A Review of Scleral Flap Shape on Trabeculectomy Outcomes

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Abstract

Introduction: Trabeculectomies are amongst the most common surgical procedures to lower intraocular pressure (IOP). Scleral flap dimensions are a key factor in influencing aqueous outflow and subsequent IOP reduction, especially in the early postoperative period. Despite the substantial diversity of scleral flap shapes that is used in practice, there is little information comparing outcomes between them. In this study, we review the literature on the uses and outcomes of various scleral flap shapes.

Methods: A literature review was performed using the databases: MEDLINE, SCOPUS, and Web of Science. Search terms for relevant studies included the following: trabeculectomy AND (square OR triang* OR rectang* OR polygon* OR arc OR shape) AND flap.

Results: Our initial literature search revealed 71 unique articles, six of which met our inclusion and exclusion criteria and were reviewed. Four articles reported the use of triangular flaps, one rectangular flap, one square flap, and two arc-shaped flaps. The data from each article were reviewed for the following:

1. Surgical technique;
2. Early postoperative intraocular pressure reduction;
3. Final postoperative intraocular pressure reduction;
4. Postoperative complications.

Conclusions: A myriad of scleral flap shapes is utilized in surgical practice. Essentially all of the trabeculectomy procedures, regardless of scleral flap shape, achieved substantial reductions in IOP with similar success rates. However, due to the variability in surgical technique and lack of direct comparison, we cannot definitively conclude or deny that one flap shape is superior to another. We believe our review provides the most comprehensive analysis of scleral flap shape to date and highlights its importance in regulating aqueous flow, especially in the early postoperative period.

Keywords: Trabeculectomy; Glaucoma; Intraocular Pressure; Sclera; Surgical Flap.

Introduction

Trabeculectomies are amongst the most common surgical procedures to lower intraocular pressure (IOP). This procedure creates an outflow tract within the sclera through which aqueous humor can pass. This new drainage pathway filters aqueous humor from the anterior chamber into the subconjunctival space, where the fluid is then either absorbed by conjunctival blood vessels, lymphatics, or passes into the conjunctival tear layer. Ideally, this reduces IOP and prevents further damage to the optic nerve.

Trabeculectomies were first described by Cairns in 1968 and have since undergone several technical modifications. Surgeons may now opt for limbal or fornix-based conjunctival flaps, adjuvant antimetabolite therapy, releasable sutures, etc.

Scleral flap dimensions are a key factor in influencing aqueous outflow and subsequent IOP reduction, especially in the early postoperative period. The most common approach for scleral flap shape, per a survey of American Society of Cataract and Refractive Surgery (ASCRS) members, is the use of a rectangular flap. However, there is considerable variation. Within this same ASCRS cohort, 30% preferred triangular flaps, 3% used parabolic, and 7% were “other.” Conversely, in a review of trabeculectomies performed by residents, the majority opted for triangular scleral flaps (50%), followed by trapezoidal (28%), rectangular (10%), unknown (10%), and square (2%) (Figure 1).

Despite the substantial diversity of scleral flap shapes that are used in practice as well as its
importance in regulating aqueous outflow, few trials have specifically compared outcomes between them. Moreover, the literature often reports no demonstrated superiority between different shaped scleral flaps, but these conclusions seem presumptive given the dearth of comparative clinical trials and absence of review articles. To address this knowledge gap, we have performed a literature review to compare the uses and outcomes of varied scleral flap shapes.

**Methods**

A literature review was performed using several databases, including MEDLINE, SCOPUS, and Web of Science. Search terms for relevant studies included the following: trabeculectomy AND (square OR triangle OR rectangular OR polygon OR arc OR shape) AND flap. Titles and abstracts were reviewed for relevance, and articles were advanced to full text review if they described scleral flap shapes and surgical outcomes in a trabeculectomy procedure. References of relevant publications were reviewed for additional sources. Articles were excluded if they could not be obtained in English, included combined trabeculectomy or microtrabeculectomy surgeries, involved placement of multiple scleral flaps, performed scleral tunnel incisions, or did not use human subjects.

**Results**

Our initial literature search revealed 71 unique articles, six of which were deemed appropriate based on our inclusion and exclusion criteria. Each article was reviewed, and the following data were collected if reported: scleral flap shape, flap dimensions, trabeculectomy technique, preoperative diagnoses, preoperative and postoperative intraocular pressures, and complications.

**Surgical Techniques**

A multitude of scleral flap shapes were described in these studies. Four articles reported the use of triangular flaps, one rectangular flap, one square flap, and two arc-shaped flaps (Table 1).

