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REVIEW

Vitreoretinal Injury Associated with Sports Ball Ocular Trauma

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Abstract: Sports are a common cause of ocular trauma. Vitreoretinal injuries secondary to sports ball trauma can cause permanent vision loss and may be a source of significant morbidity. Trauma most frequently occurs in young males and over half of injuries involve the posterior segment. Injuries typically occur as a result of direct contact with the globe either before or after initial contact with the orbit and are dependent on the size, mass, and velocity of the ball. Compressive forces and subsequent equatorial expansion lead to direct tissue damage and dehiscence of posterior segment layers. Smaller balls with relatively high mass and velocity such as golf balls and paintballs are associated with rupture injuries while larger balls frequently cause contusive trauma and distortion of the globe which may lead to vitreoretinal traction and damage to posterior segment layers. Retinal detachment may occur and is frequently associated with retinal dialysis and giant retinal tears. Traumatic macular hole is uncommon and, unlike idiopathic macular hole, frequently closes spontaneously. The institution of eye protection standards in select sports have dramatically reduced the incidence of eye injuries. Continued evaluation of the most appropriate and logical protective measures is essential to promote the safety of all athletes and reduce the incidence of frequently-disabling ocular injury.

Keywords: ocular trauma, sports injury, open globe injury, retinal detachment, traumatic macular hole

Introduction

Ocular trauma secondary to sports ball injury is a significant cause of morbidity.[1] There are over 40,000 emergency department visits per year for sports-related ocular trauma in the United States.[2] Injuries most commonly occur in young males.[3,4] Anterior segment injuries include corneal abrasion, corneal laceration, traumatic iritis, hyphema, angle recession glaucoma, and lens subluxation or dislocation.[5] Over half of eye injuries involve the posterior segment and may include commotio retinae, open globe injury (OGI), vitreous hemorrhage (Figure 1A), retinal detachment (Figure 1B), choroidal rupture, retinal hemorrhage, and retinal tear (Figure 2A and B).[6,7] In the current manuscript, we review the clinical characteristics and outcomes of vitreoretinal injuries secondary to sports ball trauma.

Pathophysiology

While the bony orbit provides protection of the globe against many objects, some sports balls such as golf balls, paintballs, and badmintons are small enough to contact the globe directly. Furthermore, larger balls are frequently able to contact the globe by molding to the orbit in the setting of sufficient force. Vitreoretinal injury occurs as a result of blunt forces directed in the anterior-posterior direction, causing compression of the anterior chamber and coup-countrecoup injuries such as commotio retina. This compression also causes equatorial expansion and stretching of the posterior eye wall which can lead to choroidal rupture, macular hole, retinal dialysis, vitreous hemorrhage, retinal tear, and scleral rupture. Injuries that disrupt the integrity of the globe and those that lead to uveal or retinal prolapse are typically associated with a poor prognosis.[9] Vitreous hemorrhage and optic nerve injury have also been demonstrated to be associated with worse visual outcomes.[9]

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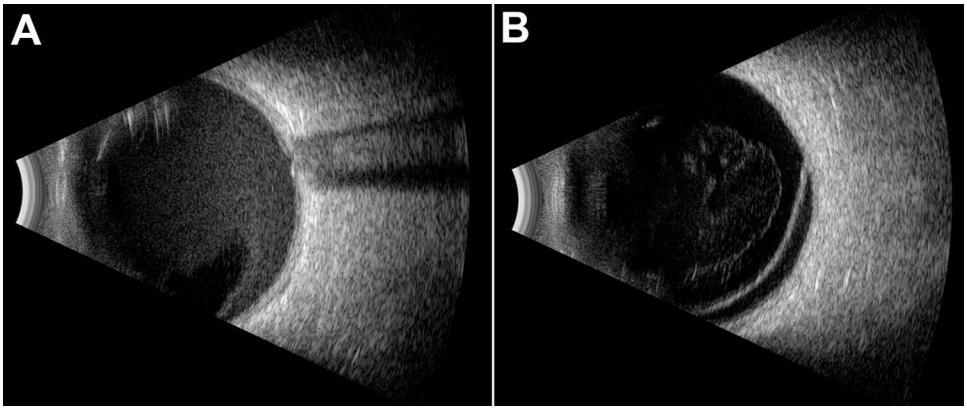

Figure 1 B-scan ultrasonography of vitreous hemorrhage and retinal detachment B-scan ultrasonography demonstrating (**A**) vitreous hemorrhage and (**B**) retinal detachment.

