

Diploma Thesis

**Comparison of 27-gauge vs 23-gauge vitrectomy in
epiretinal membrane surgery**

submitted by

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Affidavit

I declare in lieu of oath that this diploma thesis is entirely my own work except where otherwise indicated. The presence of quoted or paraphrased material has been clearly indicated and all sources have been quoted.

Graz, 11.12.2021

Tom Müller m.p.

Aknowledgements

I thank my supervisor for the great support during my work for this diploma thesis!

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Zusammenfassung

Einleitung

Die minimal invasive Pars Plana Vitrektomie mit Membranpeeling ist die Standardtherapie bei epiretinalen Membranen. Die dafür verwendeten Instrumente wurden immer dünner wobei damit auch erhöhte Instabilität und reduzierter Fluss verbunden ist. Typische Lumina, die für diese Operation verwendet werden sind 23-, 25- und 27-Gauge. Ob kleinere Durchmesser zu längeren Operationszeiten führen, wird widersprüchlich diskutiert.

Methoden

In dieser retrospektiven, monozentrischen Studie wurde die 23-Gauge mit der 27-Gauge Vitrektomie bei idiopathischen epiretinalen Membranen verglichen. Alle Operationen die in dieser Studie inkludiert wurden, wurden von demselben erfahrenen Chirurgen durchgeführt. 104 Augen (104 Patientinnen und Patienten) mit 23-gauge Vitrektomie und 109 Augen (109 Patientinnen und Patienten) mit 27-gauge Vitrektomie wurden hinsichtlich Operationszeit, prä- und post-operativem bestkorrigiertem Visus, Veränderung der zentralen Netzhautdicke und Komplikationen innerhalb eines Jahres nach Operation verglichen.

Ergebnisse

Die Operationszeiten zwischen der 23-Gauge (17 Minuten) und 27-Gauge (18 Minuten) Gruppe wiesen keinen signifikanten Unterschied auf ($p > 0,05$). In einer Subgruppen-Analyse blieb das Ergebnis gleich für die Vitrektomien mit gleichzeitiger Katarakt Operation, allerdings war das Ergebnis für Patienten und Patientinnen die keine gleichzeitige Katarakt Operation erhielten nicht eindeutig. Endophthalmitiden traten in der 23-Gauge Gruppe in 1 Prozent und in der 27-Gauge Gruppe in 2,8 Prozent der Fälle auf ($p > 0,05$).

Der bestkorrigierte Visus verbesserte sich in der 23-Gauge Gruppe von 0,4 logMAR (Snellen Equivalent 0,4) und in der 27-Gauge Gruppe von 0,3 logMAR (Snellen Equivalent 0,5) auf postoperative Werte von 0,2 logMAR (Snellen Equivalent 0,63). In beiden Gruppen zeigte sich eine signifikante ähnliche Reduktion der zentralen fovealen Netzhautdicken, verglichen mit präoperativen Werten.

Zusammenfassung

Die Ergebnisse unsere Studie zeigen ähnliche Operationszeiten und Erfolgsprofile für die 23-Gauge und 27-Gauge Pars Plana Vitrektomie.

Abstract

Introduction

Small incision pars plana vitrectomy is the standard of care for epiretinal membranes. As the instruments and their lumina have been becoming smaller trade-offs between minimal invasiveness and flow restriction are becoming more salient. The lumina typically used range from 23-gauge to 27-gauge. There is conflicting evidence regarding the impact of gauge on the duration of surgery.

Methods

This retrospective single center, single surgeon study compared 23-gauge and 27-gauge vitrectomy for idiopathic epiretinal membranes. 104 eyes (104 patients) for 23-gauge vitrectomy and 109 eyes (109 patients) for 27-gauge vitrectomy were analyzed in terms of surgery time, pre- and post-operative best corrected visual acuity, change of central foveal thickness and complications within one year after the surgery.

Results

The surgery times between the 23-gauge and 27-gauge group did not differ significantly, being 17 and 18 minutes respectively ($p > 0,05$). In a subgroup analysis, this remained true for vitrectomies with concurrent cataract surgery, but in the small subset of patients without concurrent cataract surgery the data was inconclusive. Endophthalmitides occurred in 1 percent and 2,8 percent in the 23-gauge and 27-gauge group respectively ($p > 0,05$).

The visual acuity improved for the 23-gauge group from 0,4 logMAR (Snellen equivalent 0,4) and for the 27-gauge group from 0,3 logMAR (Snellen equivalent 0,5) to postoperative values of 0,2 logMAR (Snellen equivalent 0,63). The central foveal thickness decreased significantly after the surgery compared to pre-operative values similarly in both groups.

Conclusion

23- and 27-gauge pars plana vitrectomies showed similar surgical times and success profiles.

Introduction

Three port pars plana vitrectomy is the main stay treatment for epiretinal membrane surgery. For this purpose, various calibres of instruments are used, they now commonly range from 23 to 27 gauge. Smaller trocar systems have the advantage of a less invasive approach, but larger trocar systems provide more stable instruments and higher flow rates. Recent improvements to vitrectomy systems aim to overcome some of the drawbacks of small gauge vitrectomy, that is 27 gauge currently. However, due to their recent introduction to the market there is little data regarding many aspects.

The purpose of this diploma thesis is to compare the duration of the surgery with a 23-gauge system to a 27-gauge system for epiretinal membrane surgery by a single surgeon. The secondary outcome measurements were best corrected visual acuity (logMAR) before and after the surgery, intraocular pressure after the surgery and possible complications within one year after the performed surgical intervention.

Epiretinal Membranes

Synonyms for epiretinal membranes are macular puckers and cellophane maculopathy. An epiretinal membrane is a fibrocellular, avascular, translucent membrane that proliferates in the vitreomacular interface. [1][2]

Causes for the membrane include idiopathic forms, which are the most common, and secondary forms after retinal detachments, retinal laser treatment or trauma.

The pathogenesis of idiopathic epiretinal membranes is not completely understood and various theories have been suggested to explain the development and proliferation of the membranes.

As 95 percent of the idiopathic cases have had a posterior vitreous detachment, a widely accepted theory suggests that the posterior vitreous detachment causes breaks in the internal limiting membrane and subsequently enables cells to migrate from retinal layers to the innermost surface of the retina, where they start to proliferate. However, the

explanations are challenged as breaks in the internal limiting membrane are exceedingly rare.

Another theory proposes that the vitreous liquification and shrinkage outpaces the weakening of the vitreoretinal adhesions and therefore causing abnormal posterior vitreous detachment with tractions and vitreoschisis. Tissue and cells from the cortex of the vitreous remain attached to the retina and are stimulated to proliferate and grow due to cytokines induced by the vitreoretinal tractions. Examples for these cytokines are nerve growth factor and basic fibroblast growth factor. It is also proposed that the remaining vitreous cells stimulate the migration of other cells through the internal limiting membrane.

The predominant cell type are glial cells, but the exact aetiology remains unclear, as the cells are able to transdifferentiate. Research and certain evidence exist that these glial cells originate from astrocytes or Müller cells. Another type of cells that are found in epiretinal membranes are hyalocytes, which can also differentiate and are of macrophage lineage. If retinal pigment epithelial cells are present in idiopathic epiretinal membranes or only found in secondary epiretinal membranes after retinal detachment is a subject of debate. Fibroblasts and myofibroblasts are also present and produce collagen and induce intracellular contractions respectively.

The pathogenesis of secondary epiretinal membranes shares some mechanisms with idiopathic epiretinal membranes but are in addition associated with diseases such as retinitis, retinal detachment, retinal photocoagulation, uveitis, cytomegalovirus, trauma, diabetic retinopathy, retinal vein occlusion and cataract surgery. Research suggests that the cause for secondary epiretinal membranes is an abnormal wound healing process with inflammation and increased expression of cytokines. Interleukins 6 and 8 and monocyte-chemoattractant-protein-1 are cytokines that activate inflammatory cells, especially macrophages, B- and T-cells. Vascular endothelial growth factor can also be found in secondary epiretinal membranes and supports vascular tissue proliferation. Patients with secondary epiretinal membranes tend to be younger in age and are associated with greater foveal thickness in the optical coherence tomography and worse visual acuity. [3]

The main risk factor for the idiopathic form is higher age. The vitreous body is a transparent gel-like substance that fills the eye at a young age and shrinks when people mature. The composition of the vitreous is primarily water, hyalocytes, hyaluronan and collagen. The vitreous body is attached to various structures inside the eye, most firmly at the optic disc, perimacular region, retinal vessels, peripheral retina and the posterior lens

capsule. The shrinkage with age causes the vitreous body to partially separate from the retina and the remaining adhering vitreous body can cause traction on the retina. This phenomenon is called posterior vitreous detachment, symptoms can be flashes and floaters. Epiretinal membranes can develop at any stage of posterior vitreous detachment. It is assumed that it takes the membranes years to develop. [1] [3]

According to a study in the British Journal of Ophthalmology another risk factor is ethnicity. The prevalence of epiretinal membranes is significantly higher within the Chinese population compared to Caucasians and patients of African descent. [4]

Patients with diabetes (even without diabetic retinopathy) are also more likely to develop epiretinal membranes compared to patients without diabetes. Hypercholesterolemia and cataract surgery are further risk factors to develop epiretinal membranes. [5][4]

Early forms of epiretinal membranes are called cellophane macular reflex and are mostly asymptomatic, whereas the more advanced form is termed pre-retinal macular fibrosis and can be associated with severe symptoms and painless vision loss. Due to the proliferation of the membrane and contractions on the retina the vision becomes blurred and metamorphopsia are perceived. The metamorphopsia can be tested using an Amsler grid or quantitatively using M-CHARTS. A higher M-CHARTS score correlates with worse postoperative visual acuity and less improvement of the visual acuity after surgery. [6][7] A macular involvement and a higher degree of tissue distortion correlate with worse visual acuity. The preoperative best corrected visual acuity correlates with the preoperative foveal thickness. The same is true for the respective postoperative values. [2][1][8]

Secondary forms of epiretinal membranes most often occur after retinal detachment surgery. They can further occur after retinal breaks, retinal cryotherapy, panretinal photocoagulation, inflammation, trauma and retinal vascular diseases. Retinal vascular diseases can be venous occlusive disease or diabetic retinopathy. The tissue and cell type for the secondary forms is more varied and pigment cells from the retinal pigment epithelium are thought to be the origin at least in some of the entities listed above. [1][9]

The most important imaging method to assess the severity of the epiretinal membrane is Optical Coherence Tomography (OCT). OCT shows the epiretinal membrane as a highly reflective layer on top of the retina, see Figure 1 for an example.

