

LAWN TRIMMER-RELATED OPEN-GLOBE INJURIES IN TAIWAN

JIA-RONG ZHANG, MD,* TSUNG-CHENG HSIEH, PhD,† FANG-LING CHANG, MD,*
MING-SHAN HE, MD*‡

Purpose: Work-related ocular trauma remains the leading cause of unilateral visual impairment worldwide. Many preventable work-related ocular injuries continue to occur, even at home. This study describes the characteristics, surgical techniques, and prognostic factors of lawn trimmer-related open-globe injuries in eastern Taiwan.

Methods: This was a retrospective, consecutive case series study. Slit-lamp biomicroscopy, dilated funduscopy, and orbital computed tomography (CT) images were collected.

Results: Twenty-six eyes of 26 patients were enrolled in the study. Fifteen patients (57.7%) had an intraocular foreign body (IOFB). The IOFB was metallic in 13 cases and glass and stone in the other 2 cases. Seven IOFBs (46.7%) were retained in the anterior chamber, 7 (46.7%) in the posterior segment, and 1 (6.7%) in the intracanal space. Univariate analysis showed that the presence of IOFB trended toward the development of endophthalmitis; however, this was not statistically significant (hazard ratio, 2.25; 95% confidence interval 0.35–14.61; $P = 0.658$). Eleven patients had metallic IOFBs noted on CT scans with metal artifacts, whereas two patients had small metallic IOFBs without metal artifacts. One patient had a glass IOFB mimicking metal artifacts on the CT scan. In one case, CT failed to reveal the IOFB, and an intralenticular metallic foreign body was incidentally found intraoperatively.

Conclusion: Our study provides a broad characterization of lawn trimmer-related open-globe injuries. The informative and diverse findings of IOFBs on CT scans will help clinicians detect and recognize IOFBs more precisely and perform the surgery without causing further damage.

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Work-related ocular trauma remains the leading cause of unilateral visual impairment worldwide. Open-globe injury is an ocular emergency, and work-related eyeball rupture requires immediate addressal. Most patients with work-related ocular trauma are young and male; thus, the trauma and poor prognosis significantly affect patients and their families. Despite

the emphasis on industrial safety awareness and using personal protective equipment, many preventable work-related ocular injuries continue to occur, even at home. In cases of lawn mower injuries, the most frequently injured body part is the hand/finger, followed by the lower extremity, with the head/neck being the least frequently injured.¹ By contrast, the head, specifically the eye, was the most frequently injured body part when using a lawn trimmer.² Open-globe injuries are encountered more frequently while operating lawn trimmers than other industrial tools, owing to the material from the blade or ground accidentally shooting toward the eye at high speeds, leading to devastating injuries of the eye.

Eastern Taiwan is famous for its beautiful landscape and the Taroko National Park. Behind the scenes, many garden workers are required to keep their beauty. The agricultural population accounts for 14.7% to 20.87% of the total workforce, which is significantly higher than that in other metropolises,

From the *Department of Ophthalmology, Buddhist Tzu Chi General Hospital, Hualien, Taiwan; †Institute of Medical Sciences, Tzu Chi University, Hualien, Taiwan; and ‡Department of Ophthalmology and Visual Science, Tzu Chi University, Hualien, Taiwan.

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J.-R. Zhang and T.-C. Hsieh contributed equally to this study.

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Reprint requests: Ming-Shan He, MD, Department of Ophthalmology, Buddhist Tzu Chi General Hospital; Tzu Chi University, No. 707, Sec. 3 Chung-Yung Road, Hualien, 970 Taiwan; e-mail: mingshanher@gmail.com

such as Taipei. The rural population accounts for 0.17% to 1.0% of the city's total employment. Hence, lawn trimmer-related ocular injuries are more common in eastern Taiwan.

Because no known study has broadly characterized open-globe injuries associated with lawn trimmers, we aimed to describe the characteristics, surgical techniques, and prognostic factors of lawn trimmer-related open-globe injuries in eastern Taiwan.

