Assessment of deeply embedded metallic corneal foreign bodies by anterior segment optical coherence tomography

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ABSTRACT

Purpose: This study aimed to present the characteristics of deeply embedded metallic corneal foreign bodies using anterior segment optical coherence tomography (AS-OCT).

Materials and Methods: The study included one eye of 163 patients who presented with a deeply embedded, metallic corneal foreign body to an ophthalmological emergency clinic. All patients were assessed using anterior segment photographs and AS-OCT to determine the characteristics of the foreign bodies and wound features. All foreign bodies were removed, and wound debridement was performed.

Results: The study population included 160 men and 3 women with a mean age of 32.1±8.4 years. The mean diameter of the foreign body and burn halo were 776.8±21.1 µm and 1299.6±54.2 µm, respectively. The mean areas of the foreign body and burn halo were 0.41±0.14 mm^2 and 0.81±0.32 mm^2. The mean foreign body penetration depth was 141.0±26.0 µm. During follow-up, there was no corneal foreign bodies-related keratitis in any patients. A decrease in visual acuity was observed in all patients with central cornea involvement. In these cases, the mean final visual acuity was 20/25 (20/20 to 20/32).

Conclusion: This study showed that AS-OCT can define characteristics of corneal wounds associated with metallic foreign bodies. By detecting the diameter and depth of the foreign body in AS-OCT images, the size of the corneal scar that will occur after the injury can be predicted. Being able to make this estimation is critical, especially in centrally located foreign bodies, as it will reduce visual acuity.

Keywords: Anterior segment optical coherence tomography, cornea, metallic foreign body, corneal scar.

INTRODUCTION

Corneal foreign bodies are one of the most common ocular emergencies. Organic materials such as wood, glass, or sang are better tolerated by the cornea, while metallic foreign bodies such as iron are more difficult to tolerate. In particular, metallic corneal foreign bodies are commonly seen in industry workers who do not use eye protection. The foreign bodies may lead to corneal edema, inflammation, and blurred vision based on their localization as well as corneal nephelion and vascularization in the long term.[1] Thus, corneal foreign bodies should be removed timely using appropriate methods.[2-4]

In general, a slit-lamp microscope is used for examination and intervention in these patients.[4,5] Patient's history and biomicroscope examinations are adequate for diagnosis. However, they may not be sufficient to determine penetration depth and the optimal method for managing the foreign body in some cases.[6-8] The failure to display corneal tissues has been overcome by using optical coherence tomography (OCT) for anterior segment imaging (AS-OCT).[4] In the literature, publications emphasize the value of AS-OCT in the diagnosis and management of various corneal foreign bodies.[9] Deep corneal foreign bodies require more careful handling due to the risk of perforation in particular.[10] Under certain conditions, foreign body type and depth cannot be clearly discerned on slit-lamp examination, and inappropriate interventions to remove deep corneal

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foreign bodies may result in corneal perforation.[11] The AS-OCT provides an image of a corneal foreign body and information regarding its localization, size, and depth.[5]

In our study, we aimed to determine the characteristics of the foreign bodies and wound features after excluding corneal perforation using AS-OCT.

MATERIALS AND METHODS

This prospective cross-sectional study included the traumatic eyes of 184 patients presented with the metallic corneal foreign body to the ophthalmological emergency clinic between April 2019 and January 2022. The study included patients with a deeply embedded corneal metallic foreign body extending beyond the epithelium. Since the metallic corneal foreign body did not exceed the corneal epithelium in 21 patients, these patients were not included in the study, and the study was performed on 163 patients. All included patients were consecutively selected, and all types of corneal metallic foreign bodies were included in this study. Patients diagnosed with corneal perforation due to metallic foreign bodies and patients who did not complete follow-up after three months were excluded from the study. In addition, pediatric patients, patients who had undergone any previous ocular surgery, and those with a progressive corneal disease such as keratoconus, which may cause different responses in corneal wound healing, were also excluded. The Kayseri City Hospital Ethics Committee, University of Health Sciences, approved the study protocol. All patients or legal guardians gave written informed consent. Tenets of the Helsinki Declaration conducted the study.

