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# *Text and Atlas on*
# Corneal Pigmentation

*Editor*
**Jorge L Alió**

**2nd Edition**

JAYPEE

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## SECTION 1: Keratopigmentation Techniques

***Editors:*** **Jorge L Alió, Sandie Tiziano-Shaer, Ronald Steven Medalle II, María Alejandra Amesty**

CHAPTER 8

# Keratopigmentation Techniques

*Jorge L Alió, Ronald Steven Medalle II*



## INTRODUCTION

Various techniques have been proposed for performing corneal tattooing, with commonly used instruments described in previous chapters (*see Chapter 6*). Currently, two primary types of keratopigmentation methods are in use:

1. Superficial keratopigmentation (superficial corneal staining):
   a. Superficial corneal staining (SCS)
   b. Superficial automated keratopigmentation (SAK)
2. Intrastromal keratopigmentation (intralamellar or intrastromal corneal staining):
   a. Manual intrastromal keratopigmentation (MIK)
   b. Femtosecond-assisted keratopigmentation (FAK)

The choice of technique depends on the intended purpose of the corneal pigmentation, which may be cosmetic or therapeutic. Additionally, the specific method chosen is influenced by the location and characteristics of the corneal scar. Generally, intrastromal keratopigmentation is recommended; however, certain corneal scars may not be suitable for this approach and might benefit from more superficial methods.

To fully understand the advancements in this field, it is helpful to consider the evolution of techniques used historically.

## SUPERFICIAL KERATOPIGMENTATION TECHNIQUES

Historically, techniques for superficial corneal tattooing were notably different from those currently in use. Early keratopigmentation was achieved through either chemical staining—inducing pigment precipitation within corneal tissue using solutions of metals like gold chloride,[1,2] silver nitrate, or platinum chloride,[1,2,4] —or by directly injecting insoluble pigments[3,5,6] such as India ink,[1] iron oxide,[1,7] or titanium dioxide[8,9] into the corneal stroma.[10] However, these initial methods often proved unsatisfactory due to issues with fading, discoloration, and anterior segment inflammation.[11]

The first approach, known as chemical staining, was primarily developed in Western countries, and pioneered by Knapp, Kerautbauer, Bietty, and others.[12] Another approach involved carbon impregnation. While chemical staining was easier and quicker to perform, it tended to fade more rapidly than nonmetallic techniques.[13]

To apply pigment to the cornea, practitioners used various tools, including simple needles,[1,14] bundles of fine needles,[15] and more sophisticated devices like dermographs, which were also employed in dermatological tattooing procedures **(Fig. 1)**.[16] For this type of keratopigmentation, pupil size measurements are necessary. After applying the stain, micropunctures were made in the superficial stromal layers using the selected needle, gradually introducing pigment to achieve a satisfactory cosmetic outcome.[17-20]

Another superficial pigmentation method, automated keratopigmentation, utilizes a specialized puncture device (Vissum Eye MP System, Madrid, Spain; Apl. No. 2.949.539) to perform automated micropunctures. This system punctures the superficial stromal layers to a controlled depth of approximately 120 microns, with the needle penetration depth regulated by the longitudinal axial vibration of the tip.[17-20]

A drawback of superficial techniques is that they can disrupt the corneal epithelium, potentially causing postoperative discomfort. Despite this, they remain particularly valuable when treating scars located in the anterior stroma.

## INTRASTROMAL KERATOPIGMENTATION TECHNIQUES

Recent advancements in keratopigmentation techniques highlight the anatomical benefits of the lamellar corneal

**Fig. 1:** Dermograph for micropigmentation.

structure. These approaches offer the potential for more precise pigment distribution and consistent, reproducible outcomes, promising a new standard in accuracy and uniformity.[5,6,17-21]

## Manual Intrastromal Keratopigmentation

In 1984, Panda et al.[5] conducted a series of keratopigmentation cases comparing the intralamellar tunnel technique with the superficial pigmentation technique. They found that intralamellar procedures led to significantly less inflammation and fading compared to superficial techniques.

