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The Comparison of Long-term Visual Recovery Between Acute and Sub-acute Macula-off Retinal Detachment After Scleral Buckling Surgery

Dissertation

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By

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Table of Contents

1. Abbreviations ……6

2. Abstract ……7

3. Introduction ……9

4. Review of literature ……12
4.1. History ……12
4.2. Rhegmatogenous retinal detachment (RRD)……15
4.2.1 Posterior vitreous detachment (PVD)……15
4.2.2 Pathogenesis of Retinal breaks ……16
4.2.3 Predisposing factors ……17
4.2.4 Prevention ……18
4.2.5 Treatment ……19
4.2.6 Outcome ……20
4.2.6.1 Anatomical outcome ……20
4.2.6.2 Functional outcome ……21

5. Aims of the study ……26

6. Patients and Methods ……27
6. 1 Patients ……27
6.1.1 Inclusion and exclusion criteria ……27
6.1.2 Number of the patients ……27
6. 2 Methods ……27
6.2.1 Collection of retrospective data (I, II) …… 28
6.2.2 Equipment of clinical examination ……28
6.2.3 Treatment of retinal breaks ……30
6.2.3.1 The Peritomy ……30
6.2.3.2 Isolating the Rectus Muscles ……30
6.2.3.3 Localizing and treating the break with cryotherapy ……31
6.2.3.4 Closure of retinal breaks ……31
6.2.3.4.1 Scleral buckling materials ……32
6.2.3.4.2 Configuration of the scleral buckle ……32
6.2.4 Grouping ……35

6.2.4.1 Retrospective Study I (Ia, Ib) ……..……35
6.2.4.2 Retrospective Study II ……..……35
6.2.4.3 Retrospective study III ……..……..35
6.2.5 Statistical analysis ……..……..36

7. Results ……..……...38
7. 1 Retrospective Study I ……..……...38
7.1.1 Retrospective Study Ia ……..……38
7.1.2 Retrospective Study Ib ……..……39
7.1.3 The effects of age, preoperative VA on the post-operative VA……....41
7.1.3.1 Age ……..……..41
7.1.3.2 Preoperative VA ……...……..……...41
7. 2 Retrospective Study II ……..……..42
7.2.1 The effects of age, preoperative VA, refractive error on the post-operative VA. ……..……..43
7.2.1.1 Age ……..……..43
7.2.1.2 Preoperative VA ……..……...……....44
7.2.1.3 Refractive error ……..……...44
7.2.1.4 Line regression ……..……44
7. 3 Retrospective study III ……..……..46
7.3.1 The effect of the DMD on final VA ……..47
7.3.2 The effect of preoperative VA on the final VA ……..…...50
7.3.3 The effect of patient's age on final VA. ……..…..50
7.3.4 The effect of refractive error on the final VA ……..…..50
7.3.5 Optical coherence tomograpy ..……..51

8. Discussion ……..……...55
8.1 Duration of macula-off detachment ……..……55
8.2 Prognostic factors ……..……..57
8.2.1 Age ……..……..57
8.2.2 Preoperative VA ……...……..……58
8.2.3 Refractive error ……..……58
8.2.4 Line regression ……..……59
8.3 Long-Term visual recovery ……....59
8.4 Other factors ……..……..60
8.5 OCT on evaluation of the incomplete visual recovery in the macula-off retinal detachment ……..……..……61

9. Summary and Conclusions ……...……..63

10. Reference ……..……...……..65

11. List of Figures and Tables…… ….77

12. Curriculum Vitat ……...……79

13. Acknowledgments ……..……...……85

1. Abbreviations:

BCVA	Best-corrected VA
DMD	Duration of marcular detachment
LogMAR	Logarithm of the minimum angle of resolution
OCT	Optical coherence tomography
Pre-op	Preoperative
Post-op	Post-operative
PVD	Posterior vitreous detachment
PVR	Proliferate vitreoretinopathy
RRD	Rhegmatogenous retinal detachment
RPE	Retinal pigmental epithelium
SB	Scleral buckling
VA	Visual acuity
VF	Visual function

2. Abstract

Purpose: The primary goal of this study was to investigate retrospectively the best corrected post-operative long-term visual recovery after macula-off retina detachment, and to explore the effect of variable factors on the final visual recovery after scleral buckling surgery. The secondary outcome measure was to evaluate eyes with incomplete VA recovery by optical coherence tomography 5 years after scleral buckling (SB) for macula-off retinal detachment .

Methods: The retrospective studies included 96 eyes of 96 patients with primary, uncomplicated, macula-off rhegmatogenous retinal detachment. These patients were divided into 3 study groups accorrding to the DMD: Study I- (n=73) within one week of DMD, which was further subdivided into Study Ia and study Ib. Study Ia (n=73) consists of 1 to 2 days, 3 to 4 days and 5 to 7 days groups; Study Ib (n=73) consists of 1 to 3 days and 4 to 7 days groups. Study II- (n=96) with macula-off retinal detachment were included. Patients were divided into RRD less than 7 days and RRD more than 7 days. In study I and II, all the patients were follow-up from 3 months to 7 years (mean 43.5 months). Study III – (n=47) followed for 5 years were included in this study. Patients were divided into DMD less than 7 days and more than 7 days groups. Additionally, we analyzed the effect of patient's age, preoperative VA, DMD, and refractive error on the post-operative VA changes.

Results: In Study I, the mean post-operative VA was 0.45± 0.08, significantly higher than the preoperative VA 0.06± 0.04 (P<0.001). 68.4% patients (50/73) regained 0.4 or better VA after scleral buckling surgery. We found that there was no statistical difference in visual recovery between 1 to 3 days' duration and 4 to 7 days' duration. However, if the patients were subdivided into 1-2 days, 3-4 days, 5-7 days after macular detachment, there was a statistical difference in visual outcome among the three groups (p=0.037). In Study II, post-operative VA of 0.4 or better was found in 68.5% patients (50/73) with macular detachment in less than 7 days, which was significantly higher than it in more than 7 days of macular detachment and (52.2%) (12/23) (P<0.001). In Study III, the mean VA was 0.32± 0.08 at 3 months after surgery, increased to 0.46± 0.101 after 5 year (increased 1.6 lines). Among 8 patients, with no improvement of VA at 3 months post-operative, we detected 5 patients get visual progress by 2.8 lines in 5 years follow-up. All patients (47/47) showed a retina anatomically reattached on

indirect ophthalmoscopy. 10 patients of them were randomly selected to do optical coherence tomography. A residual subretinal fluids on 2 of 10 cases gain in VA was found to statistically correlate with the DMD ($p=0.002$) and pre-operative VA ($p<0.001$).

Conclusion: First, macula-off detachments of less than 7 days were not emergent and can wait for the next scheduled available operation room and for systemic evaluation of the patient. These findings help to support the recommandations of *Hartz et al.* [61], who opposed to emergent retinal detachment procedures to be cost effective.

Second, the ultimate anatomic success with more conventional buckling or vitrectomy surgery is not adversely affected.

Third**,** scleral buckling surgery performed within the first week, or preoperative vision more than 0.1 were associated with significant better visual recovery from macula-off retinal detachment. It implies that shallow retina detachment can get better visual recovery after surgery.

Fourth, the DMD and pre-operative VA were significant factors associated with the final post-operative VA.

Fifth, patients aged 60 years or younger were more likely to achieve post-operative VA of 0.4 or better, compare to those aged 61 years or older.

Sixth, surgeon should be aware that the visual function of reattached retina may continue to improve over the long period.

Seven, we strongly recommand OCT in those patients with incomplete VA recovery, although the retina seem attached by funduscopy. This study may provide useful guidelines for the clinical management of macula-off retinal detachment and for assessing the potential for visual recovery in patients after successful scleral buckling.

Key Words: Rhegmatogenous Retinal Detachment - Scleral Buckling - DMD - VA- Optical Coherence Tomography

3. Introduction

Rhegmatogenous retinal detachment (RRD) often causes severe visual loss. Visual recovery after successful surgery for the macula-off RRD continues to be an important topic for ophthalmologists. During the past decades, with the developments of diagnosis and microsurgical techniques, the anatomic success rate of RRD operation increased to more than 90% [28, 54, 68, 91, 120, 140, 153]. Although scleral buckling (SB) surgery achieves a high anatomical success rate in patients with RRD, the visual recovery remains less satisfactory, particularly when the macular is involved. Most patients present central visual loss after macular detachment, because 37% to 60% of these regain visual acuity (VA) of 0.4 or better after successful treatment [13, 14, 26, 112, 124, 145, 153, 161]. It is therefore recommanded to achieve macular reattachment as soon as possible to regain good central vision. However, the impact of the duration of macular detachment (DMD) and the time point of surgery on the visual recovery are less certain, and remains controversy.

Several preoperative factors, including poor preoperative VA, older age, bullous macular elevation, and the long DMD, have been associated with poorer outcomes after SB [13, 34, 36, 37,54, 55, 75, 82, 112, 124, 140, 144, 145, 161]. Numerous studies have shown that preoperative VA is the most reliable predictor for visual and anatomic recovery. On the other hand, have DMD in uncomplicated, primary, macula-off RRD a significant impact on the post-operative outcome after SB. However, these studies did neither separate macula-on from macula-off RRD, nor exclude eyes with other significant preoperative ocular pathology in their analysis [13, 34, 54, 124, 125, 140, 144].

A number of series have correlated the DMD with the anatomic success after SB. One week [37,125], 2 weeks [14], 1 month [36, 86, 144], 2 months [55, 75, 81, 112, 128], and 6 months [73] were identified as the DMD. The longer the DMD, the worsen the visual and anatomic outcomes were detected after SB [50]. In a classic report, *Burton* [14] demonstrated that a DMD within 9 days had significant better final VA of 0.4 or better compared to DMD of 10-19 days. He revealed that visual recovery in relation to increasing DMD declines in an exponential fashion. It remained unknown whether surgical delay during the first week of macula-off retinal detachment affected final post-operative VA. *Ross et al.* [124] in 1998 published an article to clarify this interesting question. They examined results after SB in eyes with macula-off RRD of 7 days or less duration. The patients were

further divided into three groups, with group I consisting of patients with macular detachment of 1 to 2 days duration, group II, 3 to 4 days duration, and group III, 5 to 7 days duration. They found that the recovery of vision was equal in the three and concluded that DMD within the first week did not influence post-operative VA. Although they did not evaluate outcomes in eyes with a longer DMD, they recommended that macula-off detachment can be treated with less urgency and may wait for the next scheduled available operating time. Recently, *Hassan et al.* divided the DMD into 3 arbitrary intervals: acute (10 days or fewer), subacute (11 days to 6 weeks) and chronic (more than 6 weeks). They found that eyes with acute DMD had a much greater likelihood of achieving a final VA of 20/40 or better than eyes with a longer DMD [62].

Due to these different results between DMD and the VA, we divided DMD into less than 7 days and more than 7 day duration. The first group was further subdivided into two groups: group I consisting of 1 to 2 days, 3 to 4 days and 5 to 7 days; group II consisting of 1 to 3 days and 4 to 7 days.

In most studies presenting visual outcome of macula detachment surgery[11, 14, 26, 34, 50, 57, 75, 78, 82, 106, 144, 161], the follow-up period was less than 2 years. Even in reports [34, 75, 82, 161] with relatively long follow-up periods of 11 years, factors affecting long-term changes in macula function have not been documented.

Kusaka et al. [86] retrospectively investigated the long-term visual recovery in 32 macula-off retinal detachments with follow-up of more than 5 years. They found that the best-corrected VAs were better at 5 years than at 3 months post-operatively by two lines or more in 17 eyes (53%), which continued to improve VA for up to 10 years post-operative. The remaining 15 eyes contained within one line of the 3-month values. The long-term improvement during the follow-up period was statistically correlated with younger age, no or mild myopia (less than -5.00 D), and shorter DMD (30 days or less). They classified the DMD into less than 30 days and more than 30 days. However, it is still remains unknown whether the DMD less than 7 days (acute) and more than 7 days (sub-acute) affects long-term visual outcomes after 5 years. In our study, we analysed the long-term VA results of the two different duration groups with a 5 years follow-up.

The histologic feature of the detached retina in rhegmatogenous retinal detachment is not well described because of lack of pathologic specimens. Optical coherence tomography (OCT) obtains cross-sectional retinal images in-vivo with 10-μm to 20-μm resolution [119]. The introduction of OCT [63, 70, 79] has led to many new findings in studies of retinal abnormalities, especially of macular disorrders [63, 79, 118, 119, 151]. In RRD, residual foveal subretinal fluid is observed with OCT even if the foveal retina was successfully reattached by surgery [57]. This residual subretinal fluid is reported to cause poor recovery of VA after surgery [163]. Contrary to this, *Baba et al.* demonstrated that the presence of residual subretinal fluid did not influence visual recovery [8]. However, the follow-up of these patients was within one year. Thus far the tomographic anatomy of the macula has also not been documented by OCT for long-term follow-up, of more than 5 years. In this study, we evaluated the architecture of the foveal that were performed by OCT in 10 patients with more than 5 years after successful SB surgery of RRD. The result were compared to the functional outcome.

Therefore, unlike prior series, we used strict inclusion criteria to confine our retrospective analysis of outcomes after SB to the consideration of the major variable of DMD on post-operative VA results. Moreover, the following factors: patient's age at the time of presentation, preoperative VA, DMD, and refractive error, were statistically compared with the post-operative VA. It is important to analyse the visual recovery after macular detachment, which helps to improve our understanding of visual recovery after SB.

4. Review of literature

4.1 History

Recognition of RRD, determination of its cause, and the development of surgical techniques for its repair have been one of the most interesting challenges facing ophthalmologists for generations. As one examines the history of ophthalmology, it becomes apparent that our current approach to vitreoretinal pathology has emerged from the interdigitation of scientific theory and clinical experience with the sequential evolution of new diagnostic and surgical technology.

Observations of abnormalities of the red reflex predated the development of the ophthalmoscope [Fig.1] [126]. However, it was shortly after the development of the *Helmholtz* ophthalmoscope that *Coccius* first observed a retinal break and made the association of retinal breaks with retinal detachment [31]. Thereafter numerous observations were made describing retinal breaks and detachment, and several theories regarding etiology of detachments were presented.

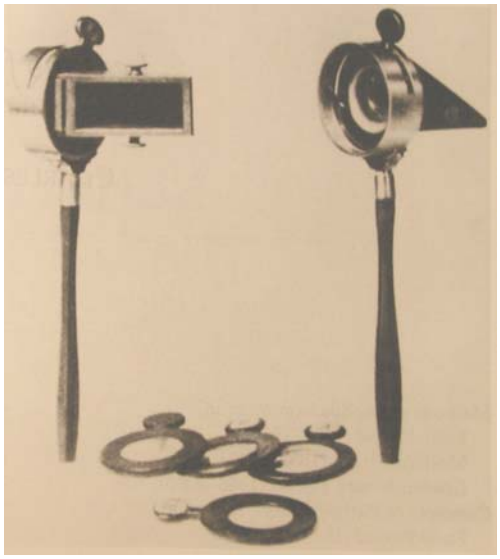


Fig.1. Helmholtz direct ophthalmoscope (1851)

The technology for observation of the retina included modification of the original Helmholtz ophthalmoscope, the development of a monocular indirect ophthalmoscope, and subsequent alterations that ultimately led to the binocular indirect ophthalmoscope [Fig.2] [130, 131]. In a parallel fashion the technology for examining the anterior segment advanced during the same era and led to slit-lamp biomicroscopy [9]. It is the combination of these techniques, slit-lamp biomicroscopy and binocular indirect

ophthalmoscopy with scleral depression, which serves as the basis of modern diagnostic examination techniques for the evaluation of vitreoretinal pathology [131].

