

# Sutureless superficial anterior lamellar keratoplasty for recurrent corneal haze after repeat excimer laser surface ablation

James Myerscough,<sup>1</sup> Cristina Bovone,<sup>2,3,4</sup> Peter Benjamin Michael Thomas,<sup>5</sup> Michael Mimouni,<sup>6</sup> Faisal Aljassar,<sup>7</sup> Sara Padroni,<sup>3</sup> Massimo Busin<sup>3,4</sup>

<sup>1</sup>Department of Ophthalmology, Southend University Hospital NHS Foundation Trust, Westcliff-on-Sea, UK

<sup>2</sup>Department of Ophthalmology, Ospedale Privato "Villa Igea", Forlì, Italy

<sup>3</sup>Department of Ophthalmology, Leicester Royal Infirmary, Leicester, UK

<sup>4</sup>Department of Morphology, Surgery and Experimental Medicine, University of Ferrara, Ferrara, Italy

<sup>5</sup>NIHR Biomedical Research Centre, Moorfields Eye Hospital NHS Foundation Trust, London, UK

<sup>6</sup>Department of Ophthalmology, Rambam Health Care Campus and Ruth Rappaport Faculty of Medicine, Technion-Israel Institute of Technology, Haifa, Israel

<sup>7</sup>Department of Ophthalmology, The Eye centre and The Eye Foundation for Research in Ophthalmology, Riyadh, Saudi Arabia

## Correspondence to

Dr Massimo Busin, Ophthalmology, Villa Igea Hospital, Forlì 47122, Italy; mbusin@yahoo.com

Received 25 March 2019

Revised 20 May 2019

Accepted 11 June 2019

## ABSTRACT

**Background/Aims** To evaluate the 5-year outcomes of sutureless superficial anterior lamellar keratoplasty (SALK) in the treatment of surface ablation-related corneal haze recurring after phototherapeutic keratectomy (PTK).

**Methods** Prospective interventional study at a tertiary referral centre in Forlì, Italy. Ten consecutive eyes with corneal haze following photorefractive keratectomy, recurring after treatment with PTK with or without mitomycin C, undergoing sutureless SALK. Sutureless SALK was performed using a microkeratome in donor and recipient. Main outcome measures: best spectacle-corrected visual acuity (BSCVA), surgically induced astigmatism (SIA), rate of recurrence and complications.

**Results** There were no intraoperative complications and there was no recurrence of haze in any eye postoperatively. BSCVA showed significant improvement at all postoperative time points. Mean preoperative visual acuity improved from 0.46 logMAR units (SD=0.12) to 0.12 (SD=0.12,  $p=0.0001$ ) at 5 years. At 6 months, SIA was  $2.50 \pm 1.04$  with no further significant change at 5 years ( $2.53 \pm 1.39$ ,  $p=0.95$ ). There was no significant change in mean spherical equivalent and no significant difference between preoperative and postoperative astigmatism vector values at 5 years.

**Conclusions** Sutureless SALK provides a useful treatment option in patients with recurrent haze after excimer laser treatment. It can eliminate haze recurrence for at least a period of 5 years and can improve BSCVA, although there may be significant SIA.

## INTRODUCTION

Photorefractive keratectomy (PRK) is a well-established treatment modality in the management of refractive errors. Progress has been made in reducing the associated complications, evidenced in particular by a reduction in the incidence of postoperative corneal haze.<sup>1</sup> Superficial keratectomy with or without phototherapeutic keratectomy (PTK), and PTK alone or augmented by mitomycin C (MMC) have all been described in the treatment of visually significant corneal haze following PRK.<sup>2–7</sup> However, this complication can recur following these treatments requiring further re-treatment.<sup>7</sup>

The aim of this study was to investigate the efficacy and safety of sutureless superficial anterior lamellar keratoplasty (SALK) in the treatment of corneal haze secondary to PRK, recurring after at least one PTK treatment with or without MMC.

## MATERIALS AND METHODS

All eyes undergoing sutureless SALK for recurrent postexcimer laser corneal haze since January 2008 were followed up prospectively at our institution, and the outcomes at 6, 18 and 60 months after surgery were evaluated. To be considered for SALK, grade 3 corneal haze (according to Fantès *et al*<sup>8</sup>) with moderate obscuration of the iris detail was necessary. There was no absolute inclusion criteria for best spectacle-corrected visual acuity (BSCVA), only that patients not satisfied with their BSCVA were included. The study followed the tenets of the 2013 Declaration of Helsinki and was approved by the local ethics committee of 'Villa Igea' Hospital (Forlì, Italy).