Sharma et al. performed a randomized clinical trial comparing two groups of patients with 11 eyes each. Trabeculectomies utilizing a 4x4mm triangular scleral flap were compared to those using a 4x3mm rectangular scleral flap. A limbal conjunctival flap was created 8mm posterior to the limbus for both groups. An equilateral triangular 4x4mm scleral flap was created at 12 o'clock to half the depth of scleral thickness, and a 4x3mm rectangular scleral flap was created in the second group. The deep rectangular block (1.5 x 1.5mm) was excised using scissors to complete the trabeculectomy, then followed by peripheral iridectomy. Two interrupted 10-0 nylon sutures were placed at the apices of the rectangle, and a single 10-0 nylon suture was placed at the triangle apex. Tenon's capsule and the conjunctival layer were closed in two layers with running 8-0 Vicryl. Postoperatively, dexamethasone sodium phosphate 2mg and gentamycin 20mg were injected sub-conjunctivally.7

Kimbrough et al. compared triangular and square scleral flaps in 11 eyes each. They report that the surgical techniques for both groups were "identical", with the exception of scleral flap shape and number of sutures placed. Two sutures were used to close the square scleral flap, and one suture was used for the triangular flap.8

Krasnov et al. reported the use of a 4x4mm triangular scleral flap in 300 eyes. A meridional cut was made in the conjunctiva extending from 12 o'clock to the superior rectus muscle insertion. Then a 4 x 4mm triangular, limbal scleral flap was created. A short radial cut was made through the deep scleral layers just behind and perpendicular to the limbus, using a Schnaudigel's instrument. A 1.5 x 4mm strip of scleral tissue was excised parallel to the limbus. One suture was placed at the triangular scleral flap, and the conjunctival incision was closed by continuous suture.9

Hung et al. described the use of a triangular scleral flap. A limbal-based triangular half-thickness lamellar scleral flap, measuring 5 x 5 x 5mm was constructed. A rectangular 4 x 2mm sclero trabecular lamella was excised, peripheral iridectomy was performed, and a single 8-0 virgin silk suture was placed at the triangle apex.10

Koev and Tanev reported results from a 4x6mm arc-shaped scleral flap used in a series of 34 eyes. They first created an arc-shaped conjunctival flap parallel to and 7-8mm from the limbus. A vertical, arc-shaped, non-perforating incision of the sclera was made, of approximately half-scleral thickness. This extended to 4mm from the limbus and with a width of 6mm in the limbal zone. Transpalpebral massage was performed depending on the firmness of the filtering bleb. The scleral strip was 4mm x 1mm from the scleral spur.11 Koev and Tanev also published results from another series of 4x6mm arc-shaped scleral flaps used in 18 eyes. The surgical technique was identical to their previous study.12

**Early Postoperative Intraocular Pressure Reduction**

The postoperative data are listed in Table 2. On postoperative day one, Sharma et al.'s mean IOP for the triangular flap was 12.36 ± 6.74, and mean IOP for the rectangular flap was 11.91 ± 5.49. At postoperative week 1, mean IOPs were 9.91 ± 4.11 and 11.09 ± 6.04 for the triangular and rectangular flaps, respectively.7 At one week, the arc-shaped flaps lowered IOP to 18.32 ± 0.33 and 19.21 ± 0.53; p-values were not reported.11,12

**Final Postoperative Intraocular Pressure Reduction**

Sharma et al.'s results demonstrate a 68.9% IOP reduction and 91% surgical success rate (final IOP < 21 mmHg) in the triangular flap group versus a 66.5% IOP reduction and 82% surgical success rate in the rectangular flap group at three months follow-up. There were no significant differences between...
the two techniques. Kimbrough et al. did not report numerical data for their square or triangular techniques. However, their ANOVA analysis revealed no significant difference on final IOP between the groups. Krasnov et al. reported a 90% surgical success rate when using a 4x4 mm triangular scleral flap. At 3 weeks following triangular flap use, Hung et al. reported that IOP had improved from 30.4 to 10.5 mmHg, achieving a 65.1% reduction. At one-year follow-up, Koev and Tanev (2005) observed a 27.9% IOP reduction, from 26.4 mmHg preoperatively to 19.1 mmHg postoperatively following their use of arc-shaped scleral flap. They also reported a 94.1% surgical success rate in lowering IOP to less than 21 mmHg.

Postoperative Complications

Several complications were reported with the use of all scleral flaps, regardless of shape. These data are presented in Table 3. The most common complications observed were hypotony, hyphema, and flat blebs.