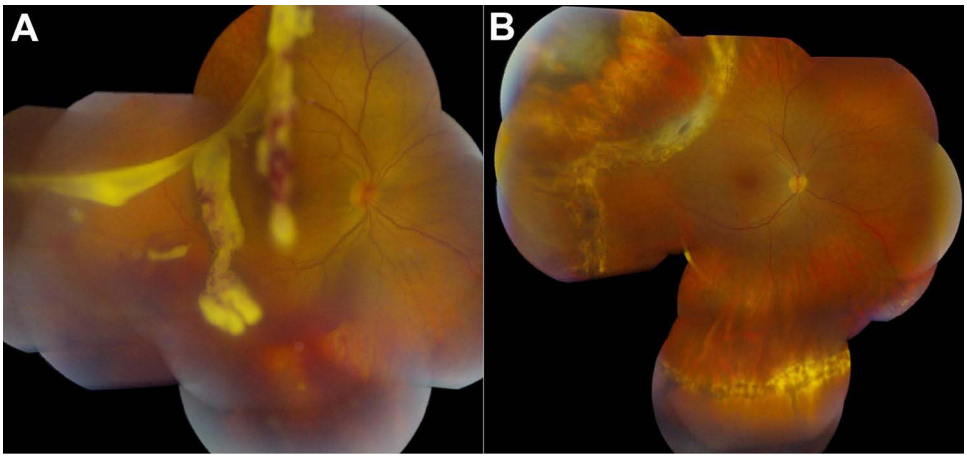

Figure 2 Giant retinal tear secondary to baseball injury (**A**) A 36-year-old male with a history of baseball-related ocular trauma presented with a giant retinal tear in the superotemporal quadrant of the right eye with associated vitreous hemorrhage. The patient underwent scleral buckling, pars plana vitrectomy, and silicone oil insertion. (**B**) The retina was attached at last follow-up 2 years later and best-corrected visual acuity was 20/20. Reprinted from *Am J Ophthalmol Case Rep,* volume 6, Read SP, Young RC, Flynn HW Jr. Outcomes in bullous retinal detachment. 18–20, copyright 2016, Creative Commons.[8]

The institution of standards for eye protection in select sports has drastically reduced the incidence of sports-related ocular trauma. In 2006, the American Hockey League instituted a mandatory requirement for the use of protective visors and in 2013, the National Hockey League made protective visors mandatory for all new players in the league. Accordingly, the number of eye injuries in the National Hockey League decreased from 10 in the 2010–2011 season to 0 in the 2017–2018 season.[10]

Furthermore, the introduction of rules on protective eyewear in racquetball have decreased the incidence of ocular injury. Organizations such as the American Society for Testing and Materials (ASTM) and European Committee for Standardization have been influential in developing and recommending standards for protective eyewear in racquetball and other sports. While racquetball players initially wore eye guards without lens ("open" eye guards), injuries continued to occur as the ball was able to deform and fit through the gap between the rims.[11,12] Furthermore, the use of CR39 lenses frequently led to injury as a result of an opponent's racquet striking and shattering the lens.[11,12] However, in 1983, many racquetball clubs began to mandate the use of ASTM-compliant eyewear, which led to a drastic reduction in eye injuries. Indeed, there have been no reports of racquetball-related eye injuries in individuals wearing eye protective devices compliant with the ASTM F803 standard.[7,12] While the use of eyewear approved by the ASTM and other organizations has been demonstrated to be beneficial, eyewear not compliant with these standards such as prescription eyeglasses and sunglasses may actually be detrimental due to injury caused by the devices themselves.[13–16] As such, it is important for patients and providers to be aware of these standards.

Epidemiology

Sports are one of the most common causes of traumatic eye injuries worldwide. In a study using data from the Eye Injury Registry of Alabama from 1982 to 1986 blunt injury, which includes ball injuries, was the most common type of injury reported. The retina and/or vitreous were involved in nearly half of cases, the sclera in 8%, and the optic nerve in 5%.[9] In 2003, Filipe et.al reported 25 cases of eye injuries caused by "modern sports." Over half of eyes experienced posterior segment injury and the most common cause was paintball. More recently, large database studies evaluating emergency room encounters for sports-related injuries in the United States have demonstrated that the most common sports causing eye injury include basketball, baseball, soccer, and air gun sports.[2,5] Out of all injuries, the rate of posterior segment involvement is around 2.5%, with commotio retina, globe rupture, and retinal detachment as the most common reported injuries. Soccer, paintball, and golf, specifically, are the most likely to cause major posterior segment injury in the setting of ocular trauma.[5]

The prevalence of sports-related injuries is dependent on the corresponding geographic popularity of various sports. A 1986 study from the Sussex Eye Hospital in England demonstrated that squash was the most frequent cause of sports-related ocular injury followed by soccer and badminton.[14] On the other hand, the most common sports causing ocular injury in Korea in 2021 were soccer, baseball, and badminton.[3] Handball, soccer, and floorball are the most common causes of sports-related ocular trauma in China, Australia, and Sweden, respectively (Table 1).[17–19] As such promotion of awareness, education, and counseling should be directed according to the popularity of individual sports.