Demographic data was recorded, and every patient underwent a complete preoperative ophthalmological evaluation, including slit-lamp examination, BSCVA in logarithmic unit of the minimum angle of resolution (logMAR), as well as Snellen fraction, refraction, tonometry, funduscopy, endothelial specular microscopy (EM-3000; Tomey, Erlangen, Germany) and anterior segment optical coherence tomography (AS-OCT) (Casia; Tomey, Tokyo, Japan).

All procedures were performed by a single surgeon (MB) at 'Villa Igea' Hospital (Forlì, Italy) according to the technique described below.

## Surgical procedure

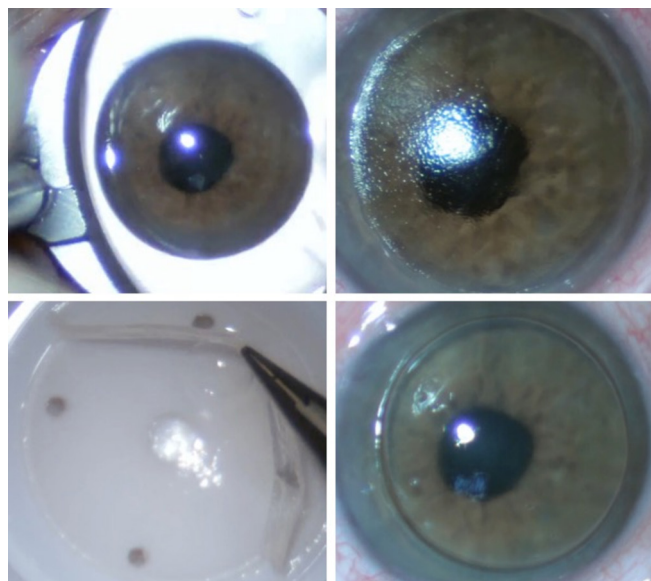
The main surgical steps are illustrated in figure 1. Intravenous droperidol 3 mL was administered intravenously followed by peribulbar anaesthesia (50% mixture of 2% lidocaine and 0.5% bupivacaine).

Similar to the previous description,<sup>9</sup> a superficial free cap 9 mm in diameter was cut from the recipient cornea, employing a 130 µm microkeratome head (Moria, Antony, France) with a 'zero' suction ring on an intact epithelium. Continuous slow advancement of the microkeratome with counter rotation of the fixation ring was performed to achieve a planar cut of the correct diameter. The donor cornea was mounted on the artificial chamber of the automated lamellar therapeutic keratoplasty system (Moria), and an anterior donor lamella was dissected by means of a 90 µm microkeratome head. The donor tissue was punched to 9 mm using a Hessburg-Baron punch (Katena Products, Denville, New Jersey, USA), and



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**To cite:** Myerscough J, Bovone C, Thomas PBM, *et al.* *Br J Ophthalmol* Epub ahead of print: [please include Day Month Year]. doi:10.1136/bjophthalmol-2019-314316



**Figure 1** Main steps of the surgical technique. Top left: superficial 'free cap' 9 mm in diameter cut from the recipient cornea using a 130 µm microkeratome head; top right: prepared host stromal bed; bottom left: donor tissue punched to 9 mm using a Hessburg-Baron punch; bottom right: graft laid onto the host stromal bed without sutures.

the graft obtained this way was laid onto the host stromal bed. No sutures were used. A soft 16 mm diameter bandage contact lens was inserted.

Postoperatively, all patients received tobramycin (0.3%) and dexamethasone (0.1%) eye drops every 2 hours during daytime hours for 1 week, then four times a day for 1 month, at which point tobramycin was stopped, and dexamethasone was continued on a slowly tapering dose to once a day by 4 months, and discontinued completely at 1 year.