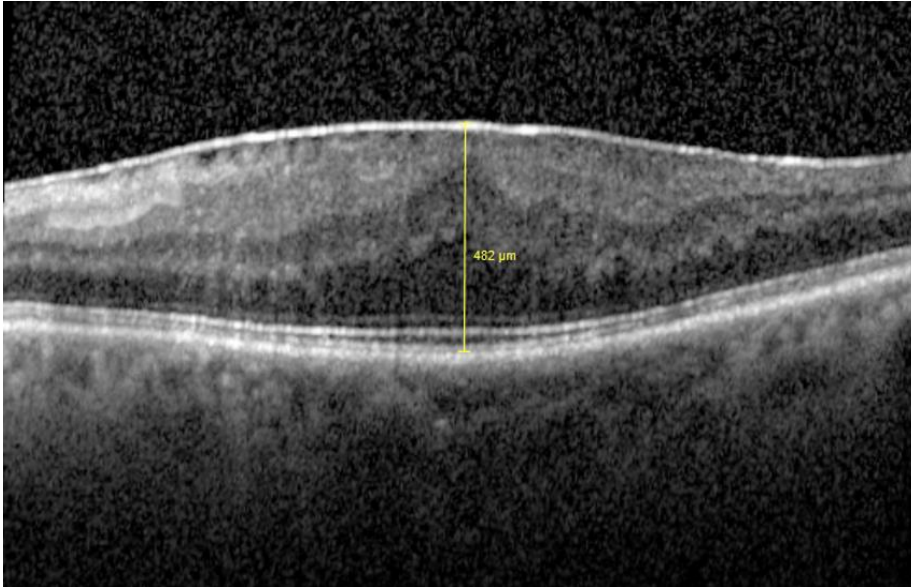


Figure 1: OCT of a retina with an epiretinal membrane. The retinal thickness is measured manually by callipers (yellow line).

Epiretinal membrane disorders had been traditionally diagnosed and classified through clinical examinations. However, optical coherence tomography (OCT) has become a valuable objective diagnostics method for the diagnosis of epiretinal membranes. [3]

“The OCT is a medical imaging technique used to produce non-invasive high-resolution cross-sectional images of biological tissues”. [3] The type of OCT mostly used is the SD-OCT (spectral domain), which is more sensitive, with resolutions up to around 4 μm and higher scanning speeds, compared to the time-domain OCT. The importance of OCT imaging in the diagnosis and classification of epiretinal membranes is likely to increase, as the International Vitreomacular Traction Study Group is working on definitions and classifications systems for various pathologies of the vitreomacular interface. [3]

Early stages of epiretinal membranes can also be visualized with funduscopy pictures with red-free, green light. Blood vessels become distorted, the retina wrinkles and macular pseudoholes can be found in cases with thick and severe epiretinal membranes. [1]

The treatment of epiretinal membranes spans from observation to surgery. If the epiretinal membrane is mild it can be monitored and if non-progressive and not affecting vision significantly observed in regular intervals. In patients with adherent vitreous a spontaneous separation of the membrane from the retina can occur and therefore relieving symptoms such as metamorphopsia and improving visual acuity. Such a spontaneous separation was

observed by Don Gass and led to the first vitrectomy with membrane peeling by Machemer et al. in 1976. [9]

Severe symptoms due to the epiretinal membrane, cystoid macular oedema or tractional detachment requires a surgical intervention in the form of vitrectomy and membrane peeling. This procedure usually improves the symptoms and visual acuity of at least two lines in approximately 75 percent. It usually takes several months for the visual acuity to improve to its final result. The internal limiting membrane can be removed during the same surgery, but opinions about the associated benefits and risks remain controversial. [1]

Pars plana vitrectomy

In 1970 Machemer et al. introduced the concept of pars plana vitrectomy, which is nowadays a common surgical procedure in vitreoretinal surgery around the world. The pars plana vitrectomy enables access to the posterior segment of the eye for further surgical interventions without touching the anterior segment. Possible indications are vitreous haemorrhage, retinal detachments, infections such as endophthalmitis, macular holes, proliferative vitreoretinopathy, diabetic retinopathy, epiretinal membranes, subretinal surgical interventions, vitreous floaters and tumour excisions. [10] [11]

Current pars plana vitrectomy systems use a valved setup that allows intraocular pressure control while removing the vitreous. [11]

Prior to Machemer et al. an ‘open-sky’ technique was used which was first described by David Kasner. This method was invasive and the vitreous body was removed using forceps or Weck-Cel sponges and scissors. An enlarged cataract wound or partial excision of the temporal cornea and a lens extraction was needed to gain access to the vitreous cavity and body. Despite the invasiveness of the procedure, this method was used successfully to treat patients with amyloidosis and opacification of their vitreous body. [9]

The pars plana vitrectomy was in various ways revolutionary.

First, the instruments for this new surgical approach had to be designed, engineered and constantly adapted and improved. Machemer invented a tool with a diameter of 17 gauge that combined aspiration, grasping and cutting of the vitreous body. He subsequently had to add another function in order to prevent the collapse of the eye – an infusion tube was

added to the vitreous cutter. [9] Second, the approach to the vitreous cavity was chosen through the pars plana of the ciliary body and therefore the anterior ocular chamber left untouched.

In the following years various improvements were made and in 1974 Connor O'Malley and Ralph Heintz presented a new concept that allowed the use of smaller instruments of 20 gauge diameter. They used three separate pars plana entries into the vitreous cavity, one for aspiration and cutting, one for infusion and one for illumination. This new three port method was successful and dominates the field of vitreoretinal surgery until today. [9] Further modifications and adaptations to this system were constantly made as many technical problems had to be solved in order to make this surgical method a safe procedure.

Intraocular illumination poses a challenge as there is a trade-off between sufficient illumination for the surgeon and photochemical toxicity to the retina. At first coaxial light from the microscope was used through the dilated pupil but soon endoillumination was developed and implemented. Initial experimental studies on monkeys have shown the susceptibility of the retina to visible light. Damage to the retina is dependent on the duration of the light exposure, light wave lengths and the light intensity. According to Ham et al. the retina in an aphakic eye is six times more sensitive to near-ultraviolet wavelengths of 325nm than to blue light with 411nm. An aphakic hazard curve was created for different wavelengths. At first unknowingly, vitreoretinal surgeons had used room temperature infusion fluid which cooled the eye and protected the retina to a certain degree against photochemical toxicity from endoillumination. [9] [12] [13]

During the last decade advances in endoillumination were made, due to the implementation of light filters to improve visualization and safety and more powerful lighting systems to allow instruments with smaller diameters. The characteristic spectral wavelengths of light emitted from a specific light bulb is given and can only be modified by applying filters in order to filter out certain wavelengths. The spectrum is measured using a spectrophotometer. In addition, filters can enhance visualization of different tissues which helps surgeons distinguish between tissues during surgery. According to de Oliveira et al. the hazard to watt ratio for different commercially available light sources is led by mercury vapor and followed by xenon, also see Figure 1. [14][15]

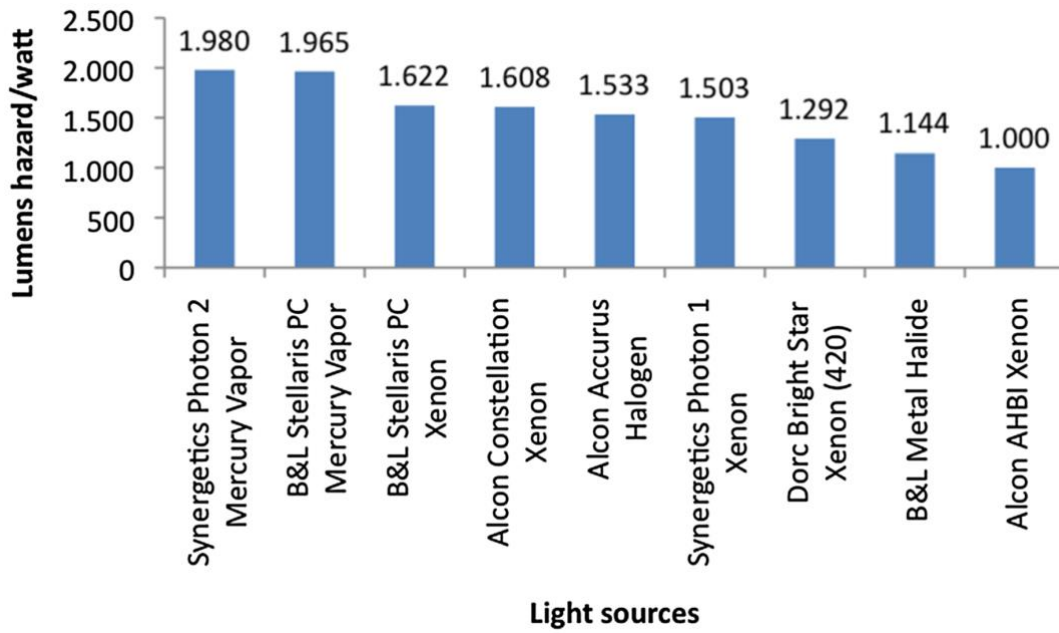


Figure 2: Lumens/watt ratio for different light sources - the light source is safer the higher the lumens necessary to cause a watt of hazard

[15]

Chandeliers are a relatively new light source concept with various advantages. It allows surgeons to perform surgeries bimanually due to self-retaining chandeliers. The risk for phototoxicity is reduced as the working distance to the retina is bigger compared to standard light pipes. Therefore, the threshold time of a chandelier is hours instead of minutes and emphasizes the value of maximizing working distance to the retina. [14]

Gauge System

The instruments used in pars plana vitrectomy and vitreoretinal surgery are very small and the diameter of the instruments are described using the Birmingham gauge system. Table 1 lists the different gauge sizes used in vitreoretinal surgery and their corresponding equivalents in millimetres. The bold rows highlight the sizes of the instruments that were used for the comparison of the data in this work.

