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Influence of operating parameters on the suture retention test for scaffolds in ophthalmology

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ABSTRACT

The strength of a suture used to attach a graft to a patient can be quantified using the suture retention test. In order to gain deeper insight on the influence of testing and application conditions testing parameters were varied. Different pull rates, suture and jaw positions, and suture materials were tested to show their influence on the result of the test. The results of the different states were analyzed using statistical tests. Based on the statistic analysis conditions for testing with a maximum of accuracy and as close as possible to in vivo conditions have been revealed.

1. Introduction

Grafts are often used in ophthalmology in order to restore or improve the sight of a patient. Depending on the needs of the patient there are various different grafts available including donor tissue, human based biomaterials, and synthetic grafts. Because many of the grafts still are based on human donor tissue, there are various approaches for developing novel grafts of a different origin [1–4]. A requirement of any graft is the ability to be attached to a patient, therefore the graft is normally sutured to the native tissue [5].

In order to be sutured a graft may not burst, crack, or tear when the needle is passed through the graft and must be able to resist suture tear out under its workload. Because suture tear out is of crucial importance a suture retention test is used on cardiac vascular grafts [6–9]. There is a big difference between the tubular geometry of a vascular graft and the disk to dome like geometry of grafts used in ophthalmology. Further the size of the ophthalmologic grafts usually is smaller than a cardiac vascular graft. Therefore the suture retention test was modified to match ophthalmologic grafts and first results were shown in previous work [10]. There are several factors potentially having impact on the results of the modified suture retention test.

For instance it is well-known that the pull rate of a tensile test affects its results [11–13]. Because the suture retention test is basically a strongly modified tensile test the pull rate is considered to be a parameter of crucial importance. Furthermore the pull rate is of importance for any graft placed on the eye's surface, where it will have to face the movement of the eyelid with an average speed of 51.9 ± 21.6 mm/s when closing and an average speed of 32.6 ± 11.6 mm/s when opening [14]. Each time the patient blinks the graft will have to face a pressure of 1.07 ± 0.45 kPa on an area of 1.14 mm^2 [15]. This means a force of 1.22 ± 0.51 mN will be applied with the mentioned rates.

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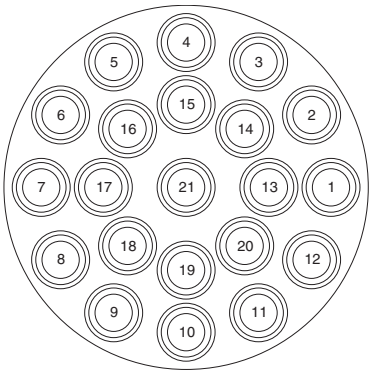


Fig. 1. Pattern with circles in 1 mm and 3 mm to the sample rim.

In surgery the choice of the suture is up to the surgeon and often based on personal experience or recommendations from literature [16–18]. According to the rules of mechanical engineering a suture of a smaller diameter should cause a higher local stress to the graft when the same force is applied. Due to the higher local stress an earlier material break down is expected for smaller suture diameters.

Like the choice of the suture material the position of the suture is determined by the surgeon's decision. Again there are recommendations from literature for different types of surgeries [19–21]. This means the distance of the suture to the rim of the graft will vary and its influence on the mechanical properties of the graft needs to be known.

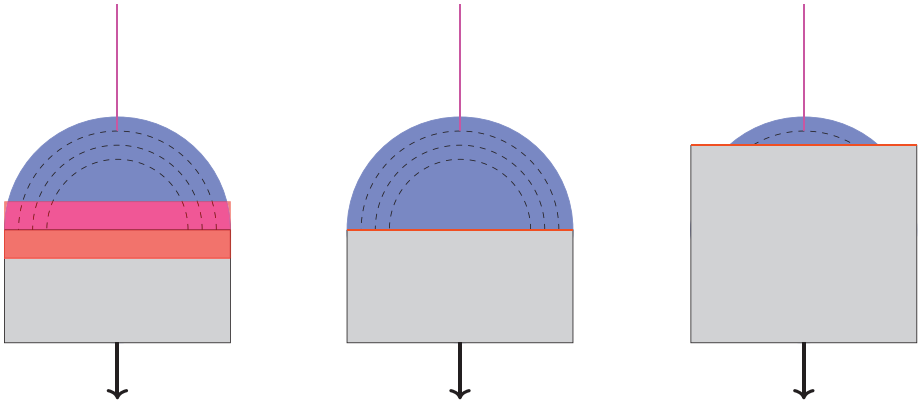
Also the distance of the clamp to the suture is important because the amount of material that can be deformed by the applied force is depending on this position.

Using these parameters the experimental setup can be tuned towards two important aspects. The first aspect is to improve the reproducibility of the results by decreasing the variance. The second aspect is to mimic the application state as close as possible. This includes information about the influence of the surgeon's choices during the operation on the material's reaction.

2. Materials and methods

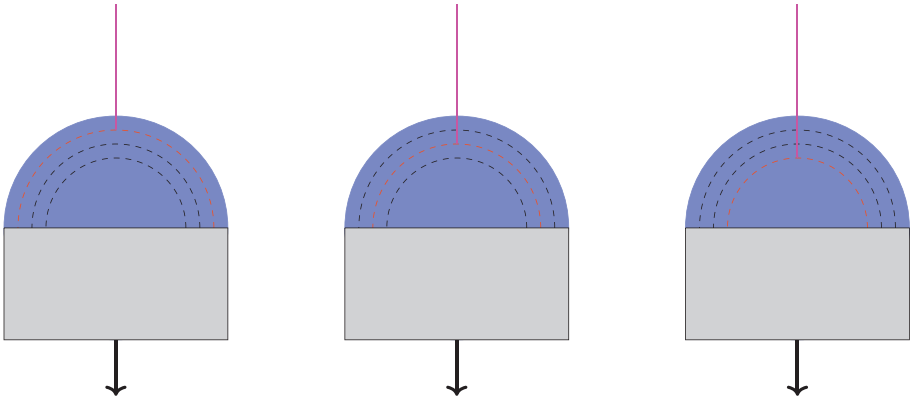
2.1. Suture materials

Suture materials used in the every-day practice in eye departments have been studied: Polyglactin 910 4-0 (Vicryl Polyglactin 910 Suture, Johnson & Johnson Medical GmbH, Norderstedt, Germany) with a minimum diameter of 150 µm, Nylon 8-0 (Ethilon Nylon Suture, Johnson & Johnson Medical GmbH, Norderstedt, Germany) with a minimum diameter of 50 µm, and Nylon 10-0 (Ethilon Nylon Suture, Johnson & Johnson Medical GmbH, Norderstedt, Germany) with a minimum diameter of 20 µm sutures have been purchased.



(a) Near center (b) Exact center (c) Near suture

Fig. 2. Different locations of the jaw.



(a) Suture distance of 1.0 mm (b) Suture distance of 2.0 mm (c) Suture distance of 3.0 mm

Fig. 3. Different suture distances.