Case Report

Intrastromal Corneal Foreign Body – Case Series and Discussion on the Physics of Injury

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Abstract

Traumatic injury to the eye can occur due to various causes, most of which are avoidable. Here we report three cases of intrastromal corneal foreign bodies (FB) which required surgical removal. Most corneal FBs are removed easily at the slit lamp, however, these cases required surgical intervention due to the mechanism of which the FB penetrated into the stroma. Although the mechanism of injury was similar, with all three cases occurring at high velocity, we observed that the entry and level of penetration differed in each case. In the first case, the corneal FB penetrated the cornea and was embedded in the anterior stroma, whereas in the second case, the FB was embedded in the posterior stroma, but with an intact endothelium. In the third case, the FB caused a full thickness, self-sealed laceration wound but remained embedded in the stroma. Through further evaluation, we noted that several factors contribute towards the severity of the injury, namely, anatomy of the cornea, area affected, shape, size, mass and velocity of the object. We speak in depth about the mechanism of injury and physics associated with these injuries and why the penetration differed in each case.

Keywords: corneal stroma, foreign bodies, injury, mechanics, physics

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Introduction

The cornea forms the anterior 1/6th of the eyeball, making it highly susceptible to injury. Corneal FBs compromise 30.8% of all ocular injuries, making it the second commonest type of eye injury (1). In a study of 69 eyes with intraocular foreign bodies (IOFBs), 67% entered through the cornea, but only 33% entered via the sclera (2). Of this, 40% and 87% respectively, hit the retina, indicating that although the cornea has higher susceptibility to injury, involvement of the posterior segment is less (2). Several factors such as the anatomy of the cornea, area of cornea affected, shape, size, mass and velocity of the object, contribute to the prognosis of the injury, management and final visual outcome (2, 4, 6, 8).

The 3 cases discussed below incites an interesting discussion on the mechanism of injury of corneal foreign bodies with regards to their extent of injury. Although all 3 cases had similar mode of injury, the penetration differed in each case. Here, we highlight the physics of corneal penetration and the factors that determine severity of the trauma by reviewing relevant studies looking at these aspects.

Case Report

Case1:

A 27-year-old gentleman, presented with progressive left eye (LE) pain and photophobia for one month. A metal nail piece entered his LE one month prior to

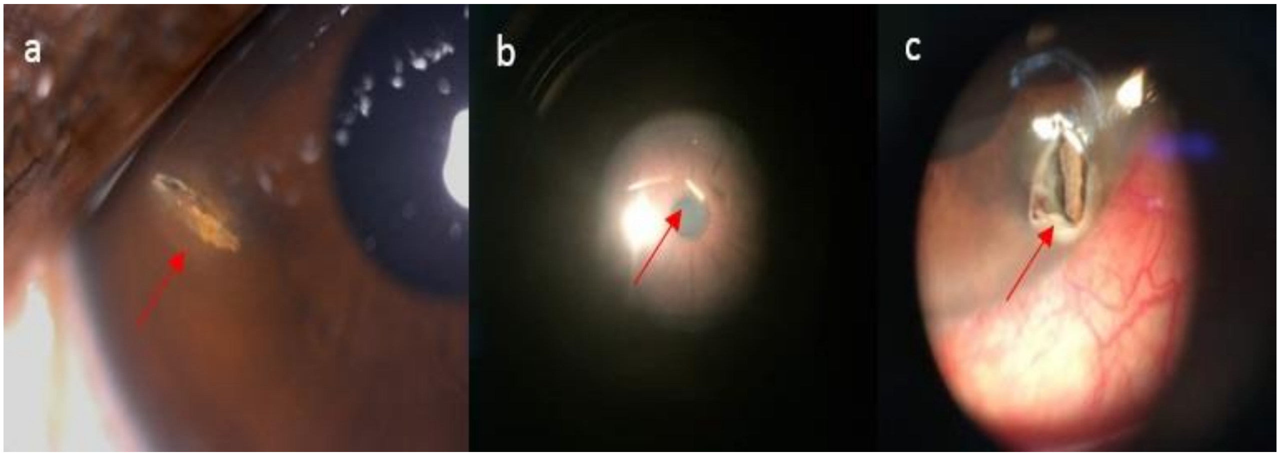

Figure 1a: FB embedded in the stroma is metallic and cylindrical shaped with sharp edges. There is surrounding corneal edema; **Figure 1b:** FB seen in the posterior stroma is cylindrical; **Figure 1c:** FB seen is metallic has a flat base and sharp apex. Apex is embedded in the wound

presentation, while hammering. Visual acuity in LE was 6/12, pinhole 6/9, N6 and normal in the right eye (RE). There was a metal piece measuring 1.8mm, embedded in the cornea, at 9 o'clock position, 2mm away from the limbus (Figure 1a). Other findings were unremarkable. Anterior segment optical coherence tomography showed that the FB was embedded in the anterior stroma, at an oblique angle (Figure 2). The FB was removed but no toilet and suturing was done as the wound was partial thickness and there was tissue loss. The FB was metal, cylindrical and with a sharp end. Visual acuity was 6/24, 6/12, N8 on day one post operation and on discharge. The patient subsequently defaulted further follow-up.

Case 2:

Our second case is of a 37-year-old man, who presented a day after a FB entered his RE. He was using a metal brush to clean a car engine, when a bristle broke off and entered his RE. His friend pulled out the metal bristle, but the patient still had persistent RE pain and redness. His vision was 6/9, pinhole 6/6, N6 bilaterally. There was a cylindrical intrastromal metal FB situated at the superior margin of the pupil, measuring 1mm in length, penetrating up to posterior stroma (Figure 1b). The Descemet membrane was not breached. Anterior chamber showed mild inflammatory reaction but fundus was normal. The FB was removed surgically and corneal wound was sutured. He had no visual deficits and recovered well postoperatively.