Initial sclerotomies made in pars plana vitrectomy had a diameter of 20 gauge. These openings had to be sutured in order to prevent leakage and intraocular hypotony. Nowadays these instruments are seldomly used, unless bigger instruments have to be used inside the eye for indications as e.g. removal of intraocular foreign bodies or the removal of retained lens material. The instruments being used today, have developed and become smaller and smaller and today trocar systems with 27-gauge instruments are standard for many vitreoretinal surgeries. The sclerotomies are small and normally self-sealing and sutures are not needed. [11]

Table 1: Outer diameter of the surgical instruments in gauge and millimetres. The conversion is based on Birmingham gauge values, which differs for example from the American wire gauge values.

Size in gauge	Size in mm
17-gauge	1,473
20-gauge	0,9081
23-gauge	0,6414
25-gauge	0,5144
27-gauge	0,4128

[16]

Materials and methods

Ethics Committee permission

This retrospective study was conducted according to all guidelines of the ethics committee of the Medical University Graz. All patients analysed in this work signed an informed consent agreement before the surgery.

Calculation of sample size

The number of patients needed for this analysis was calculated using the G*Power programme from the Heinrich Heine University Duesseldorf. [17] The parameters were estimated and based on data from existing similar works. For the sample size calculation the following parameters were used:

Power: 80 percent

Confidence interval: 95 percent

$P=0,05$

The mean duration of surgery for the 23-gauge group was estimated to be 23 minutes with a standard deviation of 6,5 minutes. [18]

Given an allocation ratio between the groups of 1 and a clinically significant difference in surgical time of 3 minutes (10%) or more, a sample size of at least 75 patients in each group would be required to fulfil a power of 80% and a confidence interval of 95%. Owing to its retrospective nature and the possibility of missing data we included 100 patients for each group.

Data acquisition

The patients included in this analysis were all patients from the department of ophthalmology of the Medical University Graz. The data were generated from the internal data base systems EyMed and the surgery times were gathered from the anaesthesia report in Medocs. The surgery time was defined from the time the surgeon first touched the

patient's eye, with the application of the eyelash retractor until the last manipulation, removal of the eyelash retractor. The 23-gauge and 27-gauge vitrectomies were performed by the same surgeon during the period 2017 to 2020 and 2019 to 2020 respectively.

Retinal thickness was analysed from SD-OCT images (Spectralis, Heidelberg Engineering, Heidelberg Germany).

Prior to the vitrectomy an optical coherence tomography examination of the retina was carried out in all patients.

In this retrospective, comparative study 213 eyes with an epiretinal membrane from 213 patients were included. 104 patients underwent a 23-gauge vitrectomy, and 109 patients underwent a 27-gauge vitrectomy. In the 23-gauge group, 53 percent of the study participants were male and in the 27-gauge group 58 percent.

The indication for all surgeries was an idiopathic epiretinal membrane.

The inclusion criteria were the following:

- Idiopathic epiretinal membrane
- Surgical intervention with vitrectomy and peeling of the membrane with either a 23-gauge or 27-gauge instrument

The exclusion criteria were the following:

- Prior ophthalmological surgeries, except for cataract surgeries that were performed more than one year before the vitrectomy
- Secondary epiretinal membranes
- The vitrectomy was performed using oil or gas

The visual acuity of the patients before and after the surgery was documented with the Snellen best corrected visual acuity (BCVA) system. For this analysis the data was subsequently converted to logMAR units.

The intraocular pressure (IOP) was measured with the Goldmann applanations tonometer. Hypotony was defined as intraocular pressure smaller or equal to 6 mmHg.

The intra- and postoperative complications that occurred within one year after surgery were analysed for this work by reviewing the patients' charts.

Methods for statistical analyses of the data

For the statistical analysis IBM SPSS Statistics 26 and Microsoft Excel 2021 for Mac was used. The data was tested for normal distribution using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Furthermore, histograms were made for visual interpretations of the distribution of the data. For the comparison of the normally distributed data an unpaired t-test was used. For data, which was not normally distributed, the Wilcoxon-Mann-Whitney (Mann-Whitney-U test) test was used. P values of 0,05 or smaller were considered statistically significant. The results are presented using the mean and standard deviation if the data was normally distributed or the median and interquartile range if not normally distributed.

Results

Descriptive preoperative statistical patient data

Gender

The gender distribution in both groups was similar ($p = 0,169$) with a slight predominance of male subjects. Table 2. shows the respective percentages of each group.

Table 2: Gender distribution in the two groups

	23-gauge	27-gauge
number of patients	104	109
male	53%	58%
female	47%	42%

Age

Age was similar in both vitrectomy groups. The median age in the 23-gauge group was 78,00 years with an interquartile range of 9 years. The median age in the 27-gauge group was 77,00 years with an interquartile range of 8 years. This was analysed numerically and graphically as shown in the histograms in Figures 3 and 4.

The data was tested for normal distribution using the Kolmogorov-Smirnov and Shapiro-Wilk test, see Table 3. The 23-gauge group had a significance of 0,003 and 0,006 in the Kolmogorov-Smirnov and Shapiro-Wilk test respectively and was therefore not normally distributed. The significance in the 27-gauge group was 0,20 (Kolmogorov-Smirnov) and 0,507 (Shapiro-Wilk) and therefore the data was normally distributed.

Table 3: Tests of normality for age. 23-gauge group is not normally distributed and 27-gauge group is normally distributed according to Kolmogorov-Smirnov and Shapiro-Wilk.

	Groups	23-gauge	27-gauge
Kolmogorov-Smirnov	significance	0,003	0,200
Shapiro-Wilk		0,006	0,507

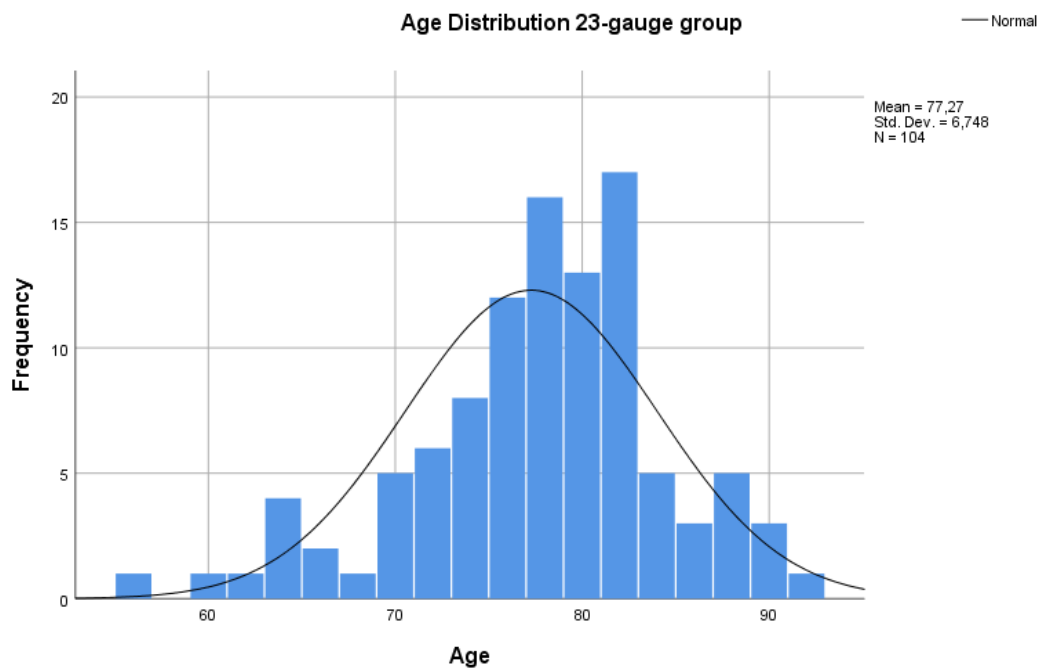


Figure 3: Histogram for the age distribution for the 23-gauge group. The data is skewed to the left (negative) and not normally distributed.

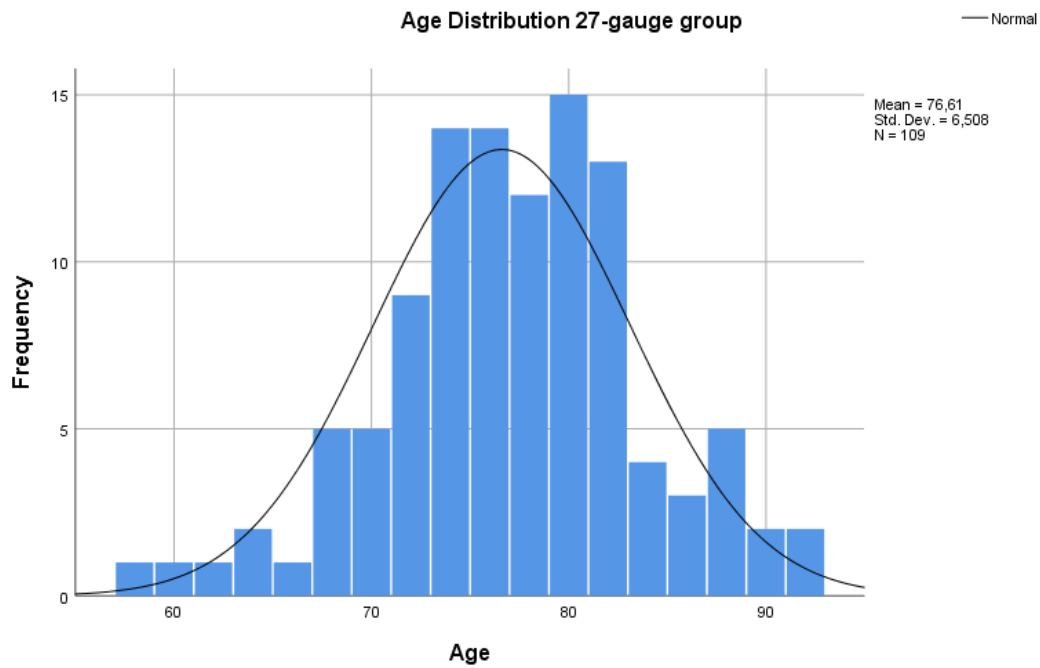


Figure 4: Histogram for the age distribution for the 27-gauge group. The data is normally distributed.