Types of Vitreoretinal Injury

Retinal Tear/Detachment

Retinal tear and detachment may occur following sports ball injury as a result of equatorial expansion of the globe with resultant vitreoretinal traction.[9] Retinal tears are frequently located in the infratemporal or supratemporal quadrants and are occasionally associated with a full-thickness macular hole.[23,24] Initial visual acuity is a predictor of postoperative visual acuity and myopia may be a risk factor.[25] Common symptoms include flashes, floaters, blurred vision, decreased peripheral vision, and a curtain-like shadow in the field of view.[26] Concurrent injuries include retinal dialysis, giant retinal tear, or avulsion of the vitreous base.[8,24,27,28]

Retinal Dialysis

Retinal dialysis is defined as the disinsertion of the retina at the ora serrata.[29] The condition most frequently occurs in young males and may be either symptomatic or asymptomatic.[29] Retinal dialysis has been reported in associated with

Table 1 Most Common Causes of Sports-Related Eye Injury by Country

Authors (Year)	Country	Sport
Gregory (1986)[14]	England	Squash
Filipe et al (1997)[20]	Brazil	Soccer
Yulish et al (2013)[21]	Israel	Soccer
Leivo et al (2015)[22]	Finland	Floorball
Bro et al (2017)[18]	Sweden	Floorball
Lee et al (2021)[3]	Korea	Soccer
Zhang et al (2021)[17]	China	Handball
Ashraf et al (2022)[19]	Australia	Soccer
Patel et al (2023)[5]	United States	Basketball

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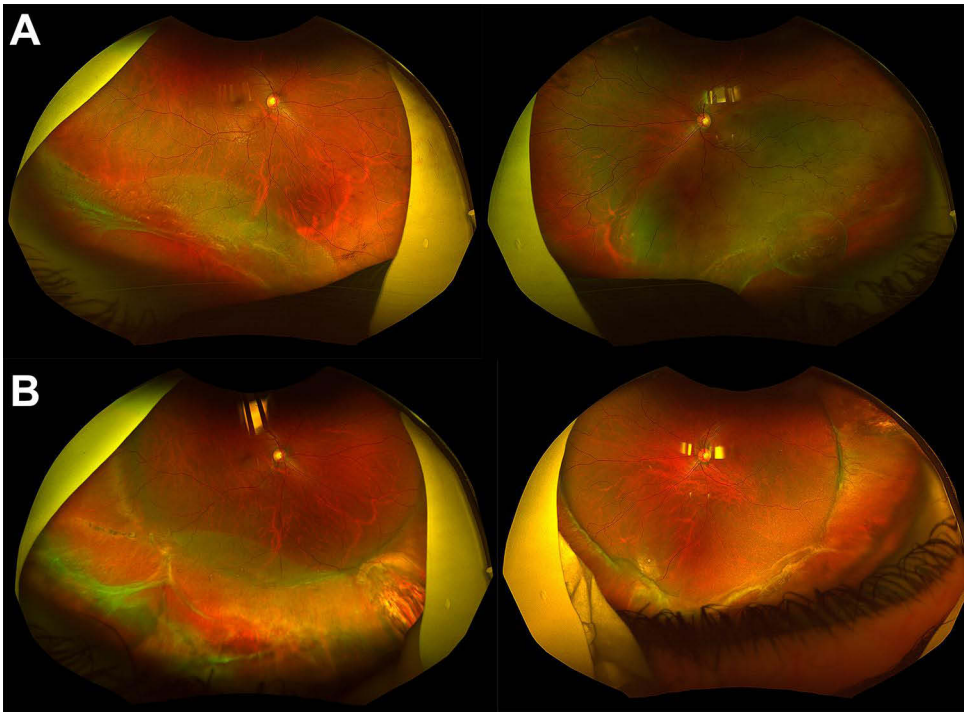

Figure 3 Retinal dialyses secondary to soccer ball injury (**A**) A 22-year-old male soccer player presented with bilateral retinal dialyses. Best-corrected visual acuity was 20/20 in the right eye and 20/300 in the left eye. Examination revealed a macula-sparing retinal detachment in the right eye and a macula-involving retinal detachment in the left. Scleral buckling with external drainage of subretinal fluid was performed in both eyes. (**B**) At postoperative year 2, the retina was attached in both eyes and best-corrected visual acuity was 20/20 and 20/200 in the right eye and left eyes, respectively.

tennis, badminton, racquetball, basketball, and soccer injuries.[27,28,30,31] When associated with retinal detachment, scleral buckling alone is generally the treatment of choice for retinal dialysis (Figure 3A and B).[29]

Open Globe Injury

Open globe injury frequently occurs in sports ball-related ocular trauma, particularly in those involving small balls with high impact velocity such as golf and paintball.[13,32] Injuries generally involve globe rupture due to the blunt configuration of the ball unless there is simultaneous contact with an adjacent object such as eyeglasses.[13] Visual acuity outcomes are generally poor and patients often require multiple surgeries including evisceration or enucleation.[32]

Commotio Retinae

Commotio retinae is a common injury following blunt ocular trauma, characterized by photoreceptor outer segment disruption or loss manifesting as retinal whitening.[33] Damage may occur at the site of injury (coup) or at distant sites (countrecoup) and may result in traumatic retinal pigment epitheliopathy.[34] The presence of commotio retinae within the macula (Berlin's edema) is associated with poor visual acuity outcomes.[35]