A comprehensive ophthalmological examination was performed in all patients, including the measurement of best-corrected visual acuity. In addition, they were assessed using anterior segment photographs and AS-OCT to determine the characteristics of the foreign bodies and wound features. The foreign body was classified into 5 regions based on corneal localization: central (3 mm), nasal (120º), temporal (120º), superior (120º), and inferior (120º) (Fig. 1). After flushing the conjunctival sac using normal saline, topical proparacaine hydrochloride (Alcaine, 0.5%, Alcon) was administered. After achieving topical anesthesia, the foreign body was removed using a 27-G insulin needle with a bent tip (90°). Corneal debridement was performed by 45 degrees crescent bevel up the ophthalmic microsurgical knife. In all patients, a topical antibiotic and 24-hours eye closure were prescribed over 7 days. The diameters of the foreign body and the surrounding burn halo, areas of the foreign body and the surrounding burn halo, as well as foreign body penetration depth, were measured on AS-OCT images (Figs. 2A-D). The patients were classified according to the number of previous scars as those with 1, 2, and 3 previous scars. Control visits were scheduled in weeks 1 and 2 and months 1, 2, and 3 in all patients. During the recovery process, the scar size that developed at the wound site was assessed in all control visits.

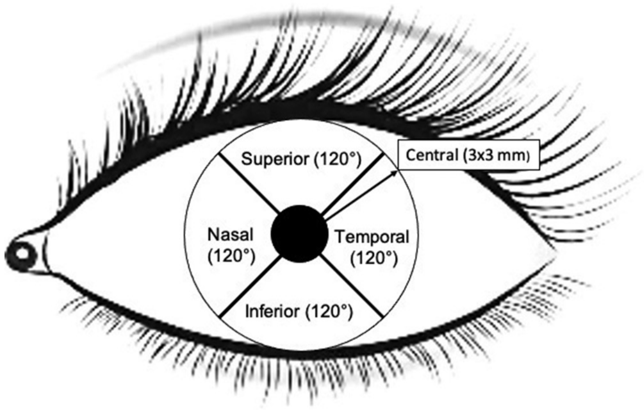

Figure 1: *The illustration shows that the cornea is divided into five different regions to determine the localization of corneal foreign bodies.*

Statistical analyses

All statistical analyses were performed using IMB Mac OS SPSS version 26.0 (SPSS, INC., Chicago, IL). The continuous variables are presented as mean ± standard deviation. The associations between corneal scar size and foreign body diameter, corneal burn diameter, area of foreign body, area of the corneal burn, and penetration depth were assessed at a 3-month follow-up using Spearman's correlation coefficient. A p-value <0.05 was considered statistically significant.

RESULTS

The study population included 160 men and 3 women with a mean age of 32.1 ± 8.4 years. The metallic corneal foreign bodies showed hyper-reflective features with hypo-reflective shadowing effects, and their anterior and posterior border signals were clearly identified. The corneal burn area around the foreign body was observed as hyper-reflective. The mean diameter of the foreign body and the surrounding burn halo were 776.8 ± 21.1 µm and 1299.6 ± 54.2 µm, respectively. The mean areas of the foreign body and the surrounding burn halo were 0.41 ± 0.14 mm^2 and 0.81 ± 0.32 mm^2. The mean foreign body penetration depth was 141.0 ± 26.0 µm (Fig. 2D). Previous corneal foreign