Due to the results from the normal distribution tests, one group being normally distributed and one not being normally distributed, a non-parametric Mann-Whitney-U test was used, for testing the similarity between the two groups. The distribution in the 23-gauge group and the 27-gauge group was similar, with a significance level of 0,239. The null hypothesis, that the age distribution in both groups is similar, can therefore be retained.

Phacoemulsification and implantation of an artificial lens

The rate of concurrent cataract surgery in both groups was the similar. Within the 23-gauge group 86 percent of the patients had a phacoemulsification and implantation of an artificial lens during the same surgery and 85 percent in the 27-gauge group. Table 4 shows the rate of concurrent cataract surgery for both groups and the respective male and female subgroups.

Table 4: Number of patients treated with concurrent phacoemulsification during the surgery.

	23-gauge	27-gauge
total number of patients treated	104	109

number of patients who received phacoemulsification	89	93
phacoemulsification total percentage	86%	85%
phacoemulsification male percentage	85%	86%
phacoemulsification female percentage	86%	85%

Visual acuity preoperative

The preoperative visual acuity was similar in both groups and around a Snellen equivalent of 0,5. The visual acuity in the original data was documented using the Snellen best corrected visual acuity system. For this analysis the data was transformed into logMAR values. The values were tested for normal distribution. Both groups were not normally distributed with p-values well below 0,05. The median was 0,40 (Snellen equivalent 0,4) for the 23-gauge group with an interquartile range of 0,20. For the 27-gauge group the median was 0,3 (Snellen equivalent 0,5) with an interquartile range of 0,30. For a graphic depiction see the boxplot in Figure 5.

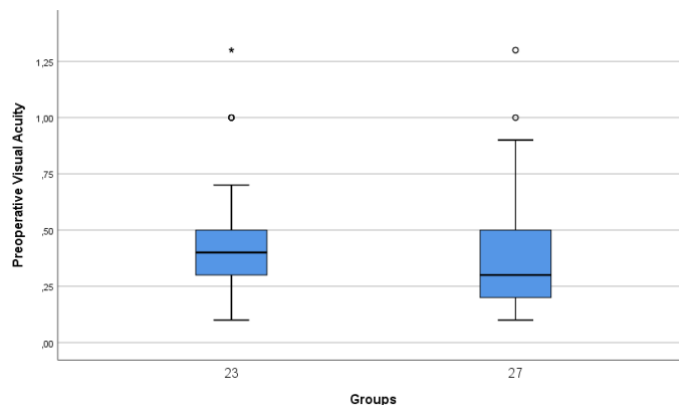


Figure 5: Boxplot for preoperative visual acuity distribution for both groups [logMAR]. The visual acuity was similar in both groups.

As the data in both groups was not normally distributed a Mann-Whitney-U test for independent samples was carried out to test for similarity between the two groups. The significance value was $p = 0,205$ and therefore the assumption and null hypothesis that the

distribution of preoperative visual acuity was similar across the two groups could be retained, also see Table 5 and Figure 6.

Table 5: Test for similarity of preoperative visual acuity. The visual acuity is similar across both groups.

Null Hypothesis	Test	Significance	Decision
The distribution of preoperative visual acuity is similar across the two groups.	Independent-Samples Mann-Whitney U Test	0,205	Retain the null hypothesis.

The significance level is ,050.

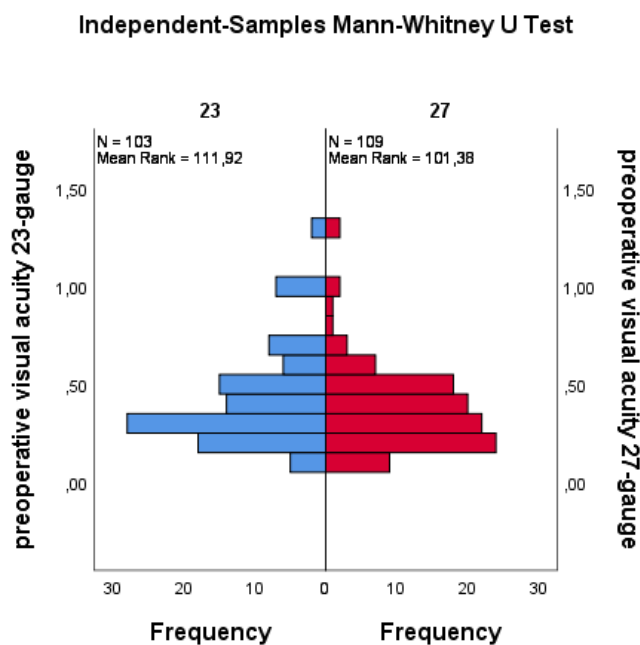


Figure 6: Preoperative distribution of the visual acuity. The distribution of the visual acuity was similar in both groups.

Retinal thickness

The preoperative central foveal thickness values across the two groups were similar, with a median of around 420 μm . The OCT pictures of all patients, prior to the surgical intervention have been viewed and the retinal foveal thickness measured. The central foveal thickness was measured from the epiretinal membrane to the layer of the retinal pigment epithelium. An example of such a measurement is shown in Figure 1.

The data was tested for normal distribution, see Table 6.

The data of the 23-gauge group was normally distributed with a significance level of 0,2 (Kolmogorov-Smirnov) and 0,08 (Shapiro-Wilk).

The data of the 27-gauge group was not normally distributed. The significance level was 0,047 (Kolmogorov-Smirnov) and 0,007 (Shapiro-Wilk).

Table 6: Tests of normality for preoperative central foveal thickness measured with SD-OCT. The 23-gauge group was normally distributed. The 27-gauge group was not normally distributed.

	Group	
	23-gauge	27-gauge
Kolmogorov-Smirnov	0,200	0,047
Shapiro-Wilk	0,080	0,007

The median for the 23-gauge group was 418 μm with an interquartile range of 137 μm .

The median for the 27-gauge group was 424 μm with an absolute deviation of 97 μm .

To compare the data of the retinal thicknesses across the two groups a non-parametric independent Mann-Whitney-U test was used, as the 27-gauge group was not normally distributed.

The null hypothesis was that the distribution of the retinal thickness prior to the surgery was similar across the two groups. The significance level was 0,964 and therefore the null hypothesis could be retained. The distribution was similar across the two groups, also see Figure 7.

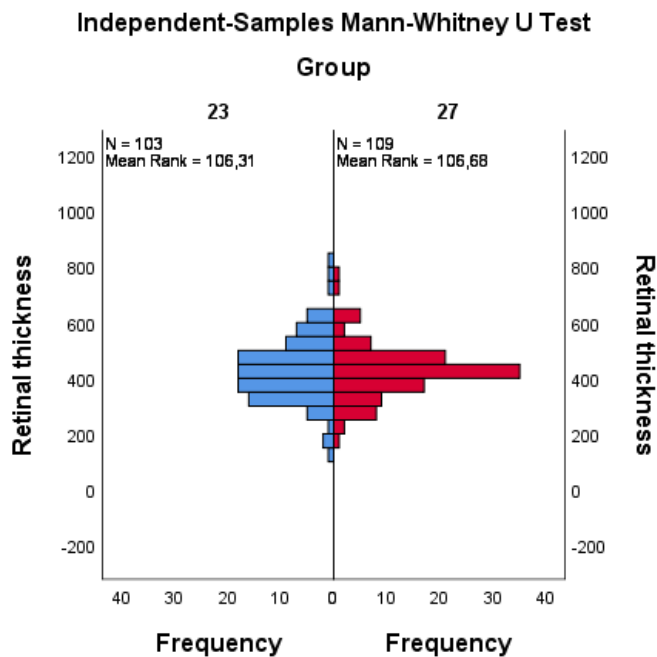


Figure 7: Distribution of the preoperative central foveal thickness data for both groups [μm]. There was no significant difference between both groups; $p=0,964$. Mann-Whitney-U test.

Comparison of the surgery time between the 23-gauge and 27-gauge group

There was no significant difference in surgical time between the two groups. However, surgeries were slightly faster in the 27-gauge group for eyes receiving vitrectomy without concurrent phacoemulsification, albeit the latter being a small proportion of patients.

The surgery time was defined as the time between the surgeon's first touch of the patient's eye (application of the eyelash retractor) and the last manipulation (removal of the eyelash retractor).

We analysed the data set as a whole and in a second step patients with and without cataract surgery separately.

Surgery time for complete data set

The surgery time across the two groups was similar with the median surgery time for the 23-gauge group being 17 minutes and 18 minutes for the 27-gauge group, see Figure 8.

The surgery times for both groups were tested for normal distribution. The 23-gauge group was normally distributed ($p = 0,077$ Kolmogorov-Smirnov; $p = 0,518$ Shapiro-Wilk) and the 27-gauge group was not normally distributed ($p = 0,013$ Kolmogorov-Smirnov; $p = 0,013$ Shapiro-Wilk), see Figures 9 and 10.

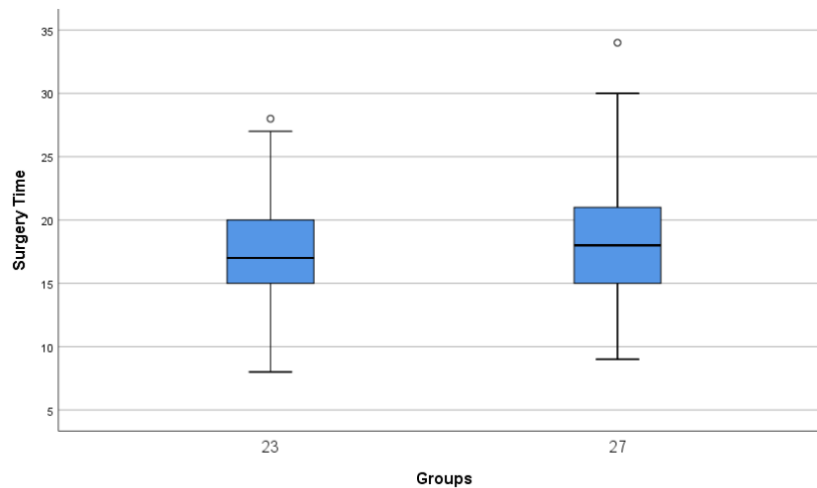


Figure 8: Boxplot for the surgery times [minutes] for the complete data set. The median in the 23-gauge group was 17 minutes with an interquartile range of 5 minutes. The median in the 27-gauge group was 18 minutes with an interquartile range of 6 minutes. The surgery times were similar in both groups.