Macular Hole

Macular hole is a common complication of sports-related retinal injury. Unlike non-traumatic macular holes, traumatic macular holes may resolve spontaneously without treatment due to the tangential forces of the attached vitreous and as such may be observed for a period of time.[36–40] Some authors have reported the presence of parafoveal cysts as a poor prognostic factor caused by radial traction from the internal limiting membrane and contraction of activated Müller cells.[41] In refractory cases, pars plana vitrectomy generally results in good anatomic outcomes and modest improvements in visual acuity.[42] Shallow macular hole-related retinal detachment may occur and has been reported to resolve spontaneously.[37]

Traumatic Retinal Pigment Epitheliopathy

Traumatic retinal pigment epitheliopathy may be identified early by hyperautofluorescence and the presence of leakage on fluorescein with ellipsoid zone loss on OCT. The finding has been reported in many causes of sports ball-related ocular trauma and is an indicator of poor long-term visual prognosis.[36,41]

Other Injuries

Central retinal vein and central retinal artery occlusion have been reported and are theorized to occur as a result of compressive forces transmitted to the vitreous and retina.[43] Retinal pigment epithelial tears and detachments may occur due to the aforementioned equatorial expansion and stretching of posterior segment layers.[41] Additional reported injuries include choroidal rupture, choroidal neovascularization (Figure 4A and B), sclopetaria (Figure 5), subretinal hemorrhage, sub-pigment epithelium hemorrhage, optic neuropathy, and optic nerve avulsion.[44–51]

Sports

Soccer

In the past, it was thought that injury due to soccer balls were rare because of the ball's relatively large and relatively soft shape. However, frequent reports of ophthalmic injury from soccer ball trauma led Vinger et.al to perform a study in which they simulated soccer ball injuries using artificial orbits and demonstrated that while the depth of penetration is less in soccer ball-related injury compared to injury caused by other balls, the ball remains in contact with the globe 2.5 to 10 times longer. As a result, while the peak force of a soccer ball is less than that of smaller balls, the duration of globe impact can lead to significant distortion and resultant vitreoretinal trauma.[52] Furthermore, a suction effect of the ball can cause further globe distortion and corresponding injury.[52] Indeed, soccer-related ocular injury has been associated with