In 1998, Beekhuis et al.[21] introduced lamellar stromal keratography to alleviate photophobia in patients with aniridia. This technique involved injecting pigments intrastromally following a lamellar dissection of the stroma.

Burris et al.[6] further explored the intrastromal lamellar approach as a potential treatment for iris defects, both for optical correction and cosmetic purposes, utilizing eye bank samples for their research.

Alió et al.[20] conducted a study comparing the outcomes of superficial and intrastromal corneal staining techniques, employing micronized mineral pigments in severely impaired eyes. Their motivation was to provide an alternative to invasive reconstructive procedures such as enucleation or evisceration. The study found that intrastromal staining offered superior results over superficial techniques, yielding a more homogenous appearance of the pigmented area. The procedure was faster and patients experienced a quicker, less symptomatic recovery. A key advantage was that the corneal surface and epithelium remained unaffected, preventing pigment exposure to the tear film, thereby reducing the risk of fading **(Figs. 2A to I)**.[20]

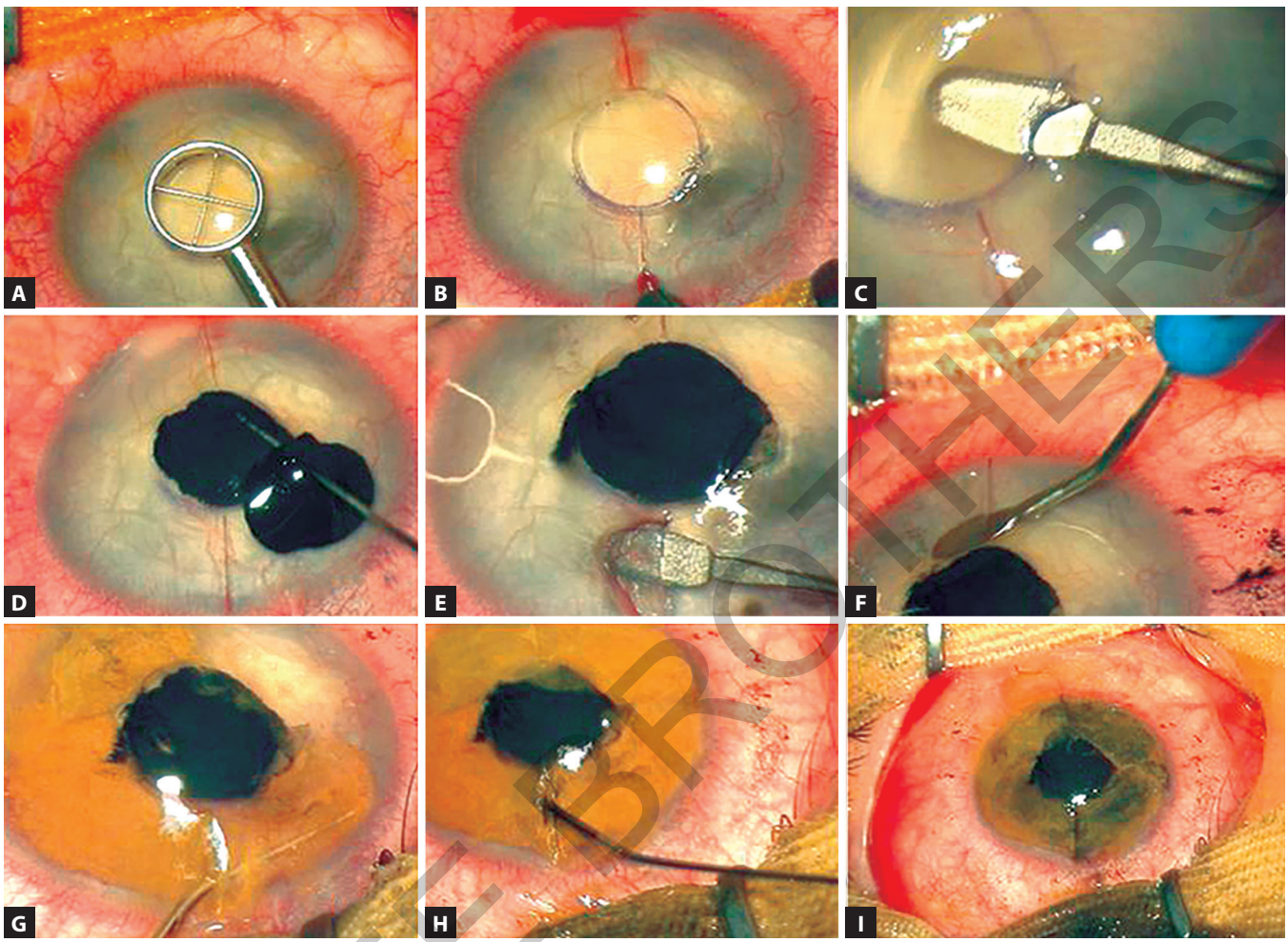
Another technique for dissecting the intralamellar tunnel involves making a single radial incision and using a pigtail corneal dissector—also known as the helicoidal tunnel corneal dissector—to create a 180° dissection clockwise and counterclockwise along the pupil margin. This instrument is depicted in Chapter 6.[17-20,22]