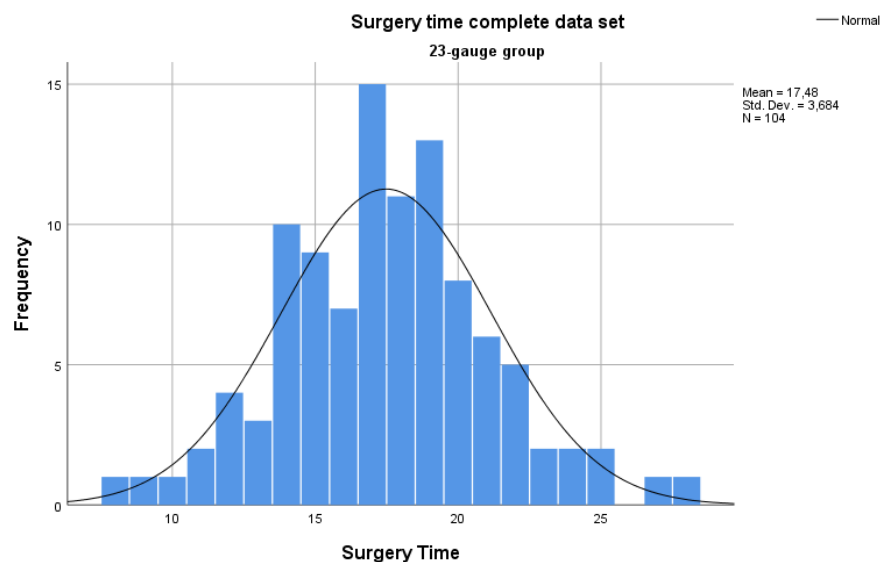


Figure 9: Distribution of the surgery time [minutes] for the complete data set for the 23-gauge group. The data was normally distributed ($p = 0,077$ Kolmogorov-Smirnov; $p = 0,518$ Shapiro-Wilk).

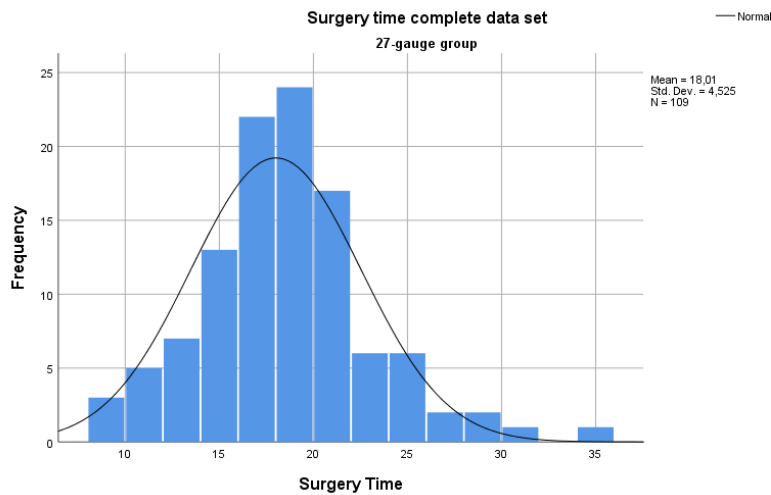


Figure 10: Distribution of the surgery time [minutes] for the complete data set for the 27-gauge group. The data was not normally distributed ($p = 0,013$ Kolmogorov-Smirnov; $p = 0,013$ Shapiro-Wilk).

The surgery times in both groups were subsequently tested for similarity. As the 27-gauge group was not normally distributed according to the normal distribution tests, a non-parametric Mann-Whitney-U test was used for testing the similarity. The p-value was 0,50 and the surgery times in both groups were therefore not significantly different.

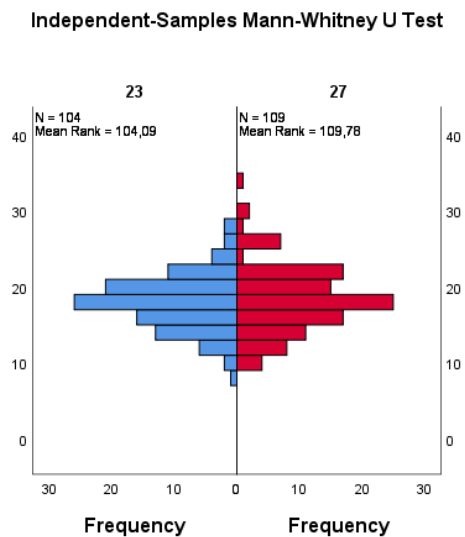


Figure 11: The surgery times between both groups for the complete data set are not significantly different ($p = 0,50$). Mann-Whitney-U test.

Surgery time for patients with concurrent phacoemulsification and implantation of an artificial lens

The duration of the surgery with concurrent phacoemulsification was 18 minutes in both groups ($p = 0,166$).

In the 23-gauge group 89 patients (86%) received a cataract surgery during the same surgery and in the 27-gauge group 93 patients (85%).

The surgery times of both groups were tested for normal distribution using the Kolmogorov-Smirnov and Shapiro-Wilk test and in a depiction in the form of a histogram, see Figures 12 and 13.

The 23-gauge group was normally distributed with the significance levels of both tests being greater than 0,05. The values were $p = 0,052$ and $p = 0,173$ for the Kolmogorov-Smirnov and Shapiro-Wilk test respectively.

The 27-gauge group was not normally distributed. The significance levels were in both tests far below 0,05. The values were $p = 0,000314$ and $p = 0,002$ for the Kolmogorov-Smirnov and Shapiro-Wilk test respectively.

The median for the 23-gauge group was 18 minutes with an interquartile range of 4 minutes.

The median for the 27-gauge group was 18 minutes with an interquartile range of 5 minutes.

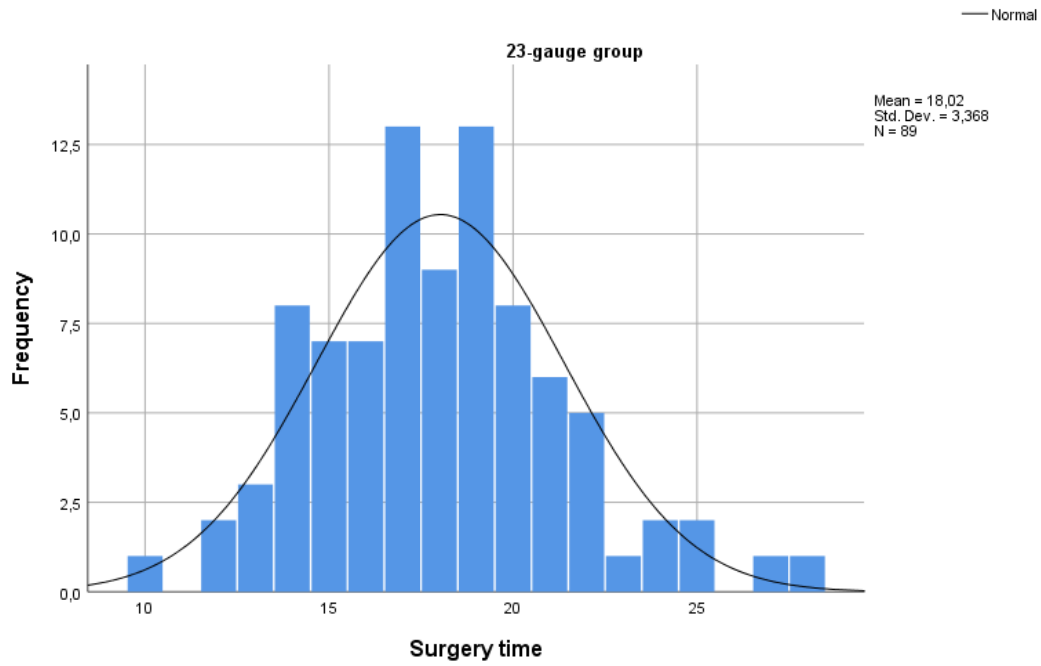


Figure 12: Histogram for the surgery times [minutes] with concurrent phacoemulsification for the 23-gauge group. The data was normally distributed.

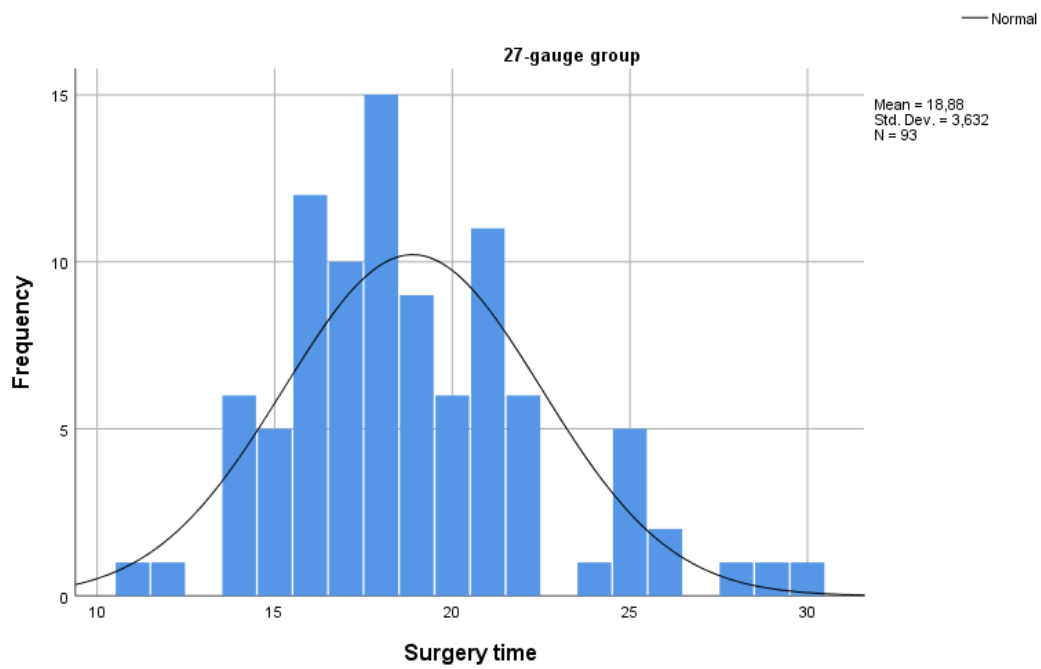


Figure 13: Histogram for the surgery times [minutes] with concurrent phacoemulsification for the 27-gauge group. The data was not normally distributed.