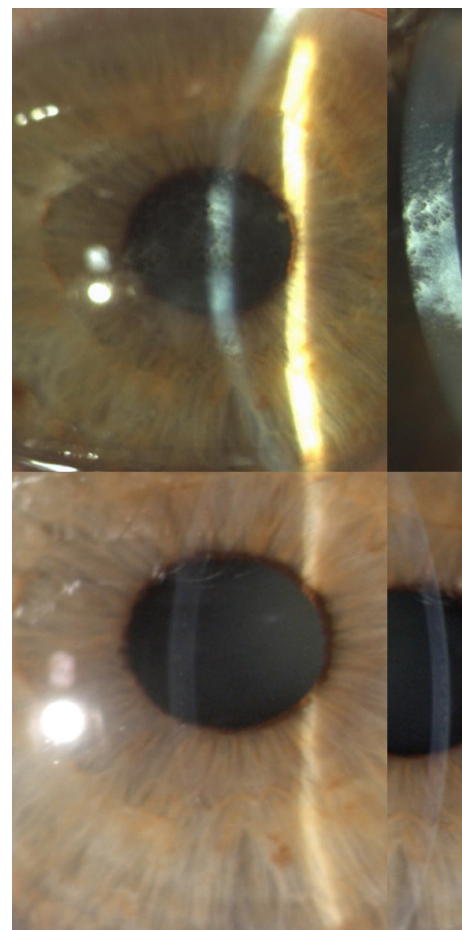
Each patient was examined two times per week until the ocular surface had re-epithelialised, at which point the bandage contact lens was removed. Refraction and BSCVA were assessed at subsequent follow-up appointments scheduled for 3, 6, 12 and 18 months and then annually.

### Vector analysis

For the purpose of this study, we looked at changes in the astigmatic component of the power vector, that is, the two-dimensional vector ( $J_0$ ,  $J_{45}$ ).<sup>10</sup>  $J_0$  refers to cylinder power set at 90° and 180° meridians, and is positive when astigmatism is WTR and negative when it is against the rule (ATR);  $J_{45}$  refers to a cross-cylinder set at 45° and 135°, representing oblique astigmatism, and is positive when the axis of the negative cylinder is closer to 45° and negative when it is closer to 135°.<sup>11</sup> Alpin's vector analysis was used to calculate the surgically induced astigmatism (SIA) at each postoperative time point.

### Statistical analysis

All data collected in the study were entered into an electronic database. Statistical analyses were performed using SPSS Statistics V.20. A paired t-test was used to identify statistically significant postoperative changes in BSCVA, spherical equivalent and refractive astigmatism. P values of <0.05 were considered to be statistically significant.



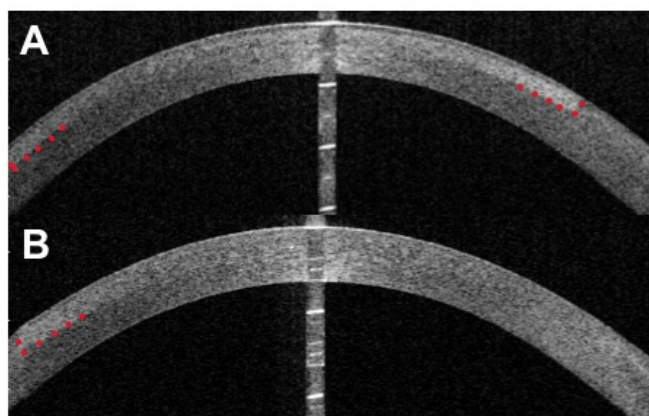
**Figure 2** Preoperative and postoperative images illustrating sutureless SALK. Top left and top right images illustrate one patient with corneal haze related to photorefractive keratectomy recurring after treatment with phototherapeutic keratectomy; bottom left and right images illustrate postoperative appearance in the same patient following sutureless SALK. SALK, superficial anterior lamellar keratoplasty.

### RESULTS

Ten eyes from 10 consecutive patients undergoing sutureless SALK with the indication of PRK-related corneal haze recurring after PTK were included in the study. The age of patients at the time of SALK was  $48.8 \pm 10.2$  years (mean  $\pm$  SD), and 5 of 10 patients were female. No intraoperative complications were observed. During the 5-year follow-up period, no recurrence of haze nor any primary or late graft failure occurred in any eye. **Figure 2** illustrates the preoperative and postoperative appearances of one of the patients in the series, while **figure 3** illustrates graft–host apposition in two patients using AS-OCT.

Mean BSCVA showed significant improvement, with the entire dataset shown in **table 1**. Mean preoperative visual acuity improved from 0.46 logMAR (SD=0.12) to 0.21 (SD=0.12,  $p=0.0004$ , by paired t-test) at 6 months, 0.15 (SD=0.13,  $p=0.0002$ ) at 18 months and 0.12 (SD=0.12,  $p=0.0001$ ) at the 5-year follow-up. At the final follow-up examination, 3/10 eyes saw 20/20, 5/10 eyes saw 20/25, 9/10 eyes saw 20/40 or better, and all eyes could see 20/50 or better.

Mean spherical equivalent (MSE) ( $\pm$ SD) changed from  $-2.26 \pm 4.63$  diopters (D) preoperatively to  $-2.67 \pm 3.73$  D ( $p=0.65$ ) at 6 months,  $-2.46 \pm 4.60$  ( $p=0.82$ ) at 18 months and  $-2.85$  D (SD=4.85,  $p=0.46$ ) at the 5-year follow-up.