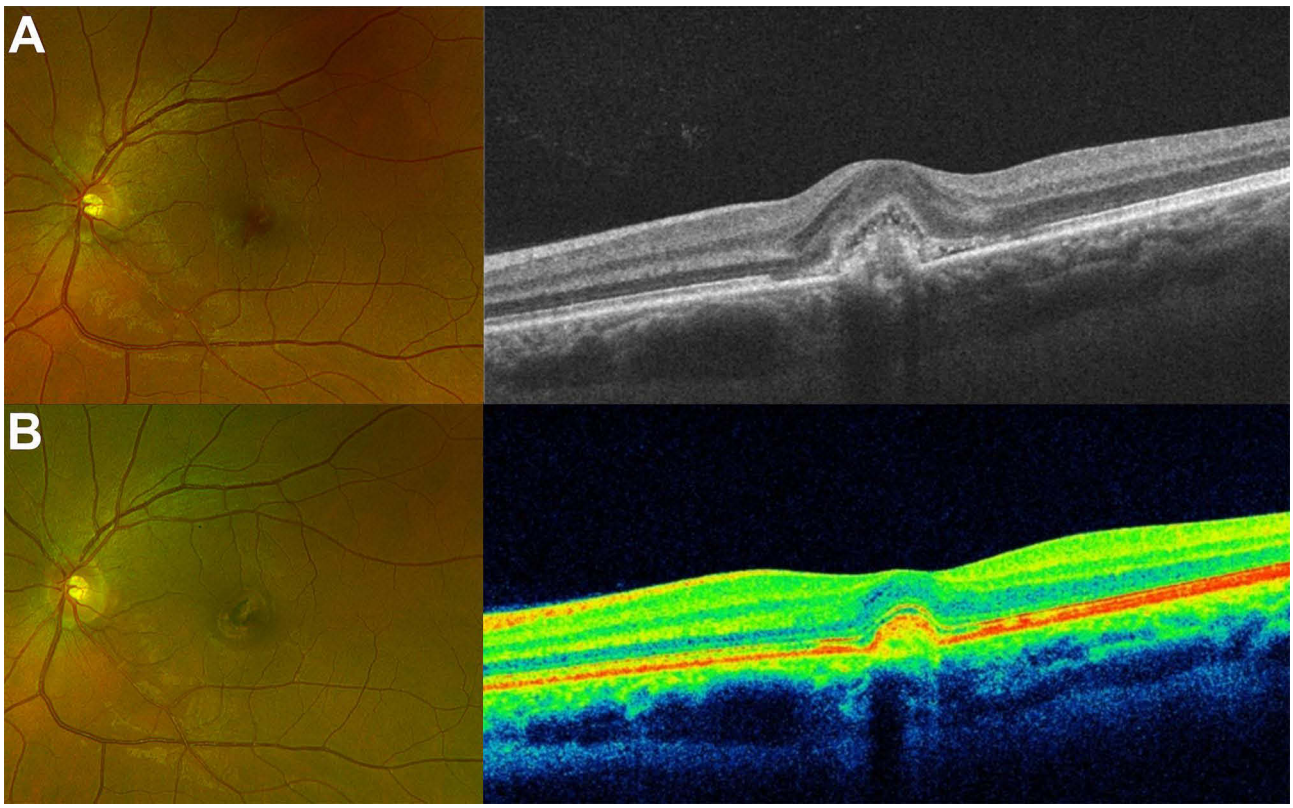

Figure 4 Choroidal neovascularization secondary to tennis ball injury (**A**) Fundus photography and optical coherence tomography of a 52-year-old male with a history of tennis-related ocular trauma presenting with a pigment epithelial detachment and subretinal fluid consistent with choroidal neovascularization. (**B**) 1 month after receiving intravitreal bevacizumab, the subretinal fluid had resolved although the pigment epithelial detachment persisted.

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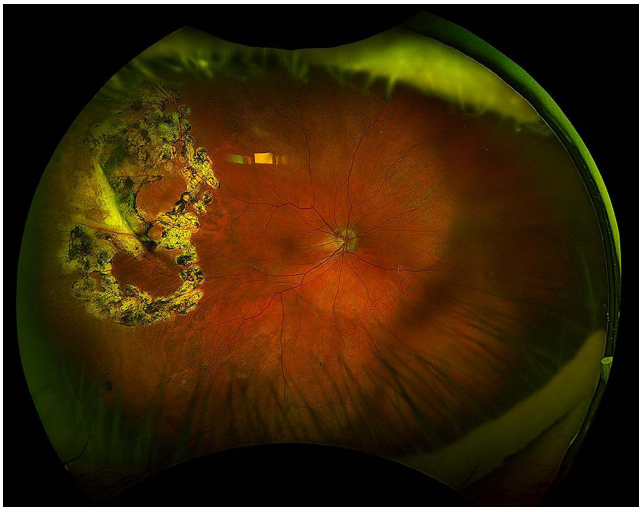

Figure 5 Retinal detachment and sclopetaria secondary to golf ball injury A 69-year-old male presented after being struck by a golf ball in the right eye. Best-corrected visual acuity was hand motions and examination demonstrated dense vitreous hemorrhage. Pars plana vitrectomy was pursued and intraoperative examination revealed temporal sclopetaria and a localized temporal retinal detachment. Endolaser was performed and air tamponade was placed. At postoperative year 4, the retina was attached and best-corrected visual acuity was 20/25.

a higher rate of visual impairment compared to injuries caused by other sports.[2,3] Common injuries include retinal dialysis, giant retinal tear, retinal detachment, and macular hole. Injuries frequently occur in the superior hemisphere due to the upward trajectory of the ball. In a study evaluating sports-related ocular injuries in Korea, soccer was the most common cause of OGI. Notably, eye protection was worn by all patients who experienced OGI, demonstrating the importance of using eye protection adhering to certain standards such as those developed and published by the ASTM.[4]

Golf

Golf ball injuries, while rare, are typically severe due to the high velocity and resultant force of the small ball.[53] Open globe injuries (OGIs) have been reported in over half of cases and visual acuity outcomes are generally poor with about one-third of cases resulting in enucleation or evisceration.[13,14,32,54] In a report of 22 golf ball-related ocular injuries, the mean number of total surgeries per eye was 1.5. All patients with a rupture injury eventually underwent evisceration and the final visual acuity in all eyes with penetrating injury was 20/100 or worse.[32] All patients with zone III OGIs either underwent enucleation or had a visual acuity of no light perception at last follow-up examination.[32] Reported closed globe injuries include lens subluxation, commotio retinae, retinal dialysis, and choroidal rupture.[32] In one study, 9% of injuries occurred in spectators, demonstrating the importance of appropriate protective measures in fans and players alike.[54]

Tennis

As the popularity of tennis increased in the United States in the 1970s, Seelenfreund and Freilich published a report describing 10 eyes with vitreoretinal trauma secondary to tennis ball injury. All 10 eyes in their report had vitreous hemorrhage. Retinal tear and retinal dialysis also occurred and 5 (50%) eyes required surgery.[27] However, the authors point out that the rate of retinal tear and retinal detachment was low compared to the overall incidence of tennis ball injury and reported that retinal detachment after trauma in the absence of a predisposition is rare.[27] In 2007, Qureshi et.al reported 28 cases of retinal detachment secondary to tennis ball injury, 34% of which had more than 1 break. Fifty-nine percent of breaks were in the infratemporal quadrant and 10% of retinal detachments were associated with a full-thickness macular hole. All patients underwent scleral buckling only with a single operation success rate of 75%. Visual acuity of 20/60 or better was achieved in 29% of eyes at last follow-up examination.[23]

