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LITERATURE REVIEW

Various Corneal Foreign Body Materials

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Abstract

Introduction: Cornea is an important refractive part of the eye. The corneal foreign body can disturb corneal function, depending on its material. Any materials are inert and can be retained with serial observation, while others can cause an inflammatory reaction. **Purpose:** To determine the effects of various foreign body materials on the cornea. **Review:** Corneal foreign body materials are divided into non-organic and organic materials. Organic foreign bodies (plant and insect parts) often cause severe inflammation; meanwhile, the effects of non-organic foreign bodies (metal, glass, graphite) depend on their materials. Some metals, such as iron and copper, can develop a stained deposition, disturb corneal clarity, and lead to inflammation. Other metals such as gold, silver, and platinum are almost inert and cause little or no reaction. Glass, sand, or stone is relatively inert if it is sterile. Intrastromal graphite is also inert, however, organic materials are associated with infection. Wood can lead to bacterial or fungal infection. Insect parts such as caterpillar hair can cause ophthalmia nodosa, and insect stings elicit an inflammatory response. **Conclusions:** Any non-organic corneal foreign bodies (gold, silver, platinum, glass, sand, stone, and graphite) may be retained safely if the removal of the foreign body results in significant scarring, which can distort the topography of the cornea. Iron, copper, and organic materials (wood and insect parts) must be removed due to their toxicity or risk of infection.

Keywords: corneal foreign body; intraocular foreign body; ocular trauma; ocular disease; ocular infection

Introduction

The cornea is an avascular, transparent tissue consisting of five layers: epithelium, Bowman's layer, stroma, descemet's membrane, and endothelium. [1] The corneal epithelium is composed of 5-7 cell layers. These epithelial cells undergo involution, apoptosis, and desquamation over 7–10 days.[1] Beneath the epithelium layer is the bowman's membrane. This membrane lies anterior to the stroma and is composed of condensation of collagen and proteoglycans.[1] Injury to the Bowman's layer cannot be healed and may result in a scar. Cornea stroma consists of keratocytes and extracellular matrix (ECM).[1] Descemet's membrane is composed of Type IV collagen and laminin; meanwhile, the endothelium is a single layer of hexagonal cells controlling the cornea's water.[1]

The cornea is vital as it contributes to the eye's refractive function and protects eye structures.[1],[2] Ocular trauma, especially corneal trauma, can interrupt this function. Corneal foreign bodies account for the second most common form of ocular trauma.[3] In adults, most cases are associated with occupational accidents frequently seen in construction and metal industry workers.[4] Foreign bodies can be found within the cornea in any layer with various foreign body materials, including metal, glass, graphite, or organic matter.[5] Corneal foreign body injuries often fail to heal if any fragments of the foreign body are left behind; however, removing deep foreign bodies may result in significant scarring, distorting the cornea's topography and disturbing vision.[6]

Determining the materials and depth of extension of corneal foreign body is essential to deciding on the management plan and the prognosis. The patient can

be observed serially if the object is considered inert, such as glass or plastic.[3],[6] This review discusses the effects of corneal foreign body materials and depth of extension.

Method

An observational literature review study used PubMed and Google Scholar databases. Those resources were used to conduct the medical literature search. The keywords searched were: corneal foreign body; metallic intraocular foreign body; iron intraocular foreign body; copper intraocular foreign body; aluminum intraocular foreign body; gold intraocular foreign body; glass intraocular foreign body; graphite intraocular foreign body; wood intraocular foreign body; insect intraocular foreign body; and caterpillar hair intraocular foreign body. All of the articles that discuss various materials of foreign body within the cornea were identified. Non-English articles were excluded. The author thoroughly reviewed all selected articles to examine corneal foreign body injury.

