Minimally Invasive Ophthalmic Surgery

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2.1 Conjunctival Surgery

The ocular surface is composed of both the cornea and conjunctiva, which constitute a unit of the mucosal epithelial layer with subepithelial fibrous tissues. As the area of the conjunctiva is 7–8 times larger than that of the cornea, even a minor involvement of a conjunctival disease can greatly affect the ocular surface and corneal integrity. The same holds true for ocular surface surgery, as any damage to the conjunctiva can easily produce tissue fibrosis, thus resulting in symblepharon and sustained conjunctival inflammation. Therefore, it is essential that there be a minimal amount of manipulation of the conjunctiva when performing conjunctival surgery, and in cases where extensive conjunctival surgery must be performed, proper additional treatments that include the use of mitomycin C (MMC) and/or amniotic membrane transplantation (AMT) must be combined with the primary surgery to minimize subepithelial fibrosis. Postoperative medical treatments using the topical application of steroids and/or systemic administration of steroids and immunosuppressives are also effective in controlling the scarring events.

In this chapter, several conjunctival surgeries which incorporate the concept of minimally invasive surgery, such as those for conjunctivochalasis, recurrent pterygium, limbal dermoid, and strabismus surgery, are summarized. However, specific extensive conjunctival surgeries for scarred-stage chemical injury, ocular cicatricial pemphigoid, Stevens-Johnson syndrome, and glaucoma filtering surgery have been excluded as they involve different surgical concepts.

2.2 Conjunctivochalasis

2.2.1 Background of the Disease

Conjunctivochalasis (CCh) [1] is a very common ocular surface disorder that is generally seen among elderly people. According to Meller and Tseng, CCh is defined as redundant, loose, nonedematous conjunctiva between the globe and eyelid which tends to be bilateral and prevalent in older patients [2]. Pathologically, the breakdown of elastic fibers in the redundant conjunctival tissue was seen in all examined cases without any inflammatory cell infiltrates [3, 4]. Lymphangiectasia was found to be associated with this disease in more than 80% of the cases [3], although the other theories emphasize the association of inflammation with this disease [5, 6]. In our recent in vivo study, however, we confirmed the breakdown of subconjunctival tissue and lymphangiectasia by using optical coherence tomography (Fig. 2.1).

Although common, CCh is a very unique disease in that it can become a common risk factor for eyes with epiphora as well as for dry eyes [7], because redundant conjunctiva is likely to distribute at the lower tear meniscus and may inhibit the meniscus tear flow, thus leading to a dysfunction of the lower tear meniscus. This dysfunction can cause delayed tear clearance in dry eye which leads to the exacerbation of dry eye-associated inflammation. On the other hand, CCh-related blockage of the meniscus can cause exacerbation of epiphora symptoms in an eye with lacrimal duct stenosis.
In addition to tear meniscus dysfunction, redundant conjunctiva may cause precorneal tear film instability adjacent to the redundant conjunctiva and mechanical friction may be exerted between the redundant conjunctiva and the ocular surface, especially in cases of dry eye. In cases of CCh accompanied by dry eye, dry eye-related corneal damage and the patients’ symptoms may be worsened via the CCh-related mechanisms compared to dry eye alone.

### 2.2.2 Indication for Surgery

The most important point to be noted is that surgery for CCh is considered only for cases with symptoms. An asymptomatic case, even if there is prominently redundant conjunctiva distributed along the meniscus, is not an indication for surgery. Cases with irritation, epiphora, and recurrent subconjunctival hemorrhage are the appropriate indications for surgery when those symptoms can be explained by tear meniscus dysfunction and/or the mechanical action of redundant conjunctiva.

Before determining the symptom for surgery, it is important to examine the eye with a slit-lamp biomicroscope under forced blinking because some CCh is hidden under the lower eyelid. In such cases, however, forced blinking may exert friction on the cornea which results in superficial punctate keratopathy. When CCh is accompanied by dry eye, which may be diagnosed based on an abnormal Schirmer I test value and/or short fluorescein breakup time in addition to the superficial punctate keratopathy, surgery should be considered, if the case cannot be managed with eye-drop treatment alone and due to the fact that the accompanying CCh is prominent.