**Figure 3** (A,B) AS-OCT illustrating postoperative graft–host apposition postoperative AS-OCT of two patients, with red dots annotating the graft–host interface where visible. AS-OCT, anterior segment optical coherence tomography.

There was no significant difference between the mean preoperative  $J_0$  ( $-0.83 \pm 1.29$ ) and postoperative values at 6 months ( $-1.40 \pm 1.82$ ,  $p=0.31$ ), 18 months ( $-1.12 \pm 2.16$ ,  $p=0.43$ ) or 5 years ( $-1.24 \pm 2.13$ ,  $p=0.34$ ). Similarly, there was no significant difference between the mean preoperative  $J_{45}$  ( $-0.44 \pm 0.92$ ) and postoperative values at 6 months ( $-0.09 \pm 2.48$ ,  $p=0.63$ ), 18 months ( $-1.11 \pm 1.65$ ,  $p=0.27$ ) or 5 years ( $0.46 \pm 1.85$ ,  $p=0.27$ ). The mean SIA at 6 months was  $2.50 \pm 1.04$ , with no further significant change at 18 months ( $2.05 \pm 0.84$ ,  $p=0.33$ ) or at 5 years ( $2.53 \pm 1.39$ ,  $p=0.95$ ).

Secondary ocular hypertension (intraocular pressures of 24 and 26 mm Hg) occurred in 20% (2/10) of the eyes within 3 months from SALK; it was transient in both cases and normalised on cessation of topical steroid therapy without the need for any medical or surgical intervention. In one patient (39, female), although visual acuity improved from 0.70 to 0.30 logMAR at 18 months, vision was limited to 0.40 logMAR at final follow-up by concurrent diabetic macula oedema.

## DISCUSSION

Although relatively rare (0.3%–3%<sup>12</sup>), haze following excimer surface ablation can significantly impact on visual performance. The goal of treatment for this complication is trifold: to improve vision, minimise refractive change and eliminate recurrence. PTK

with or without MMC augmentation is a common treatment for PRK-related corneal haze, but this approach does not eliminate the risk of further recurrence. To treat recurrences, various types of keratoplasty procedures have been proposed. Bowman layer transplantation has been described in isolated cases, but only a very short follow-up is available.<sup>13</sup> Deep anterior lamellar keratoplasty (DALK) is technically feasible, although the removal of stroma extends unnecessarily to the pre-Descemet layer. In addition, DALK recovery of stable vision requires up to 1 year, that is, the time necessary for safe complete suture removal, and high-degree astigmatism can be present, strongly affecting vision. In 2006, Busin described SALK for the treatment of superficial corneal scars.<sup>14</sup> This technique was aimed at retaining the benefits of DALK in terms of eliminating the risk of recurrence while optimising visual recovery. In limiting the dissection to the superficial stroma, the mechanical structure of the host cornea is maintained, which is regular in shape in such patients. Since then, variations of SALK have been described for different diseases of the superficial corneal stroma, including sporadic cases of excimer laser-related opacities.<sup>12 15 16</sup> Most recently, femtosecond laser-assisted sutureless anterior lamellar keratoplasty (FALK) was conceived for greater accuracy in the sizing of the diameter of lamellar grafts<sup>17</sup> because, if the graft is larger than the host bed, epithelial ingrowth tends to occur, which can be difficult to manage.<sup>14</sup> An undersized graft is less of a problem since in our experience the stroma epithelialises without complication,<sup>9</sup> and, in any case we found that the use of a '0' suction ring gets a 9 mm diameter cut in all cases. FALK also aimed at achieving better apposition of the graft–host interface.<sup>17</sup> However, the quality of the stromal bed created in FALK is inferior to that made by means of microkeratome-assisted dissection.<sup>15</sup> Furthermore, FALK is technically possible only in cases with good corneal transparency, and there are cost implications of FALK compared with SALK. In 2006, Wiley *et al* described a two-staged approach to SALK with a flap created initially with a microkeratome but not trephined until 6 weeks later for transplantation of a sutured 7.25 mm graft.<sup>15</sup> Fogla and Knyazer later refined this two-staged technique with a sutureless approach with promising results.<sup>16</sup> However, in their series AS-OCT found the postoperative central corneal thickness to be significantly thicker than the peripheral host. We demonstrated that using a microkeratome cutting head of 40  $\mu$ m less for the donor compared with host resulted in uniform apposition in all cases (as illustrated in figure 3) without the need for sutures and,