Review and discussion

1. Corneal foreign body depth

Foreign bodies can become stuck in the cornea at varying depths and undetected without high suspicion.[6] Corneal foreign bodies are usually removed during primary globe repair and should be removed immediately.[7] Epithelial defects caused by foreign body impregnations typically heal fast and can be tolerated without any pathogenic reaction to the cornea. Bowman's membrane defects from foreign bodies can leave a permanent scar because the Bowman cells cannot regenerate. Corneal stroma defects will result in corneal opacification because the disruption of the alignment of collagen fibers provides corneal transparency. Descemet membrane defects from foreign bodies can be regenerated if injured. Endothelium trauma by the foreign body is concerning because it suggests that the foreign body has penetrated the eye, and loss of endothelial cells can cause corneal edema.[2] Removal of foreign body within 24 hours is ideal because after this time, the foreign body may be embedded inside the stroma, and the removal becomes harder.[3]

Foreign bodies confined to the corneal epithelium are classified as superficial foreign bodies. At the same time, those buried in the corneal stroma or below are classified as deep. Superficial ones are easily recognized with a slit lamp and can be removed in one sitting. In the case of deep foreign bodies, anterior segment optical coherence tomography before the procedure will assist the surgeon in determining the penetration depth and arranging the procedure appropriately. A superficial epithelial foreign body, such as a ferrous one, can be removed using a hypodermic needle to lift it off. In contrast, the anterior stromal foreign body can be removed with forceps or by epithelial debrided with a microblade and pulling the foreign body with forceps. The removal can be done in the stromal foreign body by scrapping the superficial stroma, cutting open the tunnel using a keratome, and evacuating the foreign body using a suture needle. In case of full-thickness damage with the distal end of a foreign body in the anterior chamber, the foreign body removal using a pair of forceps to grasp the edges of the entry wound, then a jeweler or intravitreal forceps can be used to remove the foreign body after a 6 mm suture needle has helped to evert the tract's margins.[8]

2. Corneal foreign body materials

Corneal damage by a foreign body depends on the foreign body materials, size, number, location, and retained time.[9] Corneal foreign bodies can become lodged at various depths in the cornea and go initially undetected without high suspicion.[6] In many cases[10],[11],[12],[13], some foreign bodies are retained safely within the cornea and cause no reaction. These materials of the foreign bodies are inert, such as gold, silver, platinum, aluminum, glass, and graphite. Organic foreign bodies (wood, vegetable, insect part) often cause severe inflammation; meanwhile, inflammation from non-organic foreign bodies (metal, glass, graphite) depends on their materials.[9] However, foreign bodies may carry infectious agents like fungi or bacteria, especially in organic foreign bodies. Fungal and bacterial infections can lead to endophthalmitis.[6]

A. Metallic foreign body

Iron foreign body

Metallic foreign body injuries of the cornea often fail to heal if any fragments of the foreign bodies are left behind.[6] Iron can cause cell and tissue damage due to the deposition of ferritin complexes in the cellular cytoplasm, especially in the form of siderosomes.[14] This condition is known as ocular siderosis (OS).[15] There are three phases of ocular siderosis. First, a latent period occurs after injury. No clinical signs manifest during this phase; the duration varies between a few weeks and several years. Second, iron spreads within intraocular tissues with a high affinity for epithelial cells. Then, tissue degeneration occurs.[16] Ocular siderosis is divided into two types: direct siderosis and indirect siderosis. In direct siderosis, iron is deposited in the immediate neighborhood of the foreign body. Meanwhile, in indirect siderosis, the iron is diffused widely throughout the eye's tissue and causes retinal detachment or glaucoma.[17]

Ocular siderosis development and severity depend on foreign body dimensions, shape, and composition. The higher the iron content of the foreign body, the quicker siderosis develops. It also occurs more slowly if the foreign

body is encapsulated in tissues with low metabolism, such as cornea.[16] Iron will undergo partial disintegration and will be deposited in the tissue. This deposition is seen as a brown particle called a rust ring.[17] Rust rings can be left if the size is small, as they will often go away on their own, or they can be serially shaved away as the stroma regenerates. Aggressive removal of rust rings should be performed if they are located in the center of the cornea due to vision disturbance.[3] Removal of the iron foreign body also can stop siderosis progression. Early surgical removal with recent surgical advance is recommended to maintain the patient's good visual.[18]