Once the tunnel is prepared, the appropriate color pigment is injected through it using a 27-gauge cannula attached to a 1 mL syringe. Notably, no sutures are required for the keratopigmentation procedure.[17-20,22]

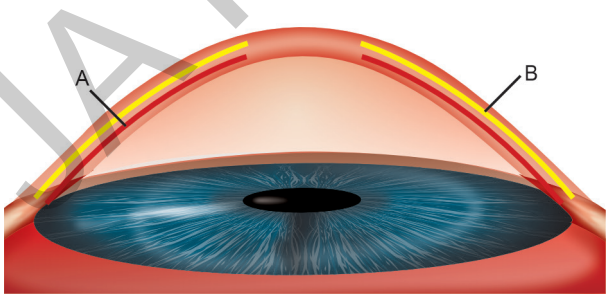
## Femtosecond-assisted Intrastromal Keratopigmentation

Femtosecond-assisted keratopigmentation, described for the first time by Prof. Jorge Alió (Alicante, Spain) represents an innovative approach to corneal pigmentation. In this technique, one or two intrastromal tunnels are created within the cornea using a femtosecond laser, followed by the injection of pigments into these tunnels. When two tunnels are employed, each serves a distinct function. The deeper tunnel is designed for more functional use, where a dark pigment is injected to block light transmission, providing relief from photophobia or other visual disturbances. Meanwhile, the more superficial tunnel is used for cosmetics, allowing the pigmentation to closely match the color of the patient's other eye, enhancing the aesthetic outcome **(Fig. 3A)**.[17-19]

Prior to surgery, pachymetry and tomography are measured across various areas of the cornea using the time-domain Visante optical coherence tomography system (Carl Zeiss Meditec AG) to determine the optimal stromal depth for femtosecond laser-created tunnels.




**Figs. 2A to I:** Manual intrastromal keratopigmentation, intralamellar corneal staining technique. (A) Pupil diameter is marked (in this case 4 mm); (B) 3 or 4 radial incisions are performed using a 1 mm diamond blade previously calibrated; (C) Corneal intrastromal dissection in the pupil area using a microcrescent blade (Sharpoint; Surgical Specialties Corporation, Readying, Pennsylvania); (D) Intralamellar staining in the pupil area with black using a 30 G cannula; (E and F) Peripheral corneal intrastromal dissection through the radial incisions previously performed; (G) Intralamellar peripheral corneal staining using brown pigments to mimic the iris color; (H) This pigment is then mixed with a darker pigment to simulate a normal iris color and to match the color of the other eye; and (I) Outcomes after the intrastromal staining technique.[20]




**Figs. 3A and B:** (A) Darker and deep, light absorbing layer; (B) Superficial layer, light-colored to match the color of the other eye.[19]

Two surgical approaches can be used: either creating a single intrastromal tunnel or two intrastromal tunnels with a 60 kHz femtosecond laser (e.g., IntraLase AMO, Irvine, CA or VisuMax 500, ZEISS). Following this, the white-to-white horizontal and vertical diameters of the cornea are measured with calipers to establish the lamellar dissection diameter.

