

Epidemiology of Open Globe Injuries in Children

DIPLOMA THESIS

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Affidavit

Hereby I declare that I wrote the following diploma thesis independently and without any assistance from third parties.

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ABBREVIATIONS

BB gun ball-bearing gun

BETT Birmingham Eye Trauma Terminology

IOFB Intraocular foreign body

IVA Initial Visual Acuity

LP Light perception

NLP No light perception

OTS Ocular Trauma Score

PPV Pars plana vitrectomy

PV Posterior vitrectomy

USEIR United States Eye Injury Registry

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ABSTRACT

Background and Aims: Open globe injuries range among the most severe eye injuries. A special challenge is the treatment of injured children. This study aims at the assessment of etiological factors, outcome and other aspects of this kind of injuries and is designed to give impulses for prevention.

Methods and Patients: In a retrospective study 91 open globe injuries in children less than 18 years of age were analyzed. A long-term follow-up was obtained by means of the establishment of contacts with patients and their office-based physicians. The Birmingham Eye Trauma Terminology was used to classify the injuries. As statistical tools the Wilcoxon Signed Rank Test and the Mann-Whitney-U Test were used among others.

Results: On average, 6 patients were treated per year. 79% of them were male and 21% female. 70% of the injuries were penetrating, 21% intraocular foreign body injuries, 6% ruptures and 3% perforations. 89% of the patients were injured by a sharp, 5.5% by a blunt and another 5.5% by an explosive object. 63% recovered a vision of at least 20/40, 21% of 20/50 to 20/200, 9% achieved a visual acuity of 10/200 to light perception and 7% no light perception. In 78% of the cases the entrance wound was corneal, in 12% scleral and in 10% corneoscleral. The most common injury objects were splinters which were produced during hammering, tools and glass fragments. Alongside to the general wound care the most frequent primary and secondary operations were lensectomies and vitrectomies.

Significance: This study points out multiple ways of preventing a very momentous type of injury. An example is the predominance of injured boys which could be induced by a higher readiness to take risks, a condition which can be prevented via appropriate education. 68% of the circumstances of the injuries of this study were similar: A sharp object entered the globe through the cornea. Nevertheless the consequences forced the surgeons to choose from over 20 different operation methods which had to be individually adapted to each patient. In the absence of clearly specified management strategies, the experience of the surgeon could be a fundamental influencing value for the success of surgical intervention.

ZUSAMMENFASSUNG

Hintergrund und Ziele: Bulbuseröffnende Augenverletzungen gehören zu den schwersten Augenverletzungen. Besonders prekär gestaltet sich die Behandlung von verletzten Kindern. Diese Studie zielt auf die Darlegung von Verletzungsursachen, visuellen Endergebnissen und anderen Aspekten dieser Verletzungen ab und gibt Impulse für Prävention.

Patienten und Methoden: 91 bulbuseröffnende Augenverletzungen von Kindern unter 18 Jahren wurden retrospektiv analysiert. Eine lange Nachbeobachtungszeit wurde durch telefonische Kontaktaufnahme mit PatientInnen und betreuenden niedergelassenen FachärztInnen gewährleistet. Klassifiziert wurde mittels der Birmingham Eye Trauma Terminology. Als statistische Werkzeuge dienten unter anderem der Wilcoxon-Test und der U-Test nach Mann und Whitney.

Ergebnisse: Im Schnitt wurden 6 PatientInnen pro Jahr behandelt. 79 % der PatientInnen waren männlich und 21 % weiblich. Als Verletzungsart wurden 70 % penetrierende Verletzungen, 21 % intraokulare Fremdkörper, 6 % Rupturen und 3 % Perforationen gefunden. 89 % der Verletzungsobjekte waren spitz, 5,5 % stumpf und 5,5 % explosiv. Der Endvisus von 63 % der PatientInnen betrug zumindest 20/40, von 21 % 20/50 bis 20/200, von 9 % 10/200 bis Lichtempfinden und 7 % konnten kein Lichtempfinden wiedererlangen. Die Eintrittswunde war zu 78 % in der Kornea, zu 12 % in der Sklera und zu 10 % korneoskleral. Die häufigsten Verletzungsgegenstände waren Splitter, die beim Arbeiten mit Hämmern entstanden, Werkzeuge und Scherben. Die häufigsten Operationen waren neben der allgemeinen Wundversorgung Lensektomien und Vitrektomien.

Schlussfolgerung: Die Studie beschreibt viele Wege der Prävention bulbuseröffnender Augenverletzungen. Beispielhaft dafür sei der hohe Anteil an verletzten Buben erwähnt, der durch Risikobereitschaft bedingt sein dürfte, die durch Erziehung beeinflusst werden kann. Weiters bleibt anzumerken, dass sich 68 % der beschriebenen Verletzungen auf die gleiche Art präsentierten: Ein spitzes Objekt drang durch die Kornea in den Bulbus. Die OperateurInnen wählten jedoch aus einem Register von über 20 verschiedenen Operationsarten. In Ermangelung klar zugeordneter Managementstrategien könnte die Erfahrung des Operateurs einen wesentlichen Gradmesser für das Gelingen einer operativen Versorgung darstellen.

1. INTRODUCTION

Eye injuries are a leading cause of monocular blindness. The WHO Programme for the Prevention of Blindness suggests that worldwide 750,000 eye injuries require hospitalization each year, including 200,000 open globe injuries, and that worldwide almost 19 million people suffer from unilateral blindness or low vision caused by an eye injury (1).

Compared to adults, visual impairment in children has a more consequences on social and psychological development of the victim and a greater socioeconomic impact.

The epidemiological analysis of injuries is momentous for their prevention. The world's largest database of eye injuries is the so-called "United States Eye Injury Registry" (USEIR) (2). It was founded in 1988 and monitors serious eye injuries which result in "permanent and significant structural or functional change" (3). An identical database is the "World Eye Injury Registry" which is available for ophthalmologists from all over the world. With these possibilities to collect great amounts of data it will be easier to analyze eye injuries in the future.

1.1. Natural Protective Mechanisms of the Eye

There is no organ in the body which is better protected than the eye. Embedded by the bony orbit it lies in a depression of the skull, protected by the nose which sticks out beside it. The brow catches small objects which come from above, the lids close instantly reflexly at the first sight of sound of danger. The lashes of the upper lid curl downward, the lashes of the lower lid curl upward and prevent small particles from reaching the eye wall. They are especially dense on the upper lid, because in the history of evolution most foreign bodies came from above. The cornea and the sclera are so sensitive, that the smallest foreign body is felt instantly and painfully, so that the signal for defense goes out. The lid closes regularly, so that the cornea is constantly sheltered by a layer of lacrimal fluid which has antiseptic properties. But human being manages to invent objects against which the body has no protective mechanisms. During the history of

evolution the human body has adapted to lots of changing circumstances, but it is doubtful that it will ever find strategies to protect itself from injuries with objects like knives or guns (4), (5).

1.2. Difference Between Eye Injuries in Children and Adults

Injuries in children are strongly influenced by the status of their development.

SCHENK-DANZINGER (6) explains that from the beginning of the second year of life on, a child has to learn a lot of fundamental movements, of which the maintenance of balance is especially important. Between 16 and 19 months, it learns to climb up stairs, but it has to hold on to the banisters in order not to fall down. Furthermore it learns to sit down, to go backwards, to throw a ball, and to make other movements. Many children like to carry things in their arms when they are walking. Knowing this, the parents can for example prevent the child's tendency to pick up and carry dangerous things by offering him or her to carry safe toys whenever taking a walk.

In the third year of life the fine motor skills start to develop. A two-year-old child can learn to lead a spoon to his or her mouth.

Between three and four years of age, children learn to climb up a stair without help. They succeed in tiptoeing and suddenly interrupting movements without falling down. They can coordinate movements better and better and have little problems with carrying a water-filled vessel without spilling.

In the fifth year of life, 75% of the increase in weight is due to the growth of muscles, a fact that shows that the child becomes more and more active. It succeeds in turning a somersault and carrying out a head-stand and with the bigger radius of action the possibilities of injuries change.

But nevertheless the child needs freedom of movement and SCHENK-DANZINGER points out that occasionally children have little access to physical activities because their parents are too anxious. But this fear can lead to huge deficiencies in coordination. A target of the present thesis is to increase the

reader's awareness of potential dangers and the accuracy of his or her preventive measures so that they are neither exaggerated nor neglected.

1.2.1. Growth of the Eye

The anteroposterior dimension of the eye is 16.5 mm at birth, increases to 22.5 mm by 3 years of age and continues to increase around 0.1 mm per year until 14 years of age, after which further growth is negligible.

Various parts of the eye grow at different times and the structures of the anterior part of the eye proportionally grow much less than the posterior eye tissues. The cornea grows the least of all ocular tissues. Its transverse diameter is 10 mm in the newborn and 12 mm in the adult. The pupils are small at birth because the dilatator muscle of the iris is poorly developed. The color of the iris is blue in newborn infants of the white race, since the melanocytes of the tissue contain little or no pigment. The lens is embryologically pinched off from the surface ectoderm. Through the whole life surface ectoderm cells continue to form new cells, a fact that is obvious with skin cells. Desquamation removes skin cells, but the lens cells are not desquamated and gather in the inside of the lens, making it denser and denser until a cataract develops in the late years of life.

In the infant, the concentration of hyaluronic acid and collagen in the vitreous body is low, but it increases until 13 years of age. Destruction of the vitreous body (liquefaction, degeneration) begins in the late childhood and is pronounced in myopes.

At birth the orbit is almost round and its walls are very close to the globe. As the orbit's bones grow, the eye becomes more loosely fitted in it (4), (7).

1.2.2. Change in the Refraction with Growth

- ✓ In the first two weeks of life, a child can only primitively differentiate between light and darkness and has a physiologic central scotoma.
- ✓ In the first or second month of life, the child starts to fixate, but until the fourth month peripheral vision is pronounced.

- ✓ In the fourth month the macula begins to fixate more and more (7), (8).

Refraction in growth depends of two factors: The axial length of the bulb and the radii of the curvature of the anterior surfaces of lens and cornea. In the infantile eye the axial length is too short for the refractive power, so that the normal infant's eye is 1 to 2 diopters farsighted. But the axial length grows rapidly and the focal point of the images gradually moves forward, especially during the first year of life (4).

1.2.3. Recommendations for Examining a Child

Examining a wake child

- ✓ If possible, a good rapport with the parents should be established at the beginning.
- ✓ The child can sit on the lap of a parent.
- ✓ The child could be given a colorful gift prior to or after the examination.
- ✓ The doctor should approach in a nonthreatening manner, and talk in a calm, soft voice. Forced cooperation seldom works.
- ✓ The child is calmer when the doctor explains procedures he or she plans before acting.
- ✓ The child should be assured that the doctor will not hurt him or her, if this is the truth.
- ✓ White lab coats should be removed if the child is frightened.
- ✓ Crying children are more likely to open their eyes if the room is darkened.
- ✓ The ophthalmoscope's light intensity should be kept to a minimum.
- ✓ Pictures are easier to distinguish for young children than letters, even if they know the letters.

- ✓ The most painful parts of the examinations should be saved for the end (9), (10).

Sedation / Anesthesia

- ✓ Sometimes eye examinations and suture removals can only be performed in sedation or under general anesthesia. A brief mask anesthesia is recommended for short procedures and intubation for longer procedures like suturing open wounds (10).

Accurate assessment of the visual acuity of preverbal patients is difficult to obtain. For their examination special techniques including the Preferential Looking Test, skiascopy and pattern-evoked visual potentials can be used (8), (11), (9).

1.3. Factors Influencing the Treatment of Open Globe Injuries in Children

Orbit

In children, the loss of an eye reduces the growth of the orbit in which it was embedded, but when the largest possible orbital implant is chosen, this effect can be prevented. Typically the reduced orbital growth is induced by enucleations, but it can also follow eviscerations (12), (10), (13), (14).

Fibrosis

The fibrotic component of healing is particularly pronounced in children. This can lead to a reduction of functions. Scars of children have the tendency to widen when the face grows and hypertrophic scarring is more common (10), (15), (16).

Fibrinous exudation

The fibrinous exudation of the iris as an effect of a paracentesis is pronounced in children. Operations like a penetrating keratoplasty are disturbed (17).

Sclera, Lens and Vitreous

The sclera of a child is less rigid than the sclera of an adult. The adherence between lens and vitreous is tighter, so that operation techniques have to be adapted (9).

Amblyopia

Amblyopia (also called lazy eye) is a development disorder with loss of vision of one or (rarer) both eyes without changes in the eye's structure. Changes appear only in the lateral geniculate body and visual cortex. In traumatology, amblyopia is caused by deprivation of vision. The eye is not stimulated for a period of time (because of a traumatic cataract, a vitreous hemorrhage and other pathologies) and the central nervous system reacts with a suppression of the eye. The danger of amblyopia is especially high in children below the age of six. It is treated with occlusion of the healthy eye with patches on the eye or on the glasses of the patient. The prospects for successful treatment decrease with age, and it becomes very difficult to treat amblyopia beyond the age of eight years. Amblyopia can be prevented by a prompt clearing of the visual axis of the child, by minimizing astigmatism during wound repair, by the early removal of corneal sutures and by rapid employment of optical correction (18) (5) (11) (19).

Anamnesis

The precise circumstances of an injury are important predictors for the nature and extent of an injury. A history of striking a nail with a hammer for example should raise suspicion of an intraocular foreign body. Injuries with objects which contain lots of microorganisms, such as wood, are especially prone to develop endophthalmitis. Young children cannot describe the history of their injury properly, and in addition they occasionally prevaricate, especially when the true history would betray some misbehavior.

Furthermore, another problem might disturb the search for the exact anamnesis: Child abuse. If children and parents provide contradictory information, the doctor should be alarmed. In Austria doctors are obliged to inform the Youth Welfare Office if a suspicion of child abuse is raised (legal background: Article 1 § 54 Doctor's law) (9) (20) (10).

Lens

After a contusion of the eye a special form of cataract develops: The rosette cataract, a rosette-shaped subcapsular opacity in the anterior part of the lens. To ensure that the child does not develop amblyopia, a lensectomy has to be performed and the resulting loss of vision has to be corrected, if possible. The difference between adults and children undergoing lensectomies is that in children the development of an aftercataract is pronounced.