The 27-gauge group was not normally distributed, therefore the groups were tested for similarity using the non-parametric Mann-Whitney-U test for independent groups, see Table 7 and Figure 14.

The null hypothesis was as follows: the distribution of the surgery time is the same across the two groups. The significance level was 0,166 and therefore greater than 0,05 and the null hypothesis could be retained. **There was no significant difference in surgery time between the two analysed groups.**

Table 7: Mann-Whitney-U test for similarity of surgery times between both groups with concurrent phacoemulsification. The surgery times are similar (p = 0,166).

Null Hypothesis	Test	Significance	Decision
The distribution of surgery time is the same across the groups.	Independent-Samples Mann-Whitney U Test	0,166	Retain the null hypothesis.

The significance level is ,050.

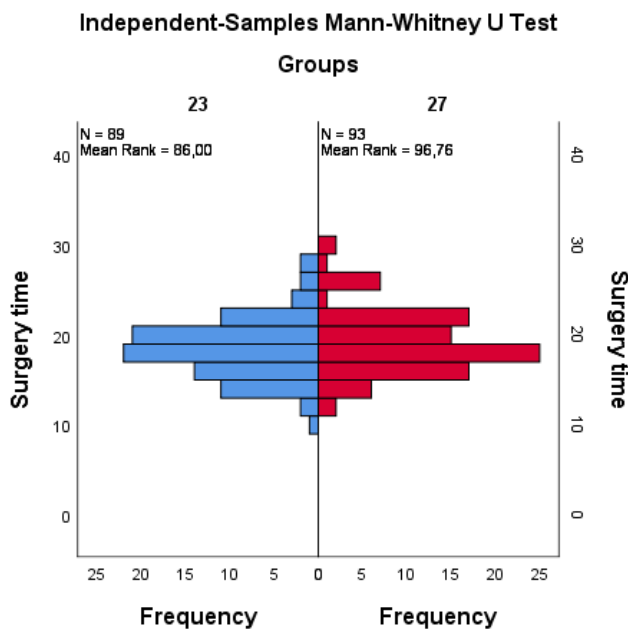


Figure 14: Distribution of surgery times [minutes] with concurrent phacoemulsification. The surgery times are similar (p=0,166). Mann-Whitney-U test.

Comparison of the surgery time for patients who received a vitrectomy and epiretinal peeling without concurrent phacoemulsification

The duration of the surgery showed more variation between the 23-gauge and 27-gauge group, with a respective median time of 14 minutes and 12 minutes respectively. According to a two-sided t-test the surgery times between the two groups were not similar, with a p-value of 0,036, whereas for the Mann-Withney-U test the p-value was marginal with 0,06.

In the 23-gauge group 15 patients did not have a phacoemulsification and implantation of an artificial lens and in the 27-gauge group 16 patients. The data was tested for normal distribution. The significance in both tests for both groups, Kolmogorov-Smirnov and Shapiro-Wilk were greater than 0,05. The surgery times in both groups were normally distributed, see Table 8 and Figures 15 and 16.

The median for the 23-gauge group was 14,00 minutes and 12,00 for the 27-gauge group. The interquartile ranges were 6 minutes and 3 minutes for the 23-gauge and 27-gauge group respectively.

The mean value for the 23-gauge group was 14,27 minutes with a standard deviation of 3,96. The mean value for the 27-gauge group was 11,81 minutes with a standard deviation of 2,01.

Table 8: Tests of normality for surgery times without concurrent phacoemulsification. Both groups are normally distributed according to the tests (Kolmogorov-Smirnov and Shapiro-Wilk).

	23-gauge Significance	27-gauge Significance
Kolmogorov-Smirnov	0,200	0,200
Shapiro-Wilk	0,829	0,483

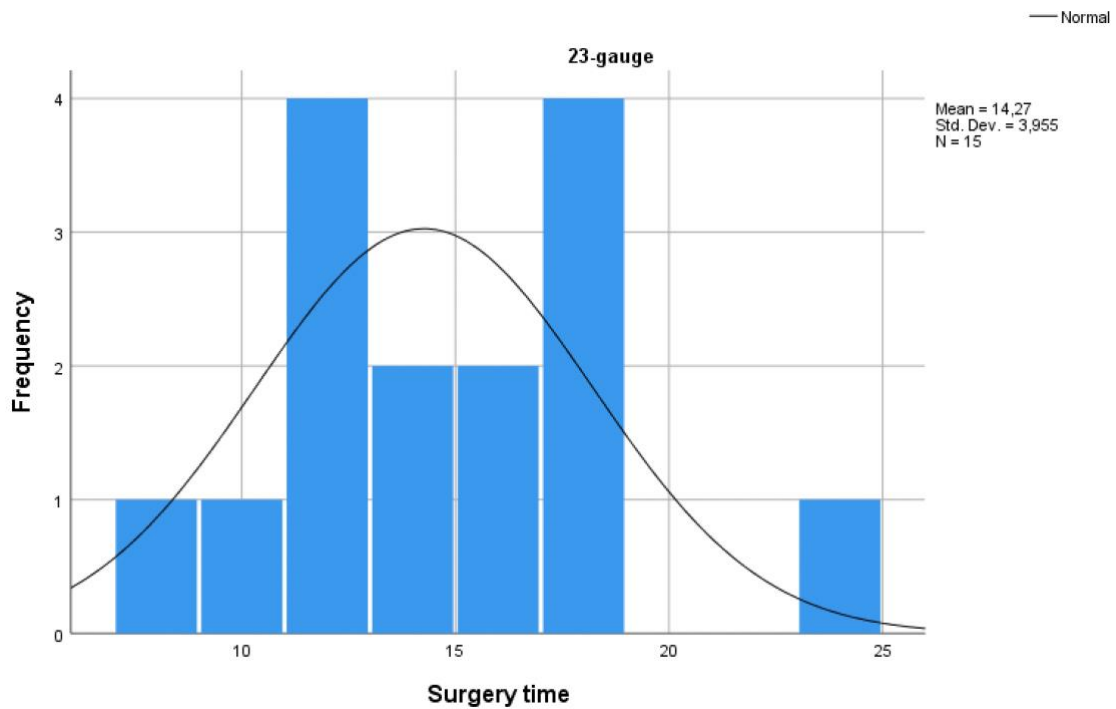


Figure 15: Distribution of the surgery times [minutes] without concurrent phacoemulsification for the 23-gauge group. According to the tests the data was normally distributed, but the histogram did not support this result.

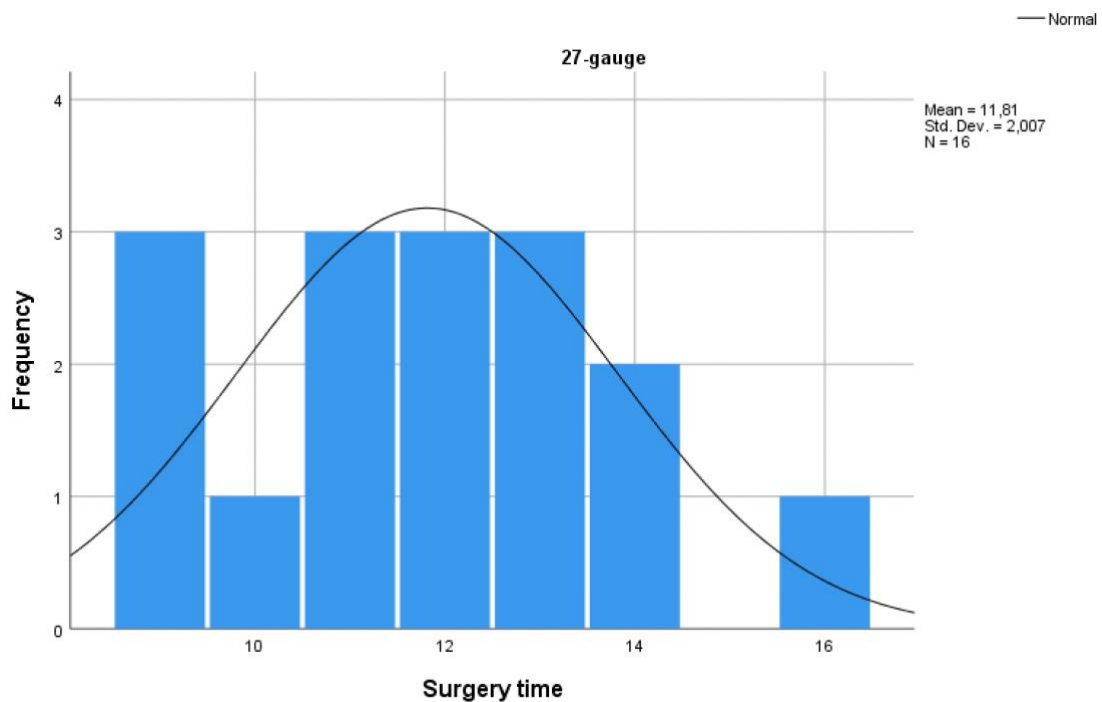


Figure 16: Distribution of the surgery times [minutes] without concurrent phacoemulsification in the 27-gauge group. According to the tests the data was normally distributed, but the histogram did not support this result.

