SCLERAL GRAFTS IN OPHTHALMIC SURGERY. A REVIEW

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SUMMARY

Aim: To summarize the history and current trends in the use of scleral grafts in ophthalmology.
Materials and methods: We conducted a review of the literature through the MEDLINE and Cochrane Library databases. The search terms were "sclera", "graft", and "surgery". The search resulted in 1596 articles, of which we evaluated 192 as relevant. The relevant articles were sorted chronologically and according to the method of using scleral grafts, which enabled the development of a review article.
Results: The sclera has been routinely used in ophthalmology since the 1950s in many different indications. Some of these indications have become practically obsolete over time (for example, use in the surgical management of retinal detachment), but a large number still find application today (especially use in glaucoma or oculoplastic surgery, or as a patch for a defect in the sclera or cornea).
Conclusion: Even though allogeneic sclera is currently used less frequently in ophthalmology compared to other tissue banking products and the range of its indications has partially narrowed, it remains a useful material due to its availability and properties.
Key words: sclera, graft, surgery, ophthalmology, review

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INTRODUCTION

The sclera is formed during embryonic development from the cells of the neural crest, and together with the cornea it forms the tunica fibrosa oculi. It constitutes approximately five sixths of the surface of the eyeball, and similarly to the cornea is composed especially of type 1 collagen fibers, which, however, in the case of the sclera are not regularly organized, with the result that unlike the cornea it is not transparent. It also contains only a relatively small quantity of cells and blood vessels. It is made up of four layers – the episclera, the stroma, the lamina fusca and the endothelium. The thickness of the sclera is 0.3–1.0 mm, reaching the highest values in the region of the posterior pole, and the lowest in the surrounding area of the tendons of the oculomotor muscles.

With regard to its structure, which gives it strength as well as relatively low antigenicity and low susceptibility to rejection thanks to the small quantity of blood vessels and cells, the sclera has long been considered promising material. It can be used in ocular surgery, not only in autologous but also in allogeneic transplantation.

MATERIAL AND METHODS

During the compilation of this review article we conducted an analysis of the literature through the MEDLINE and Cochrane Library databases. The search terms were “sclera”, “graft”, and “surgery”. The search resulted in 1596 articles, of which we evaluated 192 as relevant. The relevant articles were sorted chronologically and according to the method of using scleral grafts, which enabled the compilation of this review article. The sources of the articles we found were also investigated for the purpose of potentially finding further relevant sources of literature which were not identified during the original search.

THE FIRST MENTIONS OF THE USE OF THE SCLERA

The first mention of the use of the sclera in ophthalmic surgery originates from the 1940s, when Costa published an article on the subject of subconjunctival scleral grafts [1], and Larsson described the treatment of corneal per-

foration with the aid of a patch from an autologous sclera [2]. In the following years, further authors including Kurz [3,4] focused on compensating for a defect in the cornea by means of a scleral graft. Another possible use of the sclera was described at the beginning of the 1950s by Paufique, who made use of a scleral patch in the surgical treatment of scleromalacia [5].

Originally, autologous [2] or fresh allogeneic tissue [6,7] was used exclusively. However, the 1950s and 60s saw a period of precipitous development of tissue banking, which thanks to new methods of conservation and storage of tissues enabled a previously unimaginable expansion of the use of allogeneic tissues in ophthalmic surgery, which related also to the sclera. In 1961 Payrau was the first to publish the use of a lyophilized sclera [8]. In 1962 Rodriguez-Vasquez then described the use of a sclera conserved in xylol [9], in 1964 Wilson published the use of a sclera conserved in glycerol [10], and in 1965 Knobloch described the use of a sclera conserved in ethanol [11]. These new procedures enabled a further dramatic expansion of the possibilities of using the sclera in ophthalmic surgery.

CORNEAL DEFECTS

As mentioned in the introduction, one of the oldest available publications describing the use of the sclera in ophthalmology is Larsson's article from 1948, which outlines its successful use for the closure of a corneal defect upon the background of a corneal ulcer [2]. In the 1950s his study was followed up by further authors including Kurz [3,4]. Even despite the fact that this is a rather rare method it still has its application, and in very complicated cases or in case of a lack of other options it is still used to this day for the closure of corneal perforations of various etiology [12–22]. An interesting fact is that after implantation into the cornea, the sclera has a tendency towards translucency [3,13,15]. In addition, in contrast with corneal grafts, only a thin scleral patch is required for closing the defect, thanks to which, according to Prydal, more rapid visual rehabilitation takes place upon use on the corneal periphery, at the same time with lesser induced postoperative astigmatism [15].

DEFECTS AND THINNING OF THE SCLERA, INCLUDING SCLEROMALACIA

The surgical treatment of scleromalacia with the aid of a scleral patch was described by Paufique as early as in 1953 [5], and his work was progressively followed up also by other authors [7,23]. Over the course of the following years, methods of treating immune-conditioned [24–30], surgically induced – most often as a consequence of a pterygium removal surgery [8,28,31–40], infectious [41–46], post-traumatic [40,47] and post-irradiation [35,37,48–50] scleral thinning were successfully described.