In injuries, sometimes aphakia cannot be corrected with an intraocular lens, especially when the lens capsule or the zonule of Zinn is ruptured. It is corrected with contact lenses then, since the difference in size of the pictures on the retina would be too big if an aphaque eye was corrected with glasses. The correction of aphakia with glasses is only possible if both eyes are corrected in this way (5), (11).

Vitreotomy

The vitreous body of children is very tense and there is a special danger of traction on the retina (9).

Psychology

The society is especially sensitive towards suffering children. And the coping-mechanisms of children differ from those of adults. Young children are more likely to seek refuge in a caregiver than older children. And girls use this coping strategy more often than boys. Besides, children often do not understand why they have to see medical doctors so often and are frightened (10), (21).

1.4. Terminology

1.4.1. Overview

Unfortunately the vocabulary used for eye injuries is very heterogeneous in the literature. An injury which produces an entrance wound as well as an exit wound in the globe can either be called “double perforating” (22), (23), (24), “double penetrating” (25), (26), (27) or “perforating” (2), (28). Sometimes a single injury can also be called “penetrating“ as well as “perforating“ in one article (29). An injury with only one entrance wound can be called “perforating” (30), (31) or “penetrating” (28), (32).

The search for literature is hence very challenging, and sometimes it is impossible to know with certainty what kind of injury the authors refer to (33).

But a homogenous classification system is the basis for unambiguous transmission of clinical data which simplifies research activities and improves efficiency of patient treatment.

KUHN ET AL. developed such a classification system which is recognized by the „Society of Ocular Trauma“, the „World Injury Registry“ and other organizations. It is called “Birmingham Eye Trauma Terminology” or “BETT” (32), (34), (35), (10).

In this diploma thesis the expressions „penetrating“, „perforating“, „rupture“ and „intraocular foreign body“ are used in accordance with the BETT.

An overview of the definitions is provided in Figure 1.

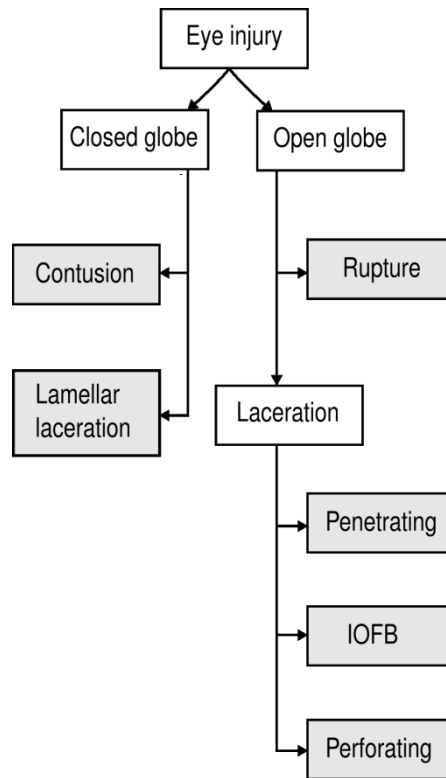


Figure 1: Overview of the BETT, designed by KUHN ET AL. (35)

Rupture

A rupture is defined as a “full thickness wound of the eyewall, caused by a blunt object” (35). Since the eye is filled by the incompressible vitreous body, the impact of the injury results in a momentary increase of the intraocular pressure. This pressure makes the eyewall give way at its weakest point, which is not necessarily the impact site. The vector of the force which induces the rupture therefore runs from the inside of the eye to the outside. As a clinical consequence tissue prolapse is even more frequent than in the other types of open globe injuries.

Laceration

The expression “laceration” is the umbrella term for penetrating injuries, intraocular foreign body injuries and perforating injuries. It is defined as a “full-thickness wound of the eyewall, usually caused by a sharp object” (35). The wound occurs at the impact site, the vector of force runs from the outside to the inside of the

globe. Further classification is based on whether an exit wound or an IOFB is also present.

Penetrating injury

A penetrating injury is a laceration of the eyewall which shows an entrance wound, but no exit wound, and no intraocular foreign body. If more than one entrance wound is present, each must have been caused by a different agent.

Intraocular foreign body injury

In an intraocular foreign body injury a foreign body rests inside the eye, having perforated the eye wall. This kind of injury is “technically a penetrating injury but is grouped separately because of different clinical implications” (35).

Perforating injury

A perforating eye injury shows “two full-thickness lacerations of the eyewall” (35) (entrance wound and exit wound). Both wounds must have been caused by the same agent.

In contrast to old terminologies which used either the eye wall or the globe as tissue of reference, the BETT always refers to the whole globe as a whole. There are some limitations of this classification, though. In some cases an injury agent produces both an entrance and an exit wound, but remains at least partially in the globe. And there are injury objects which can have signs of a rupture or a perforating injury (air gun pellet injuries). They can either be subsumed under a separated group of mixed injuries or under the group of the predominating injury signs. For the study for this diploma thesis the second variant was chosen and no injury in which an object with entrance and exit wound rested in the globe.

1.5. Operation Techniques

Primary Wound Closure

Most of the patients with an open globe injury require primary wound closure (see below).

Lensectomy

If its capsule is wounded, the lens may be observed to swell with fluid and to become opacified. A traumatic cataract has developed. The operation techniques which can be used to treat it are the intracapsular and the extracapsular cataract extraction. Today the extracapsular cataract extraction is used much more often, but when the lens is subluxated or dislocated, the intracapsular cataract extraction is still performed. After the removal of the natural lens, in most of the cases an artificial intraocular lens is implanted or contact lenses are prescribed (17), (11).

Iridotomy and Iridectomy

In ocular traumatology, iridotomy is often used to resolve synechiae, and iridectomy predominantly serves as a method to establish a suitable intraocular pressure (17).

Vitrectomy

In case of pathologies like a vitreous prolapse, most intravitreal foreign bodies or a vitreous hemorrhage, the vitreous body has to be removed at least partially. An anterior vitrectomy is the “removal of vitreous from the anterior chamber and the anterior one-third to one-half of the vitreous cavity” (36). It is performed through the cornea or the limbus and usually aims at removing a prolapsed part of the vitreous body. During a posterior vitrectomy three instruments (infusion cannula, light source and vitrectome) are introduced into the globe through the pars plana. The vitreous body is cut and aspirated and simultaneously the infusion refills the vitreous cavity. In cases if an unabsorbed vitreous hemorrhage, for example, the eye can be filled with Ringer’s solution, but when the retina is detached, it has to be held with a tamponade of fluid with a high specific gravity such as a

perfluorocarbon liquid. At the end of the operation it is recommended to replace these fluids with gases or silicone oil (11), (13).

The vitrectomy is a great advance in the management of open globe injuries. It has increased the recovery rate in severely injured eyes which were once considered inoperable and enucleated. It permits to clear intraocular opacities and to identify and treat retinal damage. Furthermore, it prevents formation of a cyclitic membrane (a retrolental fibrovascular membrane which stretches across the back of the lens) and traction of the retina. For children the clearance of intraocular opacities is especially important, with regard to the development of amblyopia (37), (38).

Scleral Buckle

A scleral buckle is used to treat retinal detachment, which is rarer in children than in adults. Trauma is the leading cause for retinal detachment in children. Initially this pathology of the retina may be asymptomatic (until the macula is threatened), and if it is not, children are unfortunately reluctant to report symptoms, so that especially in blunt trauma, a latent period of several months or even years may pass between the beginning of the detachment and the diagnosis (39).

In general anesthesia, an encircling band is sewn around the bulb, in order to minimize the traction on the detached retina. In infants, there is the danger, that scleral buckling inhibits the eye growth or induces anisometropic amblyopia. Therefore it has to be explained to the parents before the therapy that maybe further operations will be required (40), (41).

Enucleation and Evisceration

The term “enucleation” defines the removal of the bulb, the term “evisceration” the removal of the contents of the bulb, without the sclera and with or without the cornea.

Advantages of an evisceration are that the operation is shorter, the eye can be moved nearly normally, the atrophy of the orbital fat is less pronounced and the subarachnoid space does not have to be opened.

Advantages of an enucleation are that it undermines the risk for sympathetic ophthalmia and that postoperative pain is rare (13), (42).

Ocular trauma is one of the most frequent underlying causes for enucleations, but over the last decades the total number of these operations has decreased (1), (43) (44).

Penetrating Keratoplasty

A penetrating keratoplasty is indicated when a deficiency of the cornea has to be covered. All the layers of a round disc of the cornea are removed and replaced by a graft (17).

2. AIM OF THE WORK

The WHO Programme for Prevention of Blindness suggests that 750,000 cases of eye injuries are hospitalized each year and 200,000 of them are open globe injuries, which count among the most severe eye injuries. Their treatment is especially challenging, when the patients are children. This is why this diploma thesis is dedicated to them.

Injury causes and circumstances vary with the culture in which they happen. No study about open globe injuries in children has been published with data of patients from Austria so far. One study has been published in the culturally very similar neighboring state Germany in 1998. But this study covers other aspects as the present study and has fewer patients.

3. MATERIAL AND METHODS

In a retrospective study we analyzed 91 open globe injuries in children less than 18 years of age who were operated between the 1st September 1992 and the 31st December 2007 in the Department of Ophthalmology of the Medical University Graz with the diagnosis of an open globe injury.

The terms “open globe injury”, “penetrating injury”, “perforating injury” and “intraocular foreign body” are used in accordance with the Birmingham Eye Trauma Terminology which is described in the introduction of this thesis.

The patient’s records were reviewed for the following criteria:

- Age
- Sex
- Type of injury
- Entrance wound
- Injury cause
- Operations
- Final visual acuity
- Injured eye

- Responsibility for the injury

To ensure a long-term follow-up, contact with patients and their office-based physicians was established. Ten patients with a follow-up of less than one year were excluded from the analysis of the visual outcome.

Suture removal and eye examinations under anesthesia were not ranked among operations. Patients who underwent operations in other hospitals were excluded from the analysis of operations if no exact description of the surgical interventions could be obtained.

Visual acuities were grouped as at least 20/40, 20/50 to 20/200, 10/200 to light perception and no light perception.

Statistical analysis was conducted with XLSTAT and SPSS. The Wilcoxon Signed Rank Test, the Mann-Whitney-U Test and crosstabs were chosen as the most important tools for comparison of the recorded data.

4. RESULTS

4.1. Frequency of Injuries

On the average 5.9 ± 1.5 patients were treated per year with a range from 1 in 2002 to 11 in 1993. The numbers of patients treated per year is shown in Figure 2.

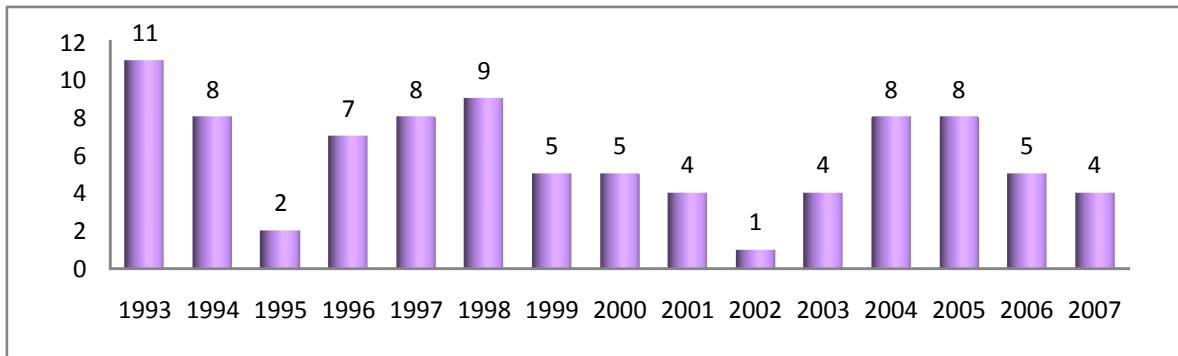


Figure 2: Number of patients treated per year

4.2. Age Distribution

The mean age was 9.7 ± 1.04 years with an age range from 1 to 17 years. No statistically significant trend in frequencies of injuries of different age groups was observed, like Table 1 shows.

Age group	Percentage of patients
0-8	48
9-17	52
1-5	33
6-10	37
11-15	30

Table 1: Age distribution

4.3. Gender Distribution

72 patients (79%) were boys and 19 (21%) girls.

In the group of the children younger than 11 years of age 66% of the children were male and 34% female, and in the group of the children who were at least 11 years old, 91% were male and 9% female (Figure 3). This difference is statistically highly significant ($p = .001$ in the Mann-Whitney-U Test).

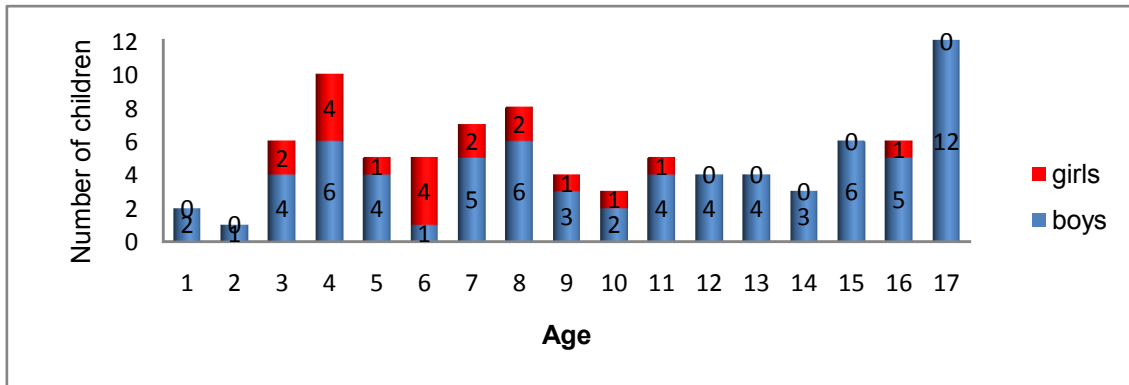


Figure 3: Age-related gender distribution

We also analyzed if the final visual acuity ($p = .3$), the type of injury ($p = .4$), the entrance wound ($p = .6$), the proportion of self-inflicted injuries ($p = .3$) and other parameters varied with the gender, but no statistically significant correlation was detected.

4.4. Type of Injury

We found 65 (71%) penetrating injuries, 18 (20%) injuries with an intraocular foreign body, 5 (5%) ruptures and 3 (3%) perforating injuries.