Materials and Methods

This retrospective study was approved by the Institutional Review Board of the Research Ethics Committee, Hualien Tzu-Chi Hospital, Buddhist Tzu-Chi Medical Foundation. This study was conducted according to the guidelines of the Declaration of Helsinki. Data were obtained from the tertiary medical transfer center, Hualien Tzu Chi Hospital, from 2009 to 2018. All patients with open-globe injuries related to lawn trimmers were included. Initial visual acuity was assessed using the Snellen chart and converted to logarithm of the minimum angle of resolution (logMAR) units for further analysis. Findings of the slit-lamp biomicroscopy, dilated funduscopy, and B-scan ultrasound were collected in cases where the retinas were obscured. Orbital computed tomography (CT) images were obtained using multidetector CT scanners with a 2.5-mm slice thickness along the transaxial direction with the sections parallel to the optic nerve along a line from the inferior orbital rim to the upper pinna. The coronal sections with a 1- to 2.5-mm slice thickness from the globe to the dorsum sellae were obtained. The same radiologist reviewed the CT images in the bone and soft tissue windows with obfuscated patient data. Subsequent management was based on CT imaging and ophthalmologic examinations. All data, including the types of injury, sex and age distribution, surgical techniques, associated complications, and further visual recovery results, were reviewed. Statistical analysis of the data was performed using SPSS (version 17.0; SPSS Inc, Chicago, IL). Continuous data are presented as mean \pm SD, and categorical data are presented as n (%). We calculated the Pearson correlation coefficient to evaluate the relationship between the time interval to surgical intervention and initial logMAR with the final logMAR. We reported the odds ratio (OR) to evaluate the association between the predictive factors and endophthalmitis. Fisher's exact test was performed to compare the preoperative and postoperative best-corrected visual acuity. The predictive factors for visual outcomes were studied using univariate analysis (Fisher's exact test

or the Mann–Whitney *U* test). Statistical significance was set at $P < 0.05$.

Results

Twenty-eight patients diagnosed with lawn trimmer-related open-globe injuries between January 2009 and December 2018 were retrospectively reviewed. Two patients who were lost to follow-up after discharge were not enrolled in the study. Twenty-six eyes from 26 patients (24 male and 2 female) were enrolled in the study; none wore safety goggles while trimming, except 1 patient who was injured while driving past a functioning lawn trimmer. Among the enrollments, 18 patients had full-thickness corneal lacerations, whereas 8 had scleral lacerations. The average time from injury to surgical intervention was 2.62 days (1–6 days). The demographic data and patient characteristics of the patients are listed in Table 1. The patients had an average follow-up of 12.6 \pm 15.7 months (range: 0.5–69.8 months).

Four patients had endophthalmitis at the initial presentation. Three patients developed endophthalmitis after the primary surgical intervention. After the surgery, endophthalmitis developed in 1 patient (14.3%) despite prophylactic intravitreal injection (IVI) of antibiotics with ceftazidime (2.2 mg/0.1 mL) and vancomycin (1 mg/0.1 mL) and in 2 patients (13.5%) without prophylactic IVI of antibiotics. Six patients received prophylactic IVI, with no signs of infection occurring afterward. The incidence rate of endophthalmitis did not differ significantly between patients with (1 of 7, 14.3%) or without (2 of 15, 13.3%) prophylactic IVI of antibiotics ($P > 0.999$). Univariate analysis of risk factors for endophthalmitis revealed that endophthalmitis was not associated with the site of laceration, traumatic cataract, vitreous hemorrhage (VH), retinal detachment (RD), or the location of intraocular foreign body (IOFB) (Table 2). However, among the patients with IOFB, 5 (5 of 15, 33.3%) had endophthalmitis, whereas 2 (2/11, 18.2%) had endophthalmitis without IOFB. Univariate analysis showed that the presence of IOFB trended toward the development of endophthalmitis; however, this was not significant (HR, 2.25; 95% confidence interval 0.35–14.61; $P = 0.658$).