### 2.2.3 Basic Concept of Surgery

The objectives of CCh surgery are to establish the lower tear meniscus from the lateral canthus to the punctum, and make the surface of the conjunctiva as smooth as possible, to restore the tear meniscus function and reduce mechanical friction between the redundant conjunctiva and the ocular surface [4]. Many surgical methods have been reported, such as a crescent resection, resection combined with inferior peritomy and radial relaxing incision, and excision with AMT and scleral fixation [2, 8]. However, these methods involve no firm concept for tear meniscus reconstruction and most of the procedures target only the redundant conjunctiva inferior to the cornea, while redundant conjunctiva in the nasal and temporal areas are ignored, although all those procedures can provide an effective reduction in the extent of CCh. Especially in eyes with epiphora, complete establishment of the lower tear meniscus from the lateral canthus to the punctum is required to restore the meniscus route for the lacrimal drainage pathway. Therefore, the ideal surgical method must include a surgical step for the treatment of redundant conjunctiva in the nasal and temporal areas, and the reconstruction of the entire lower tear meniscus as well as the elimination of ocular surface undulations should be achieved in any variations of CCh.

### 2.2.4 Surgical Procedure

(Figs. 2.2 and 2.3)

To completely reconstruct the lower tear meniscus and totally smooth the conjunctival surface (Fig. 2.4), the
lower half of the bulbar conjunctiva, where CCh is predominantly distributed, is divided into three blocks. The redundant conjunctiva within each block is then independently resected depending on the redundancy within the block. The surgical procedure for simple CCh is comprised of the following steps:

1. Topical anesthetic eye drops including 2% oxibuprocaaine and epinephrine are instilled.
2. Planned incision lines are made using a newly developed marker (Chalasis Marker M-1405; Inami Co., Ltd., Tokyo, Japan); for small eyes, forced bilateral eye movement is necessary to obtain appropriate marking.
3. Subconjunctival anesthesia is performed using 2% lidocaine, followed by making an arc-like incision to the anesthesia-ballooned conjunctiva using newly developed scissors (Chalasis Scissors M-1406; Inami Co., Ltd.) along the line created by the marker at the lower half of the bulbar conjunctiva.
4. Subconjunctival fibrous tissues are excised distal to the arc-like incision to easily stretch the lax conjunctiva and obtain a firm attachment of the conjunctiva to the episclera.
5. Radial incisions are made with the chalasis scissors in the lax conjunctiva to create three conjunctival blocks distal to the arc-like incision.
6. The conjunctiva in the lower block is pulled upward and redundant conjunctival tissue that can be overlaid on the limbal conjunctiva is then resected and sutured using approximately five 9–0 silk stitches.
7. For treating lateral blocks, resection of redundant temporal and nasal conjunctiva is performed, with the eye being positioned in a contra-lateral direction to avoid postoperative wound breakage due to postoperative eye movement, and then tightly sutured with 9–0 silk stitches.
8. Plica semilunaris is subsequently resected when it is encountered and is left un-sutured.
2.2.5 Postoperative Follow-Up

Postoperatively, patients are advised to wear an eye patch for a period of 1 week to prevent any conjunctival breaks while sleeping; sutures are removed 2 weeks after the operation. During the first two postoperative weeks, 0.1% betamethazone sodium phosphate and 0.3% levofl oxacin are instilled 4 times daily; after the removal of stitches, 0.1% fluorometholone is instilled instead of betamethazone 4 times daily, together with 0.3% levofl oxacin twice daily. Instillation times for the 0.1% fluorometholone are reduced according to the extent of postoperative inflammation and are then discontinued within 2 months after the operation.