Case 3:

Our third case, a 41-year-old gentleman, was hammering a nail at work when he felt a FB hit his RE. On examination, his vision was 6/9, pinhole 6/9 in both eyes (BE). There was a full thickness laceration wound of the cornea situated at the 5 o'clock position, not involving the limbus or visual axis. A metal FB, measuring 2x1.6mm was embedded into the laceration wound. Siedel's was negative and the anterior chamber was deep and quiet. Fundus findings were normal. Cornea toilet and suturing with removal of the FB was done the next day. The wound was shelved and the FB had a blade shaped body and a flat base with its apex embedded into the wound (Figure 1c). Patient had no residual visual defects. All the patients were not wearing any protective goggles at the time of the incidents.

Discussion

The cases described above had similar modes of injury, but the FB penetration differed in each case. The first case showed FB penetration up to the anterior stroma (anterior 1/3rd), whereas the FB in the second case penetrated the cornea to the posterior stroma (posterior 2/3rd), but did not breach the endothelium. The third case caused a full thickness self-sealed laceration wound and was embedded in the cornea. This difference is due to various factors, as elaborated below.

Woodcock et al., showed posterior segment IOFBs had poorer visual outcome and prognosis as compared to anterior segment IOFBs (2). This is most likely due to retinal involvement which results in scar or predisposes to retinal detachment. Injuries limited solely to the cornea also had better outcome than corneoscleral and scleral wounds (4). This could be due to less involvement of the posterior structures like

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the uveal tissue and retina, which lie just beneath the sclera.

The structure of the cornea itself, may be a defensive factor which prevents further penetration. The cornea consists of 5 layers, of which the stroma is the thickest, making up 90 percent of the total thickness (5). The stroma is divided into anterior 1/3rd and posterior 2/3rd. The anterior stroma consists of densely packed, thin, interwoven collagen lamellae with random orientation, whereas the posterior stroma contains loosely packed, thicker lamellae which course the full width of the cornea in an organized limbus to limbus orientation (5). These structural differences contribute to the anterior stroma being almost 40% stiffer, more elastic and having a greater adhesion force than the posterior lamellae, which is more hydrated and swells easily (5). The limbus to limbus arrangement of collagen in the posterior lamellae also increases its strength (6). In a study done by Randleman et al, they concluded that the anterior 40% of the central corneal stroma is the strongest region of the cornea, with the posterior 60% being at least half as strong (7). These anatomical factors of the stroma, may play a role by slowing down high velocity projectiles and prevent further penetration.

The geometry and energy of projectiles are significant predictors of eye injury (8). The energy transmitted by a FB to the eye, is directly proportional to its mass and velocity (2), and hence determines the depth and severity of penetration. The mass and velocity of the object can be quantitatively correlated with poorer outcome (8). In a study done by Duma S. et al, kinetic energy was found to have a direct association with injury occurrence (8). It stated that there is a 50% risk of corneal abrasion at 0.184J and globe rupture at 3.949J (8). In our series, all three cases had FBs impacting the cornea at high velocity. The exact velocity in our cases was not quantifiable, but we assume the kinetic energy to be around the same as that for corneal abrasion as all 3 involved only the cornea. The bigger the size of the FB, the worst the outcome and the more damage is seen (2) likely as more surface contact is made and thus, more area is involved in the injury. In a retrospective study by Woodcock et al., FBs which involved the posterior segment had a larger mass (2). Lower mass FBs generally had better outcomes (2). The first two cases had FBs with smaller masses as compared to the third case, another factor preventing deeper penetration.

Besides the mass and kinetic energy, the shape of the object also plays a role. Woodcock et al. categorized FBs into 4 categories, namely blade (mean mass 30g), disc (mean mass 113g), cylinders (mean mass 12mg) and spheres (mean mass 204mg) (2). The foreign body in case 1 and 2 were cylindrical, whereas the FB in the third case was blade shaped, estimating the mass to be 12mg in the first two cases and 30mg in the third case. Penetrating injuries caused by sharp objects have a more favourable outcome compared to blunt trauma, which more commonly causes globe rupture (4). That being said, objects which are sharper and blade shaped, penetrate deeper and more frequently (2). Blade shaped IOFBs had a higher chance of entering the posterior segment as compared to disc, cylinder and sphere shaped IOFBs (2). Hammering, as seen in the first and third cases, was more likely to produce blade or disc shaped FBs, which even with a lower mass, penetrates the eye easily (2). Spherical projectiles, compared to cylindrical shaped objects, caused higher stresses and increased pressure in the eye (9). The FBs in the first two cases, had sharp edges, thus enabling it to be completely embedded in the cornea. The shape of the object in the third case was sharp at the apex, which penetrated the cornea, but had a flat base and bigger mass which probably prevented it from further penetration.

Figure 2: Anterior segment OCT of case 1 shows a hypereflective FB embedded in the stroma

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Conclusion

These series of cases highlights that not all projectiles behave the same way and produce the same outcome. Some penetrate deeper than others and cause more damage. The magnitude of injury sustained by the eye depends on numerous factors. It can be concluded that the FBs remaining in the anterior segment and affecting the cornea alone, have a better outcome. FBs with less kinetic energy caused less damage to the eye structures. The sharper projectiles penetrated more often and deeper, but also caused less damage to the surrounding structures as compared to the blunt projectiles. Thus, thorough history is as vital as examination. Removal of the foreign body should be planned based on this.

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