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RESEARCH

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Application of intraorbital magnets in the removal of magnetic intraorbital foreign bodies

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Abstract

Background To explore a new surgical method for treating intraorbital foreign bodies.

Materials and methods From January 2015 to December 2023, 35 patients with magnetic intraorbital foreign bodies, representing 35 affected eyes, were admitted to the Department of Ocular Trauma of Hebei Eye Hospital; these patients included 32 males and 3 females aged from 2 to 63 years (average: 36.97 ± 14.28 years). In the preoperative examinations and postoperative routine follow-ups, the basic conditions of the patients' eyes were ascertained through visual acuity examination using an international standard chart, slit–lamp microscopic examination, anterior- and posterior-segment examinations with anterior slit–lamp lenses, and intraocular pressure measurements. The foreign bodies were properly localized on axial and coronal CT scans. All patients had deep, orbital, magnetic foreign bodies and underwent extraction using a strong magnet.

Results Among the 35 patients (35 eyes), the foreign body was successfully removed from 34 eyes, with a success rate of 97.1%. In one patient, the foreign body had been retained in the posterior location of the orbit for nearly 30 years, with organizational encapsulation, and was not removed, considering the risk of damaging the globe and optic nerves. None of the patients experienced postoperative complications, such as decreased visual acuity, excessive intraorbital haemorrhage, aggravated limitation of eye movement, or intraorbital infection.

Conclusion Foreign body removal using a strong magnet is the optimal surgical procedure for treating deep intraorbital metallic foreign bodies.

Keywords Intraorbital magnet, Magnetic intraorbital foreign body, CT scan

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Introduction

Open ocular trauma is a leading cause of blindness. These conditions are characterized by full-thickness injury of the eyewall caused by blunt or sharp objects, including penetrating injuries, lacerations, and intraocular foreign bodies [1], which account for approximately 16% of all injuries in this category [2]. Intraorbital foreign bodies are commonly metallic or vegetal [3, 4], with iron objects being relatively common. If these foreign objects remain unmanaged in the complicated intraorbital environment, with delicate interwoven nervous, vascular, and muscle tissues, various complications, such as loss of vision, tissue damage, infection, and ferruginous disorders, can occur [4, 5]. Depending on its size, shape, and location, an intraorbital foreign body can lead to a range of complications and various clinical outcomes [3]. Thus, the key to managing this condition is timely removal of the foreign object. However, compared with superficial intraorbital foreign bodies, it is more difficult to access and expose foreign bodies in deeper locations through surgery [6, 7]. No satisfactory operative procedures have been developed for these foreign bodies. Currently, mainstream methods remove foreign bodies by probing for the foreign body along the wound channel via an enlarged incision. Accessing a deep intraocular foreign body extraocularly via the lesion is difficult because of the deep location. In such situations, traditional surgical procedures would require cutting 1–2 extraocular muscles or a lateral orbitotomy [8, 9], which would increase the risk of further damage to ocular tissues and vision if not performed properly. Failure to remove foreign bodies can lead to serious physical and mental damage to patients. In this context, Dr Jia Jinchen of Hebei Eye Hospital designed and developed a series of constant ophthalmic magnets that can be used to extract magnetic intraorbital foreign bodies with magnetic attraction in hard-to-reach locations. The product has been satisfactorily applied in several clinical cases of intraorbital foreign bodies. The present paper reviews and summarizes cases in which we have applied our magnet-based procedure since 2015.