In 2016, Karimi et.al used magnetic resonance imaging to model tennis-related eye injuries and demonstrated that the majority of the induced stress was localized to the anterior chamber while the vitreous experienced the lowest perceived stress. However, the authors emphasize that globe deformation rather than transmitted stress may cause the majority of

tennis-related injuries.[55] In 2019, Patel et.al reviewed over 15,000 emergency department visits for tennis-related ocular injury between 2000 and 2019. Injury was most frequent in individuals under the age of 20 years. The incidence of OGI, retinal detachment, and posterior vitreous detachment was 1.5%, 0.9%, and 0.2%, respectively. There was a decrease in the rate of ocular injury between the start and end of the study.[44]

Tennis ball-related injuries associated with poor visual prognosis include retinal detachment, choroidal rupture, and vitreous hemorrhage.[45] Other reported injuries after tennis ball trauma include macular hole, choroidal rupture, choroidal neovascularization (Figure 3), subretinal hemorrhage, sub-pigment epithelium hemorrhage, and OGI.[44–50]

Squash

Squash, a popular sport in many parts of the world, is frequently associated with eye injury in the absence of adequate eye protection due to the ball's small size and high velocity. In 1978, Easterbrook described 23 cases of ocular trauma secondary to squash injury over 2.5 years, 11 of which led to hospitalization of the patient. Injuries included retinal hemorrhage, OGI, vitreous hemorrhage, and a macular cyst. Five cases resulted in a permanent decrease in vision and there was no association between the odds of injury and player experience.[56]

Squash was the leading cause of sports-related ocular trauma in a 1986 study by Gregory et.al at the Sussex Eye Hospital, causing 24 of 92 (26%) injuries. Four cases involved retinal abnormalities although there were no cases of vision loss.[14] Other previously-reported injuries include retinal hemorrhage and retinal edema.[7]

Retinal detachment has been reported in squash ball accidents.[24] Knorr and Jonas described a cohort of 26 eyes with retinal detachment caused by squash ball injury. Detachments were frequently associated with large retinal tears near the ora. The supratemporal quadrant was the most frequent location followed by the infratemporal quadrant. Avulsion of the vitreous base was noted in half of patients and final visual acuity was 20/40 or better in 42% of eyes.[24] Capão Filipe et.al also described 7 cases of squash-related eye injury, 2 of which involved retinal tears. Other previously-reported injuries included retinal hemorrhage and retinal edema.[7]

Badminton

Badminton may be associated with severe eye injury due to the small size and high velocity of the shuttlecock. Injury may also occur due to contact with another player's racquet given the relatively small court size and the players' close proximity to each other. Eye injuries secondary to badminton have been associated with higher rates of visual impairment when compared to other sports.[3]

In 1974, Chandran described 63 cases of badminton-related eye injury. Reported vitreoretinal injuries included commotio retinae and vitreous hemorrhage. Visual acuity was 20/60 or worse in 27% of eyes at last follow-up.[57] Kelly described 6 cases of badminton-associated ocular trauma, 4 of which occurred due to close-range shuttlecock injury from an opponent's smash hit. Injuries included OGI, IOFB, retinal dialysis-associated retinal detachment, choroidal rupture, and vitreous hemorrhage. Surgery was performed in 3 cases.[30] In 2020, Yu et.al reported the largest series badminton-related ocular trauma involving 85 eyes. There were 5 penetrating injuries in their study. Sixteen patients underwent pars plana vitrectomy and 2 required silicone oil tamponade. Eighty-six percent of cases occurred in doubles matches and 61% of injuries were caused by the patient's partner rather than the opponent.[16]

Racquetball

Racquetball, a popular sport in the United States and internationally, is frequently associated with eye injury in the absence of adequate eye protection due to the close proximity of players and the ball's small size, high velocity, and significant flexibility. In 1980, Doxanas and Soderstrom reported 37 cases of ocular injury in a 3-month period. No patients in the cohort were wearing protective eyewear and there was no correlation with player experience.[58]

Although eye protection began to be worn shortly thereafter, the initial standard eye protective device in racquetball was an open eye guard without lenses. The flexibility of the racquetball allowed it to come into contact with the globe despite the surrounding protection afforded by the lensless eyeguards.[11,12] Indeed, in 1981, Easterbrook et.al described 18 racquetball-associated eye injuries including 1 OGI, 1 vitreous hemorrhage, and 1 retinal dialysis. Open eye guards were

used by 10 patients at the time of injury.[31] An updated report was published in 1988 involving 292 ocular injuries from racquetball, revealing 21 cases of vitreous/retinal hemorrhage, 5 macular scars, and 3 retinal detachments, with the author noting that injuries frequently occurred with open eyeguards.[59]

Following the subsequent institution of ASTM-compliant eyewear mandates, including eye guards with impact resistant lenses, there was a significant reduction in racquetball-related eye injuries. Indeed, there have been no reports of injury in patients using eye protective devices compliant with the ASTM F803 standard.[7,12]