The initial visual acuity was the only factor related to improved visual acuity of at least two lines of the Snellen chart after surgery. An initial visual acuity of less than logMAR 2.3 (hand movement) improved more than an initial visual acuity greater than logMAR 1.2 (Snellen equivalent: 20/300). On analysis, corneal or scleral laceration, traumatic cataract, VH, RD,

Table 1. Patients' Demographic Distribution, Characteristics, and Outcome

No.	Sex/ Age	Time Interval to Surgery, Days	Site of Laceration	Size, Material, and Location of IOFB	Other Clinical Findings	Postoperative RD	Prophylactic IVI of Antibiotics	Endophthalmitis	Initial VA	Final VA	Follow-up, Months
1	M/58	5	Cornea	2 × 1 mm, metal, PS	Retinal break; VH		+		LP (+)	CF	5.2
2	M/48	1	Cornea	4 × 3 mm, glass, AC			+		0.05	0.5	2.9
3	M/73	7	Cornea						CF	0.2	3.4
4	M/61	5	Cornea						0.2	0.6	8.8
5	M/64	1	Sclera	3 × 1 mm, metal, PS	RD				CF	0.6	6.1
6	M/65	1	Cornea		VH				CF	CF	7
7	M/58	1	Cornea	2 × 1.5 mm, metal, PS	VH, retinal break				HM	CF	3.2
8	M/57	1	Sclera				+		HM	0.1	69.9
9	M/45	6	Cornea	1 × 0.5 mm, metal, PS				+ (post OP)	CF	0.1	5.7
10	M/53	1	Sclera			+			CF	CF	0.5
11	M/54	1	Cornea					+ (post OP)	LP (+)	NLP	12
12	M/57	14	Sclera	5 × 1 mm, stone, PS	VH, retinal break				CF	0.025	3.7
13	M/50	3	Cornea	Failed to remove, PS	RD, hemorrhagic CD,	+		+ (at presentation)	LP (+)	NLP	12.7
14	M/50	3	Sclera	Failed to remove, intraconal	Scleral penetration, VH		+		HM	CF	3
15	M/59	1	Cornea	3.6 × 6 mm, metal, AC					0.1	0.5	2.6
16	M/35	1	Cornea	21 × 10 mm, metal, AC	VH		+	+ (post OP)	LS+	NLP	34.6
17	M/38	1	Sclera						NLP	Evisceration	17.8
18	F/59	1	Cornea						CF	HM	9.2
19	F/57	1	Sclera					+ (at presentation)	0.2	0.8	10.8
20	M/71	2	Sclera		Retinal break	+			CF	CF	7.7
21	M/67	2	Cornea	1.8 × 2.7 mm, metal, AC			+		0.3	1.0	1.7
22	M/63	6	Cornea	2 × 1 mm, metal, AC				+ (at presentation)	CF	0.025	0.8
23	M/47	1	Cornea	3 × 3 mm, metal, intralesional	Traumatic cataract				LP (+)	0.1	25.2
24	M/42	1	Cornea	3 × 0.5 mm, metal, AC				+ (at presentation)	0.1	0.08	7.8
25	M/47	1	Cornea				+		0.05	0.5	19.7
26	M/60	1	Cornea	4 × 1 mm, metal, PS	VH, RD				HM	0.05	9.8

AC, anterior chamber; CD, choroidal detachment; CF, counting fingers; LP, light perception; HM, hand movement; NLP, no light perception; OP, operation.

presence or the location of IOFB, endophthalmitis, or interval from injury to surgical intervention revealed no significant association with the final visual acuity. Nevertheless, the initial logMAR was correlated with the final logMAR in the Pearson correlation evaluation ($r = 0.742$; $P < 0.001$) (Table 3). Fifteen patients (57.7%) had a final visual acuity equal to or less than 20/200, 3 (10.7%) had RD at the initial presentation, and another developed RD after the primary surgery. The retina was reattached in three patients after pars plana vitrectomy alone or in combination with a scleral buckle.

Fifteen patients (57.7%) had IOFB or an intraorbital foreign body (FB). The IOFB was metal in 13 cases and glass and stone in the other 2. Twenty (80%) foreign bodies penetrated the eye through the cornea and 3 through the sclera. Seven IOFBs (46.7%) were retained in the anterior chamber, 7 (46.7%) in the posterior segment (PS), and 1 (6.7%) penetrated the globe and was retained in the intraconal space. Eleven patients had metallic IOFB noted on CT scans with metal artifacts, and 2 patients had small metallic IOFB noted on CT scans without metal artifacts (Figure 1). One patient had a hyperdense IOFB with significant scatter and shadow artifacts on the CT image; however, it was revealed to be glass (Figure 2). The size of the foreign bodies measured on the CT scans was larger than the actual size. A metallic IOFB was identified on CT scan in one patient with a normal radiograph of the skull (Figure 3). One patient (passerby) underwent evisceration because of a large scleral laceration of more than 6 clock hours with retinal and

uveal prolapse, whereas the remaining 25 patients underwent primary repair. An intralenticular metallic FB was incidentally found intraoperatively in a case where the skull radiograph and CT failed to reveal the IOFB (Figure 4).