In dry eye patients, preservative-free artificial tears are instilled 7 times daily in addition to the postoperative eye drops, and are then replaced within 2 months after the surgery with the same combination of eye drops used before the surgery. Early postoperative complications may include secondary lymphangiectasia, disconnection of operative wound sutures, and pyogenic granuloma due to a reaction to the 9–0 silk suture. The secondary lymphangiectasia can be managed by needling or excision, and pyogenic granuloma can be managed with topical steroids or surgical removal.

2.3 Pterygium

2.3.1 Background of the Disease and the Concept of Minimally Invasive Surgery

Pterygium is a common ocular surface disorder with clinical features involving chronic injection of
conjunctiva and slow invasion of conjunctiva beyond the limbus onto the cornea. The prevalence rate of primary pterygium ranges between 0.7 and 31% in various regions around the world [9]. Early pterygium and pinguecula, a common type of conjunctival degeneration, are generally not problematic, except cosmetically, and therefore should not be considered for surgery. However, severe progression or recurrence of pterygium sometimes leads to clinical problems such as corneal scarring and irregular astigmatism. Advanced scarring may extend close to the optical zone and extraocular muscles, resulting in visual loss and restriction of ocular mobility, respectively. Therefore, determination of the appropriate time point for surgical treatment is essential for the prevention of visual dysfunction. Choice of the correct surgical procedure to fit the clinical features is also crucial for the prevention of recurrence. A minimally invasive and safe surgical modality is the key for reducing prolonged postoperative inflammation, one of the risk factors that greatly affects the prognosis. In addition to the various adjunctive measures such as treatment with MMC, AMT minimizes recurrence and postoperative complications. Also, AMT appears to promote early conjunctival epithelial wound healing. The current trend of performing a sutureless conjunctiva graft or AMT using fibrin glue contributes to the minimally invasive surgical concept. This type of surgical modality results in a secured graft attachment with minimal inflammation and shortens surgical time. Many current reports have demonstrated the advantage of using fibrin gel for improving the clinical success of pterygium removal, as it provides

Fig. 2.4 Panoramic picture of representative sample case with conjunctivochalasis without dry eye (upper: before operation; lower: 3 months after operation). No redundant conjunctiva is seen in the interpalpebral zone and the operation resulted in complete reconstruction of the tear meniscus.
for a minimally invasive surgery and results in less chance of recurrence of the disease.

### 2.3.2 Indication for Surgery

There are numerous reports that explore the surgical treatment of pterygium, yet medical treatment such as anti-inflammatory medications should be tried before resorting to surgery [10]. Although the main objectives of surgical treatment are apparent, the indication and timing for surgery are not clearly defined. The most important point of pterygium surgery is to excise the pterygium and inhibit recurrence of the disease. Reoperation requires substantially more invasive surgery, reduces the chances for a successful prognosis, and increases the risk of complications. The appropriate minimum area of resection and minimally invasive surgical procedure should be selected on the basis of clinical features (e.g., chronic injection, bilateral pterygium, and thickening of the Tenon’s tissue).

### 2.3.3 Basic Concept of Surgery

The purpose of surgery in primary pterygium is to remove hyperproliferating subconjunctival tissue and the abnormal pterygium head, thus minimizing the risk of recurrence. Attention should be focused on: (1) minimizing the area of excision; (2) the use of intraoperative chemicals; (3) technique or innovative usage of adhesives for wound closure; and (4) transplantation of tissue to the area of excision to promote epithelial healing and inhibit recurrence. The size of the resection and prompt wound healing are fundamental issues for minimizing surgical invasion, especially in primary cases.

In advanced and recurrent pterygium, to prevent further recurrences and/or reconstruct surgically induced conjunctival cicatrization, additional concepts have been proposed. These include: (1) reconstruction of the limbal barrier to block pterygium reinvasion and (2) reconstruction of the conjunctival area lost by excessive surgical resection and scarring. For the treatment of advanced or recurrent cases, these factors must take precedence over the concept of noninvasive surgery.