4.5. Entrance Wound

The entrance wound affected the cornea in 65 (78%), the sclera in 10 (12%) and both tissues in 8 (10%) cases. When the wound was localized in either the cornea or the sclera, fewer operations had to be conducted as when it spread over the cornea and the sclera ($p = .02$ in the Mann-Whitney-U Test).

4.6. Injury Causes

81 injury objects (89%) were sharp, 5 (5.5%) blunt and further 5 (5.5%) explosive.

Furthermore 44 of the injury objects (48.4%) were toys, tools or pens, 24 (26.4%) objects of utility, 16 (17.6%) sticks, stones or branches of trees and 2 (2.2%) of the injuries were the consequences of car accidents (Figure 4).

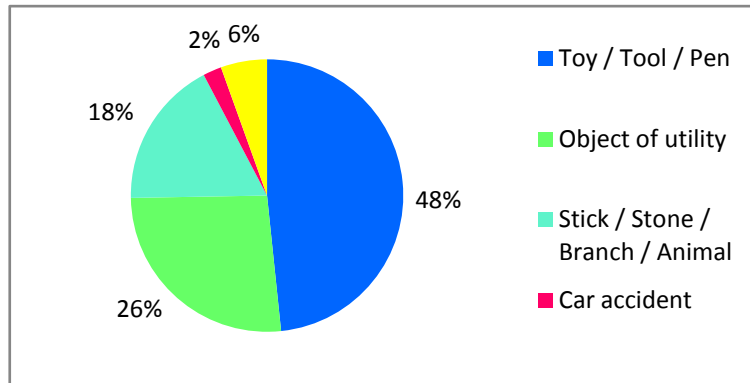


Figure 4: Groups of injury objects

24% of the injuries of which the origin was recorded were caused by splinters during hammering and tools. The children either worked with these tools themselves or they observed somebody who was working. Further injury objects are shown in Table 5.

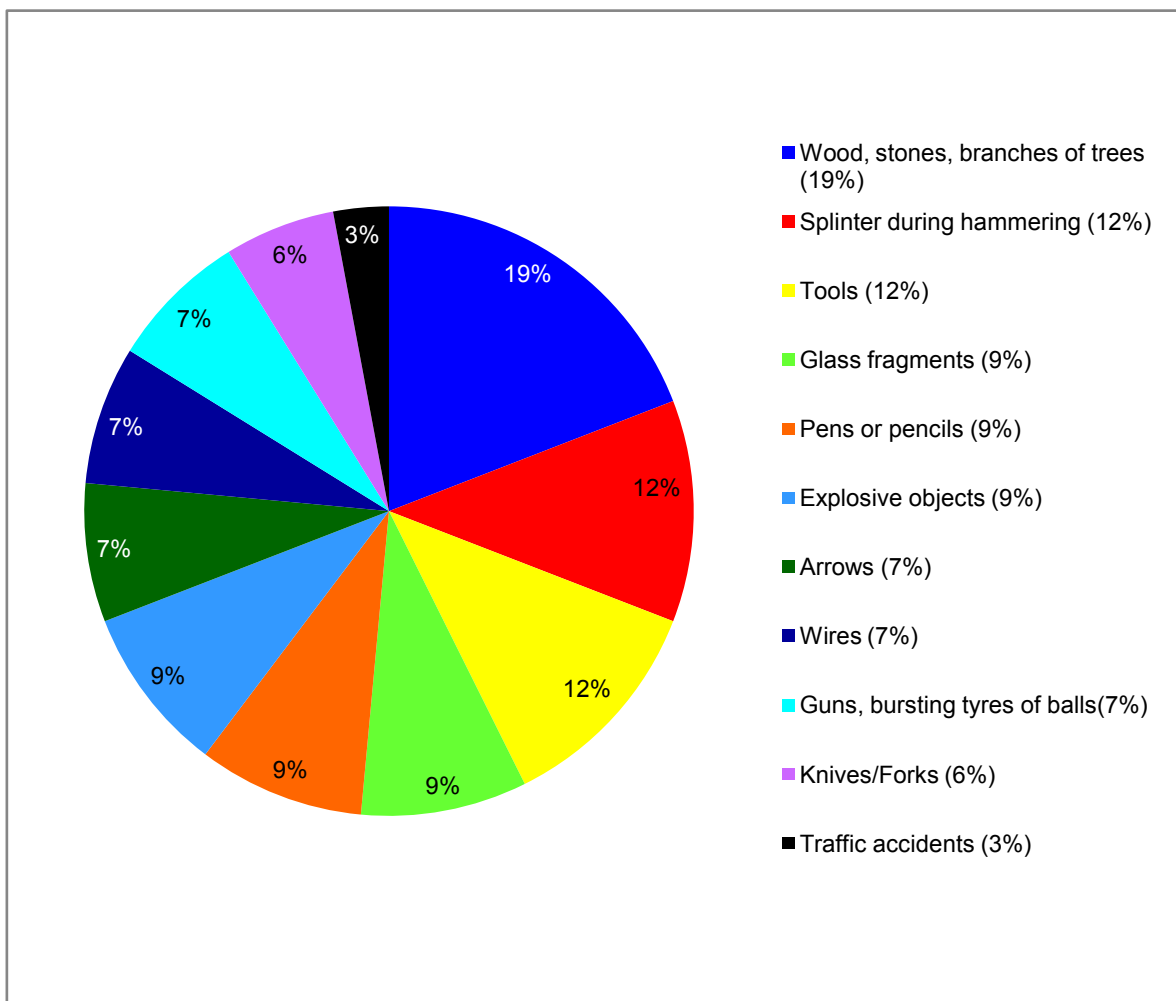


Figure 5: Injury objects

All together, 173 operations were conducted on 90 patients; the mean number of operations per patient was 1.9. More than half of the children could be treated with one single operation, one patient required 8 operations (Figure 6).

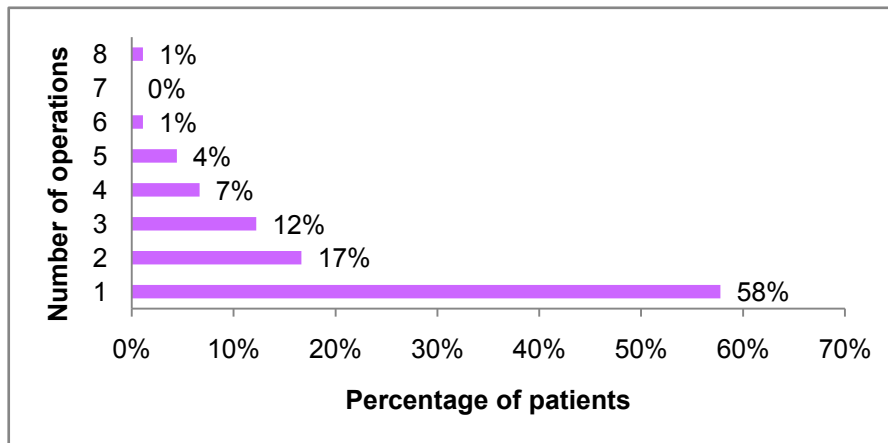


Figure 6: Number of operations per patient

A significant difference in the number of operations of boys and girls could not be observed, the mean number of operations was 2.0 ± 0.4 for boys and 1.8 ± 0.6 for girls.

A primary wound closure was conducted in every child, except for one with a lamellar penetration of the globe. This boy was only operated two months later because of a traumatic cataract.

With the primary wound closure, often performed procedures were iridectomies and iridotomies, removal of foreign bodies with pincers, reposition of the iris and the ciliary body, removal of membranes and synechiae, irrigation of the anterior chamber and suturing of disconnected tissues. Further operative techniques and the frequency of their utilization are summarized in Table 2.

Operative technique	Number
Vitrectomy	50
Lensectomy	34
Implantation or reposition of an intraocular lens	20
Extraction of an intraocular foreign body with a magnet	6
Scleral buckle	5
Operation of a secondary strabismus	4
Retinotomy / -ectomy	4
Cryopexy of the retina	3
Intravitreal injection of antibiotics	2
Evisceration / Enucleation	2
Keratotomy	2
Corneal transplantation	1
Scleral transplantation	1
Operation of a cicatricial ectropion	1
Cyclodialysis	1

Table 2: Frequency of various operative techniques

A very frequent operative technique was the vitrectomy. Anterior and posterior vitrectomies were each performed 25 times. 12 patients (14% of all 89 patients whose operations were analyzed) required 1 posterior vitrectomy, 5 (6%) required 2 and 1 (1%) required 3. 23 anterior vitrectomies (92%) were performed singularly during primary repair, only 2 (8%) later. Other frequent procedures were lensectomies and implantations or repositions of intraocular lenses.

1 eye (1%) was enucleated and one further eye eviscerated.

A trend could be perceived towards more operations of eyes with ruptures (2.4 ± 1.1) and perforating injuries (3.3 ± 5.2) than eyes with penetrating injuries (1.9 ± 0.4) and intraocular foreign bodies (1.9 ± 0.8), but since ruptures ($n = 5$) and perforating injuries ($n = 3$) were rather rare, statistically significant conclusions could not be drawn.

Most of the patients were operated on the day they sustained the injury, 29% on the next day or later (Figure 7).

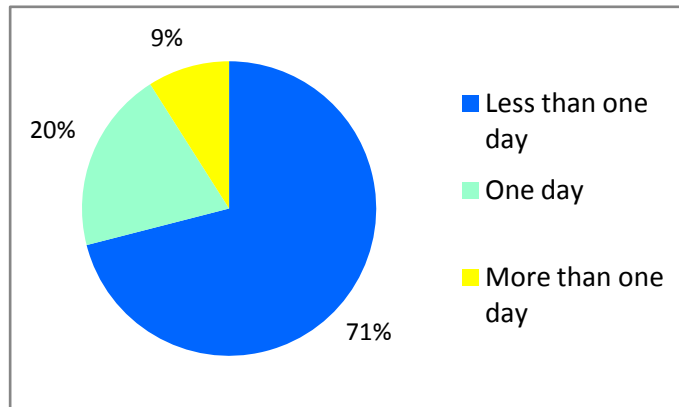


Figure 7: Time between injury and operation

We investigated the correlation between the outcome and the delay in surgery by defining two groups of penetrating injuries, since we wanted to analyze a homogenous and numerous collective. In the first group (n = 48) we analyzed patients who were operated on the day the injury took place and in the second group (n = 23) we compared patients who were operated at least one day after the injury. In each group, 93% of the patients recovered a vision of at least 20/200.

For the injuries with intraocular foreign bodies we defined the same categories and recorded 6 patients (75%) of the first group and 7 patients (78%) of the second group having a final visual acuity of at least 20/200.

4.7. Final Visual Acuity

Final visual acuity was available for 81 patients whose follow-up ranged from 1 year to 16 years. Of these, 51 (63%) recovered a vision of at least 20/40, 17 (21%) of 20/50 to 20/200, 7 (9%) achieved a visual acuity of 10/200 to light perception and 6 (7%) no light perception (Figure 8).

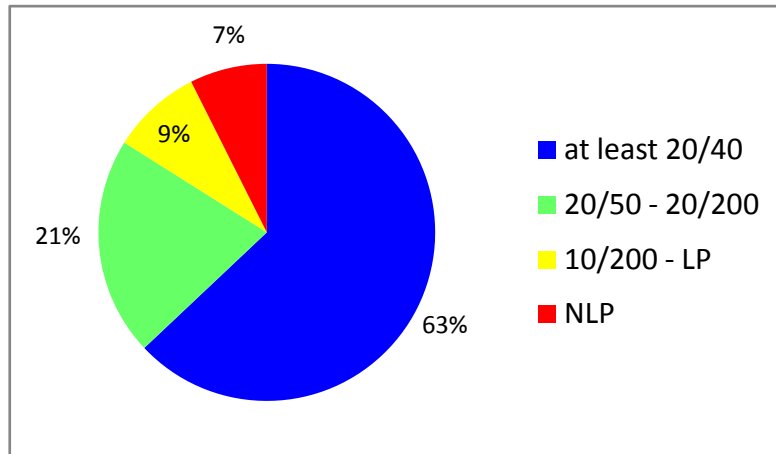


Figure 8: Final visual acuity (LP = light perception, NLP = no light perception)

A final visual acuity of at least 20/40 was achieved by 70% of the patients with an intraocular foreign body, 59% of those with a penetrating injury, 33% of those with a perforating injury and 20% of those with a rupture. In contrast to that 40% of the children with ruptures, 33% of those with a perforating injury, 6% of those with a penetrating injury and 4% of those with an intraocular foreign body did not regain light perception (Figure 9). The outcome of penetrating injuries and intraocular foreign bodies was better than the outcome of perforating injuries and ruptures ($p = .003$ in the Man-Whitney-U Test).

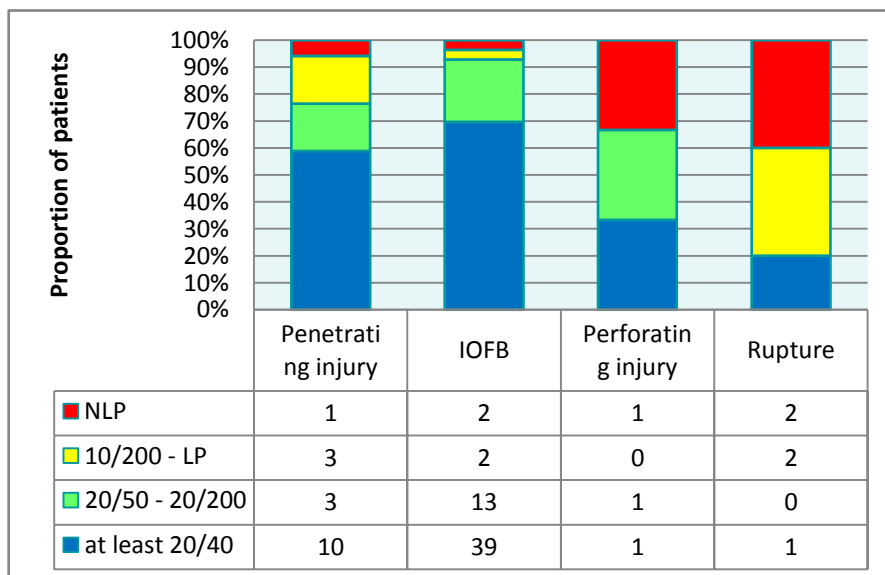


Figure 9: Type of injury and visual outcome

The visual outcome of blunt injuries was significantly worse than that of sharp injuries ($p = .005$ in the Mann-Whitney-U Test).