Intraocular foreign bodies in the anterior chamber were removed with forceps. Of the seven PS IOFBs, three were removed directly through pars plana vitrectomy and intraocular forceps. The metallic IOFB was successfully extracted through the original corneal wound with an external electromagnet in the three cases where the VH obscured the operative view. One patient (No. 14) had a scleral perforation with a small metallic FB retained in the intraconal space, which was irremovable because of inaccessibility, with no signs of orbital infection developing during the follow-up. One patient (No. 13) initially presented with endophthalmitis and extensive retinal and hemorrhagic choroidal detachment. Despite the repair of the corneal laceration, the IOFB embedded in the retina could not be removed because of poor visibility of the fundus, and the eye finally developed phthisis.

Discussion

Ocular trauma occurring at work or home remains the leading cause of unilateral visual impairment worldwide, especially in open-globe injuries associated with IOFB, resulting in devastating visual consequences. While construction work is associated with closed-globe damage, agricultural work is more

Table 2. Analysis for the Factors Which Might Cause Endophthalmitis

Factors		Endophthalmitis		Odds Ratio (95% Confidence Interval)	P
		Yes	No		
Cornea laceration, n (%)	Yes	6 (33.3%)	12 (66.7%)	3.50 (0.35–35.40)	0.274
	No	1 (12.5%)	7 (87.5%)		
Sclera laceration, n (%)	Yes	1 (12.5%)	7 (87.5%)	0.29 (0.03–2.89)	0.274
	No	6 (33.3%)	12 (66.7%)		
Traumatic cataract, n (%)	Yes	5 (27.8%)	13 (72.2%)	1.15 (0.17–7.74)	0.639
	No	2 (25.0%)	6 (75.0%)		
Vitreous hemorrhage, n (%)	Yes	1 (11.1%)	8 (88.9%)	0.23 (0.02–2.30)	0.199
	No	6 (35.3%)	11 (64.7%)		
Retinal detachment, n (%)	Yes	1 (25.0%)	3 (75.0%)	0.89 (0.98–10.30)	0.713
	No	6 (27.3%)	16 (72.7%)		
IOFB in AC, n (%)	Yes	3 (42.9%)	4 (57.1%)	2.81 (0.44–18.06)	0.263
	No	4 (21.1%)	15 (78.9%)		
IOFB in PS, n (%)	Yes	2 (25.0%)	6 (75.0%)	0.87 (0.13–5.82)	>0.999
	No	5 (27.8%)	13 (72.2%)		
IOFB, n (%)	Yes	5 (33.3%)	10 (66.7%)	2.25 (0.35–14.61)	0.658
	No	2 (18.2%)	9 (81.8%)		
Time interval to surgical intervention, days	Mean (SD)	2.71 (2.36)	2.58 (3.24)	—	0.692

AC, anterior chamber.

Table 3. Analysis for the logMAR Versus Each Factor That Might Affect the Final logMAR Value

Factor	Statistic	Presence of the Corresponding Factor		<i>P</i>
		Yes	No	
Cornea laceration	Mean (SD)	1.351 (1.011)	1.490 (0.990)	0.807
Sclera laceration	Mean (SD)	1.490 (0.990)	1.351 (1.011)	0.807
Traumatic cataract	Mean (SD)	1.522 (0.803)	1.105 (1.332)	0.196
Vitreous hemorrhage	Mean (SD)	1.580 (0.794)	1.295 (1.085)	0.426
Retinal detachment	Mean (SD)	2.075 (0.699)	1.270 (0.992)	0.112
IOFB in AC	Mean (SD)	1.043 (1.028)	1.523 (0.967)	0.279
IOFB in PS	Mean (SD)	1.460 (0.874)	1.370 (1.047)	0.821
Endophthalmitis	Mean (SD)	1.829 (1.181)	1.234 (0.887)	0.279
Time interval to surgical intervention	Pearson correlation	-0.059		0.774
Initial logMAR	Pearson correlation	0.742		<0.001

AC, anterior chamber.

likely to cause open-globe injuries.³ Because our institution is the only tertiary medical referral center in eastern Taiwan, we encounter numerous work-related ocular injuries every year, especially in agricultural laborers, with a considerable number of them related to lawn trimmer use.

