient and the graft were transferred to the operating room. This cannot be considered as a great advantage of M-DALK over F-DALK, as the time taken in moving the patient between two rooms in F-DALK cases is of course compensated. This time is saved by the ease of removal of the superficial lamellar tissue or the cap with only toothed forceps after being cut with the FSL (Fig. 2). In contrast, in M-DALK, applying the manual vacuum trephine and attempting good centration and proper depth and then performing a careful lamellar dissection using the crescent blade from the trephine edge to the other (Fig. 3) would eliminate the advantage of saving time in comparison with F-DALK.

Some of the benefits of F-DALK over M-DALK were recorded, as repeated application of the trephine to gain the proper depth was needed in six (15%) eyes of the M-DALK cases (which was even statistically significant P=0.046). This might produce irregular or serrated edges due to the inaccurate matching of the repeated trephination attempts. Such an event was unlikely to happen, and it did not happen in F-DALK.

In addition, there was cut decentration in one (2.5%) eye in a patient who underwent M-DALK due to advanced KC, which interfered with the ability of the vacuum to build up the suction trephine, which also did not take place in the eyes that underwent F-DALK.

Multiple air injections were needed before a successful single big air bubble was achieved in five (12.5%) eyes that underwent the M-DALK technique, and another four (10%) eyes failed to gain a single BB formation despite repeated attempts with conversion to a layer-by-layer manual stromal dissection technique.

However, only two (8.3%) eyes from those that underwent F-DALK needed multiple air injections before a successful single big air bubble was achieved, and only one (4.2%) eye failed to gain a single BB with conversion to a layer-by-layer manual stromal dissection technique. This clinical difference between the two groups might be attributed to the fact that the appropriate depth was reached more easily with the FSL. This made the expansion of the bubble easier because of the lower resistance of the remaining tissue on top of it, or it may be attributed to the different cause distribution between the M-DALK and F-DALK groups with a greater percentage of the KC cases in the F-DALK group, which has a higher success rate in BB formation.

DM microperforation occurred in one (2.5%) eye that underwent M-DALK but never occurred in F-DALK eyes. Chen *et al.* [11] reported DM microperforation in two (7.1%) eyes that underwent FSL-DALK, which was lower compared with the manual trephination reported by other studies. Shehadeh-Mashor *et al.* [10] did not find differences in the intraoperative perforation of DM between the two groups (F-DALK and M-DALK).

The absence of DM microperforation in the F-DALK cases may be attributed to my interest in performing preoperative pachymetry with pentacam in KC and ectasia patients, and to the fact that an anterior segment OCT to the opacified corneas gives a good

estimation of the stromal depth with easier BB formation and removal of a remaining thin-layered stromal roof.

Moreover, there was inadvertent entry by the trephine into the AC in two (5%) cases that underwent M-DALK with subsequent conversion to penetrating keratoplasty. This unplanned entry may be attributed to the different corneal thicknesses in advanced KC, especially inferotemporally. This complication did not occur in any of the eyes that underwent F-DALK due to the proper depth of cut that was gained by using the FSL as reported by several studies [9–13].There was a statistically significant difference in the overall intraoperative complications between the two procedures (P=0.004).

Limitations

The platform of the WaveLight FS200 (Alcon Laboratories Inc.) provides only a vertical cut in lamellar keratoplasty, and thus we did not get to use the stepped incision. That differs with other authors, such as Alio *et al*. [6], who used a Femtosecond Laser (IntraLase, Abbott Medical Optics, Santa Ana, California, USA) to create a mushroom-shaped cut in the DALK procedure. They found that it was significantly better in wound healing compared with a straight cut that was performed using manual trephine, which might be due to a larger area of contact between the donor and recipient cornea, and that the FSL can activate the healing process [6].

There was a different case distribution between the M-DALK and F-DALK groups with a greater percentage of KC cases in the F-DALK group, which had a higher success rate of BB formation.

Conclusion

Despite the mentioned reports of the postoperative advantages of FSL-assisted keratoplasty, this is, by far, according to the published literature, the first study to report the advantages of FSL intraoperatively. The F-DALK technique results in fewer intraoperative complications, such as the inadvertent premature entry of the AC, better centration of the cuts in patients with KC, and more success of the BB formation and thereby less conversion to penetrating keratoplasty or to manual dissection, which has a lower visual outcome.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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