The percentage of children with a good final visual acuity of at least 20/40 was 71% for the children with the entrance wound in the cornea, 63% if it was in the sclera, and 43% if both tissues were concerned (Table 3). But the results did not show statistical significance, neither when the corneal wounds were compared to those which affected both tissues, nor when the corneal and scleral wounds together were compared to the category of wounds in both tissues ($p = .16$ respectively $.20$ in a Mann-Whitney-U Test).

Final visual acuity	Cornea	Sclera	Both
at least 20/40	41 (71%)	5 (63%)	3 (43%)
20/50 - 20/200	12 (21%)	1 (13%)	3 (43%)
10/200 - LP	2 (3%)	2 (25%)	1 (14%)
NLP	3 (5%)	0 (0%)	0 (0%)
Total	58	8	7

Table 3: Final visual acuity and entrance wound

To compare the influence of the initial visual acuity on the final visual acuity, the Wilcoxon Signed Rank Test was performed and showed a statistically highly significant connection between the two measurements ($p = .000$).

We observed that during treatment 52 children (80% of all those who had initial and final visual acuity recorded) could recover to a better category of vision or stay in the best category. Further 11 (17%) children also stayed in the same categories during treatment but those were NLP (4), 10/200 – LP (5) or 20/50 to 20/200 (2). 2 children (3%) dropped into a worse category (Table 4).

The better the initial visual acuity, the better is the final visual acuity.

		Final visual acuity				Total
		NLP	10/200 - LP	20/50 – 20/200	at least 20/40	
IVA	NLP	4 (80%)	0	1 (20%)	0	5
	10/200 – LP	1 (4%)	5 (18%)	8 (29%)	14 (50%)	28
	20/50 – 20/200	0	0	2 (13%)	13 (87%)	15
	at least 20/40	0	0	1 (6%)	16 (94%)	17

Table 4: Final visual acuity compared to initial visual acuity

4.8. Child Abuse

No case of child abuse was reported in the records used for this study.

4.9. Injured Eye

The right eye was wounded in 52 cases (57%) and the left eye in 39 cases (43%).

4.10. Responsibility for the Injury

There was no significant difference in the frequency of self-inflicted injuries and those which were caused by another person. In 33 (36%) cases the action which induced the injury was carried out by the wounded child, in 32 (35%) cases by someone else. In 26 cases (29%) the responsibility for the injury was not clear.

5. DISCUSSION

The following chapter aims at giving a review of the present literature about open globe injuries in children and comparing it to the study which was written in the context of this diploma thesis.

The challenging part of the collection of literature was that the term “open globe injury” was rarely used (see above). If it was not evident from the full text of the studies, what kind of injury was dealt with, the study was excluded from the following review (33).

5.1. Studies about Open Globe Injuries in Children

ROSTOMIAN ET AL. (USA) published a retrospective study of 70 cases of children less than 16 years in 1998 (45).

SKIKER ET AL. (Morocco) published a retrospective study of 62 cases of children less than 15 years in 2007 (46).

HILL ET AL. (USA) published a retrospective study of 59 cases of children less than 18 years in 2006 (47).

THOMPSON ET AL. (Australia) published a retrospective study of 72 cases of children less than 16 years in 2002 (48).

BEBY ET AL. (France) published a retrospective study of 57 cases children less than 14 years in 2006 (30).

FARR ET AL. (USA) published a retrospective analysis of 281 children less than 15 years in 2001 (49).

JANDECK ET AL. (Germany) published a consecutive retrospective study of 38 children less than 17 years in 2000 (28).

PRADO JR. ET AL. (Brazil) published a retrospective study of 140 children less than 16 years in 1996 (31).

BEHBEHANI ET AL. (Kuwait) published a retrospective study of 95 children less than 17 years in 2002 (50).

GUPTA ET AL. (UK) published a retrospective study of 20 patients less than 17 years in 2009 (51).

NARANG ET AL. (India) published a retrospective study of 72 patients less than 14 years in 2004 (52). Patients with eyes which were prephthisical at presentation and in which primary repair was not possible were excluded. This fact should be considered during the lecture of the visual outcome.

JAISON ET AL. (India) published a retrospective study of 80 patients less than 15 years with 89 injuries in 1994 (53).

SOYLU ET AL. (Turkey) published a retrospective study of 242 patients less than 15 years in 1998 (54).

5.2. Gender Distribution

In 1982 a study was published in the American Journal of Diseases of Children which analyzed 197,516 consumer-product related injuries of children. The results indicated that “sex differences in injury rates appear within the first year of life for most types of injuries” (55). Some other studies also suggest that gender differences in behavior already start in preschool-aged children. LUNDENBERG (56) examined the catecholamine excretion and components of the type A behavior pattern (competitiveness, impatience-anger and aggression) in 3-6 year old children and discovered that boys excreted more adrenaline and noradrenaline than girls and obtained higher type A scores. An overview about the Gender distribution in literature can be observed in Table 5.

Study	Boys	Girls
USA 1993, Rostomian et al.	71%	29%
Morocco 2005	51 (=82%)	11 (=18%)
USA 2002	78%	22%
Australia 1999	67%	33%
France 2004	41 (=72%)	16 (=28%)
USA 1993, Farr et al., group 1	87%	13%
USA 1993, Farr et al., group 2	75%	25%
Germany 1998	31 (=82%)	7 (=18%)
Brazil 1993	76%	24%
Kuwait 1999	70 (=74%)	25 (=26%)
UK 2003	85%	15%
India 2000	53 (=74%)	19 (=26%)
India 1990	63 (=79%)	17 (=21%)
Turkey 2008	72%	28%

Table 5: Gender distribution in the literature

In all studies more boys than girls were injured. They make up for between 67% and 87% of all injuries, a fact that could be induced by a higher readiness to take risks which could be prevented by means of an appropriate education.

5.2.1. Gender Distribution in Various Age Groups

In the study for this diploma thesis the difference in the frequency of injuries in boys and girls varied with the age, in the age group of children below 11 years of age the predominance of boys was not as clear as in the older children (see above).

These findings are according to BEBY ET AL., whose data suggest a larger difference in the group of the 7 to 13 year olds, compared to the 0 to 6 year olds (79% versus 65% boys).

In the study of THOMPSON ET AL. the patients were divided into 5 age groups, but it is unclear which age group a patient belongs to, since the categories are described as “0-3, 3-6, 6-9, 9-12, 12-15”. The authors report an almost equal number of injuries in the less than 3 years age group and a male predominance in all other age groups.

SKIKER ET AL. also suggest that in the age groups of the 6 to 10 and 11 to 14 year old children the male predominance is clearer than in the less than 5 years old age group.

The study of PRADO ET AL. shows a clearer predominance of boys in the group of the 7 to 15 year olds, compared to the 0 to 6 year olds, but the clearest predominance occurs in the group of the 7 to 11 year olds (Table 6).

Age	Percentage of boys	Percentage of girls
0 to 6	66,03	33,97
7 to 11	82,27	17,73
12 to 15	75	25

Table 6: Visualization of the results of the gender distribution found in the study of PRADO ET AL.

(31)

BEHBEHANI ET AL. divide their patients into 4 groups of 0 to 3 year olds, 3.1 to 6 year olds, 6.1 to 10 year olds and 10.1 to 16 year olds and also show that the adolescent boys outnumber the adolescent girls more than the young boys outnumber the young girls. The exact ratios are 17:6, 19:9, 18:6, and 16:4, starting with the first and ending with the last age group.

JAISON ET AL. are in agreement with the previous studies, they divide their patients into three age groups from 1 to 5, from 6 to 10 and from 11 to 15 years and report a male to female ratio of 2.0:1 in the first, 3.6:1 in the second and 8.0:1 in the third group.

SOYLU ET AL. even suggest that open globe injuries in young children less than 5 years of age occur equally frequent in boys and in girls.

We could not find this equal distribution in our study, the age group of children younger than 6 years of age consisted of 62% boys and 38% girls and the age group of children younger than 4 years of age even of 78% boys versus 22% girls.

In the age group SOYLU ET AL. defined with children between 5 and 9 years of age, the boys made up for 69% of the injuries and 84% of the children older than 9 years of age were boys.

To sum up, all studies in which the age-related gender distribution was discussed showed a higher predominance of boys in adolescents than in young children. Some show an almost equal gender distribution in toddlers, but others do not.

5.3. Age Distribution

The age distribution of injuries has to be seen in the context of the development of the child. The patterns of the injuries vary strongly with the age and can be explained as well as prevented by the knowledge of certain behaviors which are associated with the development of the child.

5.3.1. Age Peak

According to our study no significant age peak was found in the literature, except for one study (Hill et al.) in which children less than 9 years of age outnumber the older children. The comparison of the literature is difficult, since different age groups are defined. Table 7 overviews the results.

Study	Age group one	Age group two	Age group three
Rostomian et al.	<u>0-4</u>	5-12	13-15
Skiker et al.	1-5	<u>6-10</u>	11-14
Hill et al.	<u>0-8</u>		9-17
Thompson et al.	<u>0-7</u>		9-15
Behbehani et al.	<u>0-6</u>		10-16
Jaison et al.	0-5	<u>6-10</u>	11-15
Soylu et al.	1-4	<u>5-9</u>	10-14

Table 7: Age peaks in the literature (underlined numbers mark the age groups in which the injuries happened most frequently)

The school children less than 10 years of age seem to be at highest risk, although in one study (Rostomian et al.) they are outnumbered by the children younger than 5 years of age. In no study the age group of the oldest children is the biggest.

In the study of ROSTOMIAN ET AL. the patients are divided in three groups of children aged 0-4, 5-12 and 13-15 years, and the first group contains 54% of the

injuries (38 patients), the second group, although its age range is bigger than the one of the first group, 40% (28 patients) and the third group 6% (4 patients).

SKIKER ET AL. also divide their patients into three similar age groups. The first group contains children aged 0-5, the second group children aged 6-10 and the third children aged 11-14.

But their findings differ from those of the previous study: The second age group outnumbers the first by far, being approximately two times larger. The frequency of injuries in the third age group ranges between the first two.

HILL ET AL. define two age groups, one consisting of children less than 9 years of age and another of children aged 9-17. Their finding that injuries were more frequent in the younger children (64%) than in the older children (37% [sic!]) reaches statistical significance.

The authors argue, that the reason for the predominance of young children could be, that they have no experience with hazardous objects and are therefore less cautious. As another explanation they take into consideration that younger children are more likely to be brought to a hospital.

In the survey of THOMPSON ET AL. 38 patients (70%) are younger than 7 years of age and 16 patients (30%) aged 9-15 years. Again the young children outnumber the schoolchildren and adolescents.

FARR ET AL. did not report a significant age peak. Their patient population shows slightly more 8-17 year olds than 0-7 year olds.

JANDECK ET AL. and PRADO ET AL. also did not demonstrate an age peak.

BEHBEHANI ET AL. also treated more young children than adolescents. Of the 4 groups mentioned above (0-3, 3.1-6 years, 6.1-10 and 10.1-16 years of age) the first group consists of 23 (24%), the second of 28 (30%), the third of 24 (25%) and the fourth of 20 (21%) children. So the group with the biggest age range (10 to 16 year olds) contains the fewest children.

JAISON ET AL. examined 21 children (26%) younger than 6 years of age, 32 (40%) aged 6-10 years and 27 (34%) aged 11-15 years and conclude, that school-going children are more affected by open globe injuries than younger children.

Similar results are obtained by SOYLU ET AL., who report 48 children (20%) aged 1-4, 101 (42%) aged 5-9 and 93 (38%) aged 10-14.

Besides, BAXTER ET AL. (60), who conducted studies about anterior perforating eye injuries, also conclude that the majority of childhood open globe injuries occur in children younger than 8 years of age.

5.3.2. Mean Age

Study	Age of the patients	Mean age
USA 1993, Rostomian et al.	under 16	5
Morocco 2005	under 15	7.5
USA 2002	under 18	7.1
France 2004	under 14	6.8 ± 3.5
USA 1993, Farr et al.	under 15	8.2
Kuwait 1999	under 17	6.6± 3.8
UK 2003	under 17	9.8
India 2000	under 14	7.1
Turkey 2008	under 15	8.35 ± 3.47

Table 8: Overview of the mean age in the literature

Table 8 shows the mean age of various studies. It did not show a clear predominance of younger or older children.

5.3.3. Youngest Children

Study	Youngest child
Rostomian et al. (USA 1993)	4 months
Skiker et al. (Morocco 2005)	2 years
Farr et al. (USA 2002)	1 year
Thompson et al. (Australia 1999)	7 months
Farr et al. (USA 1993)	1 year
Behbehani et al. (Kuwait 1999)	4 months
Gupta et al. (UK 2003)	1 year
Narang et al. (India 2000)	2 years
study for this diploma thesis	1 year

Table 9: Overview of the youngest patients with open globe injuries

How old the youngest patients of various studies were can be seen in Table 9. In only three of the nine studies which described their age range, patients younger than one year were treated.

5.4. Injury Type, Zone and Grade

In accordance with our study the literature also shows that the most frequent injury type is a penetrating eye injury and the rarest one is a perforating eye injury.

27 patients (71%) of JANDECK ET AL. sustained a penetrating injury without a foreign body, the eyes of 3 (8%) additional patients retained an intraocular foreign body, and another 3 (8%) patients sustained a perforating injury. A rupture was present in 5 cases (13%).

NARANG ET AL. report 59 (82%) penetrating injuries, 9 (13%) intraocular foreign bodies, of which one was in the anterior segment and 8 in the posterior segment, 1 (1%) perforating injury and 3 (4%) ruptures. The 9 intraocular and 1 orbital foreign bodies they saw were 3 eyelashes, 4 wooden splints, 2 pieces of iron and 1 stone.

The International Ocular Trauma Classification defines three injury zones (2). They can be observed in Table 10.

Injury zones	Definition
Zone 1	cornea and limbus
Zone 2	limbus to 5 mm posterior into the sclera
Zone 3	posterior to 5mm from the limbus

Table 10: Injury zones as defined by the International Ocular Trauma Classification (2)

46 eyes (64%) of the patients of NARANG ET AL. showed a zone 1 injury, 20 (28%) a zone 2 injury and 6 (8%) a zone 3 injury.