### 2.3.4 Surgical Procedures

Previously, simple resection with bare scleral closure was used for cases of early or small pterygia. Although this surgery is the most noninvasive procedure, a variety of studies have shown a high rate of recurrence associated with this technique when not accompanied by adjunctive therapy.

It is now widely accepted that adjunctive therapy and the creation of a physical barrier such as limbal transplantation dramatically reduce the risk of recurrence. The adjunctive intraoperative application of MMC has been commonly used and is found to improve the prognosis [11–14]. MMC suppresses the proliferation of conjunctival fibroblasts, which appear to be responsible for the etiology and recurrence of pterygium. The safe concentration and the time of MMC treatment range between 0.02 and 0.04% for 3–5 min. The intraoperative application of MMC is relatively safe; however, excessive use of MMC has a risk of invasive damage to both the cornea and sclera. Postoperative complications such as scleromalacia and persistent epithelial defects have resulted from overinvasive surgery [15, 16]. Therefore, from the point of minimally invasive surgery, it is important that MMC is not applied to surgically damaged or thin sclera and that the application period is minimized.

Conjunctival rotational flaps and conjunctival transplantation are commonly used surgical methods to prevent recurrence [17]. Although both procedures are invasive forms of surgery that damage the healthy region of the conjunctiva, these ectopic conjunctival grafts result in fast epithelial closure and provide a new barrier against pterygium invasion. Transplantation of a free conjunctival graft is especially useful for cases of recurrent pterygia, where a large epithelial defect may result from resection. Clinical trials have also demonstrated that conjunctival grafts secured with fibrin gel are not only as stable as those secured with sutures, but also reduce inflammation significantly [18–20]. Amniotic membrane (AM) is now widely accepted as an effective biological tool to inhibit pterygium recurrence (Fig. 2.5), as it promotes epithelial wound healing and prevents inflammation. AMT appears to successfully improve the prognosis of severely recurrent pterygium by minimizing surgically induced invasion. Freeze-dried AM can also be used for this purpose [21, 22].
2.3.5 A Biologic Adhesive for Sutureless Pterygium Surgery

A biologic adhesive such as fibrin glue (or Tisseel) is a new surgical tool that provides an alternative to sutures for conjunctival grafts and AM transplantation. The tissue glue consists of a biological two-component sealant. Lyophilized fibrinogen is reconstituted in aprotinin solution to provide the first component, and lyophilized thrombin is reconstituted in calcium chloride to provide the second component. The use of fibrin gel provides a noninvasive surgical response compared to a suture procedure. Koranyi et al. [19] reported a pterygium recurrence rate of 5.3% with glue versus 13.5% with sutures. Early reduction of inflammation and adherence of the graft may contribute to the reduction of immunoresponse. The short surgical time also contributes to the minimal-invasiveness of the surgery. Thus, our group has been seeking to create a new type of biologic adhesive made entirely of plant-based materials [23].

Minimally invasive surgery reduces the risk of intraoperative and postoperative complications, including damage to the medial rectus. Sufficient caution should therefore be paid during the removal of subconjunctival tissue, especially in cases of recurrent pterygia. Major postoperative complications associated with pterygium surgery include infection, corneal ulcers, and scleromalacia. Scleromalacia is the least desirable complication due to the fact that it can reappear even after years of MMC treatment. Therefore, the minimum amount of MMC should be applied to prevent recurrence.

Although the precise pathogenesis of pterygium is unclear, postoperative inflammation is associated with the recurrence of pterygium. Therefore, a minimally invasive surgery reduces inflammation and the cicatriz- ing response that is crucial for the prevention of fibroblast activity. The combination of minimally invasive surgery with adjunctive therapy is essential to prevent

Fig. 2.5 Pterygium surgery with MMC and AMT. (1) Head part of pterygium is removed from the cornea; (2) fibrovascular tissue in subconjunctival space is removed; (3) 0.04% MMC absorbed in microsponges is applied under the conjunctival space for 1–5 min; (4) MMC is rinsed by the excess sodium saline solution; (5) amniotic membrane and (6) conjunctiva are sutured onto the bare sclera
pterygium recurrence. Current nonsuture techniques using fibrin gel successfully reduce surgically induced inflammation and shorten surgical time.