Afterward, the white-to-white horizontal and vertical diameters are measured using calipers to determine the diameter of the lamellar dissection. The deepest tunnel could be performed first at a 400 micron depth from the

surface with an inner diameter of 6 mm and an outer diameter of 9.5 mm. The energy should be set at 2 mJ, with a vertical incision at 6 o'clock. A second superficial tunnel could be performed at 200 microns depth, with an inner diameter of 6 mm and an outer diameter of 9.5 mm. The energy was set at 2 mJ with a vertical incision at 12 o'clock **(Fig. 3B)**.[17-20]

A lamellar dissector, such as the KTP corneal dissector (Epsilon; Irvine, CA), is used to open each femtosecond tunnel at their respective incisions (12 o'clock and 6 o'clock). Pigments are then injected into the deeper and superficial tunnels using a 30-gauge cannula through the superior and inferior incisions.

This double-layer technique, involving two intrastromal tunnels, replicates iris anatomy by applying a light-colored pigment into the superficial layer for cosmetic effect, while a darker pigment is introduced into the deeper layer to block light.[17-20]

## ELECTIVE COSMETIC KERATOPIGMENTATION

The voluntary change in the eye color was first described in the ophthalmic literature by J Alió[23] and involves the use of the femtosecond-assisted technique as described earlier. The external diameter of the tunnel should be customized to the peripheral dimensions and shape of the cornea, leaving a clearance of about 0.5 mm of clear cornea, called the "limbal ring", to improve the cosmetic appearance to be more natural and convenient. This book includes a dedicated section on the elective cosmetic application of keratopigmentation, covered in Part II: Purely Cosmetic Keratopigmentation (Chapters 13–15). The pupil created by the internal limit should be ideally 5.3–5 mm, not smaller, to avoid interference with the light entering inside the eye through the corneal diopter, causing limitations in the peripheral 60° visual field and to avoid the diffraction of light at the inner edge of the keratopigmented area.