Although the surgery times in both groups were normally distributed according to the tests, a non-parametric Mann-Whitney-U test was used in addition to a two-sided t-test for testing the similarity of the surgery times between the two groups, because the number of patients in both groups was small and the p-value of the test for equality of variances was below 0,05. As such the following two analyses were performed.

First, the similarity of the means was tested using a two-sided t-test for independent samples. The null hypothesis was that the means in the two groups were similar. The significance was 0,036 and the null hypothesis was rejected. The surgical time of the two groups were not similar according to the t-test.

Second, the significance for the Mann-Whitney-U test for testing the similarity of the surgery times without cataract surgery was 0,06. The p-value is marginal and in context with the small number of patients in this group a definite statement about a significant difference is difficult.

Complications

Postoperative complications occurred in 6,8 percent for the 23-gauge group and 8,4 percent for the 27-gauge group within the first year after the surgery, see Table 9.

Postoperative intraocular hypotony was defined as the pressure below or equal to 6 mmHg, measured with the Goldman applanations tonometer.

Endophthalmitis was diagnosed based on the clinical symptoms pain, lid swelling, rubor and slit lamp results such as hypopyon, cells and fibrin in the anterior chamber and in the vitreous. [18] Overall four endophthalmitides occurred and presented on post-operative day 2, 3, 5 and 14. No correlation was found between the occurrence of endophthalmitis and the duration of the surgery or simultaneous phacoemulsification or hypotony.

Table 9: Complications within one year after the surgery. Absolute and relative values for each group are presented. There were no significant differences between the groups.

	23-gauge (absolute values)	23-gauge (relative values, %)	27-gauge (absolute values)	27-gauge (relative values, %)	P-Value
Postoperative intraocular hypotony	2	1,9	0	0	0,147
Retinal detachment	1	1	3	2,8	0,337
Endophthalmitis	1	1	3	2,8	0,328
Macular oedema, Irvine-Gass- Syndrom	2	1,9	2	1,8	0,962
Optic disc swelling	1	1	0	0	0,306
Retinal haemorrhage	0	0	1	1	0,329

Post-operative best corrected visual acuity

In both groups the post-operative best corrected visual acuity improved, compared to the pre-operative values of around 0,5, to a Snellen equivalent of 0,63. The values for the post-

operative best corrected visual acuity were available for 53 patients from the 23-gauge group and 34 from the 27-gauge group. The visual acuity in the original data was documented using the Snellen best corrected visual acuity system. For this analysis the data was transformed into logMAR values.

Both tests for normality, Kolmogorov-Smirnov and Shapiro-Wilk and the histograms attested that the data in both groups was not normally distributed.

The median for the 23-gauge group is 0,20 (Snellen equivalent of 0,63) with an interquartile range of 0,25.

The median for the 27-gauge group is 0,20 (Snellen equivalent of 0,63) with an interquartile range of 0,33 see Figure 17.

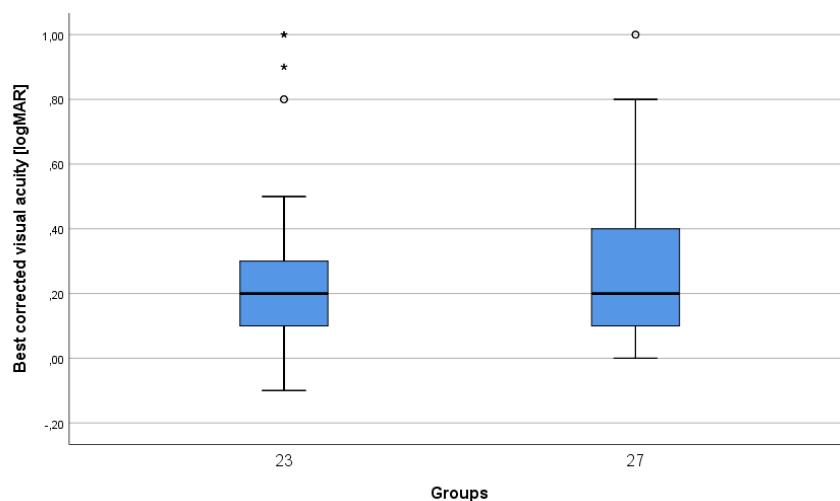


Figure 17: Boxplot for the post-operative visual acuity. The median was 0,20 (logMAR) for both groups. The post-operative visual acuity was similar for both groups.

The mean for the 23-gauge group was 0,28 with a standard deviation of 0,29.

The mean for the 27-gauge group was 0,31 with a standard deviation of 0,28.

The data was subsequently tested if the distribution across the two groups was similar, using a Mann-Whitney-U test for independent groups. The null hypothesis was that the distribution was the same across the two groups. The significance was $p = 0,531$ and therefore the null hypothesis could be retained. The distribution across the 23-gauge group and 27-gauge group was similar.

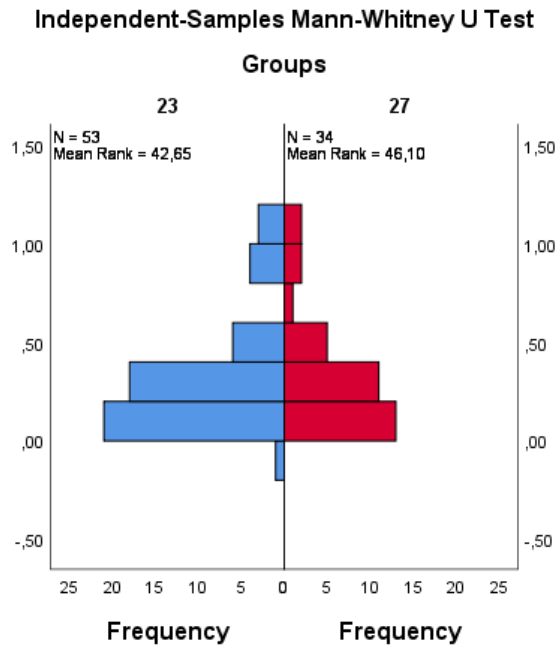


Figure 18: Mann-Whitney-U test for the post-operative visual acuity. There was no significant difference between both groups ($p = 0.531$).

The post-operative follow up was documented for 52 patients in the 23-gauge group and 34 patients in the 27-gauge group.

The median follow-up period for the 23-gauge group was 6 months with an interquartile range of 14 months. The median follow-up period for the 27-gauge group was 4 months with an interquartile range of 8 months, see boxplot in Figure 11. There was no significant difference between the two groups ($p = 0,066$; Mann-Whitney-U test).

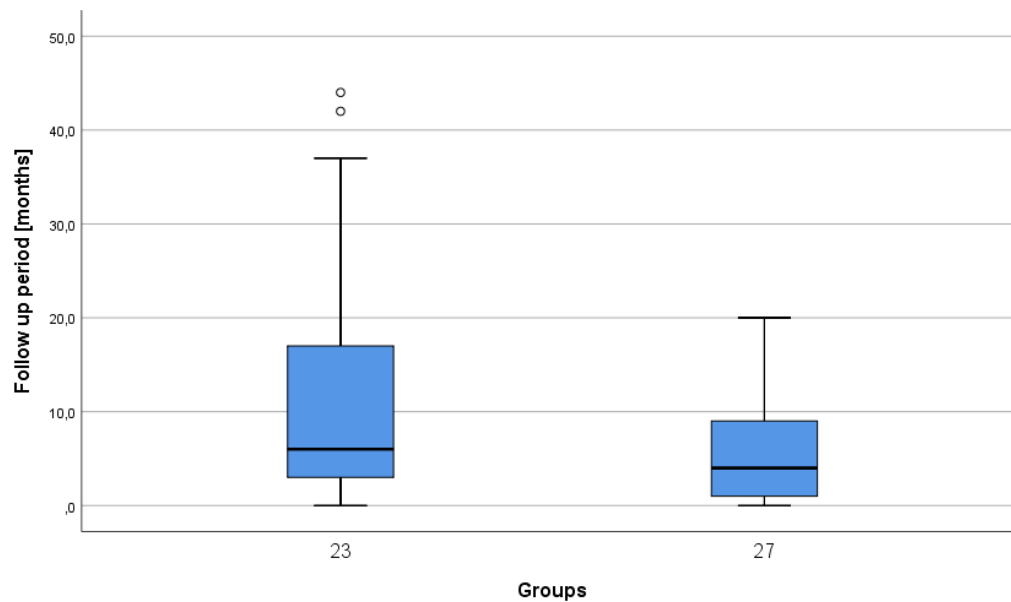


Figure 19: Boxplot for the follow-up period for the 23-gauge and 27-gauge group. The median follow-up period for the 23-gauge group was 6 months with and interquartile range of 14 months. The median follow-up period for the 27-gauge group was 4 months with and interquartile range of 8 months. There was no significant difference between the two groups ($p = 0,066$).

Post-operative retinal thickness

Retinal thickness decreased in both groups significantly from around 420 μm to 338 μm in the 23-gauge group and to 397 μm in the 27-gauge group (each $p \leq 0,001$). The post-operative central foveal thickness was significantly different between the two groups ($p = 0,047$).

Post-operative SD-OCT pictures were available for 43 patients from the 23-gauge group and 34 patients from the 27-gauge group. The data was tested for normal distribution. According to the tests, both groups were normally distributed, see Table 10.

Table 10: Post-operative retinal thickness. The data is normally distributed in both groups according to the tests (Kolmogorov-Smirnov and Shapiro Wilk).