Of those reported, hypotony (IOP < 6 mmHg) developed in 9.1% (1/11) of rectangular scleral flaps, 8.3% (2/24) of triangular scleral flaps, and 0% (0/52) of arc-shaped flaps. Hypotony tended to develop immediately after the surgery and improved spontaneously within one week. Both Hung et al. and Krasnov et al. also reported immediate hypotony following the use of triangular flaps, but they did not report the incidence and implied that these cases resolved.

Hyphema developed in 45.8% (11/24) of triangular flaps, 17.3% (9/52) of arc-shaped flaps, and 9.1% (1/11) of rectangular flaps. Suboptimal blebs were observed with triangular and arc-shaped flaps. 96% (5/52) of arc-shaped flaps were associated with flat blebs, and bleb leaks occurred in 4.2% (1/24) of triangular flaps. Other less commonly observed complications included cataract progression, choroidal detachment, and shallow anterior chambers.

Discussion

In this literature review, we examine the uses and outcomes of variously shaped scleral flaps in trabeculectomies. Essentially all of the trabeculectomy procedures, regardless of scleral flap shape, achieved substantial reductions in IOP with similar success rates. All scleral flap shapes were associated with complications, but triangular flaps were associated with higher rates of hyphema.

Recently, several computational studies have investigated the effect of scleral flap parameters on the dynamics of fluid outflow in trabeculectomy models. Samsudin et al., for example, created a model to simulate and measure trabeculectomy fluid flow and pressure through a number of scleral flap variations. They compared scleral flap shapes (rectangle, square, triangle), scleral flap thickness, and suture number and position. Triangular flaps displayed significantly higher immediate post-procedural pressures compared to rectangular and square flaps. Of note, in these comparisons, the triangular flaps had 3 sutures at the corners, while rectangular and square flaps had only 2. When 5 sutures were used for rectangular and square flaps,
Table 2: Preoperative and postoperative characteristics of patients

<table>
<thead>
<tr>
<th>Publication</th>
<th>Year</th>
<th>Scleral Flap Shape</th>
<th>Preop Diagnoses</th>
<th>Number of eyes</th>
<th>Preoperative Mean IOP (mmHg)</th>
<th>POD #1 IOP (mmHg)</th>
<th>POW #1 IOP (mmHg)</th>
<th>Follow-up Time</th>
<th>Final IOP (mmHg)</th>
<th>Postoperative % IOP reduction</th>
<th>Surgical success (IOP &lt; 21 mmHg +/- gtt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharma et al. 2009</td>
<td>2009</td>
<td>Triangular (equilateral)</td>
<td>ACG, 4 POAG</td>
<td>7</td>
<td>40.64 ± 12.18</td>
<td>12.36 ± 6.74</td>
<td>9.91 ± 4.11</td>
<td>3 mos</td>
<td>12.64 ± 3.98</td>
<td>68.9%* (p = 0.001)</td>
<td>91%</td>
</tr>
<tr>
<td>Rectangular</td>
<td></td>
<td></td>
<td>ACG, 3 POAG</td>
<td>11</td>
<td>41.27 ± 13.36</td>
<td>11.91 ± 5.49</td>
<td>11.09 ± 6.04</td>
<td>3 mos</td>
<td>13.82 ± 2.44</td>
<td>66.5%* (p = 0.001)</td>
<td>82%</td>
</tr>
<tr>
<td>Kimbrough et al. 1982</td>
<td>1982</td>
<td>Triangular</td>
<td>POAG (20/22), SOAG 2/2 steroidal use (2/2)</td>
<td>11</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR, but no statistically significant difference on final IOP between 2 groups</td>
<td>NR</td>
</tr>
<tr>
<td>Square</td>
<td></td>
<td></td>
<td></td>
<td>11</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR, but no statistically significant difference on final IOP between 2 groups</td>
<td>NR</td>
</tr>
<tr>
<td>Krasnov et al. 1974</td>
<td>1974</td>
<td>Triangular</td>
<td></td>
<td>300</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>1 year</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Hung et al. 1985</td>
<td>1985</td>
<td>Triangular</td>
<td>OAG, 1 acute ACG</td>
<td>13</td>
<td>30.4</td>
<td>5.6</td>
<td>8.0</td>
<td>3 weeks</td>
<td>10.6</td>
<td>65.1%</td>
<td>NR</td>
</tr>
<tr>
<td>Koev &amp; Tanev 2006</td>
<td>2006</td>
<td>Arc</td>
<td>OAG, 3 ACG</td>
<td>18</td>
<td>NR</td>
<td>NR</td>
<td>18.32 ± 0.33</td>
<td>1 year</td>
<td>18.23 ± 0.22</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Koev &amp; Tanev 2005</td>
<td>2005</td>
<td>Arc</td>
<td>OAG, 5 ACG</td>
<td>34</td>
<td>26.42 ± 0.66</td>
<td>NR</td>
<td>19.21 ± 0.53</td>
<td>1 year</td>
<td>19.05 ± 0.38</td>
<td>27.9%</td>
<td>94.12%</td>
</tr>
</tbody>
</table>

the pressure differences between these and triangular flaps were no longer significant.