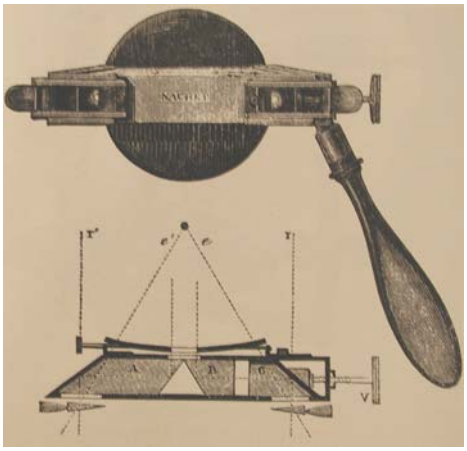


Fig.2. The binocular indirect ophthalmoscope (Giraud-Teulon 1861)

Gonin is credited with initiating a method of localization of retinal breaks and surgical treatment of the breaks [41]. He described the ignipuncture procedure, which consisted of localization of all breaks, external drainage of subretinal fluid, and cauterisation of the retinal break(s) [53]. Since the establishment of Gonin's principles, the surgical management of rhegmatogenous retinal detachment has continued to evolve. However, among the enduring principles of RRD repair are detailed examination, localization, and treatment of all breaks.

Early technically successful treatment of retinal detachment, first proposed by *Gonin* and then modified by others, consisted of methods to create chorioretinal adhesion combined with drainage of subretinal fluid. A variety of techniques to construct adhesion were used, including the use of caustic chemicals, diathermy, and ultimately cryotherapy, which is commonly used currently [116, 117]. Failure of reattachment following external drainage of subretinal fluid led to the realization that shortening the sclera might allow the retina to reapproach and contact the retinal pigment epithelium and become reattached [10]. Surgical management then evolved from scleral shortening to scleral indentation, resulting in a ridge or buckling effect [69]. Subsequently, the advantages of indentation were recognized, and procedures were developed to generate a ridge or buckle [25]. *Custodis* [35] first described scleral buckling as a means of closing retinal breaks. His technique included transscleral diathermy, but he avoided drainage of subretinal fluid. Subsequently, *Schepens et al.* [132, 133] described segmental and encircling buckles typically using lamellar scleral dissection beds with diathermy to

create a chorioretinal adhesion combined with drainage of subretinal fluid. And later, *Lincoff et al.* improved the technique[92], using silicone sponge material as external explantation. Since then, a great number of implant and explants materials have been introduced, leading to the current common buckling techniques using episcleral haRRD or sponge silicone.

While *Ohm* performed the first intravitreal gas injections [114], the work of *Rosengren* represented a major advance in the management of retinal detachment and was a precursor to current pneumatic techniques including pneumatic retinopexy [122, 123]. He described the use of intravitreal air combined with diathermy of retinal breaks and external drainage of subretinal fluid. The use of intraocular gas tamponade was popularised by *Norton* [111]. He used gas in combination with drainage of subretinal fluid and cryopexy or as an adjunctive agent in the course of scleral buckling. Intraocular gas tamponade was subsequently used in combination with vitrectomy as a primary treatment for retinal detachment and then solely as an intravitreal injection combined with cryotherapy or laser as pneumatic retinopexy [42, 67, 84, 85].

While recognition of vitreous traction as a mechanism for retinal detachment preceded the work of *Gonin* [16], instrumentation for intraoperative visualization and manipulation of the vitreous were not initially available. *Cibis* [29] was among the pioneering surgeons, who developed techniques to cut vitreous bands and to strip vitreous membranes from the surface of the retina. Yet, his techniques required visualization through the binocular indirect ophthalmoscope and demanded an unusual degree of surgical skill. It was the innovative work of *Machemer* [100, 101] that led to the modern era of vitreous surgery. Whereas initially vitrectomy was performed to restore clarity to the ocular media, the subsequent development of multiport systems, microinstrumentation, and wide-angle viewing allowed surgeons to relieve vitreoretinal traction, achieve internal drainage of subretinal fluid, and build chorioretinal adhesions, thus facilitating the repair of retinal detachments.

Currently, surgeons may choose to employ a wide variety of techniques to repair retinal detachments, including temporary plombage with external balloons or intravitreal gas or more permanent buckles using segmental or encircling external elements. Vitrectomy can be used as an adjunct to scleral buckling or as a primary approach to the retina. Self-

sealing sclerotomy in vitrectomy can save the time of surgery[139]. With the new device of external diaphanoscopic illuminator, the periphery vitreous can be visualized and removed totally[140].

Liquid fluorocarbons may be used to facilitate manipulation of the retina or to express subretinal fluid. Perfluorocarbon gases may be used for prolonged internal tamponade, and intravitreal silicone similarly may be used for even longer tamponade. Chorioretinal adhesions may be accomplished with cryopexy, laser photocoagulation, or transscleral diode laser application.

With these techniques, vitreoretinal surgeons have achieved high rates of success for the repair of retinal detachment [33, 156].

4.2 Rhegmatogenous retinal detachment (RRD)

4.2.1 Posterior vitreous detachment (PVD)

The vitreous is a gel-like structure, about 4 ml in volume, which fills the posterior cavity of the eye. It consists mainly of water (99%), but contains also a meshwork of fine collagen fibrils and spheroid hyaluronic acid molecules [158, 165]. Aging of the human vitreous is characterized by liquefaction of the gel, several structural changes occur in the vitreous. The central parts become liquefied and the configuration of hyaluronic acid molecules changes. These changes lead gradually to Posterior vitreous detachment (PVD), a separation between the posterior vitreous cortex and the internal limiting membrane of the retina [127, 158] [Fig.3].

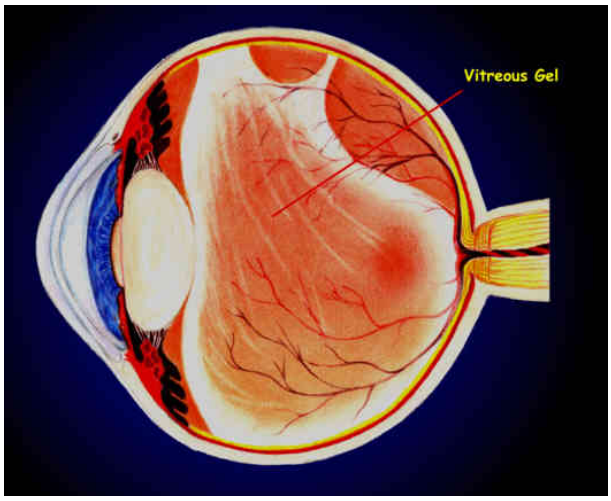


Fig. 3. Posterior vitreous detachment.

The time point of PVD is individual. In an autopsy study PVD was present in less than 10% of patients under the age of 50, and in 63% of patients above the age of 70 [49]. In a clinical survey, however, only 11% of eyes among 65 to 69 year-old patients exhibited a complete PVD. In the age group of 80 to 89 years, 46% had a complete PVD [151].

In association with acute, symptomatic PVD, 4-46% of eyes have been reported to develop a peripheral retinal break [16, 17, 40, 65, 66, 77, 113, 121]. The average risk for these breaks of progressing to RRD is reported to be 35% [77]. Therefore, any retinal break associated with acute symptoms is often prophylactically photocoagulated [16, 38, 39, 48, 158].

Asymptomatic retinal breaks in phakic eyes with no RRD in the fellow eye do not usually progress to RRD even after PVD, and prophylactic treatment is recommended only if subretinal fluid accumulates [18-20, 32, 45-47, 127].

4.2.2 Pathogenesis of Retinal breaks

Retinal breaks are classified as holes and tears [158,165]. The retinal hole is a full-thickness retinal defect that is not thought to be associated with persistent vitreoretinal traction. It occurs usually as localized vascular insufficiency in the retina and choriocapillaris causes retinal atrophy that affects all layers, especially in association with retinal lattice degeneration in myopic or otherwise elongated eyes. The liquefaction and syneresis of the vitreous gel detaches the posterior portion of the vitreous. Retinal tears are usually caused by PVD and subsequent vitreoretinal traction at the site of a significant vitreoretinal adhesion such as the posterior borders of vitreoretinal degenerations or scars. Vitreous traction usually persists at the edge of a tear, resulting in progression of RRD. The incidence of retinal breaks in autopsied individuals over 20 years of age ranges from 4 to 11% [158, 165] [Fig.4].

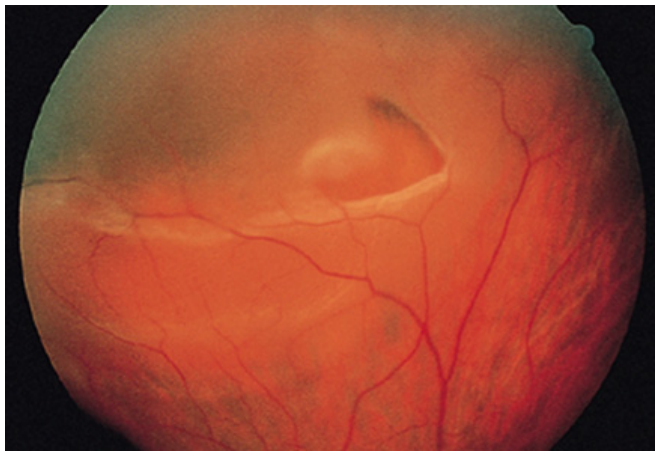


Fig.4. Retinal detachment with retinal tear in the superior quandrant.

In RRD, the neuroretina separates from the retinal pigment epithelium (RPE), because fluid from vitreous cavity passes under the neuroretina through a retinal break. The series of events usually begins from vitreous liquefaction, which induces PVD. The latter causes a retinal break at the site of former vitreoretinal adhesion. The normal retinal attachment is maintained by adhesive-like mucopolysaccharides in the subretinal space, oncotic pressure differences between the choroid and subretinal space, hydrostatic forces related to intraocular pressure, and metabolic transfer of ions and fluid by the RPE [158, 165]. Retinal detachment occurs when the combination of factors that promote retinal detachment overwhelms the normal attachment forces.

4.2.3 Predisposing factors

In the general population, the annual incidence of RRD is approximately 1:10 000 [59, 158]. However, a variety of ocular conditions are associated with increased prevalence of vitreous liquefaction and PVD, and with increased number and extent of vitreoretinal adhesions. These conditions, based on the pathogenetic factors, also are associated with increased risk for RRD. Particularly important risk factors for RRD in phakic eyes are high myopia, lattice degeneration, history of RRD in the fellow eye, and blunt or penetrating ocular trauma [87, 158, 165].

In a case-control study 253 patients with idiopathic RRD were compared with 1,138 controls. It was found that an eye with a refractive error of -1 to -3 D had a fourfold risk of RRD, and if the refractive error was greater than -3 D, the risk increased 10-fold compared with a nonmyopic eye [146]. Degenerative changes in the peripheral retina and vitreous are thought to predispose the myopic eye to RRD. Retinal breaks and lattice degeneration, important risk factors for RRD, are also reportedly more common in

myopic eyes [24]. Finally, liquefaction of vitreous, resulting in PVD, occurs earlier than average in myopic eyes [158, 165].

Lattice degeneration of the peripheral retina is a condition in which retinal thinning is associated with a pocket-like liquefaction and separation of overlying vitreous. A condensed vitreoretinal adhesion also occurs at the margin of lattice lesions. Lattice degeneration is present in 11% of autopsy eyes, occurring equally in men and women, and increases in incidence with age and axial length of the eye. Up to 25% of areas of lattice degeneration include a retinal break. In eyes with a RRD, lattice degeneration is present in up to 30% [158]. However, the great majority of eyes with lattice degeneration are not at a particularly high risk of RRD. The risk for developing RRD in an otherwise normal eye is estimated to be small [21]. Prospective randomized trials of prophylactic therapy to prevent RRD have not been performed, but routine laser treatment of lattice degeneration and asymptomatic retinal holes in otherwise normal eyes are not recommended [21, 154, 155].

Of patients with RRD, up to 20% are reported to have asymptomatic retinal breaks in the fellow eye [88, 98, 104]. The recommendations about prophylactic therapy of lattice degeneration and retinal breaks in fellow eyes are controversial [23, 88, 98, 104, 105, 141]. It has been noticed that RRD can frequently develop from a new retinal break in previously healthy retinal areas [16, 17, 23, 104]. Risk factors of RRD may also be additive. Blunt trauma in a myopic eye with degenerative changes of peripheral retina is more likely to be complicated with RRD than in a normal eye without pathologic conditions.

4.2.4 Prevention

Although prevention of RRD is an important goal, so far there have not been prospective, double-blinded clinical trials reported to test the true value of preventive treatment [154].

Accorrding to its pathophysiology, RRD could be avoided by preventing vitreous liquefaction and associated PVD, relieving vitreoretinal traction or creating a chorioretinal adhesion around vitreoretinal adhesions and retinal breaks. For practical reasons, the last of these three ways is the only one used, created by laser photocoagulation or cryocoagulation. It is generally accepted, that symptomatic patients with a horseshoe-shaped tear should be treated prophylactically because of increased

risk of RRD. However, other indications of preventive treatment remain controversial. It is often recommended that in patients with RRD, degenerative retinal lesions of fellow eyes, such as lattice degeneration, round holes or flap tears should be treated even in asymptomatic patients. Laser photocoagulation is preferred over cryopexy because chorioretinal adhesion appears more quickly, it causes less breakdown of the blood-retina barrier, and it may have a lower incidence of epiretinal membrane formation. No generally accepted guidelines exist of prophylactic treatment of retinal breaks in eyes planned to undergo cataract surgery or laser posterior capsulotomy [43, 157].

4.2.5 Treatment

The main goal in managing RRD is closing every retinal break to re-establish the physiologic conditions that normally maintain the contact between the neural retina and pigment epithelium. Long-term closure of retinal breaks may also require permanent reduction or elimination of vitreoretinal traction. The minimal procedure to safely achieve the goal is recommended [83]. The main options for the management of primary RRD are laser demarcation, cryocoagulation, pneumatic retinopexy, scleral buckling (segmental or encircling), and vitrectomy [Fig.5]. The scleral buckling and creation of a chorioretinal adhesion around each break is nowadays the most frequent technique. Vitrectomy and combinations of both techniques are performed if failure of scleral buckling is likely, such as in eyes with a very large tear, no visible breaks, posteriorly located tears and dense vitreous hemorrhage or with grade C proliferative vitreoretinopathy (PVR).

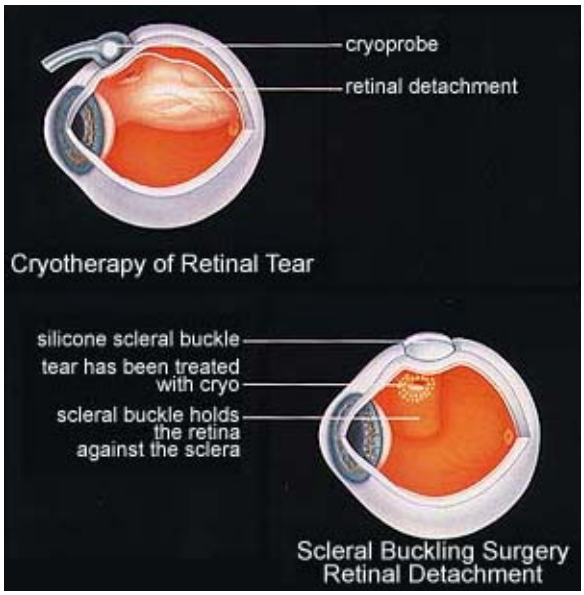


Fig.5. Segmental scleral buckling surgery.

4.2.6 Outcome

Nearly all symptomatic rhegmatogenous retinal detachments progress to total blindness unless they are repaired. Until 70 years ago, RRD was an essentially incurable disorrder. Nowadays recent technical advances and better understanding of the pathogenesis of RRD have lead to excellent results especially anatomically [1, 3, 93]. The best results are achieved, when primary RRD is operated on before the development of macular detachment [3, 7, 51, 89, 124, 125]. The outcome of RRD surgery can be expressed in several ways: anatomical, visual and functional.

4.2.6.1 Anatomical outcome

The result is anatomically good, when the retina returns to its normal position with no residual subretinal fluid, and remains attached. With recent surgical techniques the final anatomical success rate (with one or more operations) is 90-98% [60, 96, 108, 134, 140, 143, 148]. The two most common reasons for failure are PVR and a failure to close all retinal breaks. In PVR, primarily RPE and glial cells grow on both the inner and outer retinal surfaces and on the vitreous face, forming membranes. Contraction of these membranes causes fixed retinal folds, traction and generalized retinal shrinkage. As a result, the primary retinal breaks may reopen, new breaks may occur, or a tractional detachment may develop [147, 165].