**Table 1** Patient demographics and pre-SALK and post-SALK visual and refractive results

Age (years)/sex	Preop BSCVA	BSCVA 6 months	BSCVA 18 months	BSCVA 60 months	Preop SE	SE 6 months	SE 18 months	SE 60 months	Preop RA	RA 6 months	RA 18 months	RA 60 months
45/F	0.52	0.10	0.10	0.16	−7.5	−3.75	−3.75	−7	−3	−3.5	−3.5	−4
56/F	0.52	0.10	0.00	0.00	−2.0	0.5	1.5	1.5	−2.0	−3.0	−3.0	−3.0
55/M	0.46	0.22	0.40	0.16	−0.25	0.25	−1.25	−0.75	−0.5	−4.5	−4.5	−4.5
48/M	0.40	0.22	0.10	0.16	−5.25	−8.25	−8.25	−8.25	−2.5	−4.5	−4.5	−4.5
39/F	0.70	0.40	0.30	0.40	5.75	−0.375	1.0	1.0	−1.5	−1.75	−2.0	−2.0
48/M	0.22	0.16	0.10	0.22	1.5	1.25	2.5	2.25	−1.5	−4.5	−3.0	−2.5
67/F	0.52	0.16	0.00	0.05	−0.375	−2.0	−2.25	−2.625	−2.75	−2.0	−2.5	−1.75
29/M	0.46	0.40	0.22	0.00	−7.5	−7.5	−7.25	−7.75	0	−3.0	−1.5	−1.5
52/M	0.40	0.10	0.22	0.00	1.0	0.375	2.75	2.75	0	−0.75	−2.5	−2.50
49/F	0.40	0.30	0.10	0.10	−8.0	−7.25	−9.625	−9.625	0	−2.5	−1.25	−1.25

All BSCVA values are in logMAR; all RA and SE values are in diopters.

BSCVA, best spectacle-corrected visual acuity; F, female; logMAR, logarithmic unit of the minimum angle of resolution; M, male; preop, preoperative; RA, refractive astigmatism SE, spherical equivalent.



as such, minimised the prolonged visual recovery encountered in two-stage surgery.

We did not see any secondary recurrence in this series of cases of SALK for recurrent corneal haze. However, from our experience with SALK performed for other indications (eg, anterior stromal dystrophies), we know that the procedure is easily repeatable. Furthermore, although not performed in this series, theoretically the flap can be lifted at a later date for additional refractive ablation.<sup>9</sup> In lifting the flap, the subsequent laser treatment is essentially intrastromal rather than a repeat surface ablation, so the risk of recurrent haze is minimised.

There was no significant change in MSE, but there was significant SIA present at 6 months, which remained stable until final follow-up. All astigmatism was correctable with spectacles alone as opposed to contact lenses, and the astigmatic outcomes compare favourably with published rates of the other definitive treatment options, namely, DALK.<sup>18</sup> There is a theoretical risk of progressive ectasia when performing SALK in corneas that have already undergone multiple excimer laser treatments; however, we did not detect any ectasia in any cases in the 5-year follow-up. Furthermore, since it is only the superficial, anterior lamellar corneal architecture being modified during SALK, DALK would still be a technically feasible option in an eye with progressive ectasia.

One limitation of this study is that no refractive surgery is performed in this centre, and, as a result, all patients recruited into this study by definition had had both their initial PRK treatment and its subsequent management with PTK done elsewhere. Indeed, more than half of these patients were referred from abroad and, accordingly, we did not have the particular details, such as their starting refraction, whether the initial PRK was combined with MMC or whether the subsequent PTK was combined with MMC and how many times it was performed. Needless to say, all cases had had at least one PRK treatment and one PTK treatment with or without MMC at least 12 months prior to being referred to our centre for a definitive surgical solution.

Previous complications reported with microkeratome-assisted anterior lamellar keratoplasty include microkeratome failure, epithelial ingrowth and late flap/lamellar dislocation.<sup>9</sup> However, no intraoperative complications were observed in this series. Mild transient steroid-induced ocular hypertension was observed in two patients, which resolved without damage to the optic nerve and did not require intervention.

In conclusion, sutureless SALK provides excellent 5-year outcomes in cases of surface ablation-related corneal haze recurring after PTK. SIA was significant but correctable with spectacles in these patients.

**Contributors** All authors made a substantive contribution to the paper and are in agreement with its contents.

**Funding** The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient consent for publication** Not required.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** All data relevant to the study are included in the article or uploaded as supplementary information.

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