In addition JANDECK ET AL. distinguish four grades of injuries, defined by EAGLING (57). Table 11 gives an overview.

Grade	Injured tissue
Grade 1	Cornea with or without uveal prolapse
Grade 2	Cornea plus lens damage
Grade 3	Posterior segment injury with vitreous loss
Grade 4	Extensive anterior and posterior injury

Table 11: Injury grades used by JANDECK ET AL. (28)

A grade 1 injury was found in 9 out of 38 cases (24%), a grade 2 injury in 11 (29%), a grade 3 injury in 7 (18%) and more extensive grade 4 injuries in 11 (29%) eyes.

5.5. Eye Wall Wound

ROSTOMIAN ET AL. report that 59% of their patients presented with a corneal, 33% with a corneoscleral and 9% with a scleral lesion.

Wounds were confined to the cornea in 66%, to the sclera and the cornea in 29% and to the sclera alone in 5% of the patients of SKIKER ET AL.

THOMPSON ET AL. report that the cornea was affected in 58% of the cases, in 29% it was the cornea and the sclera and in 13% the sclera alone.

The injury objects of the patients of BEBY ET AL. wounded the cornea in 72%, the cornea and the sclera in 21% and the sclera alone in 7 % of the cases.

PRADO ET AL. inform about 49 % corneal, 36 % corneoscleral, 11% scleral and 4% limbal wounds.

In 62% of the cases of BEHBEHANI ET AL. the injury object passed into the globe through the cornea.

JAISON ET AL. report that 55% of their patients showed a lesion in the cornea, 37% in the cornea and the sclera and 8% in the sclera.

The eye wall wounds of the patients of SOYLU ET AL were corneal in 47%, corneoscleral in 31%, scleral in 19%, and limbal in 3%.

To sum up, in all the studies of the literature, the cornea alone is primarily affected, 49% to 72% of the cases showed a lesion in the cornea, but not in the sclera.

Interestingly, in all the studies except for ours, the corneoscleral injuries are more frequent than the scleral injuries. But there is a slight difference in terminology: we did not define eye wall wounds, but entrance wounds. This difference becomes important, because in accordance with KUHN ET AL. we excluded the ruptures from this analysis. We considered it as not too meaningful to define an entrance wound in ruptures, since this injury type is produced primarily by inside-out mechanisms. If we would include them in the analysis, the corneoscleral injuries would make up for 13%, the scleral injuries for 11% and the corneal injuries for 76% of the cases. Still the corneoscleral injuries are rarer in our study than in others, probably as a consequence of the high percentage of sharp object injuries.

5.6. Injury Cause

5.6.1. Structure of the Injury Objects

Sharp objects can penetrate the eye easier than blunt objects. This fact is reflected by the higher percentage of sharp injuries (51% to 76% in the literature).

ROSTOMIAN ET AL. announce that 47 (67%) of the injuries they analyzed were caused by sharp object injuries, of which 19 (27%) left an intraocular foreign body in the globe. 18 (26%) injury objects were blunt.

HILL ET AL. report 76% sharp and 7% blunt injuries, 14% projectiles and 3% unclear causes of injuries.

FARR ET AL. enunciate that in their first group 49% of the injuries were sharp, 34% missile, 14% blunt and 3% unknown. In their second group 66% of the injuries were sharp, 25% missile, 7% blunt and 2% unknown. If the two groups are counted together, 53% of all injuries were sharp and 32% missiles.

Sharp objects accounted for 72 (51 %) wounds of the patients of PRADO ET AL., blunt objects for 28 (20%), exploding things for 11 (8%), projectiles for 4 (3 %) and thrown objects for 8 (6%). 13 (9%) of the injuries were not classified and 4 (3 %) unknown.

BEHBEHANI ET AL. inform about 53 (62%) sharp and 32 (38%) blunt injuries. But in contrast to others they do not define the category “explosion“ and count their 6 soft drink bottle explosions and 2 firework injuries to blunt injuries and one gunshot wound to the sharp injuries.

13 (65%) of the injuries GUPTA ET AL. examined were caused by sharp objects, 6 (30%) by blunt objects. The authors examined no missile injuries.

Compared to the literature the percentage of sharp object injuries is rather high in our study. This finding correlates with a high percentage of injuries which were caused by splinters during hammering. Work was a frequent setting for the injuries of our study, which probably reflects the age group of our patients. 9 of the studies which are reviewed in detail include only less than 14, 15 or 16 year olds, 3 studies include also patients who were 16 years old and only 1 study investigated the injury patterns of children aged 0-17, like we did.

5.6.2. Injury Objects

Reflecting the different activities, injury objects of children and adults are not the same.

ROSTOMIAN ET AL. report that in their study 27% of the sharp injury objects (n=47) were broken pieces of glass, 17% sharp toys, 10% metal rods or wires, 7% knives, 5% pencils and 34% others. The blunt object injuries (n=18) were induced by falls (55%), fists (17%), a door-knob (11%) and other items (17%).

SKIKER ET AL. identify metallic objects like scissors, knives and wires, prickles and thrown stones as the principal causes of the injuries (Table 12).

Injury objects	Number of patients	Percentage of patients
Metallic objects	23	37
Wood	14	23
Stone	11	18
Glass	7	11

Table 12: Injury objects in the study of SKIKER ET AL. (46)

In the study of HILL ET AL. 15% of the injuries were induced by glass fragments and glass bottles, further 15% by sharp school supplies like pens, pencils and scissors and 14% of the injuries were caused by knives. The remaining injury objects included nails, toys, sticks and other objects (Table 13).

Injury objects	Percentage of patients
Glass fragments	15
Sharp school supplies	15
Knives	14

Table 13: Injury objects in the study of HILL ET AL. (47)

The results of THOMPSON ET AL. are summarized in Table 14.

Injury objects	Number of patients
Sharp object poked in own eye	12
Object thrown at the patient	12
Hit with sharp object	9
Fall onto sharp object	7
Motor vehicle accident	4
Plant	3
Cat scratch	2
Sling shot	2
Bycicle accident	2
Projectile shattering glass, fragment in eye	2
Snapped plasctic hair band	2
Miscellaneous or unknown items	15
Total	72

Table 14: Injury causes of THOMPSON ET AL. (48)

Thrown objects included stones, metal objects, sticks, and glass. The patients fell onto sharp objects such as table corners and bedside furniture. The sharp tools with which children were hit included sticks poked into the eye, a knife and sharp pieces of plastic or metal.

Other examples of avoidable behaviors which THOMPSON ET AL. identified as injury causes included that a child observed his or her brother crushing a marble in a vice, that another one stood next to his or her father when he was bending wire with pliers and that a third one observed his or her brother breaking a stick.

Apart from that, one child sustained his or her injury because he or she leaned against a window which broke. Another kid was hit by the fragments of a light bulb which exploded. Further injury objects were pieces of a wall that fell on a baby bouncer, a glass bitten by a child, a plastic hair band, a mirror a child pulled down onto itself, a twig that reached the eye of a patient who was jumping over a fence, and a plastic star.

A lack of security measures could be assumed in the case in which a child had access to a bullet which it lit with a cigarette lighter.

Even carrying a bag containing a soft drink bottle can end disastrously when it is dropped and explodes.

BEBY ET AL. report 10 injuries which were caused by scissors or knives, in 8 cases the injury object was a branch of a tree, in 7 cases a pen or a pencil, in 6 cases a piece of glass, in 6 cases a wire, in 3 cases a pebble, in 3 further cases a dart, in 3 cases another toy, in 2 cases the claw of a cat, in 2 cases a fork, and singular injuries were produced by a corkscrew, a screw driver, a napkin holder and a doorknob. In three cases, of which two were bike accidents, the injury object could not be identified.

JANDECK ET AL. report that the most common injury objects were darts, nails and pieces of glass. Further objects are listed in Table 15.

Objects	Number	%
Dart, Nail	7	18,4
Glass	6	15,8
Knife	6	15,8
Stick, Blow	5	13,2
Pencil	2	5,3
Toy	3	7,9
Projectile	1	2,6
Miscellaneous	5	13,2
Unknown	3	7,9

Table 15: Injury causes of JANDECK ET AL. (28)

The objects that most frequently hurt the patients of PRADO ET AL. were pieces of wood, stones, wires and scissors (Table 16).

Injury objects	Frequency	Injury objects	Frequency
Sharp objects		Blunt objects	
Knife	6	Stone	12
Scissors	9	Glass	3
Wire	10	Ball	2
Nail	2	Pipe	1
Metal	1	Fall	5
Spinning top	2	Others	5
Glass	5	Projectiles	
Wood	13	Schuss	3
Lamp	1	Lead	1
Electric cable	1	Thrown objects	
Roofing tile	1	Glass	6
Others	21	Others	2
Exploding objects		Others	
Fireworks	4	Accident	5
Soft drink bottle	4	Self-injury	8
Others	3	Unknown	4
			140

Table 16: Injury causes of PRADO ET AL. (31)

The most common injury objects which hurt the 95 patients of BEHBEHANI ET AL. were pieces of glass (15 times), pencils (12 times), and sticks (9 times). Soft drink

bottle explosions and stones accounted for 6 injuries each, metal bars for 5, plastic toys for 4, falls, fists and palm trees for 3, animals, finger nails, fireworks, catapults and hangers for 2 injuries each. Singular injuries were produced by a knife, a gunshot, a hair clip, scissors, a plastic ruler, a plastic spoon, a razor, a belt and a chair. 10 injury causes were unknown.

GUPTA ET AL. report that 3 of the 20 patients (15%) they included into their study were injured by knives, 3 by pieces of glass and 3 by BB-guns. The remaining singular sharp injury objects were a dart, a slate, a pen, the sharp end of a pencil, a stick and a metal bar and the singular blunt injury objects were the blunt end of a pencil and a metal toy. Another injury was due to a collision with a road sign.

The objects that accounted for most of the injuries of the 72 eyes examined by NARANG ET AL. are bows and arrows, crackers, wood, stone and pencils. 34 injuries occurred during outdoor sports activities, 10 were household injuries (Table 17).

Cause of injury	Number
Bow and arrow	16
Other outdoor sports	18
Household injuries	10
Cracker injuries	7
Wood	4
Stone	1
Pencil	3
Hammer and chisel	3
Door handle	1
Fall from height	2
Calendar wire	1
Barbed wire	1
Unknown	5

Table 17: Injury causes as observed by NARANG ET AL. (52)

JAISON ET AL. ascribe 44 (53%) of their injuries to sports. 19 (32%) were domestic injuries and 13 (16%) due to fire crackers.

Most of the patients (33%) of SOYLU ET AL. were wounded by sharp objects. Knives, scissors and metallic sticks accounted for 33% of these objects, which were mostly used by children during unsupervised play. The third most frequent injury objects were stones which were thrown at the injured children during assaults. Other injury causes are listed in Table 18.

Injury cause	Percentage of patients
Sharp objects	33
Wood	15
Glass	12
Stone	12
Shotguns and airguns	12
Injection needles	8
Falls	3
Animals	3
Assault	2

Table 18: Injury causes as reported by SOYLU ET AL. (54).

The authors argue that the reason why injection needles were frequent injury objects is that they were used during vaccination campaigns in the rural areas of Southern Turkey. They were not put in special garbage bags, and so they unfortunately became play objects for vaccinated children.

FARR ET AL. do not describe injury objects in their publication; only 29 injuries with an intraocular foreign body are analyzed precisely. 13 (45%) of them were BB injuries, 9 (31%) metal non-BB foreign bodies, 4 (14%) foreign bodies were inorganic nonmetal material and 3 (10%) organic material.

To sum up, some objects are mentioned again and again (glass, wood, stones, bows and arrows, knives, scissors, wires, pencils and pens). Children should be instructed how to use these objects properly and their access to them should be limited. Hammer and chisel injuries can be prevented via protective goggles. Besides, an often mentioned injury cause is a fall. The renunciation of carpets could reduce the risks of a fall and furniture with round corners could reduce the impacts.

5.6.3. Gender and Injury Cause

HILL ET AL. analyzed the injury causes of girls and boys separately.

In the group of the boys various types of injury objects were found: 70% were sharp, 9% blunt, 17% projectiles and 4% unknown.

The 13 (22%) injury objects of the girls were exclusively sharp.

5.7. Visual Acuity

5.7.1. Final Visual Acuity

ROSTOMIAN ET AL. introduce 3 categories of visual outcome. The first category is defined as a final visual acuity of $> 20/40$ and comprises 18 patients (=33%). The second category includes patients with a visual outcome between $20/50$ and $5/200$. 19 patients (=35%) met this criteria. The third category describes the most unfavorable outcome of under $5/200$ and consists of further 18 patients (=33%).

13% of the patients of SKIKER ET AL. could not regain any light projection, 38% had a final visual acuity of 0.5 or better. More than half of the patients could present a visual outcome of at least 0.1.

HILL ET AL. report the following results of visual acuity: In 42% it was at least $20/40$, in 27% $<20/40$ to $>20/200$, in 21% $<[sic!] 20/200$ to $>[sic!] \text{light perception}$ and in 10% no light perception (Figure 10).