In 1959 Kanagasundaram published the possibility of using a scleral graft in the treatment of a traumatic rupture of the eyeball [6]. In this indication also, the sclera continued to be used frequently [51,52]. Karaca described good results in the treatment of penetrating ocular trauma with the use of only an autologous lamellar scleral graft [22]. Turaga again described the successful use of a scleral patch in a patient with Marfan syndrome who was suffering from recurrent spontaneous ruptures of the eyeball [53].

Reconstruction of the orbital wall following extensive resection procedures, most often due to melanoma of the uvea, became another common indication for the use of scleral or sclerocorneal grafts. The first to describe this technique was Tarkkanen in 1967, in an surgery of melanoma on the limbus [54], after which other authors also described the possibility of reconstruction, for example following corneoscleroiridocyclectomy for melanoma of the ciliary body [55,56] or following sclerochoroidoretinectomy for melanoma of the choroid [57]. It is possible to use an analogous procedure to treat squamous cell carcinoma [58] or benign tumors – for example limbal dermoid [59,60]. Rare indications to have been described include reconstruction of the eye following resection of Kaposi's sarcoma of the anterior segment of the eye in a child following bone marrow transplant for acute lymphoblastic leukemia [61].

At present the use of a scleral graft for treating a defect or thinning of the sclera remains a highly relevant technique. Alternatively, it is possible to use the fascia lata femoris [27,62], periosteum [45], perichondrium [63,64], pericardium [65–67], temporal fascia [68], buccal mucosa [49,69], tarsoconjunctival flap [70], amnion [71,72] or cornea [71,73–75].

SCLEROPLASTY

The option of treating progressive myopia in children with the aid of scleroplasty using a scleral graft was first published by Borley in 1958, and his work was then followed up by further authors [76–80]. In 2018 Xue published good results upon the use of an allogeneic sclera treated with the crosslinking method [81].

Other biological materials are also used as an alternative in scleroplasty, for example preparations from porcine (pig) skin [82], the dura mater [83] or lyophilized fascia lata femoris [84], as well as synthetic materials (Gore-Tex) [80].

VITREORETINAL SURGERY

Based on the study by Rodriguez-Vasquez from 1962 [9], the sclera was used for a long time as an alternative material in retinal detachment surgery with an external approach, and in the following years it was successfully used in this indication with various modifications also by further authors [10,11,85–89].

With regard to the fact that today the gold standard in the treatment of retinal detachment is considered to be pars plana vitrectomy [90], and in the case of surgery with an external approach synthetic materials are used

in the overwhelming majority of cases – including silicone, hydrogel, and Gore-Tex [91,92], the use of the sclera in this indication is now practically obsolete.

Another innovative use of the sclera in vitreoretinal surgery was published by Shah in 2017. This describes the possibility of treating macular edema caused by an optic nerve pit through the implantation of a scleral graft for the purpose of closing the pit [93].

OCULOPLASTIC SURGERY

Within the field of oculoplastic surgery the sclera found its first use in 1968, when Helveston published the results of the treatment of extrusion of an orbital implant in patients following enucleation by means of covering with a scleral patch [94]. A large number of studies have been published on this subject over the course of the years [95–103], and the sclera is still used to this day in this indication in various modifications. With regard to the highly positive results of these operations and relatively frequent extrusions, mainly in the case of certain types of orbital implants (especially implants made of hydroxyapatite), Soll published a study in 1974 in which he described a very good outcome upon covering orbital implants with a scleral patch already in the primary operation [104]. This technique also became established, and in the following years several other authors also published their results [105–110]. A less frequent possibility of the use of the sclera in patients following enucleation was described in 1983 by Smith, who used it as a filling material upon atrophy of the orbital tissues [111].

Alternative materials used for covering implants are the fascia lata femoris [101], bovine pericardium [107,112], labial mucosa [113] or Vicryl mesh [114].

Another possibility for use of the sclera in oculoplastic surgery was described by Bodian in 1968 [115]. In frontalis suspension surgery for the purpose of correcting ptosis he used a fresh or conserved sclera as an alternative to the fascia lata femoris. His work was followed up in 1975 by Helveston, who recommended reinforcing the sclera with a non-absorbable suture [116].

However, at the present time substantially more commonly used materials in frontalis suspension surgery include especially the aforementioned autogenous or allogeneic fascia lata femoris [117–119] and synthetic materials such as silicone, Gore-Tex or polypropylene [119–121].

Another indication for use of the sclera is replacement of the posterior lamella of the eyelid upon treatment of cicatricial entropion, which was first published by Tenzel and Rubenzik in 1975 [122,123], and followed on from in the following years also by several other authors [124–126]. It is possible to use an analogous procedure, namely replacement of the posterior lamella of the eyelid with a sclera, also for retraction of eyelids of various etiology (including thyroid eye disease), which was first published by Crawford in 1976 [127], and subsequently by several more authors [124,128–136], or more extensive defects following resection procedures, for example as part of modification of the Cutler-Beard procedure [137,138], or following resection due to severe ligneous keratoconjunctivitis [139].