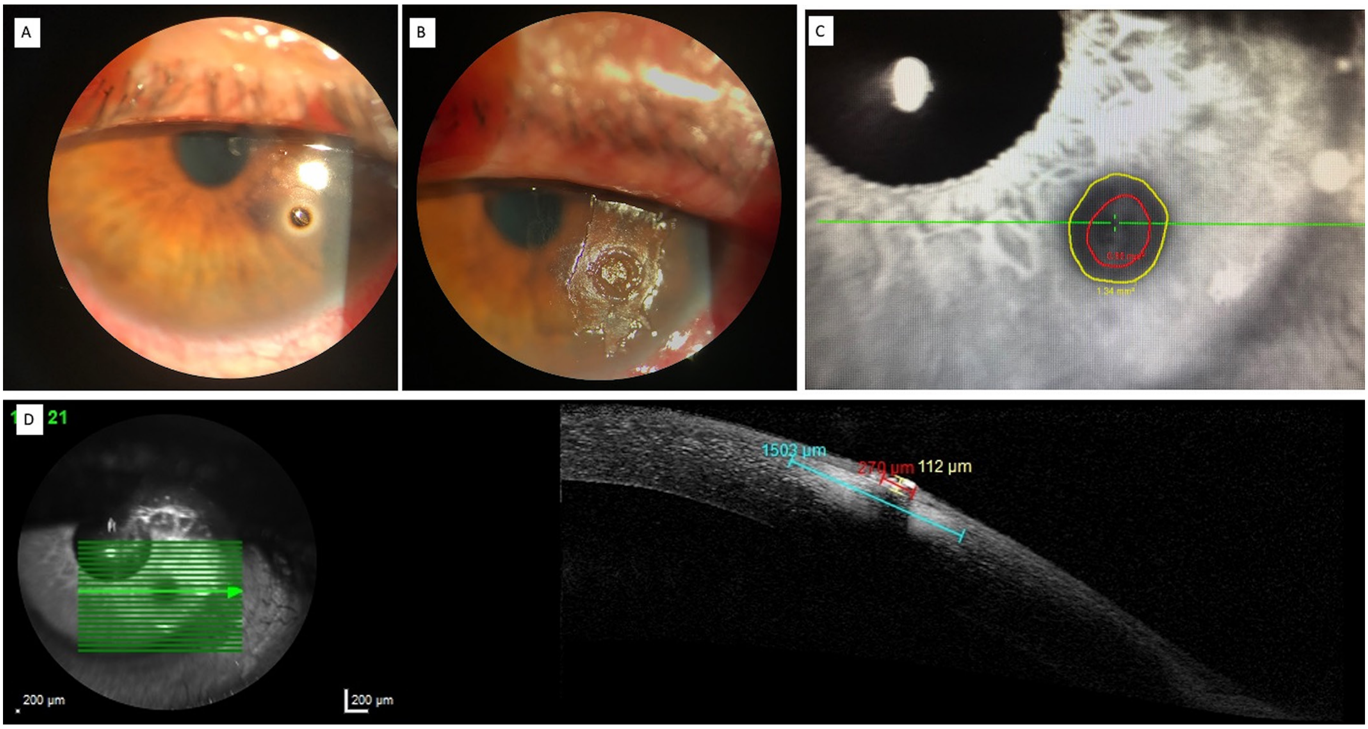

Figure 2: *The foreign body appearance at the time of diagnosis (A) and after removal of the foreign body (B) is observed in the anterior segment photographs of one of our patients. The anterior segment optical coherence tomography (AS-OCT) of the same patient shows the foreign body area and the corneal burn surrounding the foreign body area (C). The measurements on the AS-OCT scan demonstrate the foreign body diameter, the diameter of the corneal burn covering the foreign body, and the corneal depth of the foreign body (D).*

body-related scars were observed in 41(25.1%) patients. The number of corneal scars was one in 24 (14.7%) patients, two in 11 (6.7%) patients, and three in 6 (3.7%) patients. Demographic and clinical characteristics of the patients as well as anterior segment optical coherence tomography findings, are summarized in Table 1. Foreign bodies' localizations in the cornea were temporal in 62 (38.0%) patients, inferior in 44 (27.0%) patients, nasal in 29 (17.8%) patients, superior in 18 (11.1%) patients, and central in 10 (6.1%) patients (Table 1). There was a decrease in visual acuity in patients with central cornea involvement. The mean final visual acuity in these patients was 20/25 (20/20 to 20/32). Among these patients, Spearman's correlation analyses showed strong negative correlations between AS-OCT findings and decreased visual acuity (Table 2). In the correlation analysis, strong positive correlations were observed between corneal scar and foreign body diameter ($r=0.888$, $p<0.0001$), corneal burn diameter ($r=0.804$, $p<0.0001$), foreign body area ($r=0.874$, $p<0.0001$), corneal burn area ($r=0.788$, $p<0.0001$) and corneal penetration depth ($r=0.710$, $p<0.0001$).