4.2.6.2 Functional outcome

The visual outcome after RRD surgery is generally considered good, if BCVA is 0.5 or better in Snellen fractions. Visual and anatomical outcome are often somewhat different; the retina may remain attached, but the retinal function may not be well preserved. The visual results depend on the extent of damage to the macula caused by the RRD. If the macula becomes detached by subretinal fluid, some degree of permanent damage to vision usually occurs in spite of early surgical reattachment. The most important predictors of visual recovery after RRD surgery are preoperative BCVA and the DMD [1, 3, 7, 50, 54, 73, 74, 82, 124, 125, 144, 149].

However, visual function may reimprove in the long term especially in younger patients and after macular detachment of short duration [143]. If the macula is detached, only 50% of patients gain a BCVA of 0.5 or better [51, 108, 124]. In eyes with attached macula, up to 80-90 % can gain a better BCVA than 0.5. It must also be remembered though that about 10% of eyes with almost normal vision preoperatively undergo some degree of visual loss after a successful repair of a macula-sparing detachment. Among others the reason for this is gradually developing PVR in the form of epiretinal membranes.

In 1982, *Burton et al.* [14] published an important article on visual recovery in macula-off retinal detachments. In this article he reported that 53% (46/87) of patients (who could provide adequate information regarding the onset of macular involvement) operated on by 9 days after detachment achieved 20/20 to 0.4 acuity. The proportion attaining 20/20 to 0.4 acuity diminished to 34% (24/70) in those operated on from days 10 through 19 and to 29% (14/48) in those operated on after 19 days. He concluded that patients with macular detachment of 9 days or less had a statistically significant better chance of obtaining final VA of 0.4 or better than those with macular detachment of 10 through 19 days' and longer than 20 days' duration.

On the other hand, he observed the effect of the DMD on the visual recovery. By 5 days' DMD the visual recovery averaged 0.4. By 13 days, the VA decreased to 20/60. Visual recovery declined to 20/70 at 20 days, 20/80 at 27 days, 20/100 at 37 days, 20/125 at 47 days, 20/160 at 58 days, and 20/200 at 69 days. This study demonstrates that visual recovery in relation to increasing duration of detachment declines in an exponential fashion. Despite Burton's results, it remained unknown whether surgical

delay during the first week of macula-off retinal detachment altered final post-operative VA.

In 1998 *Ross et al.*[124] published an article to help clarify this interesting question. The purpose was to determine the visual results of macula-off retinal detachments operated on within the first 7 days of macular involvement. In this prospective study, 303 consecutive patients with rhegmatogenous retinal detachments seen during a 30-month period were interviewed and examined to determine the status of macular attachment. Eighty-five patients had macula-on detachments and were excluded from the study. The remaining 218 patients were carefully interviewed to pinpoint the onset of macular detachment to a specific 24-hour period within the first week. Ninety-one patients had macula-off detachments of longer than 7 days' duration and were excluded. An additional 23 patients with macula-off detachments of less than 1 week's duration were excluded because of previous retinal surgery (9 patients), proliferative vitreoretinopathy more advanced than grade C3 in patients who had undergone initial combined vitrectomy and buckling surgery (4 patients), or ocular disease that precluded a good return of central vision (10 patients: macular degeneration in 2, macular hole in 2, degenerative myopia in 2, optic atrophy in 1, end-stage glaucoma in 1, and amblyopia in 2). One hundred four patients remained, and all underwent surgical repair of detachments within 24 hours of initial examination. There were four primary failures, and these were also excluded from the study.

Therefore, 100 patients remained with macula-off detachments of 7 days' duration or less, who had no pre-existing ocular disease and had successful repair with one procedure. Patients were observed for 6 to 38 months with a mean follow-up of 10.8 months. Snellen VA was obtained and was converted to logMAR units. To apply parametric statistical testing, the patients were divided into three groups based on DMD, with group I consisting of patients with macular detachment of 1 to 2 days' duration (n = 30); group II, 3 to 4 days' duration (n = 32), and group III, 5 to 7 days' duration (n = 38). There were sufficient numbers in each group to demonstrate a difference of 0.28 logMAR units among the three groups or a doubling of the visual angle. The mean preoperative acuities in the three comparison groups were statistically similar. The mean post-operative VA for all three groups was 0.48 logMAR (20/60 Snellen acuity). The post-operative acuity demonstrated considerable variability in the results, regardless of

the DMD. An analysis of variance test indicated that the post-operative acuities for the three groups were statistically the same with no difference in the mean acuity, despite the difference in the timing of detachment repair after macular involvement (P = 0.533). The patient's age did not influence the results regarding the DMD and post-operative best-corrected VA.

Subretinal fluid was drained in 49% of patients. The subgroups did not differ statistically in preoperative acuity but the post-operative acuity in the nondrainage group was better than that in the drainage group (20/71 vs 20/ 53) and approached statistical significance ($P = 0.062$, Student's t test).

The data presented in this paper support the contention that good preoperative vision does portend a better post-operative result. Of those patients in this series who had acuities of 1.00 logMAR or better (20/100), the mean post-operative VA was 0.275 logMAR (20/38). Conversely, those with VA worse than 1.00 log-MAR at initial examination had mean post-operative VA of 0.542 logMAR (20/70; P <0.0001, Student's t test).

The main finding in this series is that the recovery of vision was equal in the three groups of 1 to 2, 3 to 4, and 5 to 7 days of macular detachment. Approximately 59% in all three groups regained 0.4 or better vision, 36% regained 20/60 to 20/200 vision, and 5% had less than 20/400 vision. The conclusion of this study is that the DMD within the first week did not influence post-operative acuity.

Elective retinal detachment repair is also supported by the findings and recommendations of *Hartz et al.* [61] In their study, which compared emergency versus scheduled retinal detachment surgery, there was no evidence that delaying the surgery contributed to a worse visual outcome regardless of the status of the macula. Patients who underwent scheduled or emergency surgery had similar outcomes, but the cost of emergency surgery was 25% more costly than that of scheduled surgical procedures.

Although most patients who undergo retinal detachment surgery have stable vision 3 to 6 months after surgery, vision continues to improve in a subgroup of patients up to 5 years after surgery. Post-operative recovery of vision has been studied previously by

Gundry and Davies [56] and by *Kreissig* [82]. *Liem et al.* [90] have shown recovery of cone photopigments after reattachment, by analysis with foveal densitometry. The improved foveal cone photopigments may be attributed to regrowth and realignment of photoreceptor outer segments and metabolic recovery of the pigment epithelium photoreceptor complex.

Kusaka et al[86] published an interesting article in the Japanese literature on long-term visual recovery. They retrospectively investigated the long-term visual recovery in 32 macula-off retinal detachments that had been followed up for more than 5 years after surgery. They found that the best corrected visual acuities were better at 5 years than at 3 months by two lines or more in 17 eyes (53%). In these 17 eyes, VA continued to improve for up to 10 years after surgery. The remaining 15 eyes demonstrated best-corrected acuities that remained within one line of the 3-month values. The eyes that demonstrated long-term improvement in the post-operative period were found to be statistically correlated with younger age, no or mild myopia (less than −5.00 D), and shorter DMD (30 days or less).

The functional outcome has been measured more often after cataract than after vitreoretinal surgery with several questionnaires, such as visual function (VF) –14 which is a reliable and valid index of functional impairment in patients with cataract (possible range: 0, inability to perform any of the applicable activities; 100, no difficulty performing any of the applicable activities)[129, 137, 150]. A few reports of vitreoretinal surgery have been published the functional outcome [95, 138, 139, 142]. The first study, published in 1993, comprised patients with RRD, diabetic retinopathy, retinal vein occlusion, and other vitreoretinal diseases. It was based on a five-item questionnaire answered by 123 patients [142]. In 1997 and 1998, binocular visual function was evaluated in 187 patients after vitrectomy for uncomplicated and complicated RRD and macular pucker. The conclusion was that visual function improved after surgery even among those who had normal vision in the fellow eye [138, 139]. The VF-14 was recently tested with 546 patients with vitreoretinal disease, 14% of whom had RRD. The median VF-14 score was 92, almost perform the applicable activities, but the score after RRD surgery was not separately reported [95]. In 1998, Liu published a paper in Chinese on the colour vision recovery after retinal detachment. It had been found that the color vision defect after retinal detachment, and blue and yellow showed more retinal

sensitivity loss than red. Blue and yellow recovered slower than the red color after surgery. Significant improvement in colour vision was observed within 2 months post-operatively[97].

5. Aims of the study

1. To use strict inclusion criteria, only in those groups with macula-off RRD without other significant preoperative ocular pathology, to confine our retrospective analysis of outcomes after SB to the consideration of the major variable of DMD on post-operative VA results.
2. To analyse acute macula-off detachments (less than 7 days) visual functional results after SB-surgery.
3. To analyse the impact of the duration of macula-off detachment in acute (less than 7 days) and subacute (more than 7 days) on the visual results after SB-surgery.
4. To get a guideline for the best time of SB-surgery of macula-off retinal detachment on the visual recovery.
5. Retrospectively investigation to evaluate long-term visual recovery between acute and sub-acute macula-off retinal detachment with a 5 years follow-up.
6. To analyse the variable factors, patient's age at the time of presentation, preoperative VA, DMD and refractive error that affect the visual recovery in acute, subacute macular detachment and the two groups for long-term 5 years follow-up.
7. To evaluate the characteristic foveal imaging by OCT after macula-off RRD.
8. To analyse the visual recovery after macular detachment, which helps to improve our understanding on visual recovery of retinal detachment involving the macula after SB.

6. Patients and Methods

6.1 Patients

6. 1.1 Inclusion and exclusion criteria

The criteria of this retrospective cohort study was RRD involving the macula who were treated by SB. The following exclusive criteria were used in this study: previous retinal surgery, proliferative vitreoretinopathy more than grade C3, prior ocular disease affecting central visual function including severe macular degeneration, macular hole, degenerative myopia, optic atrophy, and amblyopia, past history of ocular trauma; uncommunicative or cognitively impaired. Eyes with vitreous haemorrhage or significant central vitreous debris were also excluded because poor VA in these eyes could not be attributed solely to macular detachment and the estimate of DMD may have been inaccurate. No eyes with complicated RRD such as those with giant retinal tear or retinoschisis were included. No eyes with visually significant cataracts or other media opacities that could decrease VA of interfere with the assessment of DMD were included. Only eyes in patients in whom accurate VA testing was possible were included. All eyes had at least 3 months follow-up. DMD was defined as the time between the onset of symptoms of macular detachment and the time of surgery.

6.1.2 Number of the patients

From January, 1994 to December, 1997, 418 consecutive patients presenting with RRD, were interviewed and examined to determine the status of macular detachment in our center by 3 surgeons (*Kroll, Schmidt and Hesse*). All eyes had a primary, macula-off RRD and were carefully interviewed to accurately classified the onset of macular detachment to a specific 24-hour period. Among of them, 280 patients were excluded from the study because of macula-on detachment. Within 138 patients presenting with macula-off detachment, there were 42 patients lost for follow-up at 3 months post-operation. Therefore, 96 eyes in 96 patients met the strict inclusion criteria. There were 39 females and 57 males, ranged from 12 to 94 years (mean 62.5 years). Among 96 consecutive patients with rhegmatogenous macula-off retinal detachments, 47 eyes of 47 patients were follow-up for 5 years. There were 33 males and 14 females with age from 12 to 90 years (mean 61.8 years).

6.2 Methods

All RRDs were operated at Phillips University Eye Center by one of 3 vitreoretinal surgeons (Kroll, Schmidt and Hesse). The surgical repair was either a circumferential silicone sponge or a radial silicone sponge. Cryotherapy was used in all cases to achieve retinopexy. Drainage of subretinal fluid was performed in few cases (n=2) (2%).

6.2.1 Collection of retrospective data (I, II)

The following data were collected from the patient's records: age, gender, preoperative VA, the DMD, phakic status, the characteristics of RRD and the number, type and meridional location of retinal breaks, the preoperative fundus drawings, intraoperative findings, immediate post-operative retinal status, intraoperative and post-operative complications, reoperations, best post-operative VA, latest VA (at most recent follow-up visit), and follow-up period. Missing clinical information was collected from other central, regional, and private hospitals where these patients had been treated and from private ophthalmologists responsible for the referral and follow-up.

6.2.2 Equipment of clinical examination

The best-corrected VA (BCVA) was determined using a test-type projector (Rodavist 2, Rodenstock). Snellen VA was transformed into their logarithm of the minimum angle of resolution (log MAR) equivalent (negative log of the decimal Snellen acuity) to create a linear scale of VA and for statistical comparison.

Pupils were dilated with tropicamide 0.5%, phenylnephrine hydrochloride 10%, and cyclopentolate hydrochloride 1% drops, instilled twice. The anterior segment was evaluated and intraocular pressure was measured by a standard biomicroscope (Haag-Streit, Köniz, Switzerland) and Goldmann applanation tonometer (Haag-Streit, Köniz, Switzerland), respectively.

The central fundus was examined with a +78 D convex lens (Volk Optical Inc., Mentor, Ohio, USA). The peripheral retina was evaluated using a binocular indirect ophthalmoscope, a +28D lens and scleral indentation, a Goldmann 3-mirror lens (Haag-Streit, Köniz, Switzerland), or a wide-field contact lens (QuadrAspheric, Volk Optical Inc., Mentor, Ohio, USA), whichever provided better visualization. Abnormal findings were recorded on a fundus chart.

Tomographic images of the macula were obtained using an OCT 1997 device (Carl Zeiss Humphrey Instruments, Inc). OCT is a new technique for high-resolution, cross-sectional visualization of retinal structure in which the time delays of lights reflected from different depths within the retinal are localized by means of low-coherence interferometry. Low-coherence light is divided in an interferometer into a probe beam incident on the retinal and a reference optical delay path. The two beams are recombined at a detector where interference signal only occurs when the propagation distances of both beams match to within the source coherence length. The source coherence length determines the longitudinal resolution of the system and was measured to be 14 μm in air, predicting a resolution of 10 μm in the retina after accounting for the difference in refractive index between air and tissure. The optical power incident on the eye is approximately 200 μW at 830 nm, which is consistent with a conservative interpretation of the American National Standards Institute standard for permanent intrabeam viewing.

The images are displayed in false color. Bright colors (red to white) correspond to high reflectivity; dim colors (blue to black), minimal reflectivity. Six OCT scans 2.8mm long were obtained in a radial spoke pattern centered on the patient's fixation point, through a dilated pupil. The maximal longitudinal resolution is about 10 μm. Scanning was performed using an internal fixation beam. 6 of these measurements located in the central fovea. The central foveal thickness was calculated as the average of 6 measurements performed at the intersection of the 6 radial scans by using the retinal mapping program of the A-5 software. We selected one direction scan that showed the the best pictures of residual subretinal fluid.

6.2.3 Treatment of retinal breaks

6.2.3.1 The Peritomy

A 360-degree conjunctival peritomy was performed. The initial incision was made by grasping both conjunctiva and Tenon's capsule with a toothed forceps and cutting in a radial fashion using a blunt curved scissors in the sector chosen for the radial relaxing incision [Fig.6]. Conjunctiva and Tenon's capsule were incised in tandem for 360 degrees adjacent to the limbus while two separate radial relaxing incisions approximately 5mm in length and 180 degrees apart were recommended to avoid conjunctival tearing.

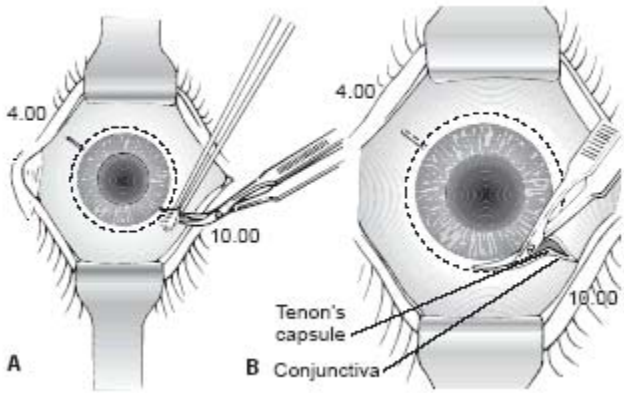


Fig.6 The schematic of peritomy A. The conjunctiva and Tenon's capsule are tented up and cut in a radial fashion. B. A 360-degree peritomy.