In general the consensus predominates among authors that in the case of replacement of part of the eyelid with a sclera it is necessary to use an implant of larger dimensions than the specific defect, because contraction of the scleral graft will take place over the course of time [123,129].

Use of the sclera upon treating retraction of the eyelids upon a background of thyroid eye disease in particular continues to be a highly topical and widely used method. Alternative materials that can be used successfully to replace the posterior lamella of the eyelid include also synthetic materials such as porous polyethylene (Medpor) [136], free tarsoconjunctival flap [135], mucosa of the hard palate [135,136], tragal cartilage (taken from the ear tragus, usually as an autotransplant) [136,138] or acellular dermal matrix (AloDerm) [136]. In patients following resection of the eyelids, an autologous graft from the periosteum of the orbital rim is frequently used, which at the same time provides fixation to the bone and is thereby advantageous for reconstruction especially of the lateral canthus [140].

GLAUCOMA SURGERY

Nesterov was the first to use the sclera in the surgical treatment of glaucoma. In his study from 1978 he described the method of implantation of scleral strips into the supraciliary space, if necessary in combination with the performance of cyclodialysis [141].

In 1987 Fredman published the possibility of preventing extrusion of a Molteno implant by means of covering with a sclera [142], which is a commonly used method to this day in the covering of glaucoma implants, published in a number of different variations also by other authors [143–154]. Lam described the covering of an Ahmed valve in an analogous manner [143], Aslanides proposed the use of an autologous sclera in this indication due to better availability [144], and Zeppa published a modification with fixation of the sclera with the aid of tissue adhesive [155].

Other materials to have been used successfully in the covering of glaucoma implants are the pericardium [145,148,150,156–159], dura mater [145,146], cornea [152,154,156,157,160,161], tragal perichondrium [162], collagen implant Ologen [163], fascia lata femoris [157] or amniotic membrane [157,158]. If necessary it is possible to insert the implant into a scleral tunnel, in which case no further covering implant is required [151,157,164,165]. In recent times the cornea especially has demonstrated itself to be an advantageous alternative in this indication due to its good availability (as a waste product of refractive surgery) and its good cosmetic effect [152].

Another very common indication for use of the sclera in glaucoma surgery is the treatment of postoperative complications. In 1991 Melamed published the method of treating persistent leakage from a filtration bleb with the aid of a scleral patch [166], which is a technique used to this day in the case of leakage or excessive filtration, and has been described by several other authors [167–179]. In 2009 King proposed a modified technique with only a small scleral patch fixed with tissue adhesive [176]. A scleral patch can be used effectively also to treat extrusion of a glaucoma implant [180,181], and if necessary it can be used in revision for postoperative blebitis with endophthalmitis [182].

In the treatment of complications with a filtration bleb, alternatives to the sclera used successfully in the past also include the fascia lata femoris [183], cornea [183,184], dura mater [183], pericardium [183], acellular dermal graft [183], buccal mucosa [183], tragal perichondrium [183], amniotic membrane [183], polytetrafluorethylene [183] or Ologen [183].

Another proposed option for use of the sclera in glaucoma surgery is its implantation in deep sclerectomy, which was described in the past by Devloo and subsequently by Mousa [185,186].

OTHER INDICATIONS

Scleral or sclerocorneal grafts can also be used in the treatment of postoperative or post-traumatic epithelial ingrowth into the anterior chamber of the eye, which was first published by Naumann in 1992 [187] and subsequently by Forster and Rummelt, who also used this technique successfully [188,189].

A relatively new method was described in strabismus surgery, which was published by Thorisdottir in 2018. In complicated cases a scleral strip is used successfully for configuring the length of the oculomotor muscle [190,191].

STATISTICAL DATA

In order to demonstrate the frequency of use of the sclera in various indications in real conditions of modern ophthalmic surgery, here we present data from Catalonia, which was published in a review article from the year 2020 by Sabater-Cruz and her team [192]. This data shows us that out of a total number of 874 grafts, 77.5% were used in glaucoma surgery, 5.2% in oculoplastic surgery, 5% in the treatment of defects of the cornea and sclera, 3.8% in reconstructions of the eyeball and 2.9% in covering orbital implants. The authors describe an increasing trend in the use of the sclera in reconstructions of eyelids, and conversely a decreasing trend in its use in the treatment of defects of the cornea and sclera.

CONCLUSION

As ensues from the studies presented above, over the course of the last approximately 80 years the sclera has been used in several different indications. Some of these are now practically obsolete (for example its use in retinal detachment surgery with an external approach), some rather rare (closure of corneal perforation), but in many other cases the sclera continues to be either the unequivocal method of choice (especially its use in glaucoma surgery, as well as treatment of retraction of the eyelids, extrusion of ocular implants or a scleral defect), or at least a relevant variant in the case of unavailability of otherwise frequently used material (for example the treatment of extensive defects of the eyelids or scleroplasty). Its main advantage is its good mechanical properties and low immunogenicity thanks to its high collagen content and only minimal content of blood vessels and cells. As a result, even despite the fact that it is now used relatively less frequently in comparison with other tissue banking products, it remains a useful material with further future potential for use in ophthalmic surgery.

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