The authors also demonstrated that, as the number of sutures placed was increased, the post-procedural pressure reduction decreased. Finally, pressure was significantly and linearly influenced by scleral flap thickness across shapes, such that thicker flaps corresponded to higher pressures.

The authors in this study ultimately conclude that rectangular and square flaps achieve greater reductions in pressure than triangular flaps, which they attribute to differences in surface area. However, it is important to bear in mind that all four of the studies that we reviewed that used triangular flaps placed only one suture at the apex, as opposed to three in this study. Although Samsudin et al. measured fluid flow in triangular flaps with one suture, they did not directly compare pressures between the one suture triangular flap and the other shaped flaps, which may resonate less with current clinical practice.

Tse et al. performed a similar study using computational models to compare pressure and flow through a variety of scleral flaps and sclerostomies. The scleral flaps differed in shape (square, rectangular, triangular, and semicircular), size, and thickness. Their results demonstrated that, when comparing similarly sized scleral flaps, triangular flaps had less aqueous drainage than square flaps. They also found that increasing flap thickness reduced aqueous outflow, while increasing flap size led to greater aqueous outflow. Interestingly, they observed that semicircular sclerostomies facilitated greater aqueous outflow than circular sclerostomies, and that smaller apertures achieved greater outflow than larger sclerostomy openings. The authors conclude that optimal outflow in the early postoperative period can be achieved using either a square, wide superficial flap with a small sclerostomy or a high flap-to-sclerostomy ratio to optimize outflow in the early postoperative period. Again, however, their triangular flaps utilized three sutures, which differs from the one suture typically used in practice. As Samsudin et al. demonstrated, increasing the number of sutures restricts outflow, so it is likely that these three sutured-models are inflating the pressures we would see in actual practice with the...
Table 3: Postoperative outcomes and complications

<table>
<thead>
<tr>
<th>Publication</th>
<th>Year</th>
<th>Scleral Flap Shape</th>
<th>Follow-up Time</th>
<th>Hypotony (IOP &lt; 6 mmHg)</th>
<th>Other Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharma et al.</td>
<td>2009</td>
<td>Triangular (equilateral)</td>
<td>3 mos</td>
<td>2/11 (18%) [improved spontaneously &lt; 1 week]</td>
<td>Hyphema (2/11, 18%), bleb leak (1/11, 9%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rectangular</td>
<td>3 mos</td>
<td>1/11 (9%) [improved spontaneously &lt; 1 week]</td>
<td>Hyphema (1/11, 9%), cataract progression (1/11, 9%)</td>
</tr>
<tr>
<td>Kimbrough et al.</td>
<td>1982</td>
<td>Triangular</td>
<td>NR</td>
<td>NR</td>
<td>“transient, non-severe, not related to scleral flap utilized”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Square</td>
<td>NR</td>
<td>NR</td>
<td>Shallow AC (“Several”), usually associated with choroidal deachment</td>
</tr>
<tr>
<td>Krasnov et al.</td>
<td>1974</td>
<td>Triangular</td>
<td>1 year</td>
<td>immediate hypotony effect “good”</td>
<td>Hyphema (9/13, 69.2%) resolved spontaneously &lt; 7 days, cho- roidal detachment (3/13, 23%) resolved spontaneously &lt; 21 days</td>
</tr>
<tr>
<td>Hung et al.</td>
<td>1985</td>
<td>Triangular</td>
<td>3 weeks</td>
<td>Yes (on POD #1 &amp; 3, increased at later follow-up, [incidence NR])</td>
<td>Hyphema (3/18) 16.7%, Flat bleb 2 (11.1%), Choroid detachment 1 (5.5%)</td>
</tr>
<tr>
<td>Koev &amp; Tanev</td>
<td>2006</td>
<td>Arc</td>
<td>1 year</td>
<td>None</td>
<td>Hyphema (6/34, 17.6%), flat bleb (3/34, 8.82%), choroidal deattachment (1/34, 2.94%)</td>
</tr>
</tbody>
</table>

References