6.2.3.2 Isolating the Rectus Muscles

A curved tenotomy scissors was then used to dissect the quadrants between each of the four rectus muscles. The cut edge of conjunctiva was grasped and elevated using a toothed forceps. Closed curved scissors were inserted between the conjunctiva and bare sclera and spread. This action would create a taut edge of Tenon's capsule. The conjunctiva and Tenon's capsule were elevated together. Closed tenotomy scissors were inserted into each quadrant between the capsule and sclera and opened with a spreading motion [Fig. 7].

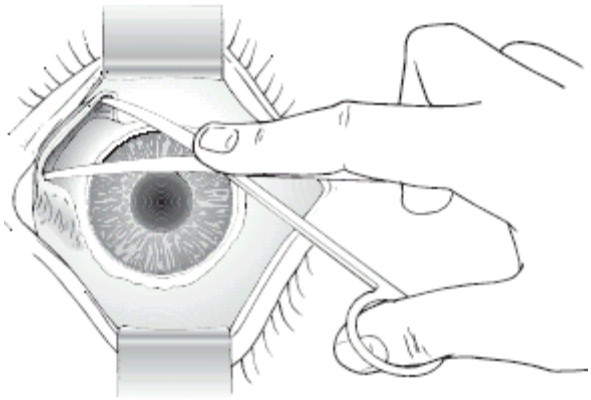
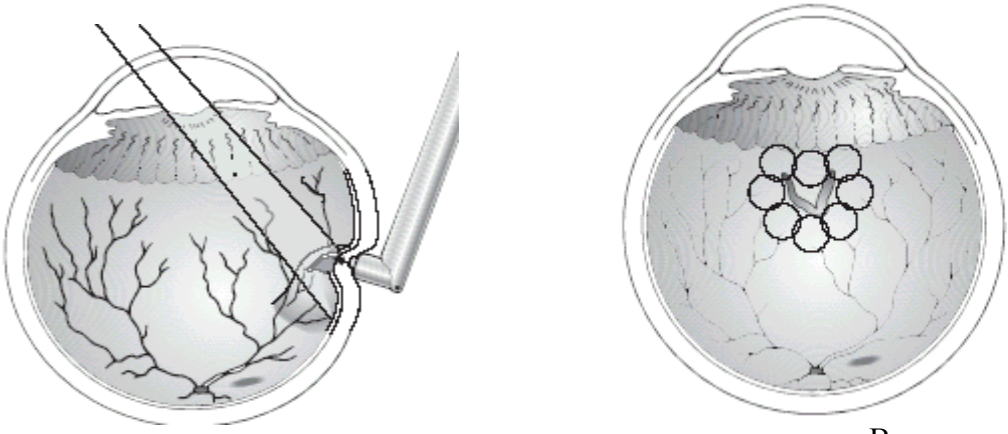


Fig. 7. Blunt dissection of the quadrants separating Tenon's capsule from the sclera.

6.2.3.3 Localizing and treating the break with cryotherapy

Indirect ophthalmoscopy was used to localize all the breaks. Once the breaks were localized, they usually are treated with cryotherapy [Fig. 8], with exception of macular

holes. This was performed while monitoring the location and effect of each application using indirect ophthalmoscopy. Each retinal break was surrounded by a 1 to 2 mm zone of contiguous cryotherapy application while avoiding refreezing of the same tissue.



A B

Fig.8. Breaks are treated by cryotherapy. **A.** Proper cryotherapy. **B**.Encircling the retinal break with cryotherapy and anterior to the ora serrata.

6.2.3.4 Closure of retinal breaks

A scleral buckle was prepared to support all retinal breaks and other areas treated with cryotherapy within the area of detachment. The configuration of the selected scleral buckle depends on the number, size, location and other physical features of the retinal breaks.

6.2.3.4.1 Scleral buckling materials

One-half thickness or full thickness cylindrical sponge of 4, 5 or 7.5 mm diameter was used to create a radial scleral buckle [Fig. 9], depending on the width of the retinal break. Using a one-half thickness sponge permits proper indentation but avoids an external bulge above the contour of the sclera.

The primary goal of encirclement was to support the entire vitreous base. 4 mm sponage encircling elements are performed under the four rectus muscles at the position of the vitreous base. 65mm length of sponage band was used.

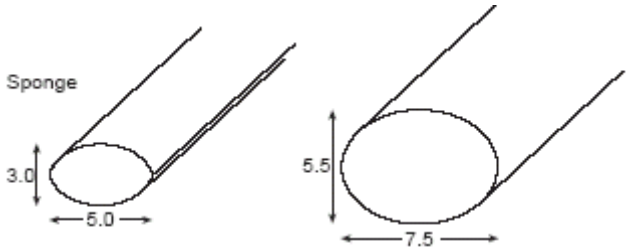


Fig.9 Commonly used scleral buckling elements.

6.2.3.4.2 Configuration of the scleral buckle

Radial Elements: Scleral buckle may be radially or circumferentially oriented. Radial scleral buckle provided focal support for a retinal tear and minimized adverse effects due to radial folding of the retina that resulted from the decreased circumference of the eyewall when a circumferential scleral buckle was used. Larger retinal tears generally required a radial element to decrease the risk of radial folds that might occur with encirclement. The “fish-mouth” phenomenon could occur when a radial fold at the posterior edge of a large retinal break remains folded open, allowing fluid to dissect posteriorly [Fig. 10]. Radial elements helped to alleviate this problem by increasing the internal surface area of the choroid underneath the retinal break and provided a larger surface for the retinal hole to rest on. The size of the sponge should be approximately 2mm wider than the retinal tear, to ensure that all borders of the tear were supported. Imbrication or “wrapping” the sclera around the borders of the element provided significant internal indentation of the choroid. The sutures were placed in a mattress style, leaving 1 mm of sclera on each side of the sponge for effective imbrication. Too much imbrication could lead to an undesirably steep indentation while too little imbrication would not support the break. The sutures should extend 2mm anterior to the anterior horns of the retinal tear and 3mm posterior to the posterior border of the retinal tear to ensure that the edges of the tear were well supported [Fig. 11]. If too narrow of a posterior border was indented, the posterior edge of the retinal tear might remain open on the posterior slope of indentation, thus allowing fluid to enter the subretinal space.

Fig. 10 The “fish-mouth” phenomenon from encirclement with radial folds.

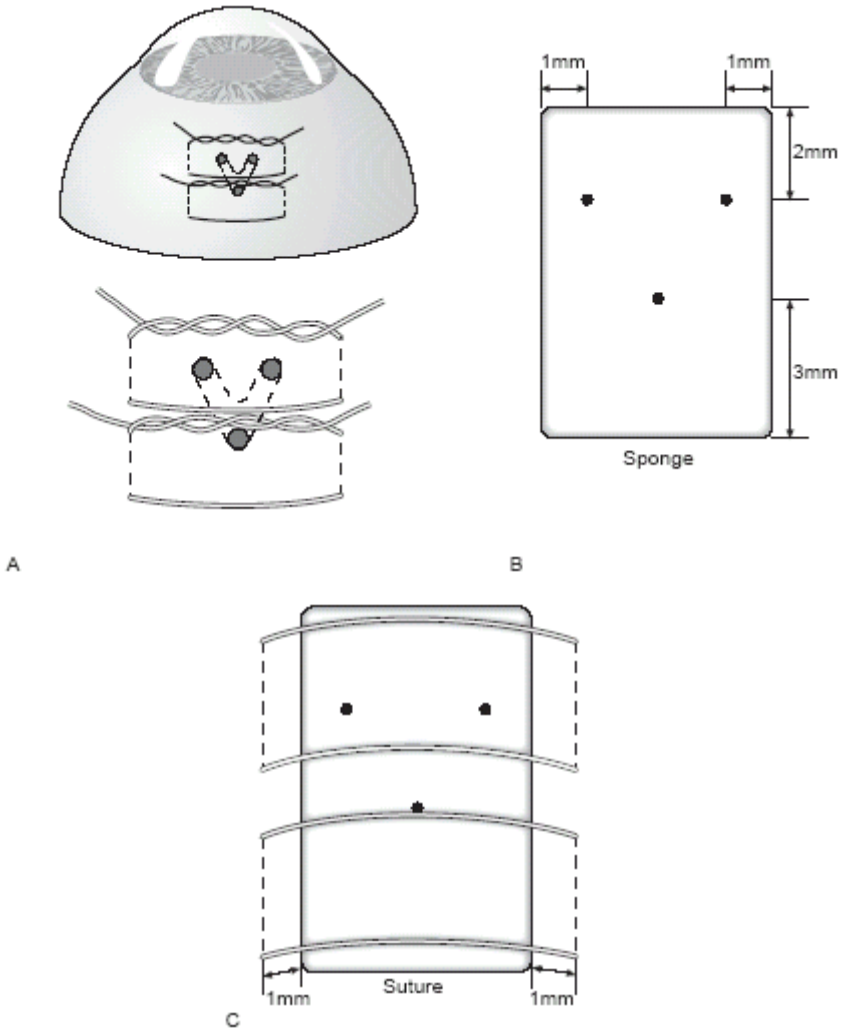


Fig.11 The suture of sponage**.** A. Suture placement for a radial sponge. B. Proper sponge size, extending beyond the borders of the retinal break. C. Proper placement of mattress sutures relative to the sponge.

Encirclement: The primary goal of encirclement was to support the entire vitreous base. Circumferential scleral buckle provided a zone of support-oriented parallel to region where vitreous traction was most severe [94]. A sponage band was used alone.

Single retinal breaks were usually supported on a radially oriented explant secured to the sclera by mattress-type suture. Multiple retinal breaks in different quadrants might be held by separate radially oriented explants beneath each break. Alternatively, multiple retinal breaks in the same or different quadrants might be supported on a wider, circumferentially oriented scleral buckle. This could be extended around the globe to support retinal breaks or areas of prominent vitreoretinal traction in three or more quadrants.

The dimensions of both radial and circumferentially oriented scleral buckles were selected to support all edges of the retinal breaks and the zone of surrounding cryotherapy within the area of retinal detachment [Fig. 12]. The elevation of the buckling effect should be sufficient to position the treated pigment epithelium near the retinal break and to relieve any clinically significant vitreoretinal traction [Fig. 13].

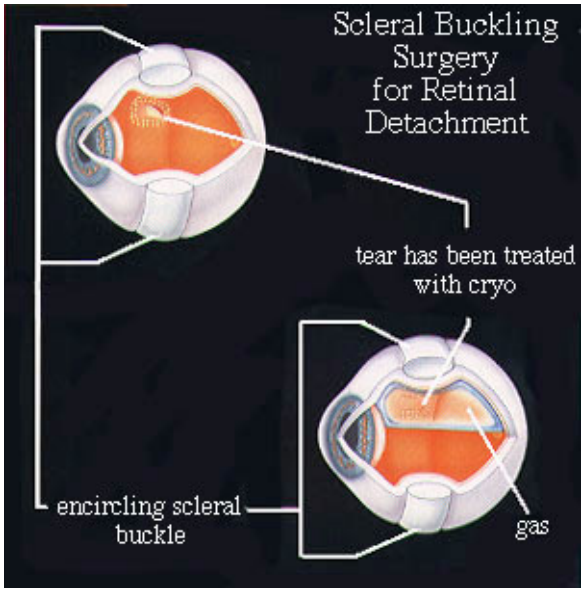


Fig. 12 Tear has been treated with cryo and with encircling scleral buckle.

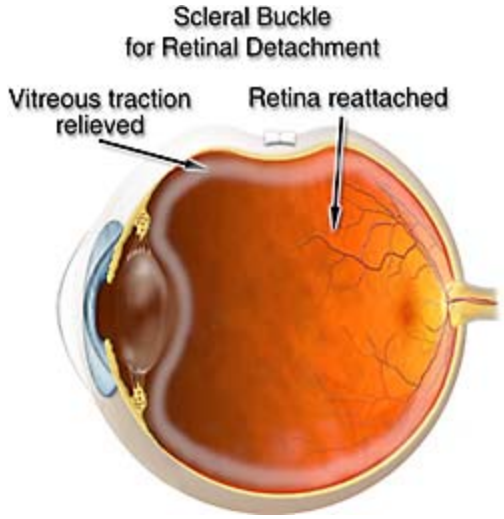


Fig. 13 The elevated buckle relief the vitreoretinal traction.

6.2.4 Grouping

The following factors: patient's age at the time of presentation, preoperative VA, number of tears, DMD, refraction error, were analysed those factors' effects on post-operative VA.

6.2.4.1 Retrospective Study I (Ⅰa, Ⅰb)

73 patients within one week of DMD were included in this study. All the patients were follow-up from 3 months to 7 years (mean 43.5 months). To compare the difference of post-operative VA at different DMD, two kinds of classification were used.

Study Ⅰa: Patients (n= 73) were divided into 3 groups: 1-2 days (n= 29) , 3-4 days (n= 14) and 5-7 days (n= 30) of macular detachment.

Study Ⅰb: Patients (n= 73) were categorized into 2 groups: 1-3 days (n= 37) and 4-7 days (n=36).

6.2.4.2 Retrospective Study Ⅱ

96 patients with macula-off retinal detachment were included. All the patients were follow-up from 3 months to 7 years (mean 43.5 months). Accorrding to the DMD, the patients were divided into 2 groups: less than 7 days and more than 7 days.

6.2.4.3 Retrospective study Ⅲ

47 patients that followed for 5 years were included in this study. Patients were divided into DMD less than 7 days and more than 7 days groups. The 3-month and 5-year post-

operative best-corrected VAs were compared in these two groups. Additionally, we analysed the effect of additional factors (patient's age, preoperative VA, DMD, and refractive error) on the post-operative VA changes. Patients were followed for 5 years.

Visual improvement was defined as an increase in 5-year post-operative VA by two lines or more on the standard eye chart between 3 months and 5 years post-operative.

Examination of macula was performed by OCT with 2.8-or 5 mm long vertical and horizontal scans through the fovea. Low reflective region observed by OCT was defined as an accumulation of subretinal fluid accorrding to previous reports [57, 72, 109, 110, 152, 159]. The relation between the presence of subretinal fluid, the duration of retinal detachment and improvement of post-operative VA was studied.

6.2.5 Statistical analysis

Statistical analyses concerning the correlation between DMD, patients age, preoperative VA, refractive error, 3 –month and 5-year post-operative best corrected VA, and final VA were performed using the SPSS for Windows 12.0. (SPSS Inc., Chicago, Illinois, USA).

Descriptive statistics were given as a mean and standard deviation (SD) for normally distributed variables and as a median and range for other continuous variables. Confidence intervals (95%) were calculated for proportions.

Pearson's chi-square test with Yates' continuity correction was used to compare proportions in 2×2 and larger unordered contingency tables, respectively [2]. Means of continuous variables that follow normal distribution were compared with the parametric Mann-Whitney T-test, while the data that follow with normal distribution were compared with the non-parametric Mann-White-U-Test [2]. All tests were 2-tailed, and a *P* value less than 0.05 was considered significant. For calculating mean and median VA, the Snellen fractions were transformed to -logMAR (logarithm of the minimum angle of resolution) units. The results were transformed back to Snellen equivalents.

Line regression was used to determine the independent correlation of each variable with final visual outcome [2, 115]. The independent variable factors include patient age, DMD, tears, preoperative VA and refraction error.

7. Results

7.1 Retrospective Study Ⅰ

73 patients, including 29 females and 44 males, within one week of DMD were included in this study. Age ranged from 12 to 94 years (mean 62.5 years). Patients were followed from 3 months to 7 years (mean 43.5 months). Study I was divided into Ia and Ib.

There were no significant intraopertive complications, such as subretinal hemorrhage or retinal incarcination.