Materials and methods

General materials

We systematically reviewed 35 cases of magnetic intraorbital foreign bodies (1/1/2015-12/31/2023), representing 35 affected eyes, that were treated in the Department of Ocular Trauma of Hebei Eye Hospital, including 32 males and 3 females aged from 2 to 63 years (average: 36.97 ± 14.28 years). The causes of injuries were as follows: industrial accidents, 17 cases; domestic work, 4 cases; falling from bikes/motorbikes, 2 cases; and unknown, 12 cases. The foreign bodies lodged in posterior locations after passing through the eyelid in 21 cases and through the eyeball in 14 cases. Thirty-two patients presented for emergency surgical treatment 2 h–7 d postinjury, and only 3 patients had chronic foreign bodies; these patients presented to the hospital 7 months, 9 months, and 30 years after the injury. Before the procedure, the patients and their families were informed about the operation in detail and signed informed consent forms. This clinical trial was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Hebei Eye Hospital (Ethics Approval Number: 2024LW06). The inclusion criterion for patients was a magnetic intraorbital foreign body as suggested by medical history, physical signs, and radiographic results. The exclusion criteria were as follows: (1) the case data were incomplete; (2) the foreign body was located in the conjunctiva, cornea or eyeball; (3) the patient had a previous eye disease or eye surgery history affecting vision; or (4) the patient had a severe systemic disease (e.g., cardiovascular, respiratory, digestive, neurologic, endocrine, or genitourinary disease).

Ophthalmic examination

In the preoperative examinations and postoperative routine follow-ups, the basic conditions of the patients' eyes were ascertained through visual acuity examination using an international standard chart, slit-lamp microscopic examination, anterior- and posterior-segment examinations with anterior slit-lamp lenses, and intraocular pressure measurements. The foreign bodies were properly localized on axial and coronal orbital CT scans. During the scan, the patient was instructed to look straight ahead because eye position deviations would produce large errors.Anteroposterior and lateral X-ray scans were also performed for large foreign bodies to ascertain the size and shape. According to the nature of the object and the density of the foreign body on orbital CT, the foreign body was preliminarily judged to be a magnetic foreign body.

Design of the intraorbital magnet

The intraorbital magnets used were designed on the basis of the anatomy of the intraorbital space, the positional relationship between the globe and orbital wall, and the physical properties of the magnets. These NdFeB (neodymium-iron-boron) magnetic devices have straight- and elbow-shaped magnetic rods with a diameter of 6 mm attached to a metal handle. The magnetic head was measured to have a remanence of up to 4500 Gausses (G), with a minimum attractable weight > 250 g. The magnetic rod can withstand repeated high-pressure steam sterilization (205.8 kPa, 132 ℃–134 ℃, for 4–5 min) without any significant loss of magnetism (Fig. 1, A).