	23-gauge	27-gauge
	significance	
Kolmogorov-Smirnov	0,200	0,200
Shapiro-Wilk	0,717	0,637

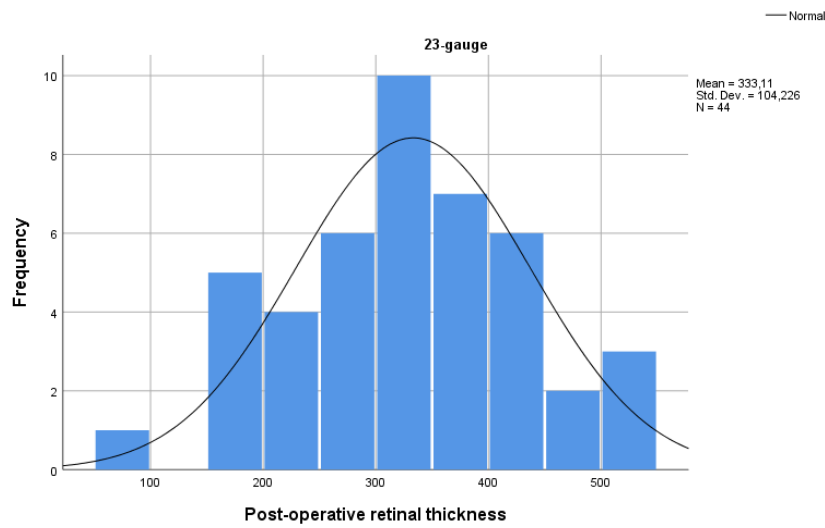


Figure 20: Histogram for the post-operative retinal thickness data for the 23-gauge group. The data was normally distributed according to the tests.

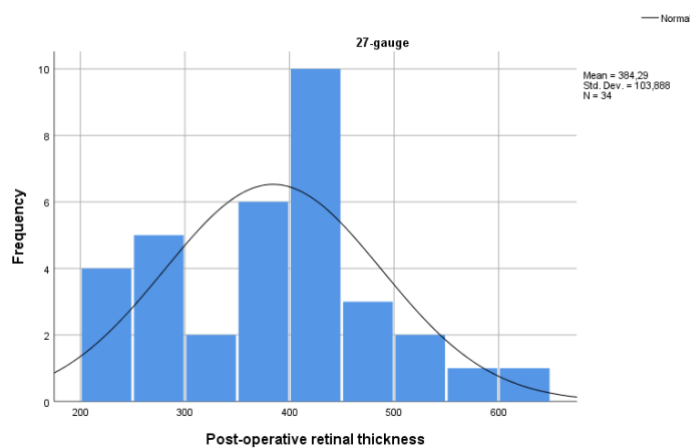


Figure 21: Post Histogram for the post-operative retinal thickness data for the 27-gauge group. According to the tests the data was normally distributed, but the histogram did not support this result.

The median for the 23-gauge group was 338 μm and the interquartile range was 161 μm . The median for the 27-gauge group was 397 μm and the interquartile range was 140 μm , see Figure 22.

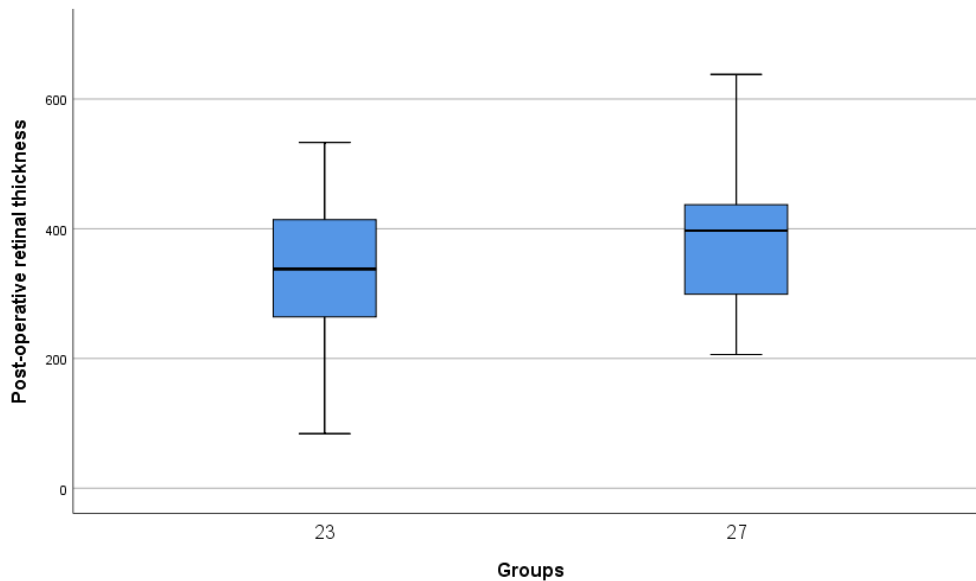


Figure 22: Boxplot for the post-operative retinal thickness data for both groups. The median for the 23-gauge group was 338 μm with an interquartile range of 161 μm . The median for the 27-gauge group was 397 μm with an interquartile range of 140 μm .

Although the post-operative retinal thickness data in both groups was normally distributed according to the tests, a non-parametric Mann-Whitney-U test was used for testing the similarity of the retinal thickness data between the two groups, as the number of patients in both groups was relatively small, the number of available data sets varied between the two groups and the histograms did not show a sufficient normal distribution. The null hypothesis that the distribution of post-operative retinal thickness was the same across the two groups had to be rejected as the significance value was $p = 0,047$ and therefore below the significance level of 0,05.

An unpaired t-test was nevertheless also run for the post-operative retinal thickness data and showed the same results as the Mann-Whitney-U test. The null hypothesis could therefore be rejected. The distribution of the post-operative retinal thickness data was significantly different between the two groups.

Discussion

In this analysis the surgery times for 23-gauge vitrectomies compared to 27-gauge vitrectomies in epiretinal membrane surgery were compared. In addition, the safety profile was evaluated with focus on intraoperative and postoperative complications and change of preoperative to postoperative best corrected visual acuity and retinal thickness. A successful removal of the epiretinal membrane was achieved in all surgeries.

All surgeries were performed by the same surgeon. The surgeon used two different machines, Oertli OS4 (23-gauge) und DORC Eva (27-gauge). Intraoperative complications did not occur in any of the 213 eyes.

This analysis has limitations due to its retrospective design. Follow up data was not available for all patients. The values for the post-operative visual acuity and post-operative retinal thickness are only partly representative for the patient population as most of the patients without complications and therefore better results were probably monitored after the surgery in an extramural setting; those values are missing for this analysis. Therefore, the values presented here probably tend to be worse than the average values in the population.

The results from our analysis, that the visual acuity improved after the surgery and the central foveal thickness decreased are in concordance with the literature. [19] [20] In our study the preoperative best corrected visual acuity improved from 0,4 logMAR (23-gauge) and 0,3 logMAR (27-gauge) to postoperative values of 0,2 logMAR. According to a meta-analysis from 2016 with 1777 eyes who received an epiretinal peeling the best corrected visual acuity improved from 0,49 logMAR preoperative to values around 0,20 logMAR after 6 months and 0.28 logMAR after 12 months. That is, albeit the average patient showed a somewhat lower preoperative and postoperative visual acuity, the visual acuity of our cohort is comparable to that in the literature. [21] In regard to visual acuity outcomes, the little data that exists suggests that 23-gauge and 27-gauge vitrectomy do not differ. [22] [23] [24]

In our study the overall surgery time was similar for 23- and 27-gauge vitrectomy. Compared to the literature our duration of the surgery was low (around 14 minutes in our study). Garweg et al. noted an average surgical time of $38 \pm 13,1$ minutes with 23-gauge

and $48 \pm 15,3$ minutes with 27-gauge [24], Saleh noted $34,8 \pm 11,4$ minutes for 23- and 27-gauge on average and no significant difference [22]. The shorter surgical duration in our study might be attributed to the following points:

1. Ill-defined surgical start/end in literature.
2. Surgical technique: In our clinic peripheral vitreous shaving is typically omitted for uncomplicated cases; however, shaving was only performed “when needed” in the literature. Additionally, some authors performed a fluid air exchange after surgery, which was not performed in our cohort.
3. The studies at hand had used or might have used older vitrectomy machines (OS3 for 23-gauge in one study [22]). In the other study the vitrectomy machine was not specified [24]. Older machines might fail to produce sufficient vacuum to achieve the maximum flow possible, especially when dealing with smaller lumina.

In our subset without concurrent cataract surgery, the 27-gauge group performed marginally faster according to the t-test. Various explanations are possible. First, the sample size for both groups was small, with 15 patients in the 23-gauge group and 16 patients in the 27-gauge group. Thus, the probably more appropriate test for detecting differences would have been the Mann-Whitney-U test rather than the t-test; the former did not show a significant difference.

Second, there was one outlier with a considerably longer duration of the surgery of 23 minutes in the 23-gauge group. After removal of this patient from the dataset, the test for similarity would not have shown a significant difference in surgery time ($p = 0,101$).

Third, due to the retrospective study design, a change in procedure during surgery could also be responsible for the change in surgery time, other than the different instrument size. Given that all surgeries were performed by one single very experienced surgeon and a time wise close proximity of the sample acquisition (mainly 2017/18 for the 23-gauge group versus 2019/20 for the 27-gauge group), a change in the surgical performance is unlikely.

Fourth, the 27-gauge group vitrectomies might truly be faster. Increased speed of the surgery could be attributed to less need for suturing for 27-gauge, but suturing is rarely needed even for 23-gauge macular surgery. Of note, in our comparison two different vitrectomy unites were used for each respective gauge group. Thus, we did not only compare lumina but also two vitrectomy unites including their respective pump and settings. Further studies using the same unit with different gauge instruments could

eliminate this issue to some extent. Generally, a different setting will be required when switching gauge size.

In our sample the rates of some serious complications were high compared to the current literature. In our analysis the endophthalmitis rate was 1 and 2,8 percent for the 23-gauge and 27-gauge group, respectively. Endophthalmitis values in the literature for micro incisional vitrectomy surgery range between 0,007 % [25] and 0,11 % [26] [27]. The following caveat, however, applies: our study was not powered to make assumptions for rare events such as endophthalmitides. Larger analysis should be performed in this regard.

Apart from its retrospective design, one limitation of this study is that the 23-gauge group had a longer follow-up on average than the 27-gauge group. 27-gauge vitrectomy had been used routinely from 2019 onward in our hospital. For 16 patients from the 27-gauge group follow-up data is not available for the complete 12 months.

The strengths of this study are the high patient number analysed in both groups and that all the surgeries were performed by the same very experienced surgeon and in a similar setting. The patient population in both groups was very homogenous and typical, in terms of age, visual acuity and pathology. Patients included in the study suffered only from idiopathic epiretinal membranes and no other retinal disease.

In short, 23-gauge and 27-gauge pars plana vitrectomy perform equally fast in cases of idiopathic epiretinal membranes.

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