7.1.1 Retrospective Study Ⅰa

73 patients within one week of DMD were divided into three groups accorrding to the DMD: 1 to 2 days of detachment (n=29), 3 to 4 days (n=14) and 5 to 7 days (n=30).

The mean post-operative best-corrected VA (0.45±0.08 Snellen acuity) of 73 patients was significantly higher than the preoperative one (0.06±0.04 Snellen acuity) (Student's t test, P<0.001). Final VA of 0.4 or better was seen in 50 of 73 eyes (68.4 %).

The mean preoperative VA among the three groups were no significant difference (ANOVA, P=0.795) [Table 1].

Table 1. Analysis of variance of preoperative acuity

Days	n	Mean of Snellen VA	LogMAR of VA (mean± SD)
1-2	29	0.24	1.15± 0.726
3-4	14	0.05	1.30± 0.813
5-7	30	0.06	1.22± 0.753

P=0.795 (ANOVA)

The post-operative Snellen VA of the three groups are present in Table 2. There was significant difference among these groups (P=0.032, ANOVA). Additionally, there was significant difference among the number of patients, who attained the VA 0.4 or better (Chi-squared test, p=0.037). Furthermore, the mean Snellen VA (0.65) in the group of 3

to 4 days' DMD was significantly higher than the 1 to 2 days (0.45) and 5 to 7 days' duration (0.35) [Fig.14].

Table 2. Analysis of variance of post-operative acuity

Day	n	Mean of Snellen VA (LogMAR ± SD) *	No. of patients with VA ≥0.4(%)†
1-2	29	0.45 (0.347 ± 0.217)	23 (79.3)
3-4	14	0.65 (0.187± 0.101)	12 (85.7)
5-7	30	0.35 (0.456± 0.186)	15 (50)

*P=0.032 (ANOVA); † Chi-squared test, p=0.037

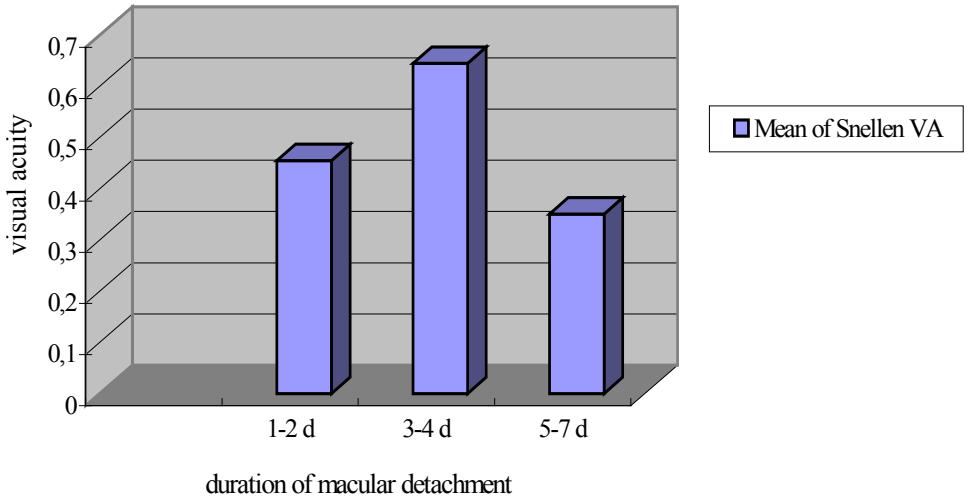


Fig. 14 There was significant difference of post-operative VA among the three groups (ANOVA, p=0.032).

7.1.2 Retrospective Study Ib

In this part, 73 patients were divided into two groups by the number of days of macular detachment: 1-3 days of detachment (n=37), 4 to 7 days (n=36).

There was no significant difference of mean preoperative VA between the two groups (student's t test, P=0.709) [Table 3].

Table 3. Analysis of variance of preoperative acuity

Day	n	Mean of Snellen VA	LogMAR of VA (mean± SD)
1-3	37	0.07	1.15 ± 0.729
4-7	36	0.06	1.22 ± 0.771

Student's t test, p=0.709

The Snellen VA of post-operative achieved by the two groups are presented in Table 4. Mean final post-operative VA (0.48) in eyes with DMD of 1 to 3 days was similar to it in eyes with DMD of 4 to 7 days (0.42) (Student's t test, P=0.455). Additionally, there was no significant difference of the number of the patients, with VA of 0.4 or better, between the two groups (Chi-squared test, p=0.907) [Fig. 15].

Table 4. Analysis of variance of post-operative acuity

Day	n	Mean of Snellen VA(LogMAR ± SD) *	No. of patients with VA ≥0.4(%)†
1-3	37	0.48 (0.322 ± 0.07)	29 (78.4)
4-7	36	0.42 (0.38 ± 0.07)	21 (55.3)

*Student's t test, p=0.455; † Chi-squared test, p=0.907

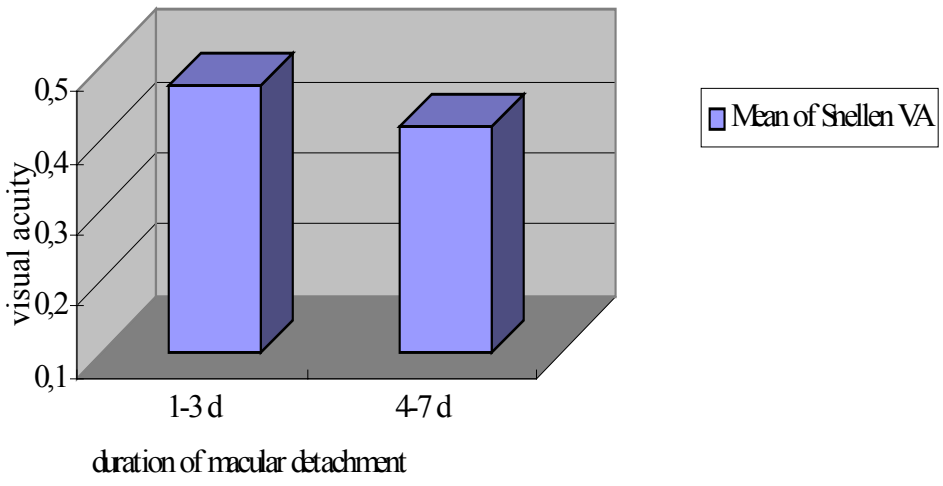


Fig.15 The difference of post-operative VA between the two groups (P=0.445, student's t test)

7.1.3 The effects of age, preoperative VA on the post-operative VA

7.1.3.1 Age

73 patients were divided into three groups accorrding to the patient's age at the time of surgery: less than 60 years, between 61 and 75 years and more than 75 years. There was significantly difference of mean post-operative VA among the 3 groups. Patients less than 60 years group was more likely to get better mean post-operative VA after surgery than the groups of 61-75 years and more than 75 years (ANOVA, p=0.006). Patients less than 75 years or younger were more likely to achieve a VA of 0.4 or better than the older patients (Chi-squared test, p=0.003).

Table 5. Correlation of age with post-operative VA

Age	n	Mean VA Snellen (logMAR, ± SD) *	No. of patients with VA ≥0.4(%)†
≤ 60	28	0.56 (0.26 ± 0.06)	22 (78.6)
61-75	34	0.4 (0.40 ± 0.08)	23 (67.6)
>75	11	0.25 (0.60± 0.05)	5 (45.5)

*P=0.006 (ANOVA); † Chi-squared test, p=0.003

7.1.3.2 Preoperative VA

Patients were divided into 2 groups by preoperative VA less than 0.1 and more than 0.1. The final VA was significantly lower in patient with preoperative VA less than 0.1 compare with VA more than 0.1 (Student's t test, p<0.001). There was also significant difference of the number of final VA more than 0.4 between the two groups (Chi-squared test, p=0.026) Table 6.

Table 6. Correlation of preoperative VA with post-operative VA

preoperative VA	n	Mean VA Snellen (logMAR, ± SD) *	No. of patients with VA ≥0.4(%)†
≤ 0.1	46	0.35 (0.46 ± 0.07)	26 (56.5)
>0.1	27	0.63 (0.20 ± 0.06)	24 (88.9)

*Student's t test, p<0.001 ; † Chi-squared test, p=0.026

7.2 Retrospective Study II

96 patients with macula-off detachment were included. The patients were divided into two groups: less than 7 days of DMD (n=73) and more than 7 days (n=23). There were 39 females and 57 males, age between 12-94 years (mean 62.5 years). Patients were followed from 3 months to 7 years (mean 43.5 months).

There was no intraopertive complication, such as subretinal haemorrhage or retinal incarcination in any of the 96 eyes.

The mean post-operative BCVA (0.36± 0.07 Snellen acuity) of 96 patients was better than the preoperative one (0.06± 0.04 Snellen acuity) (Student's t test, $p < 0.001$). Final VA of 0.4 or better was seen in 62 of 96 eyes (64.6 %). There was no statistic significant difference of mean preoperative VA in the two groups (Student's t test, $p=0.759$) [Table 7].

Table 7. Correlation of DMD with preoperative VA

Duration of macular detachment (Days)	n	Mean VA Snellen (logMAR, ± SD)
≤ 7	73	0.06 (1.22 ± 0.217)
> 7	23	0.07 (1.15 ± 0.101)

Student's t test, p=0.759

The effect of the DMD on final VA is summarized in Table 8. Mean final VA after scleral buckling less than 7 days was 0.45, while those with DMD of more than 7 days had a final VA of 0.22. The difference of final VA between these 2 groups was significant (Student's t test, $p=0.02$) [Fig.16]. Sixty eight percent of patients who received scleral buckle surgery within 7 days achieved a VA of more than 0.4. In contrast, only 52 percent of patients received VA of more than 0.4 at more than 7 days group, there is also significant difference (Chi-squared test, $p< 0.001$).

Table 8. Correlation of DMD with post-operative VA

DMD (Day)	n	Mean VA Snellen (logMAR, ± SD) *	No. of patients with VA ≥0.4(%)†
≤ 7	73	0.45 (0.34± 0.191)	50 (68.5)
> 7	23	0.22 (0.65 ± 0.408)	12 (52.2)

* Student's t test, p=0.02 ; †Chi-squared test, p< 0.001

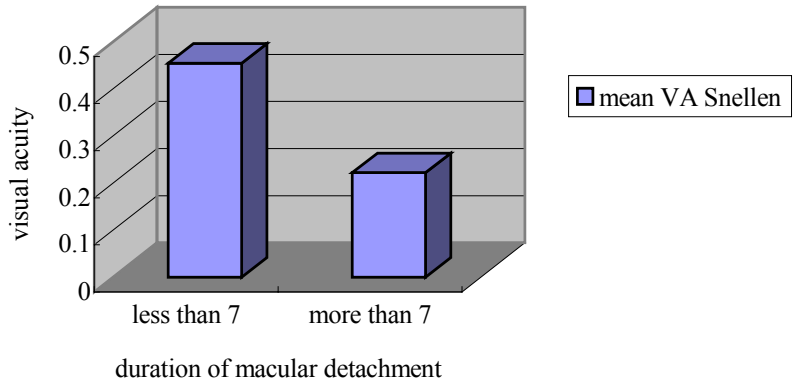


Fig. 16.The difference of postoperative visual acuity between the duration of macular detachment less than and more than 7 days(Student's t test, P=0.02)

7.2.1 The effects of age, preoperative VA, refractive error on the post-operative VA.

7.2.1.1 Age

96 patients were divided into 3 groups accorrding to the age: less than 60 years, 61-75 years, and more than 75 years. There was no significantly difference of mean post-operative VA among the three groups (ANOVA, p=0.157). Patients less than 75 years of age or younger were more likely to achieve a VA of 0.4 or better after SB-surgery than older patients (more than 75 years) (Chi-squared test, p=0.008).

Table 9. Correlation of age with post-operative VA

Age	n	Mean VA Snellen (logMAR, ± SD) *	No. of patients with VA ≥0.4 (%)†
≤ 60	36	0.45 (0.35± 0.26)	26 (72.2)
61-75	42	0.35 (0.46± 0. 24)	28 (66.7)
>75	18	0.26 (0.59± 0.28)	8 (44.4)

*P=0.157 (ANOVA); † Chi-squared test, p=0.008

7.2.1.2. Preoperative VA

Table 10 shows the effect of preoperative VA on post-operative visual outcome. The difference of final VA was significant between these 2 groups (Student's t test, $p<0.001$). There was a significant difference of final VA of more than 0.4 between the two groups, preoperative VA less than 0.1 and more than 0.1. Patients with a preoperative VA of more than 0.1 achieved better post-op visual recovery and a high percentage of the final VA better than 0.4 compared to patients with VA less than 0.1 (Chi-squared test, $p=0.004$).

Table 10. Correlation of pre-operative VA with post-operative VA

pre-operative VA	n	Mean VA Snellen (logMAR, ± SD) *	No. of patients with VA ≥0.4(%)†
≤ 0.1	62	0.28 (0.55± 0.29)	32 (51.6)
>0.1	34	0.61 (0.22 ± 0.14)	30 (88.2)

*Student's t test, $p<0.001$; † Chi-squared test, $p=0.004$

7.2.1.3 Refractive error

There was no statistic difference in final mean visual outcome between patients with less myopia (≤ -5.0 D) and high myopia (>-5.0D) (Student's t test, $p=0.644$). Patients with low-grade myopia (≤ -5.0 D) had a better VA of more than 0.4 (Chi-squared test, $p<0.001$) [Table 11].

Table 11.Correlation of refraction with final VA

Refraction error	n	Mean VA Snellen (logMAR, ± SD) *	No. of patients with VA ≥0.4(%)†
>-5.0 D	23	0.43 (0.37 ± 0.12)	14 (61.1)
≤ -5.0 D	73	0.38 (0.42± 0.09)	49 (67.1)

*Student's t test, $p=0.644$; † Chi-squared test, $p<0.001$

7.2.1.4 Line regression

The factors that influenced the final VA outcome were identified by the line regression analysis. Among the factors, including age, preoperative VA, number of tears, DMD and refraction error, only the DMD, pre-operative VA showed a significant correlation

with final visual outcome [Table 12]. The R-square value of DMD was 0.101, meant that about 10 days duration could decline one line of final VA.

Table 12. Line regression analysis of the correlation of final VA with age, DMD, number of tears, preoperative VA.

Risk factor	p value	R square	b	a
Age	0.545	0.004	-0.014	0.45
Duration	0.002	0.101	-0.02	0.9
No. of Tears	0.782	0.001	0.077	0.36
Pre-operative VA	<0.001	0.129	0.241	0.23
Refraction Error	0.229	0.017	-0.145	0.34

The relationship between final VA and age, DMD , number of tears, preoperative VA and refraction error were expressed as the equation:

$$Y= bx+a$$

(Y= dependent variable, X = independent variable, b and c are called regression coefficients).

In the study dependent variable (**Y**) is the logarithm of more than 3 months post-operative VA. For statistic calculating, the Snellen fractions were transformed to -logMAR (logarithm of the minimum angle of resolution) units. The results were transformed back to Snellen equivalents. The independent variable (**X**) factors include patient age, DMD, number of tears, preoperative VA and refraction error. The constants **a** and **b** in the regression equation are called the **regression coefficients**. The value of the constants **a** and **b** in the regression equation can be found out from the following two equations :

$$b = r\, s_y/s_x$$

$$a = M_y - bM_x$$

where **r** is the Pearson's correlation between X and Y, It ranges from +1 to -1. A correlation of +1 means that there is a perfect positive linear relationship between variables. A correlation of -1 means that there is a perfect negative linear relationship between variables. A correlation of 0 means there is no linear relationship between the two variables. $\mathbf{s_y}$ is the standard deviation of Y, $\mathbf{s_x}$ is the standard deviation of X. $\mathbf{M_y}$ is

the mean of Y, $\mathbf{M_x}$ is the mean of X. When the values of **a** and **b** are found, the regression equation can be written using these values.

Age group:

There is no relationship between age and final VA (P>0.05) Table 12.