2.4 Limbal and Conjunctival Dermoids

2.4.1 Background of the Disease

A limbal dermoid is a congenital disorder, seen mostly at the lower-temporal limbus, and its size becomes slowly larger in proportion to the size of the cornea. It is often associated with a conjunctival dermoid at the temporal area, the size and thickness of which vary in each patient. It can cause both cosmetic abnormality and decreased visual acuity by causing astigmatism. An amblyopic eye must be treated properly by visual rehabilitation, such as the wearing of an eye patch or corrective eye glasses as removal of the limbal dermoid itself does not change the best corrected visual acuity. In addition, preoperative penalization treatment improves the postoperative visual acuity.

2.4.2 Basic Concept of Surgery

To remove limbal dermoid tissue completely and to prevent the occurrence of pseudopterygium after surgery, peripheral tectonic lamellar keratoplasty over the limbus and its adjacent conjunctiva is preferable. Both fresh and preserved donor corneas may be used for this surgery. Limbal dermoids that receive a simple resection frequently develop pseudopterygium due to adjacent conjunctival over-proliferation on the residual dermoid tissue in the cornea. Furthermore, a simple resection cannot remove all the dermoid tissue from the cornea due to corneal thinning. Patients usually undergo the operation when they are 4–6-years-old due to the ease of postoperative care at that age.

2.4.3 Surgical Procedure (Fig. 2.6)

First, a minimal conjunctival resection is performed before lamellar keratoplasty. Then, the dermoid is marked by a trephine of appropriate size, and the lamellar dissection is performed from the central cornea. A donor cornea of the same size is then placed in that area and fixed with 10–12 interrupted 10–0 nylon sutures. If the dermoid is large, the conjunctiva is treated with 0.04% MMC for 3 min. It is preferable to remove the conjunctival dermoid at the same time. However, a conjunctival dermoid that has penetrated deeply into the upper-temporal sclera should be left as it is and should not be excised extensively, to avoid severe postoperative complications. Cosmetic recovery is easily achieved.

2.4.4 Postoperative Follow-Up

After keratoplasty, topical antibiotics (e.g., 0.3% ofloxacin eye drops four times daily) and corticosteroids (e.g., 0.1% dexamethasone or 0.1% fluorometholone drops four times daily) are applied for approximately 6 months. Intraocular pressure should be checked regularly as children often suffer from steroid-induced glaucoma. Systemic steroids are not usually necessary for children. Penalization treatment is not usually effective after surgery, and sutures are usually removed during the initial six postoperative months.

2.5 Strabismus Surgery (Fig. 2.7)

Debate can surround the question of the incision size of the conjunctiva in strabismus surgery. It can be proposed that a wider incision, and thus a wider field of operation, must be made to perform a safe and secure surgery. Conversely, it can be argued that a smaller/narrower incision will result in minimizing the amount of conjunctival damage, thus resulting in rapid cosmetic recovery, with white conjunctiva that is good in appearance. In fact, it has been found that careful management of the outer eye muscles through a small incision can be satisfactorily performed once a physician gains adequate experience with this type of surgery.

2.6 Conclusion

In general, a surgery tends to evolve in the direction of becoming less and less invasive. The same holds true for ophthalmic surgery. The purpose of performing
minimally invasive surgery is to avoid excessive postoperative wound healing, especially in areas with fibrovascular overgrowth. As the conjunctiva is a soft, delicate tissue, surgeons must avoid using invasive surgical modalities that promote excessive wound healing after surgery. One such approach is the use of a small incision. The other approach is the use of AM, MMC treatment, and the postoperative use of immunosuppressives that presumably suppress the TGF-beta signaling pathway and inflammatory cytokine release.
References