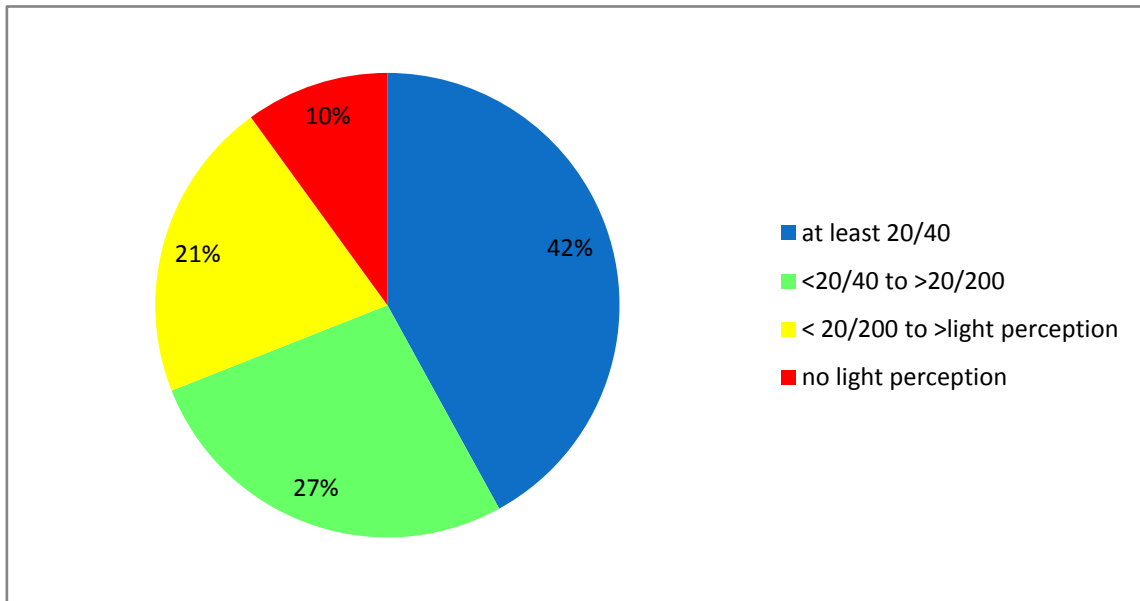


Figure 10: Final visual acuity in the study of HILL ET AL. (47)

The visual outcome of the patients of THOMPSON ET AL. can be observed in Table 19.

Final visual acuity	Proportion of patients
20/40 or better	36,1
20/60 to 20/200	29,2
less than 20/200 to LP	15,3
NLP	15,3
unknown	4,2

Table 19: Final visual acuities as observed by THOMPSON ET AL. (48)

In another study with adults and children (58), THOMPSON ET AL. describe better visual results. A final visual acuity of 20/40 or better was achieved in 61% of the cases.

BEBY ET AL. have 5 categories of final visual acuity: 20/40 or better, from 20/100 to >20/40 [sic!], from 20/400 to > 20/100 [sic!], less than 20/400 and no light perception.

The first category was obtained by 27 (53%) of the 51 patients who had a recorded final visual acuity. The second category was obtained by 10 patients (20%), the third and fourth category by 6 patients each (12%) and 2 patients (4%) could not regain any light perception.

In the study of FARR ET AL. less than half of the patients could obtain a final visual acuity of 20/40 or better. The other results are visualized in Table 20.

Visual outcome	Number of patients
at least 20/40	79 (=45%)
<20/40 to >20/800	39 (=22%)
<20/800 to NLP	30 (=17%)
Enucleation	27 (=15%)

Table 20: Final visual acuity as observed by FARR ET AL (49)

74% of the patients of JANDECK ET AL. achieved visual acuity of $\geq 20/200$ and 47% of even $\geq 20/40$.

Concerning Brazilian children examined by PRADO ET AL., 11 out of 78 (14%) obtained a final visual acuity of at least 20/40, 39 (50%) of 20/50 to 20/200 and 28 (36%) of 20/400 or less.

BEHBEHANI ET AL. announce that they could help 38 patients (40%) to obtain final visual acuity of 20/40 or better, 23 (24%) reached less than 20/40 but at least 20/200 and 12 (13%) 20/400 or less. 22 children (23%) had no record of final visual acuity.

NARANG ET AL. treated 70 patients of which they could record the final visual acuity. Of these, 15 (21%) obtained a visual outcome of 20/40 or better, 22 (31%) of 20/400 to less than 20/40.

Only 5% of 81 patients of JAISON ET AL. obtained a final visual acuity of at least 20/40. 19% saw between 20/60 and 20/125, 9% between 20/200 and counting fingers and the majority of the children, 68%, could not regain any light perception.

15% of the patients of SOYLU ET AL. had a better final visual acuity than 20/40, 12% of 20/200 to 20/40, 7% of 20/320 to 20/1000, 5% of 20/2000, 10% of light perception or projection and 23% of no light perception.

Studies of adult open globe injuries tend to show better final visual acuities.

To sum up, the groups of final visual acuity are defined heterogeneously in the literature. However, most of the authors define their best group as a visual

outcome of at least 20/40. For a better comparison Table 21 shows the percentage of patients in the first group of visual outcome in the literature.

Study	Percentage of patients
Skiker et al.	38
Hill et al.	42
Thompson et al.	36
Beby et al.	53
Farr et al.	45
Jandeck	47
Prado et al.	14
Behbehani et al.	40
Narang et al.	21
Jaison et al.	5

Table 21: Percentage of patients with a final visual acuity of 20/40 or better in the literature

None of the mentioned studies reports as many patients with a visual outcome of 20/40 or better as our study (63%). This could be linked to the high percentage of corneal and low percentage of corneoscleral injuries and to the good medical care in form of a national insurance in Austria.

The worst outcome of a study by far is that of JAISON ET AL. which was conducted in India. The authors argue that their patients were often treated with a delay, since the availability of specialized treatment is restricted in India. Furthermore lots of their patients were wounded by unsterile pointed wooden objects which carry the risk of ocular infections (see below). Besides, it has to be mentioned that the study was carried out with patients who presented between 1981 and 1990, and it is interesting to see that the second study of India (NARANG ET AL.), which was conducted between 1998 and 2000, already shows better results. Still it is obvious that the studies from India and Brazil, the poorest of the countries from which studies were available, show a worse outcome. 14%, 21% and 5% of the patients had a final visual acuity of at least 20/40, as compared to between 36% and 63% in the other studies.

5.7.2. Factors Determining the Prognosis

This chapter aims at determining factors which are associated with a poor outcome aside from the country of residence.

Ocular Trauma Score

Using 2,500 cases from the USEIR, FERENC KUHN ET AL. created the Ocular Trauma Score as a method to predict the severity of a serious eye injury (59). It is based on the initial visual acuity and five anatomical characteristics and defines a bad initial visual acuity, a rupture or a perforating injury, endophthalmitis, retinal detachment and an afferent pupillary defect as risk factors for a bad visual outcome (10). UNVER ET AL. tested its reliability for open globe injuries and recommend its usage (60), but investigations of its predictive value in trauma in children have a controversial outcome (61), (62).

In our study we could not compute the OTS since no sufficient data about the presence of an afferent pupillary defect could be obtained from the records of the patients.

THOMPSON ET AL. analyzed the influence of several initial findings in the following figure (Figure 11):

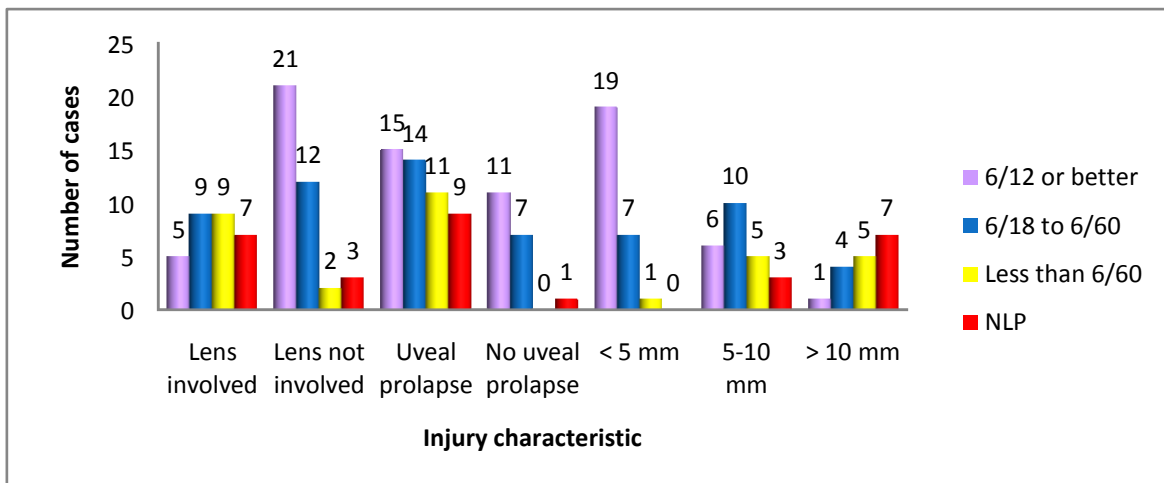


Figure 11: Prognostic factors in the study of THOMPSON ET AL. (48)

They presume a trend towards a better outcome where the lens was not involved, there was no uveal prolapse and the wound size was smaller, although they could not provide statistical significance.

5.7.2.1. Injury Type

JANDECK ET AL. report, that 48% of their patients with penetrating injuries had a final visual acuity of at least 0.5, compared to 67% of the children with perforating injuries, further 67% with an intraocular foreign body injury and 60% with a rupture. But the authors mention that the numbers of their patients was too small for a meaningful interpretation of the visual outcomes. Nevertheless it is interesting, that all of the 5 patients who sustained a rupture had a final visual acuity of at least 0.1 and 3 of them (60%) even achieved an outcome of at least 0.9.

In our study we could, in accordance with the OTS, identify perforating injuries and ruptures as risk factors for a bad visual outcome.

5.7.2.2. Grade of Injury

The 4 grades that JANDECK ET AL. defined and that are mentioned above did not show statistically significant differences in terms of visual outcome.

5.7.2.3. Zone of Injury, Entrance Wound

The analysis of ROSTOMIAN ET AL. did not show a significant difference in the prognosis of corneal, scleral and corneoscleral injuries.

In one of the two groups of FARR ET AL., injuries with scleral wounds had a significantly worse outcome than injuries with corneal wounds ($p = .01$). In the second group (the more recent part of the analysis with injuries that happened between 1985 and 1993), though, the location of the eye wall wound was not statistically associated with final visual outcome.

In the study of BEHBEHANI ET AL. the eye wall wound was also no statistically significant prognostic factor for the outcome.

STERNBERG ET AL. conducted a multivariate analysis of prognostic factors in open globe injuries in children and adults and report that a laceration limited to the cornea was a predictor of good visual outcome (63).

Like our study, the literature shows a trend towards a better outcome of corneal eye wall wounds, but this finding mostly does not reach statistical significance.

5.7.2.4. Character of the Injury Object

Patients with sharp object injuries had a better final visual acuity than patients with blunt object injuries in the Wilcoxon Rank Sum Test of Interdependence of ROSTOMIAN ET AL.(p = .04). The same authors did not notice a significant difference in final visual acuity of patients with corneal, sclera and corneoscleral lacerations.

Table 22 shows that 76% of the patients of ROSTOMIAN ET AL. who had sustained a sharp object injury reached a final visual acuity of 5/200 or better, whereas only 40% of the patients with blunt object injuries could achieve such an outcome. The proportion of patients with blunt injuries who did not succeed in obtaining a final visual acuity of 5/200 or better is more than two times as high as the corresponding proportion of patients with sharp injuries.

Final Visual Acuity	Sharp object injury	Blunt object injury	Unknown
> 20/40	13 (35%)	3 (20%)	2 (67%)
20/50 - 5/200	15 (41%)	3 (20%)	1 (33%)
< 5/200	9 (24%)	9 (60%)	0 (0%)

Table 22: Visual outcome versus type of injury object as reported by ROSTOMIAN ET AL. (45)

For the analysis of sharp and blunt injuries, FARR ET AL. combined their two groups and report results which are very similar to those of ROSTOMIAN ET AL.: 79% of the children who sustained sharp injuries had a final visual acuity of at least 5/200, in contrast to 41% of patients with blunt injuries achieving such a visual outcome.

Like in our study patients with blunt object injuries had a worse visual outcome than patients with sharp object injuries in the literature.

5.7.2.5. Age

In the study of ROSTOMIAN ET AL., young age correlates with bad visual outcome ($p = .03$). In the group of patients who were older than 5 years, 11 children (61%) reached a final visual acuity of better than 20/40, whereas only 7 (39%) of the children younger than 5 years had such a visual outcome. These results are especially meaningful since the authors underline that there was no significant difference in type of injuries or number of surgical procedures needed between the two age groups. The authors argue that they identified the amblyogenic age range as a risk factor for unfavorable outcome.

In the study of HILL ET AL., the injuries of the 9 to 17 year olds do not ameliorate as much as the injuries of the younger children. According to the authors, the reason for that could be that the wounds of the older kids were more severe, because adolescents and teenagers were more likely to participate in games that exposed themselves to blunt and projectile injuries. 75% of this kind of injuries, which are also seen as especially unfavorable by FARR ET AL. for instance, occurred in the age group of the 9 to 17 year olds.

FARR ET AL. report that age was a significant prognostic factor for final visual acuity. The visual outcome of their younger patients was worse than that of the older patients of their study. The proportion of children obtaining a final visual acuity worse than 5/200 was 63% in the age group of children aged 0-3 years, 20% in the patients aged 4-8 years and 35% in the patients aged 9-14 years. According to ROSTOMIAN ET AL., the authors assume that the reason is the amblyogenic age range.

JANDECK ET AL. mention that the visual outcome appeared worse for children less than 9 years of age in their analysis. 8 out of 21 patients (38%) aged 0-8 years and 11 out of 17 older patients (65%) achieved final visual acuity of at least 0.5. The authors also suppose amblyopia to be the cause and observed the effect despite attempts to prevent it with patching.

BEHBEHANI ET AL. report that the age was no significant prognostic factor for the outcome in their study.

Age was not a consistent prognostic parameter in the literature, but there was a trend towards a worse outcome in younger children.

5.7.2.6. Gender

According to KOO ET AL. (64) the outcome of ocular injuries sustained by men and women may differ. Various studies indicate that the immune response to trauma may be better in women than in men, but in prepubescent and peripubertal age groups no such effects were seen (65), (66), (67).

No difference of the visual outcome of boys and girls was seen in our study.

5.7.2.7. Delayed Start of the Treatment

55% of the patients of NARANG ET AL. that presented within 24 hours after the trauma obtained a final visual acuity of 3/60 or more, a result that only 35% of the patients that presented after 72 hours could achieve ($p < .05$).

In the analysis of BEHBEHANI ET AL. a correlation between the visual outcome and the delay was not significant ($p = 0.7$).

In our study the delay did not have an impact on the final visual acuity. The children who presented later even had a slightly better visual outcome than the children who presented earlier.

These facts are probably linked to the different systems of medical care. In the rural areas of India it is not understood by itself that an injured child is granted medical supply, as it fortunately still is in Austria. So in India probably even children with severe injuries present with a delay, whereas in Austria the children who do not seek medical care immediately probably do not require prompt medical treatment. Interestingly studies with both adults and children show that even in ruptured globes there is no difference in visual outcome of patients who are treated immediately and patients who are treated later, but within 24 hours. The advantage of an immediate repair seems to be little, especially if the surgeon or the patient is not prepared (68).