DMD group:

Y= -0.02x+0.9 (r= -0.317, p= 0.002)

Where y is the logarithm of more than 3 months post-operative VA, and x is the DMD. DMD is the influent factor to the final VA (P< 0.05). There is a negative linear relationship between final VA and DMD (r = -0.317) Table 12. If the duration time is 3, 10 or 50, then VA of more than 3 months would be 0.8, 0.7, and –0.1 respectively. There is a tendency of decreasing final VA when DMD increased.

No. of Tears group:

Tear is not the factor that influenced the final VA outcome (P>0.05) Table 12.

Pre-operative VA group:

Y= 0.241x+0.23 (r= 0.358, p< 0.001)

Where y is the logarithm of more than 3 months post-operative VA, and x is the pre-operative VA. There was a significant relationship between pre-operative VA and final VA (P< 0.001) Table 12. There is a positive linear relationship between final VA and Pre-operative VA (r= 0.358). If the pre-operative VA is 0.1, 0.2 or 0.3, the VA of more than 3 months would be 0.25, 0.27, and 0.30 respectively. There is a tendency of good pre-operative VA toward good final VA.

Refractive error group:

There is no relationship between refractive error and the final VA outcome (P>0.05) Table 12.

7.3 Retrospective study III

47 patients were followed for 5 years, including 14 females and 33 males and age between 12 and 90 years (mean 61.85± 16.45 years). 10 of 47 patients were examined with OCT.

There was no significant intraoperative complication, such as subretinal hemorrhage or retinal incarcination.

7.3.1 The effect of the DMD in final VA

Although the mean preoperative VA in less than 7 days was lower than it in more than 7 days group, there is no statistic difference between the two groups (Student's t test, p=0.098) [Table 13]. Mean final VA after scleral buckling in eyes with DMD of less than 7 days was 0.53, while those with DMD of more than 7 days had a final VA of 0.25. The difference of final VA between these 2 groups was significant (Student's t test, p=0.008) [Fig 17]. 28 of patients who received SB-surgery within 7 days achieved a VA of more than 0.4. In contrast, only 7 of patients who received surgery at more than 7 days obtained 0.4 vision (Chi-squared test, p< 0.001) [Table 14].

The mean VA after 5 years increased 1.60±0.02 lines compare to the 3 month follow-up mean VA [Fig 18]. Among 8 patients, with no improvement of VA at 3-month follow-up, 5 cases got VA improvement at 5-year follow-up [Fig 19]. The mean of VA after surgery of the two different DMD is shown in Fig 20.

Table 13. Correlation of duration macular detachment with preoperative VA

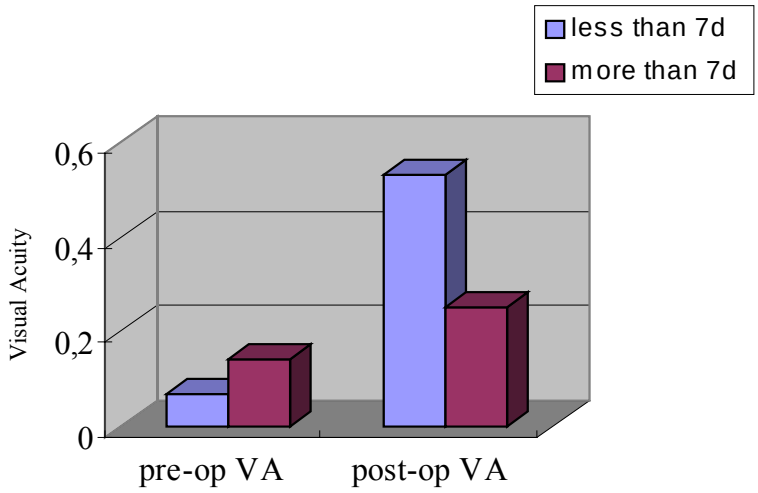
DMD (Day)	n	Mean VA Snellen (logMAR, ± SD)
≤ 7	36	0.06 (1.22 ±0.048)
> 7	11	0.14 (0.85 ±0.059)

Student's t test, p=0.098

Table 14. Correlation of duration macular detachment with post-operative VA

DMD (Day)	n	Mean VA Snellen (logMAR, ± SD) *	No. of patients with VA ≥0.4 (%)†
≤ 7	36	0.53 (0.28 ± 0.06)	28 (77.7)
> 7	11	0.25 (0.60± 0.11)	7 (63.6)

*Student's t test, p=0.008; †Chi-squared test, p< 0.001



The duration of macular detachment and visual acuity changes

Fig 17. Demonstrates the DMD and VA changes before and after surgery in two groups: less than 7 days and more than 7 days. And the duration of less than 7 days has better visual recovery than the duration of more than 7 days after 3 months follow-up (Chi-squared test, p=0.008).

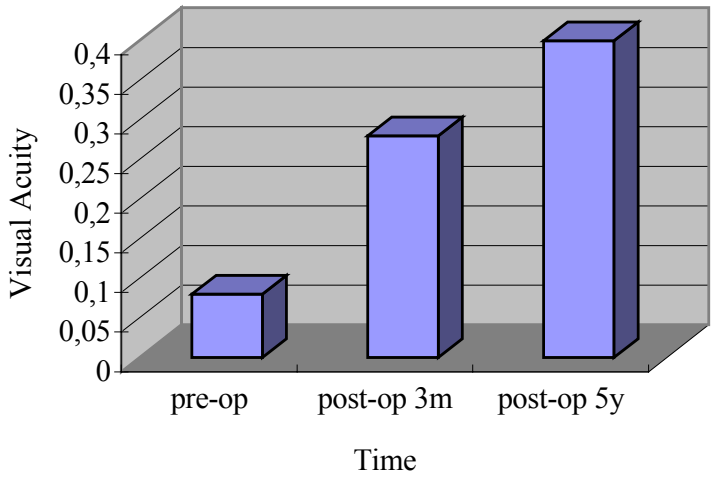


Fig. 18 Displays mean VA of pre-operative, follow-up 3 months and 5 years after surgery. The mean VA after 3 months was 0.32 ±0.08, while the 5 years of VA after surgery was 0.46±0. 101. The mean VA after 5 years increase 1.60±0.02 lines compare to the 3 month follow-up mean VA.

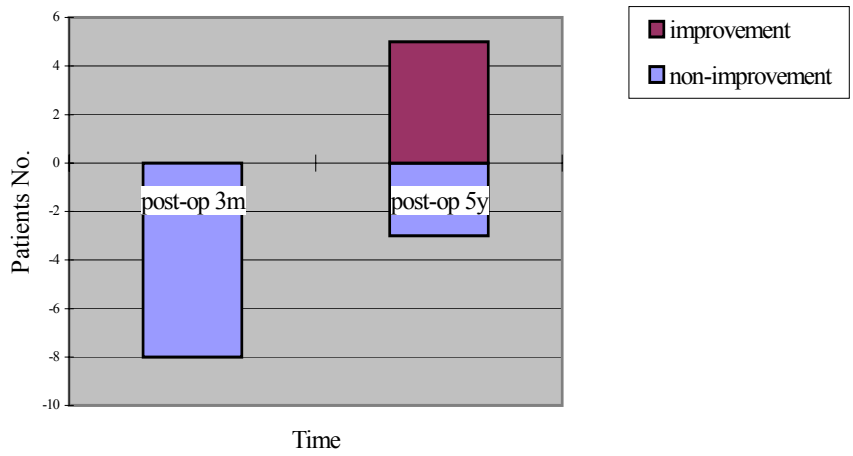


Fig 19. Exhibits 8 patients of VA with no improvement at 3 months follow-up, 5 of them get VA improvement at 5-year follow-up.

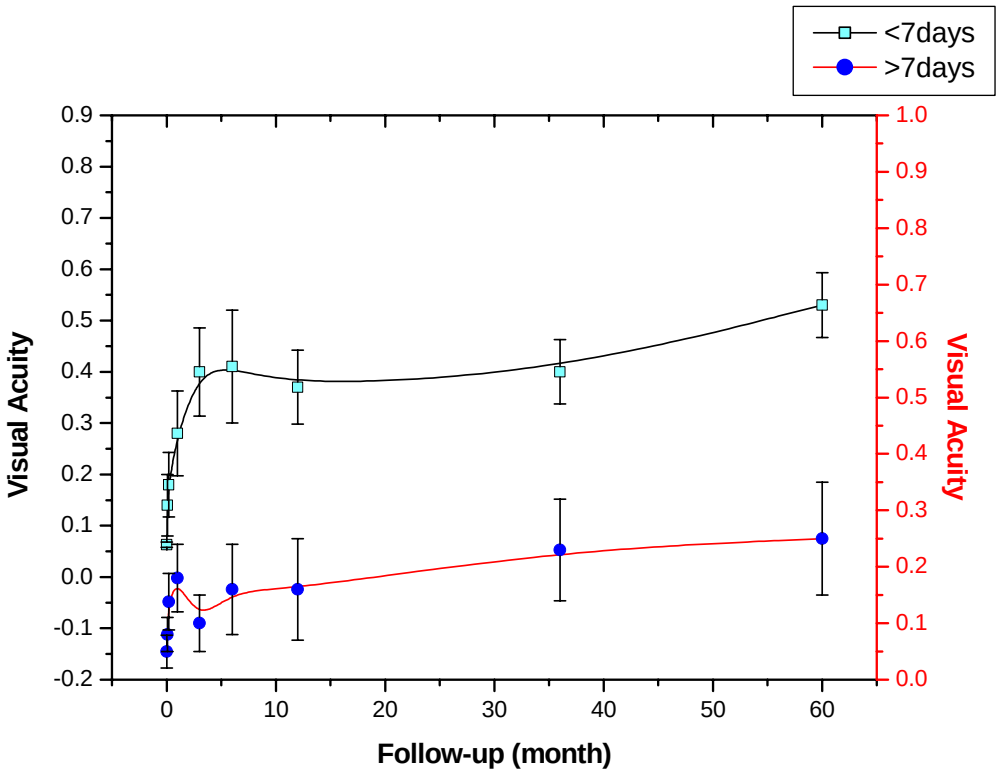


Fig. 20. Shows the mean increase of VA in two groups-less than 7 days and more than 7 days in a follow-up of 5 years. Mean VA in the group of less than 7 days group increased much more.

7.3.2 The effect of preoperative VA on the final VA

The effect of preoperative VA on post-operative visual outcome is shown in Table15. Patients were divided into 2 groups by preoperative VA less than 0.1 and more than 0.1. The final VA between these 2 groups was significant different. (Student's t test, p=0.004). There is no significant difference of final VA more than 0.4 between the groups of preoperative VA less than 0.1 and more than 0.1 (p=0.307).

Table 15. Correlation of pre-operative VA with post-operative VA

preoperative VA	n	Mean VA Snellen (logMAR, ± SD) *	No. of patients with VA ≥0.4(%)†
≤ 0.1	23	0.32 (0.49± 0.09)	16 (69.6)
>0.1	24	0.63 (0.20 ± 0.01)	19 (79.1)

* Student's t test, p= 0.004; † Chi-squared test, p=0.031

7.3.3 The effect of patient age on final VA.

Patients less than 75 years of age or younger were more likely to achieve a VA after SB of 0.4 or better than older patients (p=0.003). There was no significant difference of mean post-operative VA between the less than 60 years, 61-75 years and more than 75 years group (p=0.996) [Table 16].

Table 16. Correlation of age with post-operative VA

Age	n	Mean VA Snellen (logMAR, ± SD) *	No. of patients with VA ≥0.4(%)†
≤ 60	16	0.45 (0.35± 0.12)	12 (75.0)
61-75	25	0.45 (0.35 ± 0.08)	19 (76.0)
>75	6	0.45 (0.35 ±0.09)	4 (66.7)

* P=0.996 (ANOVA); † Chi-squared test, p=0.003

7.3.4 The effect of refractive error on the final VA

Table 17, shows that there is no statistic difference in final mean visual outcome between patients with less myopia (≤ -5.0 D) and high myopia(>-5.0D) (P=0.614). Patients with low-grade myopia (≤ -5.0 D) had a better VA of more than 0.4 (p<0.001).

Table 17. Correlation of refraction with final VA

Refraction error	n	Mean VA Snellen (logMAR, ± SD) *	No. of patients with VA ≥0.4(%)†
≤ -5.0 D	40	0.46 (0.34± 0.09)	35 (76.9)
> -5.0 D	7	0.38 (0.42± 0.15)	4 (60.0)

* Mann-Whitney U test, p= 0.614; † Chi-squared test, p<0.001

7.3.5 Optical coherence tomograpy

10 patients, presenting with macular detachment, were evaluated by OCT (3 females and 7 males, ranged from 22 to 79 years, mean 59 years). Among them, 2 patients with subretinal fluid were not detected by indirect ophthalmoscopy, but were detected by the OCT [Fig. 21 and 22]. And the mean VA of these 2 patients was 0.13 after 5 years, which was significantly lower than in the other 8 patients (without subretinal fluid) (0.54) (Student's t test, p=0.025) [Fig.23].

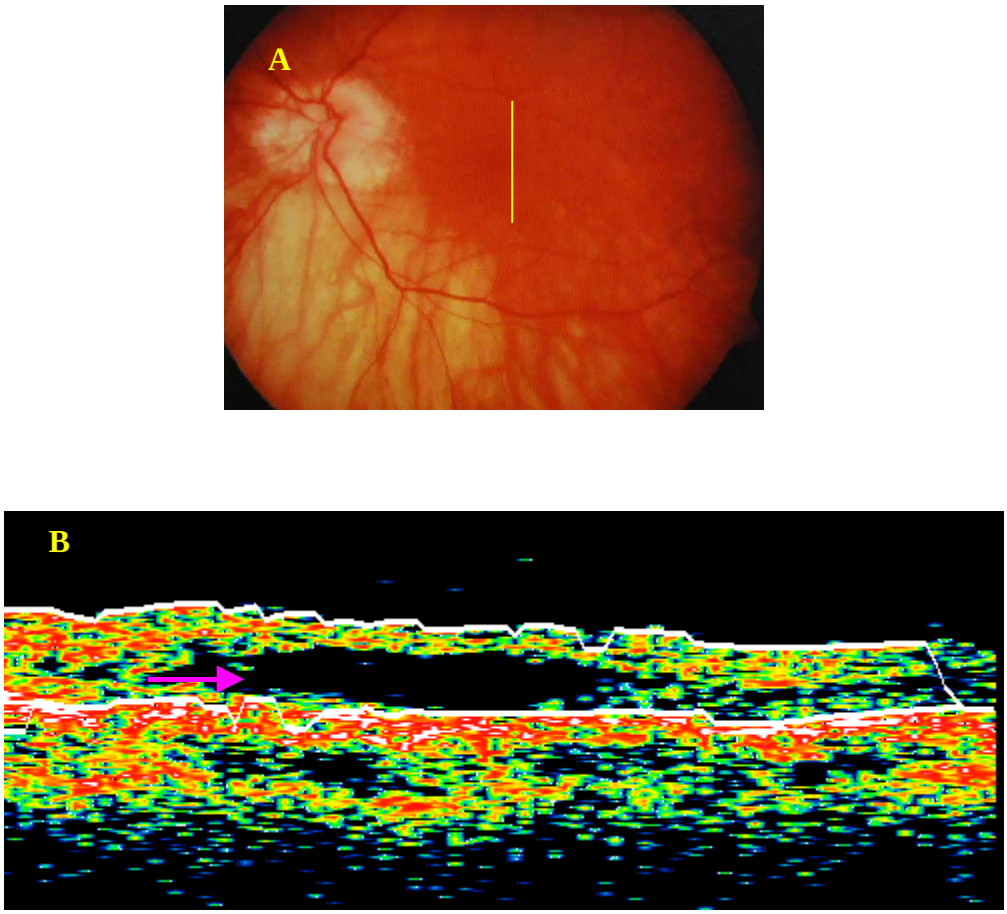


Fig. 21 **A** Fundus image of the left posterior pole. The optic disc is vital with sharp margins and visible nerve fibers in the superior and inferior quadrant. The foveal reflex is vanished. There is not obvious retinal elevation in the fovea and papillomacular area. The yellow line indicates the location, length and direction of the corresponding linear optical coherence tomography scan (scan length 2.8 mm). **B** Vertical optical coherence tomography scan of the macular region of the left eye. Optical coherence tomography with a maximal longitudinal resolution of 10 μm. The upper hyperreflective reddish-to-orange color layer, correponding to the neuroretina, consistent with nerve fiber layer and lack of photoreceptors. The photoreceptors were represented by a hyporeflective area of blue-to-black colors, and disappear at the central foveal, instead of the subretinal fluid (pink arrow). The underlying retinal pigment epithelium-choriocapillaris complex is expressed by a hyperreflective, whitish, irregular-shaped band. The swollen foveal retina has a thickness of 310 μm. The thinkness of neuroretina was 70 μm.