Table 1: *Demographic and clinical characteristics of the patients as well as anterior segment optical coherence tomography findings.*

Variable	**Patients (n=163)**
Gender (F/M)	3 (1.8%)/160 (98.2%)
Age	32.1 ± 8.4 years
Foreign body diameter	776.8 ± 21.1 µm
Burn halo diameter	1299.6 ± 54.2 µm
Foreign body area	0.41 ± 0.14 mm^2
Burn halo area	0.81 ± 0.32 mm^2
Foreign body penetration depth	141.0 ± 26.0 µm
Foreign body localization	
▪ **Central (3mm)**	10/163 (6.1%)
▪ **Nasal (120º)**	29/163 (17.8%)
▪ **Temporal (120º)**	62/163 (38.0%)
▪ **Superior (120º)**	18/163 (11.1%)
▪ **Inferior (120º)**	44/163 (27.0%)
One previous scar	24/163 (14.7%)
Two previous scars	11/163 (6.7%)
Three previous scars	6/163 (3.7%)

Table 2: *Correlation between decreased visual acuity and anterior segment optical coherence tomography findings.*

			Foreign body diameter	Burn halo diameter	Foreign body area	Burn halo area	Foreign body penetration depth	Best-corrected visual acuity
Spearman's rho	Foreign body diameter	Correlation Coefficient	1.000	0.900**	0.966**	0.860**	0.881**	-.0859**
		Sig. (2-tailed)	.	0.0004	<0.0001	0.001	0.001	0.001
		N	10	10	10	10	10	10
	Burn halo diameter	Correlation Coefficient	0.900**	1.000	0.924**	0.809**	0.745*	-0.746*
		Sig. (2-tailed)	0.0004	.	0.0001	0.005	0.013	0.013
		N	10	10	10	10	10	10
	Foreign body area	Correlation Coefficient	0.966**	0.924**	1.000	0.808**	0.815**	-0.767**
		Sig. (2-tailed)	<0.0001	0.0001	.	0.005	0.004	0.010
		N	10	10	10	10	10	10
	Burn halo area	Correlation Coefficient	0.860**	0.809**	0.808**	1.000	0.711*	-0.911**
		Sig. (2-tailed)	0.001	0.005	0.005	.	0.021	0.0002
		N	10	10	10	10	10	10
	Foreign body penetration depth	Correlation Coefficient	0.881**	0.745*	0.815**	0.711*	1.000	-0.752*
		Sig. (2-tailed)	0.001	0.013	0.004	0.021	.	0.012
		N	10	10	10	10	10	10
	Best-corrected visual acuity	Correlation Coefficient	-0.859**	-0.746*	-0.767**	-0.911**	-0.752*	1.000
		Sig. (2-tailed)	0.001	0.013	0.010	0.0002	0.012	.
		N	10	10	10	10	10	10

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed)

DISCUSSION

Corneal foreign body accounts for 30.8% of all ocular injuries, comprising the second most common cause of eye injuries.[2] In routine ophthalmology practice, the approach to the corneal foreign body is critical. The corneal foreign bodies should be removed immediately to minimize infection and wound site injury.[1] Lim et al. described a technique for removing the corneal foreign body, which involves bending a 25 G needle to 90°, improving the safety and simplicity of debridement.[12] In our study, a 27 G insulin needle with a bent tip was used to remove foreign bodies and debridement. In the standard care of metallic corneal foreign bodies, removing foreign bodies without leading trauma and antibiotic prophylaxis is recommended.[13] Mechanical trauma during the removal of the foreign body may lead to an epithelial defect in the cornea.[14] The cornea exhibits re-epithelization towards the center of a defect in cases with epithelial defects.[15-17] Antibiotic prophylaxis prevents secondary infection, facilitating corneal re-epithelization. We applied antibiotic therapy to all the patients included in the study, and we did not find keratitis related to corneal foreign bodies in any of the patients during the follow-up. The oxidation of metallic foreign bodies can lead to rust deposits in the cornea.[18] The rust ring is critical in metallic foreign bodies with central localization, leading to vision loss. Debridement helps remove loosely adherent epithelium and promotes healing from a healthy margin.[19] Also, cleansing the wound site and lacking residual foreign body is essential for the healing process.

