Scleral buckling biomaterials and implants for retinal detachment surgery

Francesco Baino*

Materials Science and Chemical Engineering Department, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy.

*Correponding author: Francesco Baino

Tel.: +39 011 564 4668

Fax: +39 011 564 4699

Abstract

Scleral buckling is a widely used surgical procedure that aims at repairing retinal detachments. Many materials and procedural techniques have been variously proposed and tested in an attempt to find the best combination for providing optimal results to the patient. This review highlights the evolution of scleral buckling implants and chronicles the main advances that have been made in such a context. Specifically, the limitations of the materials and implants fallen in disuse, as well as the advantages of currently adopted devices are critically examined and discussed. Future directions for the research are considered, underlining in particular the great potential carried by the development of accurate mathematical models for describing the postoperative evolution of buckled eye. These analytical models, supported by a comprehensive data set provided by advanced techniques of medical investigations, may become useful tools for helping surgeons to choose, and to design if necessary, the best buckling material and configuration to be used in each specific clinical case.

Keywords: Retina; Scleral buckle; Biocompatibility; Eyeball deformation.

tolerated, thereby demonstrating a good biocompatibility, except for the study of Sheu et al. who reported complications associated to massive strong adhesion [81].

In the early 2000s, silicone bands coated with porous e-PTFE have been tested with quite opposite outcomes. Roldan-Pallares et al. [82] used e-PTFE-coated silicone buckles in 32 patients affected by RRD and reported an excellent material biocompatibility without complications throughout the whole follow-up period (11 months). On the contrary, Mortemousque et al. [83,84] reported massive adhesions between material and surrounding tissue accompanied by local inflammatory reaction; the porous e-PTFE layer was also colonized by inflammatory cells and granulomas with calcium deposits were observed.

5.5. Hydrogels

Since the early 1970s, three type of hydrogels, i.e. poly(glyceryl methacrylate) (PGMA), poly(2-hydroxyethyl acrylate) (PHEA) and poly[methyl methacrylate-*co*-(2-hydroxyethyl methacrylate)] (MAI), have been widely tested in scleral buckling procedures [10,85-91] and MAI has been commercially available under the name of Miragel for several years. Hydrogels, thanks to their softness, ease of shaping and defined swelling under hydration, have been considered for many years as the revolutionary materials in scleral buckling surgery. Some authors also emphasized the potential of hydrogels to act as devices for the *in situ* release of hydrophilic drugs, which could be an additional advantage over solid silicone implants in controlling infections [92]. After the initial enthusiasm, however, many surgeons realized progressively that hydrogel buckles could induce severe mid-term and long-term complications [93-99]. Specifically, PGMA was found to suffer from a lack of tensile strength when swollen and PHEA exhibited a dramatic tendency to fragment after swelling [95]. MAI implants, which could be placed both intrasclerally and episclerally, seemed to offer better bulk features and were found to promote the formation of a strong surrounding capsule of connective tissue [45,47,100,101]; although after 3 weeks from implantation

a mild inflammatory response was generally detected, after 3 months almost no inflammatory cells were found [88]. In spite of their excellent biocompatibility, however, in many cases MAI buckles need to be removed due to foreign body sensation, ocular motility limitations, subconjunctival bulge or pain complained by patients [96,97,99]. These drawbacks were essentially ascribable to hydrogel overexpansion: Oshitari et al. quantified this problem and reported that the cross-sectional area of MAI implant could increase up to 185% due to excessive swelling [97]. In addition, experimental studies carried out in both rabbits and humans demonstrated that MAI implant became surrounded by a capsule of connective tissue, but the inner surface of this capsule was irregular due to the presence of hydrogel debris and foreign body giant cells, which indicated material fragmentation [45,47,100,101]. Therefore, also MAI implants have been progressively fallen in disuse, particularly due to buckle degradation and friability occurring after about 10 years, as reported by several researchers [93,94,98].

5.6. Other non-absorbable buckling materials

Materials different from those described in the previous sections have been occasionally used for permanent buckles manufacturing (Table 1).

In 1937 a cotton gauze pad was used to temporarily indent the eye wall for approximating the retinal layer with the choroid: this is considered the first procedure of scleral buckling, but tissue reactions to the material were not studied [102].

In 1958 Arruga tested nylon braided threads, commercially known as Supramid®, as encircling elements to overcome the drawbacks related to PE tubes [103]. It should be underlined that these threads were not properly used as a "buckle" but rather for suturing the wall of the eye to create a "fold" which then created a buckling effect. Moderate inflammatory reaction was observed by both Arruga [103] and Witschel et al. [104] around the implant, but the material could cause erosion of the underlying sclera, thereby leading to intrusion to the choroid (the so-called "string-syndrome").