This study reports a consecutive case series of patients with lawn trimmer-related open-globe injuries. There were 7 cases (7 of 26, 26.9%) of endophthalmitis after open-globe injury, including 5 (5 of 15, 33.3%) with IOFB and 2 (2 of 11, 18.2%) without IOFB. Univariate analysis showed that the presence of IOFB trended toward the development of endophthalmitis. However, this was not statistically significant (HR: 2.25; 95% confidence interval 0.35–14.61; $P = 0.658$). Similar to previous studies, the incidence rate of endophthalmitis with retained IOFB was higher than that of open-globe injury without IOFB.^{4,5} The overall incidence rate of endophthalmitis was higher than that of other traumatic open-globe injuries, ranging from 0% to 16.5%.⁴ This may be attributed to higher chances of soil and plant contamination when using a lawn trimmer, showing that rural trauma is a risk factor for posttraumatic endophthalmitis.⁶ Unlike other studies, the interval of injury to surgical intervention was not significantly different between the endophthalmitis (mean: 2.71, SD: 2.36

days; $P = 0.692$) and nonendophthalmitis (mean: 2.58, SD: 3.24 days; $P = 0.692$) groups, even when a delayed wound closure of more than 24 hours was usually considered to be a risk factor for the development of endophthalmitis.⁷ One study reported that delayed IOFB removal did not increase the posttraumatic endophthalmitis rate.⁸ The average time from injury to surgical removal of the IOFB was 39 days (median: 21 days, SD: 81 days). It was assumed that the heat generated from the high speed sterilizes the FB before it enters the eyes. All eyes underwent emergent primary repair and received systemic antibiotic treatment. Nevertheless, this study's background was extraordinary, and immediate emergent repair and prompt removal of IOFB are considered important factors in reducing the incidence of posttraumatic endophthalmitis.⁹ The early removal of IOFB promotes anatomical success and reduces the proliferative vitreoretinopathy rate.¹⁰

The use of prophylactic intraocular antibiotics in cases of open-globe injury is still under debate,⁶ yet no correlation of improved visual prognosis was found.¹¹ In our study, after excluding 4 patients who presented with endophthalmitis at the initial encounter, the incidence of endophthalmitis with prophylactic IVI of antibiotics (1 of 7, 14.3%) did not differ from the incidence of endophthalmitis without prophylactic IVI of antibiotics (2 of 15, 13.5%; $P > 0.999$). The