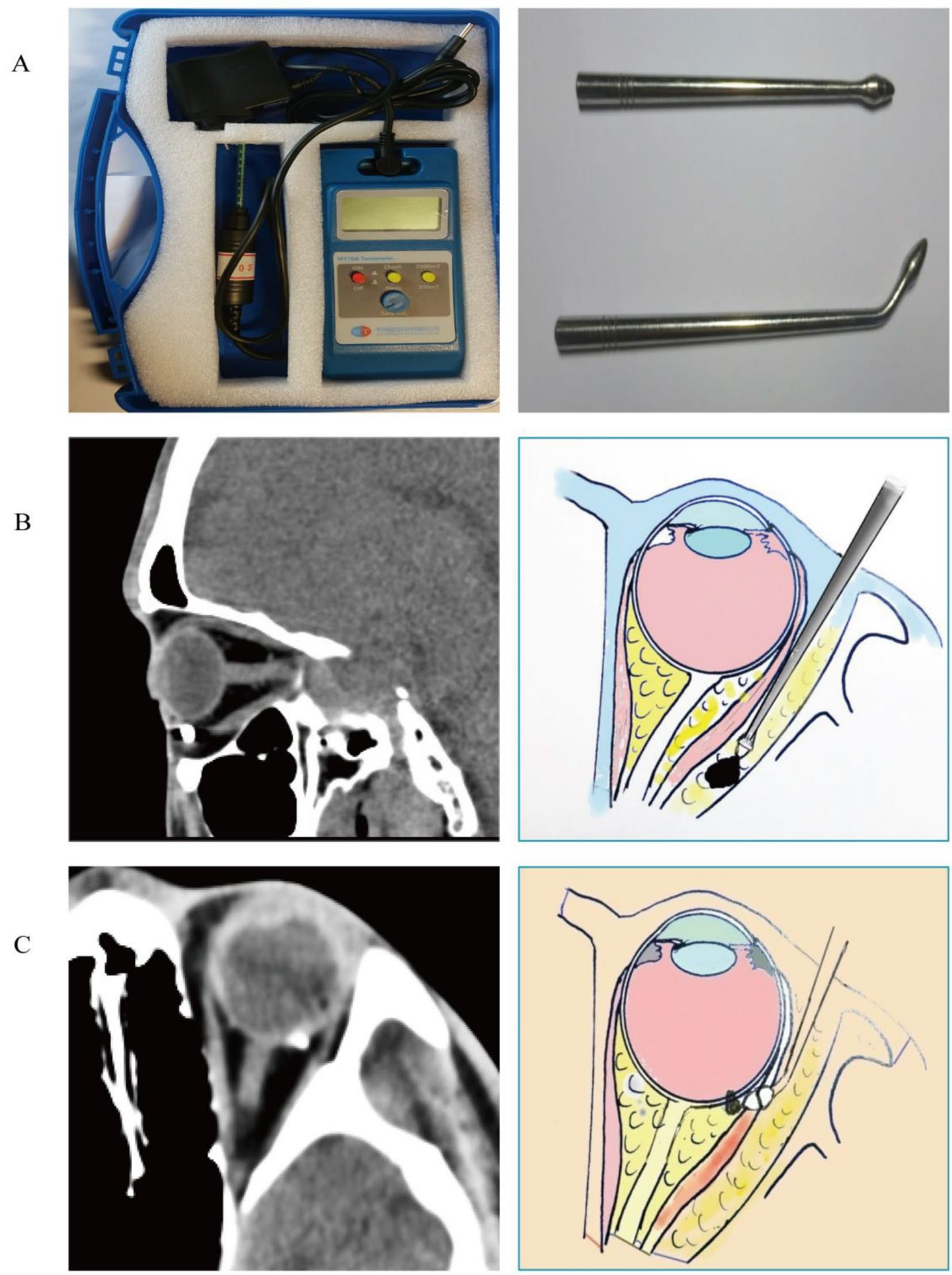
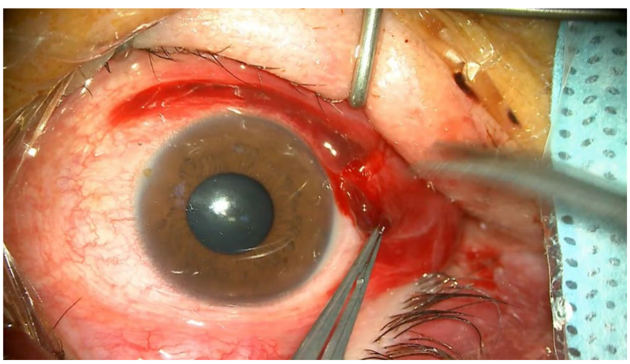


Fig. 1 **A**. Design of the intraorbital magnet. **B-C**. Surgical method for orbital foreign body removal

Operation procedures

The foreign bodies were extracted by probing along the wound channel using a straight magnet as the standard. For foreign bodies that entered the orbit through the eyelid, the magnet was inserted into the fresh wound after the tissues were gently separated from within the wound channel using vascular forceps. Wounds that were too small for the magnet rod to be inserted were enlarged along the texture of the skin. Foreign bodies lodged in the posterior muscles of the eye were probed and extracted with an elbow-shaped magnet from beneath the conjunctiva after being separated from the eyeball wall via a surgical incision. For foreign bodies associated with penetrating ocular trauma with highly exposed posterior wounds, suturing was performed, followed by vitreoretinal surgery in stage II of the treatment plan. For chronic intraorbital foreign bodies, the magnet was inserted by making an incision either in the skin or the conjunctiva on the basis of the location of the foreign body and dissecting the tissues bluntly with vascular forceps in the direction of the foreign body; additionally, any granulation tissues that encapsulated the foreign body were dissected. The patients were followed up to determine the success rate of foreign body extraction and occurrence of any postoperative complications (Fig. 1, B-C).The surgical video is as follows.