5.7.2.8. Initial Visual Acuity

The better the initial acuity was in the patients of ROSTOMIAN ET AL., the better was the final visual acuity ($p = .00005$). With the categories mentioned above ($>20/40$, $20/50 - 5/200$, $<5/200$), no patient had to endure a deterioration of visual acuity which made him or her belong to another category. 22 of the 49 patients with an initial visual acuity of less than $20/40$ could not reach a higher category with their final visual acuity than with their initial visual acuity.

In the analysis of HILL ET AL. the initial visual acuity is a significant prognostic factor for the final visual acuity in the children younger than 8 years ($p < 0,05$), but not in the group of the children between 9 and 17 years ($p > 0,05$).

For the analysis of the impact of the initial visual acuity on the final visual acuity, FARR ET AL. combined their 2 groups and observed that the two parameters were associated. None of the patients that had initial visual acuity of one of the two best categories had final visual acuity of the worst category and none was enucleated. No patient who did not have any light perception before the beginning of the treatment could achieve a visual acuity of more than $5/200$ (Table 23).

Initial Visual Acuity	Final visual acuity (number)			
	$\geq 20/40$	$<20/40$ to $>5/200$	$<5/200$ to NLP	Enucleation
$\geq 20/40$	91% (20)	9% (2)	0% (0)	0% (0)
$<20/40$ to $>5/200$	82% (37)	18% (8)	0% (0)	0% (0)
$<5/200$	25% (20)	27% (22)	28% (23)	20% (16)
NLP	0% (0)	0% (0)	17% (2)	83% (10)

Table 23: The impact of initial visual acuity on final visual acuity observed by FARR ET AL. (49)

In the analysis of JANDECK ET AL., 12 out of 22 patients (54%) who presented with an initial visual acuity of less than 0.1 reached final visual acuity of at least 0.5. The two patients who had an initial visual acuity of at least 0.5 and 0.1-0.4 stayed in their categories.

BEHBEHANI ET AL. also claim that the better the initial visual acuity of their patients was, the better was the final visual acuity ($p = 0.01$). Of the 5 patients who saw at least $20/40$, all stayed in this category. Of the patients who saw between

less than 20/40 and 20/200, one (=12%) stayed in this category and the other 7 (=88%) achieved a better visual outcome. Of the 35 patients who were in the last category at the beginning and had recorded final visual acuity, 7 (=20%) had no better final visual acuity, 16 (=46%) had a visual outcome of 20/200 to less than 20/40 and 12 (34%) of 20/40 or more.

According to our study and the OTS, other studies also indicate that the initial visual acuity is a prognostic factor for the final visual acuity.

5.7.2.9. Other Possible Risk Factors

ROSTOMIAN ET AL. conducted an investigation of the connection of several factors with the final visual acuity (Table 24).

	Visual outcome			Statistical significance (Fisher exact test)
	≥20/40	20/50-5/200	<5/200	
Corneal laceration	10 (32%)	12 (39%)	9 (29%)	p = .74
Corneoscleral laceration	7 (39%)	4 (22%)	7 (39%)	p = .00
Scleral laceration	1 (17%)	3 (50%)	2 (33%)	p = .60
Flat anterior chamber	13 (52%)	7 (28%)	5 (20%)	p = .008
Hyphema	0	12 (50%)	12 (50%)	p = .0001
Vitreous hemorrhage	2 (13%)	4 (25%)	10 (63%)	p = .004
Chemosis	8 (50%)	4 (25%)	4 (25%)	p = .15
Retinal detachment	0	1 (20%)	4 (80%)	p = .02
Afferent pupillary defect	0	1 (20%)	3 (75%)	p = .06

Table 24: Visual outcome versus initial physical findings in 55 patients of ROSTOMIAN ET AL. (45)

Initial findings that were significantly associated with an unfavorable outcome were a flat anterior chamber, hyphema, vitreous hemorrhage, retinal detachment and an afferent pupillary defect.

In the first group of FARR ET AL. (injuries which occurred between 1970 and 1993), lens damage was a significant indicator of poor visual outcome ($p < .01$), but it did not correlate with a bad final visual acuity in the second, more recent series (1985 -1993). Similarly, the presence of an intraocular foreign body was

associated with an unfavorable outcome in the first group ($p = .005$), but not in the second group. This could reflect the changes in the treatment of open globe injuries. For other kinds of analysis, FARR ET AL. combined their two groups and report that if the foreign body injuries are compared, BBs accounted for the most severe injuries. 92% of the 13 patients with BB injuries obtained a final visual acuity of $<5/200$ and 69% of the same 13 patients had to undergo an enucleation.

Besides, visual outcome of the patients of FARR ET AL. was strongly associated with the size of the entrance wound. Table 25 shows the wound size and the visual outcome.

Wound size	Final visual acuity
> 10 mm	52% $< 5/200$
≤ 10 mm	27% $< 5/200$
< 2 mm	80% $\geq 20/40$

Table 25: Wound size and visual outcome as observed by FARR ET AL. (49)

The last factor associated with an unfavorable outcome which was analyzed in the study of FARR ET AL. was the presence of retinal detachment. 75% of patients who showed this complication obtained final visual acuity $\leq 5/200$.

BEHBEHANI ET AL. inform that with their patients, iris prolapse, lens damage and vitreous loss were not statistically significantly associated with the prognosis of the injuries. The same is true for the duration of the interval between the injury and the presentation or surgery, the time of surgery (regular hours or not) and the duration of surgery.

NARANG ET AL. report that endophthalmitis was a risk factor for poor outcome in their analysis. A final visual acuity of $3/60$ or more was reached with 17 of 37 (46%) of the eyes with endophthalmitis, and with 20 of 33 (61%) eyes without endophthalmitis. Further causes for poor visual outcome were glaucoma and post-treatment retinal detachment.

Like in the OTS, retinal detachment, endophthalmitis and an afferent pupillary defect was linked with a poor final visual outcome in the literature. Besides, BB

gun injuries, wound size, a flat anterior chamber, hyphema, vitreous hemorrhage, and an afferent pupillary defect were bad prognostic factors.

5.8. Operations

The strategies in the management of open globe injuries are the same for children and adults (48). Nevertheless, due to earlier mentioned reasons the treatment of children is more challenging.

5.8.1. Operations per Patient

ROSTOMIAN ET AL. summarize the operations they conducted on their patients in Table 26:

Procedures	Patients
Single procedures (48 patients)	
Primary repair only	32 (46%)
Primary repair, cataract extraction and anterior vitrectomy	15 (21%)
Primary enucleation	1 (1,5%)
Secondary procedures (22 patients)	
Pars plana vitrectomy and lensectomy	8 (11%)
Lensectomy and anterior vitrectomy	6 (9%)
Secondary enucleation	4 (6%)
Scleral buckle	3 (4%)
Penetrating keratoplasty	1 (1,5%)

Table 26: Types of procedures performed on the patients of ROSTOMIAN ET AL. (45)

The patients who underwent primary repair alone or primary repair with cataract extraction and anterior vitrectomy had a better visual outcome than the patients who required secondary pars plana vitrectomy and lensectomy. 11 out of 12 patients (92%) who underwent primary repair with cataract extraction and anterior vitrectomy had a final visual acuity of 5/200 or better. In contrast to that, none of the 8 patients with secondary pars plana vitrectomy and lensectomy could obtain such an outcome. The authors conclude that this reflects the severity of the injuries treated with the second operation method.

The exact visual outcome of each surgical procedure can be observed in Table 27.

	Visual outcome		
	≥20/40	20/50-5/200	<5/200
Primary repair	12 (45%)	9 (33%)	6 (22%)
Primary repair with cataract extraction and anterior vitrectomy	3 (25%)	8 (67%)	1 (8%)
PPV, pars plana lensectomy	0	0	8 (100%)
Secondary cataract extraction and anterior vitrectomy	2 (50%)	0	2 (50%)
Penetrating keratoplasty	1 (100%)	0	0
Scleral buckle	0	2 (67%)	1 (33%)

Table 27: Visual outcome versus type of surgical repair as observed by ROSTOMIAN ET AL. (48)

SKIKER ET AL. report that all of their patients were operated with at least a suture of the injury in general anesthesia.

HILL ET AL. also announce that all of their patients underwent primary wound closure and 30 patients (51%) required a secondary surgical intervention.

All of the 72 patients of THOMPSON ET AL. were operated at least one time, although 2 wounds (2.8%) were self sealing and required no initial surgery, but only a delayed cataract extraction. The authors gave no exact numbers but mentioned that the majority of their eye examinations and suture removals were performed under general anesthesia. The operative techniques and frequency of secondary operations can be seen in Table 28.

Re-Operation	Number of cases
Cataract removal	8
Enucleation	3
Pupillary membrane division	1
Vitrectomy, foreign body removal	1
Esotropia surgery	1
Retinal detachment repair and lensectomy	4
Retinal detachment repair alone	1
Resuturing of laceration	1
Injection of intravitreal antibiotics/antifungals and lens extraction	1
Removal of sutures	34
Examination under anaesthesia only	27

Table 28: Re-operations of HILL ET AL. (47)

21 out of 57 patients (37%) of BEBY ET AL. had to be operated more than one time.

JANDECK ET AL. conducted 1.8 operations per patient. All patients underwent a primary surgery.

SOYLU ET AL. performed surgery on 234 patients (97%). 8 children (3%) presented with a spontaneous wound closure and endophthalmitis and received only medical treatment.

Like in our study, most of the patients of other studies underwent a primary wound closure. SKIKER ET AL. HILL ET AL. and JANDECK ET AL. did not report any self-sealing wounds, THOMPSON ET AL. and SOYLU ET AL. reported 3% each and we found 1%.

5.8.2. Lensectomy

15 out of 62 patients of SKIKER ET AL. (= 24%) were operated because of a traumatic cataract. 9 of them (= 60%) were operated without the implantation of an artificial lens because of a large rupture of the capsule.

Of the 30 patients of HILL ET AL. that underwent a secondary surgical intervention, 14 patients (47%) required a lensectomy.

The lens was removed in 20 cases (28%) of THOMPSON ET AL. The removal was primary in 8 (11%) and secondary in 12 (17%) cases.

15 out of 57 patients (26%) of BEBY ET AL. were operated because of a traumatic cataract, with a mean delay of 3 weeks after the accident. 8 of these patients could not get an intraocular lens because the lesion of the lens capsule was too big.

In 8 patients of JANDECK ET AL. (21%) a lensectomy was carried out.

33 patients of NARANG ET AL. (46%) had a lensectomy. 19 (26%) underwent an IOL implantation.

JANDECK ET AL. additionally mention that the prognosis of young children with additional lens involvement is worse than the one of older children, because of problems of correcting aphakia and of compliance.

To sum up, the rate of lensectomies in the literature about open globe injuries in children lies between 21% and 47%, suiting to our study in which 36% of the patients underwent at least one lensectomy.

5.8.3. Vitrectomy

Anterior Vitrectomy

14 patients (47%) of the study of HILL ET AL. underwent an anterior vitrectomy. All the other authors did not mention anterior vitrectomies. They probably subsumed them under the primary wound care.

Posterior vitrectomy

SKIKER ET AL. report 1 case of posterior vitrectomy which was conducted because of vitreous hemorrhage. This case represents 1.6% of the patients.

12 (40%) patients of HILL ET AL. underwent a PPV (pars plana vitrectomy). They all presented with an initial visual acuity of count fingers or worse. Seven (58%) had an improvement of the visual acuity to 20/200 or better, and 6 (50%) achieved a visual acuity of 20/50 or better.

In 38 patients JANDECK ET AL. conducted 22 posterior vitrectomies. 4 of them (18%) were conducted at the time of primary surgery, which means that 10.5% of all patients underwent a primary posterior vitrectomy. 17 patients (44.7%) underwent at least one posterior vitrectomy.

In the same study, eyes with grade 2-4 injuries (cornea plus lens damage; posterior segment injury with vitreous loss; extensive anterior and posterior injury) that underwent vitrectomy showed a better visual outcome than those without.

NARANG ET AL. report that they conducted 23 primary PPVs with lensectomies (they did not mention if other primary PVs without lensectomies were performed) and further 23 secondary PVs.

Furthermore, it has to be mentioned, that 2 foreign bodies were not detected by NARANG ET AL. before PVs. These PVs were conducted because of endophthalmitis – an often mentioned risk factor for bad visual outcome. In the debate about when a vitrectomy should be conducted this has to be remembered.

The visual outcome of children who undergo a PV is discussed controversially.

For example, MOISSEIEV ET AL. (69) investigated 28 children who underwent PVs for various reasons (11 open globe injuries, 8 high myopias and others). They describe satisfactory anatomic and functional results only in a minority of their patients. 19 patients (68%) had a visual outcome of hand motions or less. SCOTT ET AL. announce that retinal reattachment and good visual outcome were achieved in the majority of eyes using PV and silicone oil. Ambulatory vision was achieved in 19 (25%) eyes in the trauma group (70).

JANDECK ET AL. show a comparatively good visual outcome of children who underwent PV, 75% have a final visual acuity of at least 0.1 and 58% even of 0.5 or more. They argue that this could be led back to the timing of their PV and that especially early PV (within 2 weeks after the injury) can reduce the incidence of severe complications like amblyopia and retinal detachment. They recommend the usage of early PV as a standard method in the surgery of complex open globe injuries.

To sum up, posterior vitrectomies are nowadays frequently conducted operations in open globe injuries in children, which reduce the amount of enucleations and eviscerations (37). Their success could be linked to their timing.

5.8.4. Enucleation / Evisceration

The percentage of enucleations and eviscerations varied in the literature (Table 29). All the studies in which no patient underwent an enucleation or evisceration started later than 1989. This could underline the trend that enucleations and eviscerations which are due to ocular trauma decrease (44) and could show the effects of vitrectomies, which have become more and more popular since around 1980 (71).

Study	Peroid of conduction	Percentage of enucleations or eviscerations
Rostomian et al.	1980-1993	7%
Skiker et al.	2001-2005	0%
Hill et al.	1990-2002	7%
Thompson et al.	1983-1999	8%
Beby et al.	1999-2003	0%
Jandeck et al.	1990-1998	0%
Prado et al.	1989-1993	4%
Gupta	1998-2003	15%

Table 29: Percentage of enucleations and eviscerations in the literature

ROSTOMIAN ET AL. carried out only enucleations, and no eviscerations. 1 (1.5%) enucleation was primary and 4 (6 %) secondary.