Copper foreign body

Copper foreign bodies can also be found in ocular injuries. Copper is a component of many metal alloys, including brass and bronze.[19] Copper can ionize in the eye and deposit in many ocular structures. This condition is called chalcosis.[20] The clinical features depend on the amount of copper in the foreign body. The 85% or more copper-containing foreign body shows a generalized pattern of intraocular copper deposition, whereas the lower amount of copper shows deposition in the adjacent areas. Copper also has an affinity to be deposited along basement membranes. This affinity is shown in the Kayser-Fleischer ring, a copper deposition over the corneal descemet's membrane. This Kayser-Fleischer ring is a similar sign in Wilson disease.[19],[21] Pure copper foreign body with more than 99% copper content may cause severe inflammation and intraocular necrosis.[19] The minimum size of the copper intraocular foreign body to be localized on computerized tomography (CT) is 0.06 mm.[22] In chronic cases, chalcosis can also cause endophthalmitis. Early surgical intervention can reduce the risk of acute complications, prevent long-term damage, and maintain an excellent visual outcome.[23]

Other metallic foreign body

Unlike metals such as iron and copper, aluminum is inert, so it does not cause noticeable damage to eye tissues.[24] A plain X-ray film can help detect metallic foreign bodies, except aluminum, due to its relative radiolucency. The minimum size of the aluminum IOFB to be localized on CT is 1.5-1.8 mm.[22],[25]

Gold, silver, and platinum are almost inert too, and cause little or no reaction.[11] Gold is safe and non-corrosive, however, if it is contaminated with harmful elements, it can damage the eye.[26] Meanwhile, a foreign body of zinc can cause inflammation, which is usually chronic and non-granulomatous, however, usually, it can be tolerated by the eye. Zinc can also become encapsulated.[20],[21] Barium sulfate and zinc disulfide can be found in the core of golf balls. This foreign body may travel quickly and penetrate ocular tissue if cut into. Histologically, an amorphous mass without inflammation is present in the tissue. However, inert foreign bodies still carry the risk for intraocular damage both by their path and final position inside the eye.[20]

B. Glass foreign body

In traffic accidents, glass fragments can come from a broken spectacle lens, a shattered windscreen, or a broken driving mirror.[21] Sharp-edged glass fragments can penetrate the cornea. Glass is typically inert and does not elicit an inflammatory response. Glass can cause damage due to mechanical irritation that depends on its sharpness and mobility. Glass foreign bodies are difficult to visualize because of their transparency. Anterior segment optical coherence tomography (AS-OCT) may help determine the glass foreign body's location, depth, and extent. In the absence of infection or if it is found for several days after injury without infection, the glass may remain in the cornea, provided it is not obstructing vision and should be followed serially.[12],[21],[27],[28]

C. Sand and stone foreign body

Sand foreign bodies may come from tire explosions, which are relatively inert. These foreign bodies get embedded in the conjunctiva and cornea and can get deeper into the posterior segment. AS-OCT examination helps determine foreign sand bodies' location, monitoring, and management.[29] Stone is also generally well tolerated if it is in sterile condition. If sand or stone are found inside the eye for several days after injury and there is no inflammatory reaction, the foreign body may be left, provided it is not obstructing vision.[21] Superficial corneal foreign bodies are easy to remove, however, deep corneal foreign bodies need to be monitored and may require keratoplasty.[29]

D. Graphite foreign body

Eye injuries from writing tools most commonly occur in childhood.[9] High suspicion of foreign body injury is needed, especially in children under five years old, because penetrating injuries may present with a lack of pain, redness, or pertinent history. Pencil lead comprises 66% graphite, 26% aluminum silicate, and 8% paraffin. The white paraffin can elicit a nonallergic reaction, however, the most common reaction is due to the slow breakdown of graphite pencil lead into small pieces that disperse and release T-cells and macrophages, which release cytokines and growth factors.[30] Intrastromal graphite is inert and generally does not cause any eye reaction for years.[9],[13],[30] This intrastromal inertness is attributed to the inflammation confined to a region of injury because of a compartmentalization reaction. Meanwhile, silica and carbon can cause granulomatous reactions, while organic wood can cause fungal infection.[30]