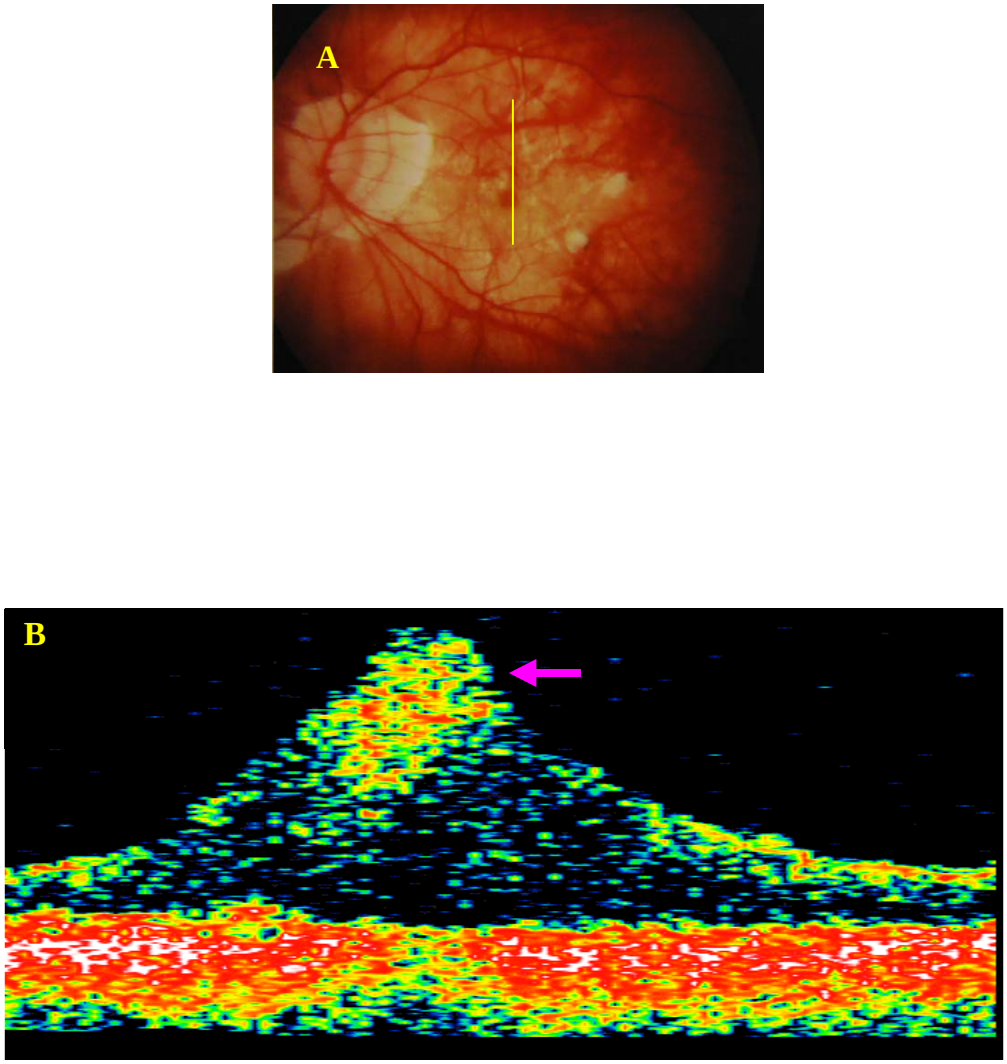


Fig. 22 **A** Another case show fundus image of the left posterior pole. The temperal side of optic disc appears atrophic. The foveal reflex is vanished with less pigment. There is not obvious retinal elevation in the fovea and papillomacular area. The yellow line indicates the location, length and direction of the corresponding linear optical coherence tomography scan (scan length 2.8 mm). **B** Vertical optical coherence tomography scan of the macular region of the left eye. Optical coherence tomography with a maximal longitudinal resolution of 10 μm. The inner retina appears as a hyperreflective compact in reddish to orange colors, corresponding to the layer of the epithelium retinal membrane (pink arrow). The reflectivity of the neuroretinal structure appears hypoflective and less compact. The underlying hyperreflective, whitish, irregular-shaped band corresponding to the retinal pigment epithelium-choriocapillaris complex.

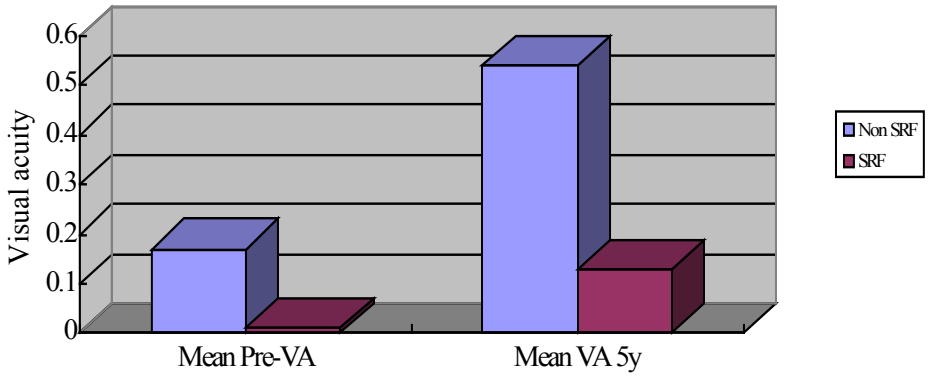


Fig.23 Shows the mean VA with subretinal and non-subretinal fluid groups preoperative and 5 years post-operative.There was significant difference between the two groups (P=0.025, Student's t test).

Additionally, foveal thickness was measured by OCT in these patients. We found that the foveal thickness of less than 7 days group presented thicker than the more than 7 days groups on 5 years follow-up, but there was no statistical difference in foveal thickness outcome between patients with less than 7 days and more than 7 days (P=0.791) [Table 18].

Table 18. Correlation of foveal thinkness with duration of retinal detachment

DMD (Day)	n	Foveal thickness (μm)
≤ 7	6	226 ± 88
> 7	4	209 ± 76

Student's t test, p=0.791

8. Discussion

Nearly all symptomatic rhegmatogenous retinal detachments progress to total blindness unless they are repaired. Until 70 years ago, RRD was an essentiallly incurable disorrder. Nowadays recent technical advances and better understanding of the pathogenesis of RRD have lead to excellent results especially anatomically [159, 160, 162]. However, the functional improvement in vision remains disappointing sometimes, especially when the macula is involved in the RRD. In our series, we retrospectively reviewed the visual recovery (including long-term follow-up) after scleral buckling in macula-off retinal detachment, and analyzed the effect of several specific factors on final visual outcome.

Our results showed that a recovery of 0.4 or better of vision occurred in 64% of patients (62/96). This result was comparable with other series, which reported a return of central VA to 0.4 or greater in 37 to 60% of patients [11-13, 78, 79, 86, 99, 102, 103, 106, 107, 115].

8.1 Duration of macula-off detachment

Previous studies have evaluated various factors in rhegmatogenous retinal detachment in relation to anatomic or functional success [13, 55, 56, 62, 106, 125, 140, 143]. Numerous studies have correlated a wide array of preoperative factors with both favorable and poor anatomic and VA outcomes after SB [13-15, 34-37, 54-56, 71, 75, 82, 103, 124, 140, 145, 161]. *Burton et al.*[15] isolated 22 factors that may affect operative results, none of which could be altered readily by the surgeon. *Kaufman* [78] found that 85% of VA variation after SB stemmed from differences in nine preoperative factors. Of these, the operating surgeon could manipulate only DMD. A number of series have suggested critical time periods for DMD, after which VA prognosis after SB would be expected to decrease. These have ranged from 1 day to 6 months [14, 26, 30, 36, 37, 55, 56, 71, 75, 82, 103, 124, 144]. Some of these series attempted to isolate DMD from other preoperative variables with statistical methods. Of these, *Burton* [15] and Ross et al.[124] did not exclude eyes with shallow macular detachments and relatively good vision (>0.1), although preoperative VA has been shown to be the factor most consistently correlated with visual and anatomic outcome after SB [13, 34, 54, 140, 144].

There were several classifications of the DMD [12, 28, 30, 44, 61, 70, 78, 80, 81, 86]. Due to different divided groups, there were different outcome. *Burton*[15] found that the DMD

within the first week did not influence post-operative acuity. *Ross et al.*[124] recently examined results after SB in eyes with macula-off RRD of 7 days or a fewer duration. They showed no statistically significant difference in post-operative anatomic reattachment or VA in eyes repaired anytime within the first week of macular detachment. However, *Yang et al.* recently found that there was significant difference of final VA between the patients with a duration of macula detachment less than 7 days and more than 7 days [164]. To apply parametric statistical testing, in our series, the patients were divided into several groups based on DMD: the patients in the first group were divided into macular detachment of 1 to 2 days, 3 to 4 days and 5 to 7 day, while 1 to 3 days and 4 to 7 days in the second group, less than 7 days and more than 7 days in the third one.

We found that there were significant differences of post-operative VA in third group [Table 8]. On the other hand, the number of patients, with VA of 0.4 or better, also had similar significant difference [see also Table 8]. These results were similar to the findings of *Burton* [15], *Hassen et al.*[62]. Recently, *Hassen et al.* demonstrated that primary RRD repaired with SB with a DMD of 10 days or fewer obtained better post-operative VA than similar eyes with a DMD of 2 to 6 weeks, which in turn obtained better post-operative VA than those with DMD of more than 6 weeks duration. Moreover, in our series, we further divided the patients, with the DMD within one week, into 1 to 2 days, 3 to 4 days and 5 to 7 days. We found that the post-operative VA in the 3 to 4 days duration was significant higher than it in the others [Table 2], although there was no significant difference of VA between the 1 to 3 days and 4 to 7 days [Table 4]. The reason was not known. We had compare the preoperative VA, age in these 3 groups, but there is no statistic difference. In the future we will do further study to include more patients in 3 to 4 days groups for statistice analysis. We suggested that the better visual recovery results were obtained with early surgery of macula-off retinal detachment. Recently, *Yang et al.* also demonstrated that patients operated within 3 days after macular detachment had a better chance of achieving a final acuity of 0.4 or better [164].

However, *Ross* and *Stockl* revealed that macula-off detachments can therefore be treated with less urgency and can wait for the next scheduled available operating room time [125]. Elective retinal detachment repair is also supported by the findings and recommendations of *Hartz et al.* [61]. In their studies, which compared emergency versus

scheduled retinal detachment surgery, there was no evidence that delaying the surgery contributed to a worse visual outcome regardless of the status of the macula.

8.2 Prognostic factors

Although prognostic factors have been studied extensively, comparison among many of these studies is difficult due to the use of different inclusion criteria, different surgical techniques, and the use of only univariate analysis to determine significance. As a result, the relationship between individual risk factors and the final visual outcome in rhegmatogenous retinal detachment is not yet well established.

Multiple factors related to preoperative and post-operative observations and surgical methods were correlated significantly with visual outcome-for example, preoperative VA, DMD, extent of RRD, patient age, status of crystalline lens, height of macular detachment, location and size of retinal break, proliferative vitreoretinopathy, preoperative ocular hypotony or hypertension, drainage or non-drainage of subretinal fluid, number of cryo applications, extent of indentation, encircling or not circling and the length of follow up [14, 15, 55, 78, 102, 106, 107, 124, 144]. *Burton* and *Lambert* [15] identified 26 of 200 observations that significantly affect visual prognosis and developed a mathematical model that predicts in a broad range of VA to approximately 67% of accuracy. In this study, we observed these factors: age, preoperative VA, refractory error, and number of tears, affected the post-operative VA.

8.2.1 Age

We found that patients aged 60 years or younger were significantly more likely to achieve post-operative VA of 0.4 or better, than those aged 61 to 75 years old and those aged 76 and older [Table 9 and 16], although the likelihood of having VA after SB was not different among the three groups [also see Table 9 and 16]. Our results were similar to the finding of *Hassan et al.* [62]. These demonstrated that patient age was a significant factor associated with the final VA. The post-operative VA tended to decrease with increasing age [15, 26, 36, 56, 75, 78, 82, 106, 144]. Several series have also found significantly lower VA after successful SB in elderly patients with macula-off RRD [15, 78, 82, 106, 144]. Others, however, have shown no significant relationship between age and post-operative VA[26, 36, 56, 75].

The older eye has a greater likelihood of having age related macular degeneration. In our series, we did not include any eye in this series with a known history of aging macular degeneration, although determination of fine central macular architectural abnormalities is difficult in the presence of a bullous macular detachment. On the other hand, epiretinal membranes, mild cystoid macular edema after earlier cataract extraction, or mild retinal pigment epithelial change is all more common in the older eye. These conditions alone may not be significant visually but may impact post-operative VA to a small degree after a macular insult such as a RRD. Furthermore, the older eye may have a greater tendency for photoreceptor damage or have less ability to recover from macular detachment. We found a slight trend of decreasing rates of retinal reattachment with increasing age.

8.2.2 Preoperative VA

To compare the effect of preoperative VA on the final vision, the preoperative VA was divided into less than 0.1 and more than 0.1. We found that there were significant difference of mean VA and the number of patients, who obtained the VA 0.4 or more [Table 10 and 15]. Our results support the contention that good preoperative vision portends a better post-operative result. *Kusaka et al.* had reported similar findings [14, 50, 86, 106, 107, 144, 156, 166]. Recently, *Yazici et al.* aslo found that a patient with potential acuity of 20/80 or better might reach a post-operative acuity of 0.4 or better, with a possibility of 81%. When potential acuity is 20/1000 or less, the possibility reduces to 32% [167]. *Michels et al.* demontrated that of the several factors, preoperative VA is the most important variable related to the final visual result after anatomically successful reattachment surgery [107].

8.2.3 Refraction Error

Refractive error is another important factor that may affect visual prognosis following surgery. However, previous studies have shown that in eyes with normal central visual function before the detachment, refractive error does not play an important role in post-operative visual recovery [15, 78, 144]. In our series, patients with low-grade myopia (less than –5.0D) had better visual recovery of 0.4 than the high myopia group (more than –5.0D) [Table 11 and 17]. This is consistent with previous reports, which showed that worse visual results occurred after successful surgery in highly myopic eyes [13, 36]. The reason for this less favorable result in the high myopia group may be due to the greater

chance of macular dysfunction and the lesser potential of photoreceptor recovery process.

8.2.4 Line regression

In addition, we studied the relation between the post-operative VA changes and various factors, such as patient's age, preoperative VA, duration macular detachment, refractive error and tears by line regression. We demonstrated that the DMD and pre-operative VA were significant factors associated with the post-operative VA. Recently, *Yang et al.* revealed that DMD was the only variable factor affecting the visual outcome by multivariate logistic regression [164].

8.3 Long-Term visual recovery

To quantify the VA changes after the reattachment of the retina, the 3-month and 5-year post-operative visual improvements were compared. The mean VA at the 3 months follow-up was significantly lower than it in 5-year follow-up (Student's t test, $P<0.001$). Also, the percentage of best-corrected VA in the 5-year follow-up was significantly higher than it in the 3-month follow-up (Chi-Squared test, $P=0.001$) [Fig. 13]. Interestingly, we found that 5 of 8 patients, with no improvement of VA, had attained the visual improvement in the 5-year follow-up [Fig. 19].

On the other hand, these factors, the DMD (less than or more than 7 days) [Table.14 and Fig.16], preoperative VA (less than or more than 0.1) [Table 15], age (less than 65 years old, 61 to 75 years old, and more than 75 years old) [Table16], refraction error (less than –0.5D or more than –0.5D) [Table 17], had significant effect on the post-operative VA at the 5-year follow-up.