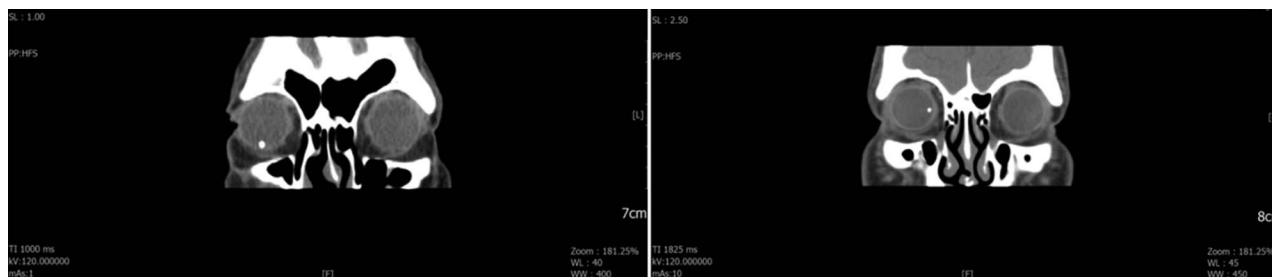
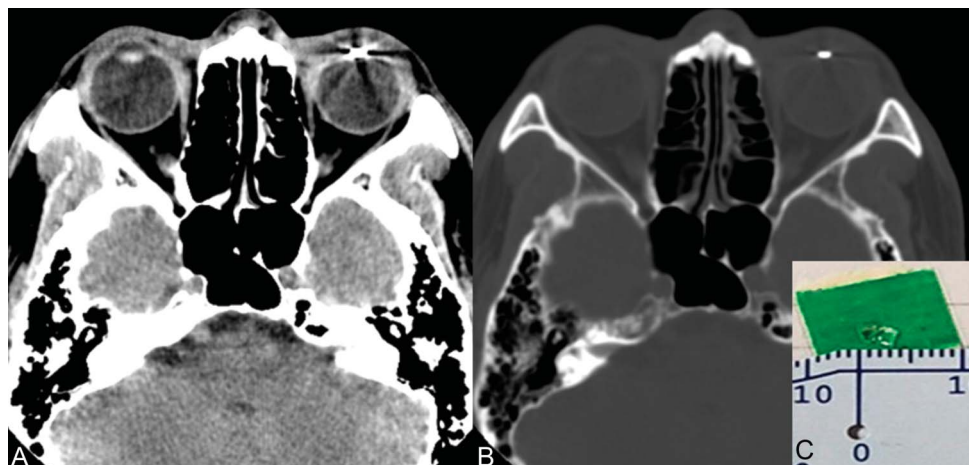


Fig. 1. Two patients with small metallic IOFB without metal artifact on CT scans.

Fig. 2. Hyperdense IOFB with significant scatter and shadow artifacts that mimic metal material on CT scans revealed to be a glass fragment on removal. The brain window (A) shows a significant metal artifact, which decreases markedly but still exists in the bone window (B). Extracted FB (C) composed of glass material, measuring 4×3 mm.



effect of IVI was not remarkable, perhaps because of the limited number of cases. Although there are no definite guidelines, previous studies show that open-globe injury with retained IOFB would benefit from prophylactic IVI of antibiotics.^{5,6}

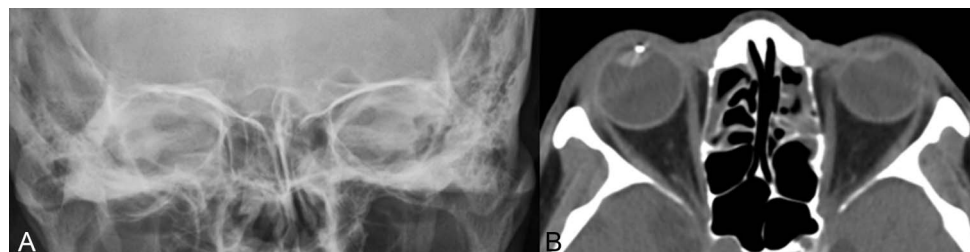
More than half of the patients in our study (15 patients, 57.7%) had a final visual acuity worse than 20/200, indicating devastating consequences of the injury. We analyzed each factor that might affect the final visual acuity to reveal that corneal or scleral laceration, traumatic cataract, VH, RD, the presence or location of IOFB, endophthalmitis, or the interval from injury to the surgical intervention had no significant association with the final visual acuity. Nevertheless, the initial logMAR was correlated with the final logMAR in the Pearson correlation evaluation ($r = 0.742$; $P < 0.001$).

Apart from endophthalmitis, a critical concern regarding lawn trimmer injury is the presence of IOFBs. Magnetic resonance imaging is contraindicated for metallic IOFBs because of the potential to dislodge the FB and cause further destruction. Plain radiography is helpful in cases with radiopaque FBs only and will not detect radiolucent IOFBs such as wood or glass. CT provides more reliable information and is the preferred imaging modality. However, the metal streak artifacts make it difficult to estimate the accurate size and the actual location of metallic IOFB.

One way to measure the size more precisely is by using the bone window rather than the soft-tissue window setting (Figure 2).