Basketball

Basketball is the leading cause of sports eye injury in the United States, with 1 in 10 college basketball players sustaining eye injuries each year.[2] While general eye injuries are frequent in basketball due to contact with other players, vitreoretinal injuries specifically are less common due to the low velocity and large size of the ball. In a study examining high school sports injuries, baseball and basketball accounted for most ocular injuries. Most basketball injuries were caused by an elbow or finger and there was 1 case of retinal detachment after a patient was hit in the eye by a rebound.[60]

The National Basketball Association reported 59 and 18 eye injuries in the 1992–1993 and 2018–2019 seasons, respectively. Notably, none of the injuries involved the posterior segment.[61,62] Similarly, a retrospective review of the Duke University men's basketball injuries over 16 seasons revealed only 1 vitreoretinal injury – a case of retinal dialysis and traumatic optic nerve head avulsion.[28]

In a retrospective review of 13 cases of retinal detachment associated with basketball injury, 70% of patients had moderate to high myopia, with −5.2 diopters as the average refractive error. Seventy percent of injuries were caused by direct blunt contusion from the basketball and the majority of breaks were superior. Most patients were young and the authors argue that the relatively undeveloped orbital rim and cavity compared to the fully-developed globe of young patients, in addition to the increased axial length characteristic of myopia, may cause relative protrusion of the eye making it more prone to injury. Concurrent injuries included retinal detachment, choroidal detachment, retinal dialysis, and giant retinal tear and there was a 76% reattachment rate after the first operation. Visual acuity was 20/200 or better in 54% of patients and the only prognostic factor was initial visual acuity although there was trend towards better visual acuity at last examination in patients with shorter symptom-to-diagnosis interval.[25]

Baseball

Given its popularity, baseball is one of the most frequent causes of sports ball-related ocular trauma in the United States.[2,5] The incompressibility and large size of a baseball typically prevents significant globe compression during injury. As such, most baseball injuries involve the orbital bones rather than the globe itself. Injury may occur from a throw, as in the case of a batter being hit by a pitch, or from a hit with a wooden or metal bat.

In 1993, Zagelbaum et.al reported all ocular injuries in Major League Baseball over a 1-year period. There were 24 total injuries, none of which involved the posterior segment. However, 1 fan suffered a ruptured globe from a foul ball.[63] Traumatic macular hole has been described in 4 cases, all of which demonstrated spontaneous closure.[39,40] In 2017, Flynn et.al described 2 patients with giant retinal tear-related retinal detachments requiring pars plana vitrectomy.[8] Other previously-reported vitreoretinal injuries include choroidal rupture, choroidal neovascularization, choroidal folds, and retinal pigment epithelial detachment.[39,64]

Pickleball

Pickleball is the fastest growing sport in the United States, with over 13.6 million individuals in the United States participating in the sport as of 2023.[65] Pickleball-related injuries have increased in recent years alongside the sport's increase in popularity, particularly among elderly individuals.[66] Over 500 injuries occurred in the United States between 2010 and 2019, 5 (0.7%) of which were eye injuries. Most of the injuries were due to contact with the ball and were generally less severe than tennis injuries.[67] In 2022, Atkinson et.al reported 2 patients with retinal tears after direct blunt ocular trauma with a pickleball. One patient had a localized retinal detachment and vitreous hemorrhage that was successfully treated with cryopexy while the other had a single retinal tear that was treated with laser retinopexy.[68]

Continued identification and reporting of pickleball-related ocular injury is essential as the sport continues to gain popularity to better understand its risks.

Paintball

Paintball was first played in 1981 in New Hampshire and has since became a popular game played around the globe.[69–71] The game involves shooting opponents with paintballs fired from carbon dioxide-powered guns.[72] The small size, relatively high mass, and high velocity of paintballs result in a sharply localized impact that typically causes significant ocular damage.[73] As paintballs are designed to rupture on impact, all of the ball's energy is released at the site of contact, contributing further to the severe tissue damage characteristic of these injuries.[74] Indeed, in a 2016 study evaluating all patients presenting to an emergency department with sports-related eye injury, the odds of impaired vision were greatest for paintball injuries, accounting for 26% of all cases of impaired vision, while only accounting for 10% of all injuries.[2]

At the time of the inception of paintball in the 1980s, the game was frequently played in unregulated settings without adequate protection. In 1985, the first study evaluating eye injuries in paintball demonstrated that over half of 26 eyes had a final best-corrected visual acuity of less than 20/800. Notably, no players in this study were wearing eye protection at the time of injury and there was only 1 reported OGI.[75] Since then, over 500 cases of paintball-related ocular injury have been reported.