## REFERENCES


1. Ziegler SL. Multicolor tattooing of the cornea. Trans Am Ophthalmol Soc. 1922;20:71-87.
2. Clark EH. Tattooing of corneal scars with insoluble pigments. Plast Reconstr Surg (1946). 1947;2(1):44-59.
3. Gifford S, Steinberg A. Gold and silver impregnation of cornea for cosmetic purposes. Am J Ophthalmol. 1927; 10:240-7.
4. Pischel DK. Tattooing of the cornea with gold and platinum chloride. Arch Ophthalmol. 1930;3:176-81.
5. Panda A, Mohan M, Chawdhary S. Corneal tattooing—experiences with lamellar pocket procedure. Indian J Ophthalmol. 1984;32(5):408-11.
6. Burris TE, Holmes-Higgin DK, Silvestrini TA. Lamellar intrastromal corneal tattoo for treating iris defects (artificial iris). Cornea. 1998;17:169-73.
7. Van der Velden/Samderubun EM, Kok JH. Dermatography as a modern treatment for coloring leukoma corneae. Cornea. 1994;13:349-53.
8. Reed JW. Corneal tattooing to reduce glare in cases of traumatic iris loss. Cornea. 1994;13:401-5.
9. Reed JW, Beran RF. Elimination of monocular diplopia by corneal tattooing. Ophthalmic Surg. 1988;19(6):437-9.
10. Müller H, Van der Velden/Samderubun EM. Tattooing in maxillo-facial surgery. J Craniomaxillofac Surg. 1988; 16:382-4.
11. Wiegmann E. Is tattooing according to knapp entirely without danger? Am J Ophthalmol. 1929;12:431.
12. Duke-Elder S, Leigh AG. System of ophthalmology. In: Disease of the Outer Eye, part 2. St Louis, Missouri: CV Mosby Company; 1965.
13. Olander K, Kanai A, Kaufman HE. An analytical electron microscopic study of a corneal tattoo. Ann Ophthalmol. 1983:15:1046-9.
14. Von Wecker L. Corneal tattooing (Tatouage de la cornée). Union Médicale. 1870;27:41 (As quoted by Ziegler S. Reference 1).
15. Taylor CB. On the Modern Art of Tinting Opacities of the Cornea. British Medical Journal. 1872;2:271. (As quoted by Ziegler S. Reference 1).
16. Wessels IF, Wessels GF. Mechanized keratomicropigmentation: Corneal tattooing with the blepharopigmentor. Ophthalmic Surg Lasers. 1996;27:25-8.
17. Alió JL, Rodríguez AE, Toffaha BT, Piñero DP, Moreno LJ. Femtosecond-assisted keratopigmentation for functional and cosmetic restoration in essential iris atrophy. J Cataract Refract Surg. 2011;37(10):1744-7.
18. Alió JL, Rodríguez AE, Toffaha BT. Keratopigmentation (corneal tattooing) for the management of visual disabilities of the eye related to iris defects. Br J Ophthalmol. 2011;95:1397-401.
19. Alió JL, Rodríguez AE, Toffaha BT, El Aswad A. Femtosecond-assisted keratopigmentation double tunnel technique in the management of a case of Urrets-Zavalia Syndrome. Cornea. 2012;31(9):1071-4.
20. Alió JL, Sirerol B, Walewska-Szafran A, Miranda M. Corneal tattooing (keratopigmentation) with new mineral micronised pigments to restore cosmetic appearance in severely impaired eyes. Br J Ophthalmol. 2010;94(2):245-9.
21. Beekhuis WH, Drost BH, Van der Velden/Samderubun EM. A new treatment for photophobia in posttraumatic aniridia: A case report. Cornea. 1998;17(3):338-41.
22. Amesty MA, Alio JL, Rodriguez AE. Corneal tolerance to micronized mineral pigments for keratopigmentation. Br J Ophthalmol. 2014;98(12):1756-60.
23. Alió JL, Rodriguez AE, El Bahrawy M, Angelov A, Zein G. Keratopigmentation to change the apparent color of the human eye: A Novel indication for corneal tattooing. Cornea. 2016;35(4):431-7.

# *Text and Atlas on*
# Corneal Pigmentation

This book deals with the practice of the new corneal surgical technique that has been named keratopigmentation.

Corneal Pigmentation has been the subject of a complete revival over the last 15 years, leading to the development of pigments, instruments, technologies, and surgical techniques that have revolutionized this topic. The book highlights its therapeutic and cosmetic applications, focusing both on the surgical details about its practice and on its potential complications and, especially, the outcomes. Evidence-based information is the base of this book, which is focused on medical education coming from evidence-based peer-review information.

**Jorge L Alió** MD PhD from Alicante, Spain, is the Founder of Modern Keratopigmentation. He is Professor and Chairman, Department of Ophthalmology, Miguel Hernandez University, Medical School; and the Founder of Vissum Miranza, Alicante, Spain. He was the first to describe these new methods, both for therapeutic and cosmetic applications back in 2016. From the first papers, the cosmetic and therapeutic applications were highlighted as emerging surgical techniques that need specific training, technologies, and instruments. The development of pigments has been done in parallel to these technologies. Professor Alió is focused on anterior segment surgery and has published 835 peer-review scientific publications, with over 25,000 citations and an h-index of 78 Scopus.

This is the second edition of the book in which the author has distilled the information provided by the most relevant publications and has invited the most relevant authors with published experience on the topic.

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