E. Organic Foreign Body

Organic substances such as vegetables, wood, and insect parts are poorly tolerated. This substance may cause infection, and it must be promptly removed.[31],[32] Vegetative foreign bodies usually contain microorganisms, which can lead to endophthalmitis and excessive inflammation, so removing vegetative foreign bodies is urgent.[33]

Wood foreign body

The most prevalent plant intraocular foreign body is wood.[17] This foreign body injury may occur in forestry, wood, and garden workers. This foreign body can lead to bacterial or fungal infection, especially if the fragment is not removed promptly. The infected wood may cause an acute pyogenic inflammation resulting in localized abscess, endophthalmitis, or fulminating panophthalmitis.[17],[31] The high infection rate is attributed to the wood surface pores and organic and vegetative matter characteristics, which provide bacterial growth medium.[31] Wood induces a less severe response that can lead to panophthalmitis and blindness at worst or, at best, a scar that impairs vision permanently.[17] Intraocular wood foreign body detection is challenging because it contains carbon and is not visible on conventional X-ray may not image well on computed tomography (CT) or magnetic resonance imaging (MRI).[31]

Caterpillar hair (setae)

Thousand microscopic hairs are the airborne weapon of caterpillars.[34] There are many ways to make contact with the caterpillar hair. It can be through direct contact with the caterpillar, contact with its larva cocoon, interwoven, or wind-borne setae.[35] The most often affected sites by setae were the conjunctiva, cornea, iris, anterior chamber, vitreous, and rarely the retina.[36] Intraocular inflammation can be brought on by caterpillar hair or setae, and deep intracorneal setae have a higher likelihood of causing intraocular penetration. Because of its unidirectional barbs and sharp, caterpillars (setae) may go toward the base.[37] The effects of caterpillar hair are associated with its toxicity, locomotion, and allergic immunoglobulin e-mediated reaction to various caterpillar proteins. The toxicity is due to the caterpillar's urticating toxin. The caterpillar's venom gland attached to the hair shaft is the source of the toxin, which is delivered through the hollow shaft shown in the electron micrographs.[34],[35] Ophthalmia nodosa, a severe granulomatous inflammatory reaction, may be caused by caterpillar hair.[35]

Insect sting foreign body

Insect sting foreign bodies may cause ocular responses from mild, local reactions in the conjunctiva and cornea to severe, extensive reactions involving other structures (lens, optic nerve, extraocular muscle).[38] Sting effects include corneal epithelial defect corneal infiltrate to anterior uveitis.[39] This sting can elicit an inflammatory response due to a reaction to the microbial pathogens, mechanical effect from its material, and/or chemical effect from its venom. Variations of venom composition among different bee species contribute to the degree of response.[38] Superficial stings in the corneal foreign body should be removed, however, embedded profound stings that do not cause inflammation can be left. In a case of retained insect sting in corneal endothelium resulting in toxic keratitis, the patient was treated with topical antibiotics and steroids. The sting persisted on the endothelium, however, the patient was symptomatically better and showed no inflammation.[39]

The effects of the corneal foreign body depend on the foreign body materials, size, number, location, and time retained. Generally, the materials is divided into organic (plant and insect parts) and non-organic (metal, glass, sand, graphite) parts. The usually metallic foreign body may cause complications related to its intraocular toxicity; meanwhile, organic foreign body is associated with a higher risk of endophthalmitis.[6],[40]

Iron-containing foreign bodies can develop iron deposition in the cornea, called ocular siderosis.[14],[15],[16] Ocular siderosis may be asymptomatic in its first development phase, lasting from a few weeks to several years.[16] This is consistent with He et al.[41], who reported a case of retained iron foreign body that is asymptomatic for 15 years until the patient undergoes a MRI scan, which is contraindicated in patient with any metallic foreign body or surgical devices. The foreign iron body in the cornea will undergo partial disintegration and be deposited as a brown particle called a rust ring.[17] Deposition of yellow-brown particles (rust) has occurred in the retention of iron corneal foreign bodies in some reported cases.[42],[43] Copper corneal foreign body can be ionized and also be deposited in the cornea.[19] This is consistent with Salman et al.[44], who reported intense corneal staining in a patient with corneal brass bullet casing injury which is copper-containing foreign body. Copper has an affinity to be deposited along basement membranes that shows as a Kayser-Fleischer ring, which is a deposition of copper over corneal descemet's membrane. Ritu et al.[45] reported that a broken copper wire was retained in the deep corneal stroma for four hours, leading to Kayser Fleischer ring formation.