In 1996, Zwaan et.al performed a literature review of all paintball-related ocular injuries. The most common posterior segment injuries were "retinal damage", vitreous hemorrhage, and macular hole. Best-corrected visual acuity was 20/300 or worse at last follow-up in 30% of eyes and 4% suffered an OGI.[74] Thach et.al described 13 eyes with paintball-related ocular injury, demonstrating an improvement in visual acuity at last follow-up in only about half of eyes. The most common reasons for poor visual acuity were posterior segment injuries including recurrent retinal detachment due to proliferative vitreoretinopathy, epiretinal membrane, choroidal neovascularization, and retinal necrosis.[76] Similarly, Peñaranda et.al described 14 eyes with paintball injury, 9 of which had no visual acuity improvement at last follow-up. Reported causes of poor vision included macular alterations, choroidal rupture, retinal tears, and retinal folds.[77] In 2008, Taban et.al described 9 eyes with paintball-related injuries, 4 of which manifested with chorioretinitis sclopetaria, demonstrating that sclopetaria can occur with soft projectiles even when they do not penetrate the orbit. The authors hypothesized that sclopetaria was previously unrecognized by ophthalmologists as it is typically associated with high speed projectiles that penetrate the orbit. The most common causes of decreased vision were traumatic maculopathy, optic neuropathy, and optic nerve avulsion.[51]

In 2009, Allman et.al described 36 eyes with paintball-related ocular injury over a 6-year period demonstrating that nearly half of eyes underwent surgical intervention within 3 days of the injury while 67% of eyes underwent surgical intervention after 3 days, either for the first or second time. Eleven percent of eyes required 3 or more surgeries and over one-quarter of eyes had a visual acuity of no light perception at last follow-up. Open globe injury occurred in one-quarter of patients and there was a strong correlation between initial visual acuity and visual acuity at last follow-up. Enucleation was performed in 7 eyes. Notably, no injuries occurred at a formal, sponsored event.[78] Furthermore, in 2022, Amin et.al reported 20 cases of ocular injury from drive-by paintball shootings and demonstrated a 30% ruptured globe rate, with 50% of eyes requiring evisceration and 38% of eyes demonstrating a final visual acuity of no light perception. Visual acuity was no light perception at last follow-up in 5 of the 6 eyes requiring surgical intervention, demonstrating the particularly poor prognosis associated with OGI.[79]

In 2000, Fineman et.al examined 35 paintball injuries over a 13-year period. The most common posterior segment injuries were vitreous hemorrhage, commotio retinae, and choroidal rupture (Table 2). Open globe injury occurred in 6% of cases. Injuries sustained after 1995 were 5.8 times more likely to occur in a non-commercial setting than those in 1995 or before, possibly related to the ASTM's institution of standard specifications for eye protection devices in paintball sports in 1997.[73]

Indeed, a 2001 review of all reported paintball injuries demonstrated no ocular injuries in individuals wearing eye protection devices meeting ASTM standards. However, injuries have been reported in individuals wearing non-ASTM-approved eye protection devices as a result of the paintball entering under the mask, displacing the mask, or causing the goggle or a goggle fragment to be projected into the eye.[73,80–83] Along these lines, Keles et.al described 10 cases of

Table 2 Common Vitreoretinal Injuries by Sport

Sport	Common Vitreoretinal Injuries
Soccer[4,36,37,41,52]	Retinal detachment, macular hole, retinal dialysis, giant retinal tear
Golf[13,14,32,53,54]	Open globe injury
Racquet sports[12,14–16,23,24,27,30,44–50,55–59,67]	Retinal detachment, macular hole, choroidal rupture, vitreous hemorrhage
Basketball[25,28,60–62]	Retinal detachment (rare)
Baseball[8,39,40,63,64]	Giant retinal tear, macular hole, choroidal rupture (rare)
Pickleball[68]	Retinal tear
Paintball[51,69–71,73,80]	Open globe injury, vitreous hemorrhage, commotio retinae, retinal detachment, macular hole

paintball-related ocular injury in 2014, all of which occurred after the injured player thought the game was over and had taken off their eye protection device.[69] Indeed, most cases of modern ocular paintball injury occur in unregulated settings with inadequate eye protection. The use of ASTM-approved eye protection is generally very effective in preventing frequently-devastating eye injuries associated with paintball-related ocular trauma.

Conclusion

Vitreoretinal injury due to sports ball trauma is a significant source of visual morbidity and disability. Injury is typically dependent on the size, mass, and velocity of the ball. As such, the extent and types of injury vary from sport to sport. Injuries due to sports with smaller balls with relatively high mass and velocity such as golf and paintball are associated with more severe damage including OGI. Larger balls frequently cause contusive injury and brief distortion of the globe which may lead to vitreoretinal traction and damage to posterior segment tissue layers. Trauma-induced retinal detachment is frequently associated with retinal dialysis and giant retinal tear and treatment is dependent on the etiology and age of the patient. Traumatic macular holes are common but, unlike idiopathic macular holes, frequently close spontaneously. The institution of eye protection standards in select sports has dramatically reduced the incidence of eye injuries. The use of eye protection should be considered based on the sport and individual player with special consideration being given to those participating in sports with a high rate of ocular trauma and those with a history of ocular disease. Continued evaluation of the most appropriate and logical protective measures is prudent in promoting the safety of all athletes and reducing the incidence of frequently-disabling ocular injury.

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Disclosure

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