Debridement following the removal of a foreign body can be a correct approach since a rust ring may occur if the corneal injury results from a metallic foreign body. Debridement will allow the removal of both rust residues around the foreign body and necrotic tissues. Thus, re-epithelization will be faster from remaining healthy epithelium, and secondary infections and rust ring formation will be prevented. In our study, we applied debridement to all patients after removing the deeply located metallic foreign bodies. As a result, we did not see any corneal rust ring in the third-month follow-up of any patient. In a study, Stepp MA et al. investigated the healing process of corneal injuries. The study using different species and trauma models showed that debridement wounds were rapidly re-epithelized in rats, emphasizing that debridement wounds are optimal for cell migration, cell proliferation, re-innervation, and naïve immune response.[20]

AS-OCT, a non-invasive method that provides high-resolution images from various depths of the ocular anterior segment, offers an advantage in the examination of corneal foreign bodies because it is reliable and reproducible, has rapid image acquisition, and enables the depth of the foreign body to be determined.[11] The AS-OCT reflectivity will change based on the type of foreign body. Metallic foreign bodies show high anterior reflectivity.[21] In our study, the corneal foreign body's size, localization, and depth were determined, and morphological changes were assessed in the cornea using AS-OCT.

In ophthalmology departments dealing with ocular trauma, AS-OCT is highly valuable for diagnosis and follow-up in various types of ocular injury.[22] As a result, there are many studies in the literature using AS-OCT. In their experimental study, Armarnik et al. analyzed the distinctive features of each material by scanning the reflections of seven different foreign bodies deeply inserted into the cornea in AS-OCT.[11] Celebi et al. applied the appropriate treatment method by detecting the depth of the foreign body with the help of AS-OCT and excluding the perforation in a patient with a corneal foreign body that could not be fully evaluated due to corneal edema.[5] Ono et al. used AS-OCT to non-invasively observe the wound shape and follow the healing process of the cornea in a case of corneal perforation due to chestnut capsule.[23] Goel et al.[24], Akbaş et al.[25], and Wang et al.[9] have also published studies using AS-OCT to describe the characteristics of different corneal foreign bodies and their OCT findings.

Uyar et al., in a study that included 63 patients with superficial metallic corneal foreign body, examined the corneal wound site change two months after removing the corneal foreign body using AS-OCT.[26] Unlike in our study, we followed the corneal scar formation using AS-OCT in the 3 months follow-up of 163 patients with deeply embedded metallic foreign bodies beyond the corneal epithelium. As a result, we found a direct correlation between foreign body diameter, area, depth, and scar size. We think that the strong positive correlations between the diameter and depth of the foreign body and the dimensions of the corneal scar may be a guide in these patients' treatment and follow-up process. Contrary to this study, which reported that most of the foreign bodies were located in the center of the cornea, in our study, foreign bodies were mainly found in the temporal cornea (62/163).

If a foreign body and resultant scar are localized at the central visual axis, they impair the quality of life in the patient.[18] Our study also observed that foreign bodies with central localization impaired acuity and quality of vision. The mean final visual acuity in these cases was 20/25 (20/20 to 20/32). We observed previous scar formation in 41 of 163 patients due to corneal foreign bodies. We explained the importance of using eye protection to all our patients. We especially emphasized the importance of protective equipment for our patients with old scars and recommended that the employer request the appropriate equipment.

CONCLUSION

In conclusion, the localization, size, and depth of deeply embedded metallic corneal foreign bodies can be determined by AS-OCT. Again, AS-OCT is extremely valuable in detecting corneal perforation early and definitively in deeply located corneal foreign bodies. In this study, we found a direct correlation between the diameter of the foreign body and the surrounding burn halo, areas of the foreign body and the surrounding burn halo and depth of the foreign body, and the size of the corneal scar that developed after injury. Based on this connection, it is recommended to plan the treatment and follow-up process by predicting the size of the corneal scar with the help of AS-OCT in patients with corneal foreign bodies.

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