Nevertheless, other metallic foreign bodies, such as gold, silver, and platinum, are almost inert and cause little or no reaction.[11] Retained gold foreign bodies are reported in many cases, especially within the cornea with various depths. These gold foreign bodies are retained safely within the cornea.[26],[46] Glass foreign bodies are typically inert, too. Many retained intrastromal corneal

glass foreign body cases reported that the glass did not elicit an inflammatory response within months and years of close follow-up.[12],[28] Sand is another foreign body that is relatively inert. Momoh et al.[29] and Rathi et al.[47] reported multiple retained corneal sand foreign bodies in the cornea that do not cause any long-term damage to the eye. Meanwhile, graphite corneal foreign bodies are retained safely in many cases.[13],[48] However, Wang et al.[49] reported a graphite intraocular foreign body that is inside the conjunctiva, and it is simulating melanoma. It is thought that the 30 years of chronic inflammation and other pencil chemical component contents may lead to inflammatory granuloma formation.

On the other hand, foreign organic bodies such as vegetables, wood, and insects are usually associated with infection.[31],[32] However, in a corneal wooden foreign body reported by Sharma et al.[50], the woods were retained for three days and did not cause infiltration or hypopion formation before surgical removal. After three days of retained wood in the cornea, topical antibiotics were given to the patients.[50],[51] Insect parts also can be found inside the cornea; it is usually poorly tolerated because it may lead to infection.[31] Ophthalmia nodosa is an ocular manifestation caused by caterpillar hair in the eye. This variable manifestation includes unspecific conjunctivitis, keratitis, uveitis, viritis, or endophthalmitis. This is consistent with Remy et al.[34], who reported a caterpillar hair in the epithelial and corneal stroma, leading to corneal edema, conjunctival chemosis, and eyelid edema. Corneal foreign body is usually related to occupational accidents in adults. High toxicity materials of the foreign body, such as iron and copper, must be removed immediately to prevent a reaction to the eye. Any organic corneal foreign body should be removed because it carries the risk of infection, and some materials (insect parts) may contain venom.

Determining the depth of extension of the corneal foreign body is important because it will affect the management decision and the prognosis. Defect of foreign body trauma within corneal stroma usually will cause corneal opacification, and the removal of foreign body can be done by using a forcep after opening the foreign body tract with the needle.[2],[8] This is consistent with Darade et al.[52], who reported a case of grass blades inside the corneal stroma that caused edematous stroma. The foreign body was successfully removed by using a 26-gauge needle to expose the foreign body tracts. Then, the loosened foreign body was removed with McPherson forceps.[52] Meanwhile, Sharma et al.[50] also reported a deep corneal stromal wooden foreign body removed using vitreoretinal forceps after opening the foreign body tract with a 26-gauge needle. Luckily, infiltrate or hypopyon were not developed.

Conclusions

Foreign bodies can penetrate every layer of the cornea. The defect in each corneal layer will result in different reactions and need different management. This is why it is essential to determine the depth of foreign body extension. On the other hand, the foreign body materials also result in various reactions to the cornea. These foreign body materials are divided into non-organic materials (such as metal, sand, stone, and graphite) and organic materials (such as wood or insect parts). Some metallic foreign bodies can cause toxic effects to the eye (Iron may cause ocular siderosis, and copper may cause chalcosis), and both iron and copper can be deposited in the cornea; however, other metallic foreign bodies, such as gold, silver, platinum, and aluminum, cause little or no reactions. Glass is inert and causes no inflammatory reaction. Sand and stone are relatively inert if they are in sterile condition. Graphite is also relatively inert, however, needs more in-depth research. Meanwhile, organic foreign bodies such as wood and insect parts usually are associated with infection. Other variables of a corneal foreign body, such as retained time and size, need more research because these variables contribute to the foreign body effects in the eye.

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