In general, metallic FBs cause a more devastating impact on injuries and are more frequently encountered. Metal streak artifacts are prevalent in CT and particularly pronounced in high atomic number metals such as iron, silver, or lead. Beam hardening and scattering result in dark streaks between the metal, with surrounding bright streaks.¹² Nevertheless, there are some inconsistencies and disagreements between different studies regarding the CT findings of IOFBs.^{13,14} Different alloys with variable compositions can also prevent ophthalmologists from applying these findings clinically. In our study, we found some notable and invaluable results. Two cases with high attenuation IOFBs without metal streak artifacts in the CT scan were presumed to be nonmagnetic. However, these were revealed to be metallic FB during the removal with an electromagnet (Figure 1). The cause of such magnetic IOFBs not showing significant metal artifacts in CT images may be due to the relatively small size (2×1 mm and 0.5×1 mm, respectively) and the material being steel instead of iron, which causes fewer scatter artifacts.¹⁴ Glass is usually presented as hyperdense without artifacts on CT.¹⁵ Nevertheless, in one patient (No. 2) with a hyperdense IOFB with significant scatter and shadow artifacts in

Fig. 3. Normal skull anterior-posterior radiograph (A), a hyperdense intraocular foreign body (metal material) found on CT scans (B).



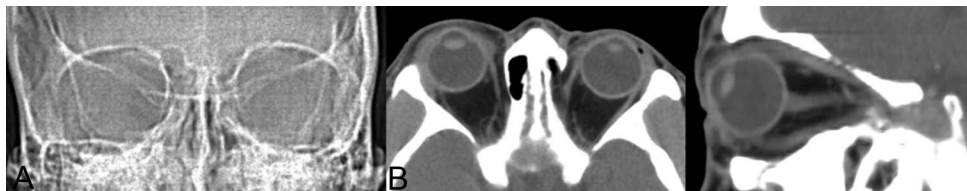


Fig. 4. Skull x-ray (A) and CT scans (B) fail to reveal the IOFB; an intralenticular metallic FB in the right eye is incidentally found intraoperatively.

CT, the IOFB was believed to be metallic but was found to be a broken spectacle glass fragment on removal (Figure 2). A possible cause influencing the detection of glass mimicking metal in CT is its variable composition because of differences in manufacturing, especially during metallization. The high attenuation coefficient values of such glass materials are likely to produce scatter and shadow in CT.¹⁵ The irregular shape of the glass fragment can also predispose the intensification of the scatter and shadow artifacts in CT (Figure 2).

One case (No. 24) with intralenticular FB was not detected in CT or clinical examination preoperatively (Figure 4). This patient presented with a central corneal penetrating wound with a traumatic cataract. During surgical intervention, a 2- × 1-mm intralenticular metallic FB was incidentally found. The intralenticular FB not being detected during the CT scan could be due to its smaller size compared with the 2.5-mm slice thickness of CT. Other studies also mention FBs being undetectable when they were embedded in the lens.^{16–19} Similarly, these FBs were very small and were at times encapsulated, thus losing their magnetic properties or becoming radiolucent to x-rays.¹⁷ As a result, ophthalmologists should always consider the possibility of intralenticular FBs and the potentially ruptured posterior capsule or the FB dropping into the PS intraoperatively.

The surgical strategy to remove IOFB must be individualized depending on the size, location, and magnetism. A PS IOFB may not be visualized well because of corneal laceration, active intraocular hemorrhage, or occasionally too large to grasp with intraocular forceps. We strongly suggest the use of an external electromagnet in such circumstances. A magnetic IOFB can be easily removed through the original wound without creating another larger passage to remove it even in the absence of a clear view after judging the metallic and magnetic properties of the IOFB with the CT images. Although relatively clinically uncommon and small cohort scales about lawn trimmer-related open-globe injuries limit the statistical power in our study, we have still presented some information that would benefit ophthalmologists in understanding the characteristics and limitations of CT scans, handling IOFB properly, and making comprehensive and individualized surgical plans.

In summary, despite the progressive improvement in medical technology and industrial and personal safety awareness, lawn trimmer-related open-globe injuries still cause catastrophic damage and continue to occur. It is mandatory to wear personal protective equipment during trimming, and passersby should keep their distance to prevent accidental ocular injuries. Our study provides a broad characterization of lawn trimmer-related open-globe injuries and the diverse findings of IOFBs on CT scans, which would help clinicians detect and recognize IOFBs more precisely and perform the planned surgery without causing further damage.

Key words: intraocular foreign body, lawn trimmer injury, open-globe injury, work-related ocular trauma.

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