SKIKER ET AL. did not enucleate or eviscerate an eye, in spite of 4 cases of phthisis.

3 (4%) patients of THOMPSON ET AL. were enucleated or eviscerated primarily and further 3 secondarily.

5.8.5. Scleral Buckle

The amount of scleral buckling in the literature varies greatly. During secondary procedures, ROSTOMIAN ET AL. conducted 3 (4% of the patients) secondary

procedures. NARANG ET AL. announce that they performed no prophylactic scleral buckling, but 13 such operations (in 25% of the patients) in secondary operations. The amount of scleral buckles in our study lies in the middle.

5.8.6. Penetrating Keratoplasty

In every study which mentions penetrating keratoplasty, there were 1 or 2 patients on whom this operation was conducted. (SKIKER ET AL. 1(1.6%), BEBY ET AL. 2 (3.5%), ROSTOMIAN ET AL. 1 (1.5%), NARANG ET AL.1 (1.4%))

5.8.7. Operation of the Retina

SKIKER ET AL. announce that 7 (11%) of their patients had retinal complications, but only 2 were operated. These operations were not specified.

BEBY ET AL. performed 1 operation (1.8%) because of retinal detachment (not specified which one). There were 3 cases of retinal detachment, but in two cases no operation was performed because of an absence of light perception.

5.8.8. Duration of Surgery

The only study in which the duration of surgery was described was the one of BEHBEHANI ET AL. In this analysis 41 patients (76%) were operated for an hour or less, and 13 (24%) longer.

5.8.9. Injury-to-presentation Interval

In the analysis of BEHBEHANI ET AL. the injury-to-presentation interval was under 1 day for 29 (85%) and at least 1 day for 5 (15%) patients. An association with the final visual acuity could not be perceived (see above).

5 (8% of all) children whose wounds were analyzed by SKIKER ET AL. were not brought to the hospital until a week after the injury. This probably reflects the poverty of the Moroccan rural population which makes the parents wait and see at first, instead of immediately transporting them to the next hospital after an injury.

5.9. Injured Eye

Table 30 shows how often the right and how often the left eye was the site of injury in the literature.

Study	Right eye	Left eye	Number of eyes
Rostomian et al.	60%	40%	70
Skiker et al.	47%	53%	62
Thompson et al.	54%	46%	72
Beby et al.	47%	53%	57
Farr et al.	55%	45%	218
Behbehani et al.	55%	45%	95

Table 30: Overview over injured eyes in the literature

Five studies (including the study for this diploma thesis with 57% of the injuries) show a predominance of the right eye and 2 of the left eye. THOMPSON ET AL. surprisingly declare that in patients whose injuries were self-inflicted, even 10 (83%) involved the right eye and only 2 (17%) the left eye. They conclude that a slight predominance of the right eye could be expected in communities where right handed individuals predominate.

5.10. Injury Location

5.10.1. At School, at Home, on the Street

Study	School	Home
Rostomian et al.	21%	72%
Skiker et al.	2%	14%
Thompson et al.	1%	58%
Beby et al.	5%	56%
Behbehani et al.	8%	46%
Soylu et al.	1.2%	25.4%

Table 31: Comparison of injuries which happened at school and at home

Table 31 shows that all studies indicate school being a clearly less frequent injury location than the home of the children. It has to be considered, that children

usually spend more time at home, but still the difference in the frequency of both locations is so large, that it cannot be explained by this fact only. In the records of our patients the injury location unfortunately was so rarely described, that we could not conduct a meaningful analysis.

THOMPSON ET AL. mention that in the district of Australia, in which this study was carried out, children between ages 5 and 16 spend approximately 10-15% of their waking hours in school. 55% of the children of this study were school children, but school was the injury location in only 1%. The authors conclude that school is a rather safe place. This thesis can also be explained by the easier access to injury objects, the probably sometimes less attentive supervision and the greater freedom of movements children experience at home.

But it remains to point out that trying to prevent injuries by limiting the freedom of movements is the wrong way, considering the need of the child to develop its motor and coordinative skills (6).

THOMPSON ET AL. also name the other injury locations of their patients. Besides the children who hurt themselves at home or in school, 7% were wounded on the road, 4% in a shop, 3% on a footpath and further 3% in a park. 1 accident (1%) happened in a caravan park.

SKIKER ET AL. also provide detailed statements about other injury locations. Interestingly, 81% of their patients sustained their injuries on the street, which probably reflects the cultural habits and the climate in the African state Morocco.

The authors also found 2 injuries which occurred during legally forbidden child labor. A 13 year old boy worked as a smith and was injured by a piece of metal he produced during hammering and a 14 year old boy worked in a gas station at night and was victim of an attack with a knife.

SOYLU ET AL. also frequently treated patients who were wounded on the street. 140 patients (58%) sustained their injury there. Additionally, 22 patients (9%) were wounded on fields in rural areas. The number of children who hurt themselves during sports was 4 (2%). A traffic accident was the injury cause in 12 children (5%).

5.10.2. Rural or Urban Area

81% of the patients of SKIKER ET AL. sustained their injury in urban regions, although the catchment area of their hospital also spreads over a large rural area. The authors deduce the importance of the socioeconomic situation on the prognosis of an injury. Since the Moroccan rural population is very poor, lots of people cannot afford to transport their children to a hospital.

Furthermore, the risk of a bad visual outcome and the duration of hospitalization are higher in injuries which happened in rural settings where agriculture is a main occupation of the population. The underlying cause is a higher rate of infections (54), (72).

5.11. Season

39% of the injuries which were the basis for the analysis of ROSTOMIAN ET AL. (USA) took place in summer, 26% in spring, 23% in winter and 12% in fall months. THOMPSON ET AL. (Australia) report no seasonal trend, and BEHBEHANI ET AL. (Kuwait) treated the fewest patients in June (4%) and most in October (16%). BEBY ET AL. (France) admitted 53% of their patients to hospital from September to January.

5.12. Time

THOMPSON ET AL. report an accumulation of injuries between 4 and 8 pm and on weekends. The data do not reach statistical significance, but because of the earlier mentioned higher injury risk at home, they are comprehensible.

5.13. Child Abuse

Child abuse was not recorded in the study for this diploma thesis and it seems to be very rare in the literature about open globe injuries in children.

ROSTOMIAN ET AL. became aware of one case of child abuse (1.4%) in their study.

SKIKER ET AL. did not detect a case of child abuse, but they acknowledge that this pathology is largely underestimated in Morocco, their country of residence.

The fact that only two studies even mention whether there was a case of child abuse or not shows that Morocco is not the only country where the issue child abuse is badly raised and therefore probably underestimated.

A child who was abused has to suffer his or her whole life. It frequently develops depression, anxiety disorders and other pathologies (73). Furthermore, an Australian study (74) about 183 sexually abused children shows that the suicide rate in this population is more than 10 times as high as the general national rate. 32% of the abused children attempted suicide and 43% thought about suicide.

If the child is not enlightened about the nature of his or her problem, he or she can have the opinion that he or she has to bear the blame for what happens (75).

It remains a momentous duty for the medical society to raise this topic both thoroughly and sensitively.

5.14. Initial Findings

During the first examinations of injured children, frequent initial findings were an iris or uvea prolapse, a vitreous hemorrhage, a hyphema, a flat anterior chamber and lens abnormalities. The exact frequencies of initial findings in the literature are summarized in Table 32, 33 and 34.

Study	Iris prolapse	Uvea prolapse	Hyphema	Vitreous hemorrhage
Rostomian et al.	59%	40%	44%	37%
Skiker et al.	48%		32%	
Beby et al.	37%		26%	
Prado et al.		68%		
Gupta et al.	75%		50%	20%
Narang et al.	40%		40%	28%

Table 32: Initial findings in the literature 1 (empty cell = no information available)

Study	Retinal detachment	Afferent pupillary defect	Vitreous prolapse	Lens abnormalities
Rostomian et al.	10%	9%		
Skiker et al.				24%
Beby et al.				21%
Prado et al.			11%	28%
Gupta et al.	10%	25%		45%
Narang et al.	6%		18%	54%

Table 33: Initial findings in the literature 2 (empty cell = no information available)

Study	Flat anterior chamber	Chemosis
Rostomian et al.	43%	29%
Beby et al.	19%	

Table 34: Initial findings in the literature 3 (empty cell = no information available)

Sometimes patients also developed endophthalmitis before any treatment was done. SOYLU ET AL. reported this initial finding in 8 patients (3%).

5.15. Late Complications

Table 35 and Table 36 overview late complications in the literature.

Late Complications	Traumatic Cataract	Retinal detachment	Endophthalmitis	Sympathetic ophthalmia
Beby et al.	26%	5%		
Skiker et al.	24%			
Thompson et al.		7%	1%	None
Prado et al.	34%	13%		
Behbehani et al.	31%	6%	1%	1%
Gupta et al.			10%	
Narang et al.		8%	39%	None
Soylu et al.			22%	

Table 35: Late complications in the literature 1 (empty cell = no information available)

Late Complications	Phthisis	Panophthalmitis	Secondary strabismus
Skiker et al.	6%		
Thompson et al.			
Prado et al.	23%	6%	
Behbehani et al.	3%		5%
Narang et al.	15%		

Table 36: Late complications in the literature 2 (empty cell = no information available)

Frequent late complications included a traumatic cataract, retinal detachment, endophthalmitis, phthisis bulbi, panophthalmia and secondary strabismus. The exact frequencies are shown in Table 29 and 30.

The one case of sympathetic ophthalmia which is described in the literature occurred in a 3-year-old boy who showed a blunt injury with an iron bar. His corneoscleral wound with iris and vitreous prolapse and lens damage was repaired on the first day and eviscerated 8 days later.

GIRKIN ET AL. observed that the frequency of posttraumatic glaucoma after penetrating eye injuries rises with the age (76). In the study of NARANG ET AL. 2

patients (3%) developed a secondary glaucoma. BEBY ET AL. report 2 cases (4%) of ocular hypertension, but no glaucoma. Other complications which were analyzed only by few authors were choroidal hemorrhages or ruptures (4 patients (20%) in the study of GUPTA ET AL.), a suture abscess (1 patient (1%) in the study of THOMPSON ET AL.), and an epiretinal membrane (1 patient (1%) in the study of NARANG ET AL.).

In the study of NARNG ET AL. endophthalmitis was especially associated with bow and arrow and household kitchen injuries and statistically significantly linked to delayed repair. 18 out of 22 patients (82%) who presented more than 72 hours after the trauma versus 17 of 33 (52%) patients who presented within the first 24 hours developed endophthalmitis.

SOYLU ET AL. also report a lot of cases of endophthalmitis and regret, that 45 (83%) of these cases developed a phthisis bulbi. 2 (4%) of the phthisical eyes with endophthalmitis had to be enucleated and 9 (20%) eviscerated.

5.16. Socioeconomics

In Austria, the socioeconomic impact of injuries of children is larger than the one of injuries in adults, as they receive incomparably long lasting compensation for the eventually resulting loss of earnings and much financial support from the society.

Besides, the socioeconomic situation of a state has clear impacts on the causes and therapy options of injuries (46), (53).

Open globe injuries are associated with a longer duration of hospitalization and more operations than less severe ocular injuries, and so they are more expensive for the society.

According to THOMPSON ET AL. the Australian community pays 155 million dollar a year for ocular injuries and 44% of these costs are due to open globe injuries.

5.17. Prevention

Regarding the injury causes and circumstances it becomes clear that the majority of open globe injuries can be prevented. Supervision plays a crucial role in the prevention of eye injuries. And for the time in which supervision is not fully possible, instruction of children is very important. Besides, parents could be instructed how to arrange the domestic surroundings in a childproof manner. The frequent hammer and chisel injuries can be prevented with special protective goggles. Instead of buying scissors with sharp ends, those with blunt ends should be bought for children. Furniture with round corners is the better option for households with kids. Plants with prickles are not suitable for gardens in which children play. Games with projectiles (darts, bow and arrow) are frequent injury causes and if parents take the time to teach their children a variety of other games, it is less probable that they get up to the dangerous games, even when they are unsupervised. The interaction with animals requires special instruction. During the work for this diploma thesis contacts of the Department of Ophthalmology with the Department of Pediatrics of the Medical University of Graz were established and a brochure on this topic is being planned.

6. CONCLUSION

Since it is impossible to continuously supervise children, and since they need a certain amount of freedom of movement (6), the crucial activities to prevent ocular injuries in children could be to instruct the children, to show and tell them which objects are dangerous and which are safe and how to use things properly.

The study provides information which can increase the reader's awareness of potential dangers and therefore improve the accuracy of his or her preventive measures so that they are neither exaggerated nor neglected.

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8. CURRICULUM VITAE

Education

2002	Secondary school: BG/WRG Körnerstraße in Linz, school leaving examination passed with distinction
2002 - 2003	Study of Law at the University of Graz, completion of the first section in the minimum time, Study of French at the University of Graz
2003	Begin of the Study of Medicine at Medical University Graz

Professional Experience

Internship at the Department of Ophthalmology of the University Hospital Graz in 8/2005
Internship at the Department of ENT of the Hospital of Steyr in 2/2006
Internship at the Department of Ophthalmology of the University Hospital Graz in 2/2007
Begin of research activities at the Department of Ophthalmology of the University of Graz in 2/2007
Internship at the Department of Ophthalmology of the University Hospital Graz in 9/2007
Beginning of the Advanced Training Course of Orthomolecular Medicine of the ÖÄK
Internship at the Department of Internal Medicine of the University Hospital Graz in 10/2007
Internship at the Department of Ophthalmology of the Hospital of Brest in France in 7/2008

Skills

Language Skills	German (mother tongue) English (excellent) French (excellent) Spanish (satisfactory) Chinese (basic)
Computer Literacy	Extensive experience with SPSS, MS Office, Medical Databases
Communication Skills	Course of Advanced Communication in the Medical Context

Voluntary Activities	Mentor for foreign students at the University of Graz
Committee Memberships	Wissenschaftliche Gesellschaft der Ärzte in der Steiermark
Personal Interests	Composing musical pieces, Latin dance, travelling, natural sciences, philology, etymology, chess