Thus, the visual function of the reattached retina can improve over the long term, and this improvement is likely to be seen in patients with features such as youth, low or no myopia, and short duration of detachment of the macula. Combined the previous study, these factors include youth, short DMD, good preoperative VA and low or no myopia, might be associated with good post-operative visual function.

It is still unclear why these factors are correlated with long-term VA. However, knowledge based on histopathologic observations in animal eyes are available. In

experimental studies of retinal detachment in the cat eye, it has been shown that a number of morphologic changes occur in the retina after detachment from RPE, such as loss of apical processes in the RPE within a few hours, outer segment changes within 12 hours [6], and the onset of RPE and glial proliferation within 24 hours and 48 hours, respectively [5].

In contrast, other studies [80, 99] using the monkey retina indicate that morphologic changes in the detached retina are reversible. A reattached retina may appear normal approximately 12 weeks after reattachment. Therefore, there may be a species difference in the morphologic recovery of a reattached retina. These experimental studies investigated the morphologic recovery of the reattached retina for up to 6 months after reattachment. Based on our results, however, functional recovery in humans appears to continue for much longer.

Following reattachment, the ultrastructural relationship between the photoreceptors and the RPE is reestablished. Although shorter duration of retinal detachment is associated with better morphological recovery, the morphology of the reattached retina never returns to the normal state even if the duration of detachment was for only 1 day [99]. Morphologic recovery is generally poor in the area with glial or RPE proliferation, because these cells appear to prevent the RPE-photoreceptor reapposition [4].

8.4 Other factors

Other factors, which may influence the visual outcome, include the height of the macular detachment at the time of retinal surgery. In his study of experimental detachment in owl monkeys, *Machemer* [99] found that photoreceptor cell degeneration increased as the distance between the pigmentepithelial layer and photoreceptors increased. Because it is difficult to record and accurately quantify the height of the macular detachment in a clinical setting, this factor was not assessed in our study.

There were several limitations of this study, including its retrospective, non-randomized, and uncontrolled design. The determination of the DMD depended on the subjective description of patient histories. In addition, the sample size was limited, due to the strict inclusion criteria. Nearly 75% of the patients with retinal detachment were excluded because of incomplete chart records, imprecise histories of the DMD, other ocular

pathology, incomplete follow-up time, or repair of detachment with operative techniques other than standard scleral buckling procedure.

8.5 OCT on evaluation of the incomplete visual recovery in the macula-off retinal detachment

Optical coherence tomography (OCT) yielded non-invasive, high-resolution tomographic images of the retina in a short period of time. New aspects of vitreo-retinal disease have been revealed by this means. In cases of rhegmatogenous retinal detachment [57, 58, 72, 76, 163], OCT is a powerful tool because of its unique characteristics permitting observation of the three-dimensional retinal structure in vivo at nearly histopathologic levels. The subfoveal clear space observed with OCT was defined as residual subretinal fluid [163]. Though the resolution of the OCT scanner is very fine (10–15 μm), there are reports of artifacts induced by OCT and OCT findings should be carefully interpreted. When OCT signals are generated, the change in the refractive index at an interface is responsible for most of the signal [27]. Thus, refractive index changes give off high signals at the borders. Cases with residual subretinal fluid had a highly refractive layer at the outer surface of the neurosensory retina; thus, the layer indicates the presence of a refractive index change. We interpreted this change to indicate the existence of subretinal fluid. In some cases, this clear space was observed preoperatively and narrowed after surgery; thus, this clear space must have been subretinal fluid. If, in fact, the clear space represents subretinal fluid, it is important to identify the subretinal fluid because the photoreceptor layer produces a low signal in a normal eye on OCT.

Persistent post-operative foveal subretinal fluid observed with OCT, but not by ophthalmoscopy, was reported in 2002 [57]. In our study, we found the retina reattached anatomically in 47 patients at 5 years follow-up after surgery, the VA of some patients were not good. 10 patients were selected to do OCT randomly at 5 years follow-up. 2 of 10 patients with subretinal fluid were detected by OCT, not detected by indirect ophthalmoscopy. Although, *Baba* revealed that though residual subretinal fluid did not influence the recovery of VA for at least 6 months after surgery [8] , we found that the mean VA of patients with subretinal fluid was significantly lower than it in the patients without subretinal fluid [Fig. 22]. It is similar to the findings of the report of *Wolfensberger* [163]. It demonstrated that the residual subretinal fluid influenced the

recovery of VA at the long-term follow-up (5 years). Careful observation by means of OCT is essential.

However, the foveal thickness between the DMD of less than 7 days and more than 7 days was not statistic significance. Further study should be done with large numbers.

9. Summary and Conclusions

First, the main finding in this series is that the recovery of vision was equal in the two groups of 1 to 3 days and 4 to 7 days of macular detachment. The main conclusion of this study is that the duration of macular detachment within the first week did not influence post-operative acuity. The implication are that, despite intuitive notions regarding outcomes in macula-off detachment, there is no improvement in final VA, even with more expedient repair within the first week. Macula-off detachments can therefore be treated with less urgency and can wait for the next scheduled available operating room time and for systemic evaluation of the patients. Not as the macula-on retina detachments that the surgery should be performed as soon as possible[3].

Second, these findings helps support the recommandations of *Hartz et al.* [61] in that they found scheduled as opposed to emergent retinal detachment procedures to be cost effective.

Third, 64.6% of patients can get VA of 0.4 or better by using scleral buckling procedure. This rate is almost same as the result of *Campo et al*.[22], they reported 65% of patients who pesented with macula-off detachment ragained 0.4 or better vision by using primary vitrectomy. It can be concluded that the ultimate anatomic success with more conventional buckling or vitrectomy surgery is not adversely affected.

Fourth, scleral buckling surgery performed within the first week, preoperative vision more than 0.1 were associated with significant better visual recovery from macula-off retinal detachment. It implications of this study that shallow retina detachment can get better visual recovery after surgery.

Fifth, the DMD and pre-operative VA were significant factors associated with the post-operative VA. The duration of macula-off less than 7 days were associated with the significant better visual recovery, it implied that the DMD more than 7 days the photoreceptor were damaged and to get completed recovery of VA after surgery is not espected.

Sixth, patients aged 60 years or younger were more likely to achieve post-operative VA of 0.4 or better, compare to those aged 61 years or older.

Seventh, the mean VA at 3 months follow-up was significantly lower than it in 5 years follow-up. And also the percentage better VA more than 0.4 in 5 years follow-up was much higher than it in the 3 months follow-up. Surgeon should be aware that the visual function of reattachment may continue to improve over the long period.

Eighth, we strongly recommand OCT in patients where the retina were successfully anatomic reattachment that retina were reattached, while VA improved incompletely. It might be detected the reason of worsen VA after surgery.

This study may provide useful guidelines for the clinical management of macula-off retinal detachment and for assessing the potential for visual recovery in patients after successful scleral buckling.

10. Reference

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11. List of Figures and Tables

10.1 Figure

Figure 1……12
Figure 2 ……13
Figure 3 ……15
Figure 4 ……17
Figure 5…… 20
Figure 6 ……30
Figure 7 ……30
Figure 8 ……31
Figure 9 ……32
Figure 10 ……..33
Figure 11 ……..33
Figure 12 ……..34
Figure 13 ……..35
Figure 14 ……..39
Figure 15 ……..40
Figure 16 ……..43
Figure 17…….. 48
Figure 18…….. 48
Figure 19 ……..49
Figure 20…….. 49
Figure 21…….. 52
Figure 22 ……..53
Figure 23 ……..54

10.2 Table

Table 1 ……38
Table 2 ……39
Table 3 ……40
Table 4 ……40
Table 5 ……41
Table 6 ……41
Table 7…… 42

Table 8…….. 43
Table 9 ……..43
Table 10…… 44
Table 11 ……44
Table 12…… 45
Table 13…… 47
Table 14 ……47
Table 15…… 50
Table 16…… 50
Table 17…… 51
Table 18…… 54

12. Curriculum Vitae

Name : Fang Liu **Sex:** Female

Date of birth: 23/04/1967 **Family Status:** Married

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Robert-Koch-Str.4, Marburg, Germany 35033

Family members:

Father Jinhua Liu, Professor, Shanxi Provice People Hospital.

Mother Xiuyun Wang, Associate Professor, Shanxi Provice People Hospital.

Husband Wentao Wang, Engineer, Taiyuan new technology developing area.

Daughter Ruochen Wang, In primary school.

Current position

Associate Professor, Clinical Dept. of Vitreous & Retina , Shanxi Eye Hospital & Eye Institute, Teaching Hospital of Shanxi Medical University.

Consultant, ORBIS ground training center, Taiyuan, Shanxi, P. R. China

Education:

Sep.1973- Jul.1978	Sanhao primary school
Sep.1978- Jul.1983	No.3 high school
Sep.1983- Jul.1988	5 years undergraduate Program. Department of Medicine, Shanxi Medical University. Bachelor of Medicine.
Sep.1997- Sep.1998	L.V.PRASAD Eye Institute, Hyderabad, India. Clinical Retina fellow. Fellowship sponsored by ORBIS.
Sep.1999- Jul.2002	Post-graduate program (employment) Ophthalmology Department, Shanxi Medical University Master degree of Science.

Working experience:

May.2004-Present	Zentrum für Augenheilkunde, Philipps-Universität Marburg Visiting scholar, scholarship granted by Shanxi scholarship committee
Aug. 2003-Sep.2003	Focus Eye Center, Ottawa, Canada Visiting doctor.
Oct.1999-Present	Shanxi Eye Hospital Associate Professor
Sep.1997-Sep.1998	L.V.PRASAD Eye Institute, Hyderabad, India. Clinical Retina fellow. Fellowship sponsored by ORBIS.
Sep.1994-Sep.1997	Shanxi Eye Hospital. Retina and Vitreous department. Attending doctor.
Aug.1988-Aug.1994	Shanxi Eye Hospital.ORBIS-Taiyuan ground training center. Resident.
Sep 1987-Aug 1988	The 2nd affiliated hospital of Shanxi Medical University Internship

Professional Experience

Service:

Consultant of vitreous & retina service.

Consultant of ORBIS ground training centre.

Teaching:

Instruction of medical students, residents, and fellows in ophthalmology and vitreous and retina diseases.

Grant Support for research

Health Bureau Research Foundation, Shanxi, P. R. China.

Title: Intravitreous Steroid use in endophthalmitis in rabbit.

Amount: **¥ 10,000**

Time Period: 5-1-1999 to 5-1-2001

Involvement: In charge of project.

Status: **Awarded the Shanxi Science and Technique Advancemnet 2nd Prize**

Science and Technology Research Foundation, Shanxi, P.R.China
Title: Inter-limiting membrane peeling in macular hole surgery.
Amount: **¥ 80,000**
Time Period: 12-5-1999 to 12-5-2002
Involvement: In charge of project
Status: **Submitted**

Eye Hospital Research Foundation, Shanxi, P. R. China
Title: Drug evaluation of Steroid in Bacillus endophthalmitis.
Amount: **¥ 30,000**
Time Period: 5-1-2002 to 5-1-2004
Involvement: In charge of project
Status: **Submitted**

Invited Lectures

June 2001 1st affiliate Hospital of Fujian Medical University, Fuzhou, Fujian.
" Endophthalmitis after cataract surgery"
Sep 2001 Tianjin Eye Hospital & the affiliate Hospital of Tanjin Medical University, Tianjin.
" Macular hole surgery with ILM peeling."

Publications

Title: " **Clinical Ophthalmology**" in Chinese, Fujian Science & Technology Press.
Involvement: **Associate chief editor**
Original editor: Jack Kansky
Status: In press

Title: " **Basic and Clinical Research of Lens Diseases**", Fujian Science & Technology Press.
Involvement: **Co-editor**
Status: In press

Journal Articles

Liu F, Das TP, Sharma S. Wide field contact lens sterlization. Chinese Journal of Nosocomiology. 12:150-152, 2002.

Liu F, Li DP. The complication of the peribulbar blocker for retina surgery. Chinese Journal of Misdiagnostics. 6:544-545, 2002.

Liu F, Shi YY. Intra- and Subretinal retina foreign body removal. Ophthalmology (Chinese). 1: 45-47, 2000.

Jiang LQ, **Liu F**. Analysis of the refraction after vitrectomy with silicon oil. Chinese Journal of Optometry & Ophthalmology. 1:162-163, 1999.

Liu F, Jia YD. Treatment of Endophthalmitis. Chinese Journal of Ophthalmology. 35:155-156,1999.

Liu F. Comparison Panel D-15with Yu ziping color chart for pre- and post- operative retinal detachment. Shanxi Medical Journal 27:108-110, 1998.

Liu F. Comparison Panel D-15 with Yu ziping Color Chart for pre- and post-EccE+IoL color examination. Chinese Journal of Practical Ophthalmology. 15:400-401,1997.

Liu F. Analysis of the failure of retinal detachment. Journal of Shanxi Medical College of Continuing Education 7:21-23, 1997.

Presentation on the conference

The Health of Chinese Women. The 4th World Conference on Women. Beijing, China. Sep 1995.

Sterilization of Wide Field Contact lens with Cidex. The 5th international Retina Conference, Hyderadad, India. Aug 1998.

Pneumatic Retinopathy for RD. The 8th national Retina Conference, Shanghai, China. May 1999.

Intra- and Subretinal foreign body removal. The 5th Shanxi ophthalmology conference. Shanxi, China. Sep 1999.

Intra- and Subretinal foreign body removal. The 7th national ophthalmology conference. Shanghai, China. May 2000.

Intravitreou antibiotic combined steroid injection in endophthalmitis in rabbit. The 9th national Retina Conference, Dalian, China. Aug 2001.

Macular hole surgery with ILM peeling. The 4th international ophthalmology conference. Shantou, China. May 2002.

Macular hole surgery with ILM peeling. The 8th national ophthalmology conference. Xian, China. Augest 2002.

The recurrence of the idiopathic premacular fibroplasias in young subject is high the old patients. The 3rd international meeting of Retina. Egypt. Feb 2003.

The recurrence of the idiopathic premacular fibroplasias in young subject is high the old patients. Pole to Pole. Ravenna, Italy. Sep 2003

Triamcinolone acetonide for macular edema. The 37th Panhellenic Ophthalmological meeting. Thessaloniki-Porto Carras, Greece. June 2004

Removal intraocular foreign body at posterior part with vitrectomy. International trauma course. Ravenna, Italy. September, 2004

Hornors and awards

The endophthalmitis research was evaluated the advanced level of China by Science and technology committee of Shanxi Province. **Awarded the Shanxi Science and Technique Advancemnet 2nd Prize.** In charge of the project. 1999

Awarded the extinguished woman of Shanxi Province in 2000.

Awarded the praise by Chinese Organization Committee of the 4th World Conference on Women. 1994.

Awarded the outstanding cadre of Student Union in Shanxi Medical University in 1985.

Awarded the scholarship in Shanxi Medical University. 1983

Membership

Chinese Society for Medicine

Licensure

Chinese

Computer skills

Microsoft Products: Windows 98, XP,office 97,2000&XP (Word, Excel, Power Point, Outlook).

Adobe Products: PDF, photoshop

Browsers: Internet Explorer.

Email: outlook express.

Languages: Chinese and English

Used frequently: HTML

Society work

Volunteer of English-Chinese interpreter for ORBIS training projects from 1991-2003. (including the projects in Haiko, Fuzhou, Dalian, and most in Taiyuan,China)

Volunteer of English-Chinese interpreter for the 1st Asia Congress of Strabismus & Pediatric Ophthalmology. Tianjin, China.

Hobbies

Computer, Music , Travel and Cooking.

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Statement of originality

"I hereby declare that the submission- *The Comparison of Long-term Visual Recovery Between Acute and Sub-acute Macula-off Retinal Detachment After Scleral Buckling Surgery* is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of this university or other institute of higher learning, except where due acknowledgement has been made in the text. All the work was done at the department of ophthalmology in Philipps University Marburg under the conduction of Prof. Dr. med. Peter Kroll and was supported by the Shanxi (China) scholarship Committee."

Fang Liu

02/01/2005