Data analysis

Patients with severe and complex ocular trauma usually have poor visual acuity, which cannot be measured using standard chart scores. Therefore, the subjects' visual acuity was evaluated in 5 grades as follows: grade 1, visual acuity ≥ 0.5; grade 2, $0.1 \leq$ visual acuity < 0.5; grade 3, $0.05 \leq$ visual acuity < 0.1; grade 4, counting fingers (CF) to < 0.05 by the standard chart score; and grade 5, hand motion (HM) perception, light perception (LP), and no light perception (NLP) [4]. According to the World Health Organization criteria, grade 3 visual impairment was defined as severe visual impairment, and grades 4 and 5 visual impairment were defined as blindness [10]. The quantitative data are summarized as the number of patients (n) and percentage (%).

Results

Patient overview

Intraorbital foreign bodies were more common among males than females, with a ratio of 10.7:1 (32 males and 3 females). The main causes of injury included industrial accidents (17/35, 48.6%), domestic work (4/35, 11.4%), falling from bikes/motorbikes (2/35, 5.7%), and unknown causes (12/35, 34.3%). The most common route of entry was via the eyelid (21/35, 60%), followed by the cornea (10/35, 28.6%). Eyelid injuries (eyelid lacerations and traumatic ptosis) were observed in 20 (57.1%) patients, conjunctival injuries in 9 (25.7%), ocular penetrating injuries in 9 (25.7%), orbital fractures in 2 (5.7%), and extraocular muscle damage in 2 (6.9%). The preoperative visual acuity of 33 patients was recorded, with the exception of 2 uncooperative children who were not testable. Among these patients, 14 (14/33, 42.4%) had grade 1 visual acuity, and nine (9/33, 27.3%) had grade 2 visual acuity. One (1/33, 3%) and nine (9/33, 27.3%) patients reported severe visual impairment (grade 3) and blindness (grade 5), respectively.

Orbital CT scan results

All patients underwent orbital CT, and all foreign bodies were detected at a rate of 100%. The results revealed that the foreign body was located outside the intraorbital muscle cone in 21 eyes and within the muscle cone in 14 eyes.

Foreign body extraction results

Among the 35 patients (35 eyes), the foreign body was successfully removed from 34, with a success rate of 97.1%. In one patient, the foreign body had been retained in the posterior location of the orbit for nearly 30 years, with organizational encapsulation, and was not removed, considering the risk of damaging the globe and optic nerves. The size of the removed foreign bodies ranged from $1 \times 1 \times 1$ mm to $20 \times 2 \times 2$ mm.

Postoperative complications

None of the patients experienced postoperative complications, such as decreased visual acuity, excessive intraorbital haemorrhage, aggravated limitation of eye movement, or intraorbital infection.

Case study

A male patient, aged 61 years, presented to the hospital with bleeding, pain, and loss of vision 5 h after he had been injured in the left eye with a marble. Ocular examination after admission revealed that the impacted eye had no light perception. An irregular laceration approximately 1.0 cm long on the upper eyelid of the left eye was observed under the slit lamp. A full-thickness laceration was found in the temporal sclera, with multiple sites of collapsed uvea and vitreous gel. The orbital CT scan suggested potential globe rupture and retention of a metallic foreign body in the posterior left eye. As shown by the orbital CT image (Fig. 2A), the marble penetrated the eyelid of the man and grazed the globe while travelling obliquely at a high velocity until it lodged in the muscle cone of the eye, damaging the optic nerve and causing loss of vision. Although removing a foreign body is imperative, the severity of the injury poses a great challenge for ophthalmologists as far as how to remove the foreign body while minimizing secondary damage during surgery. The traditional surgical procedure requires

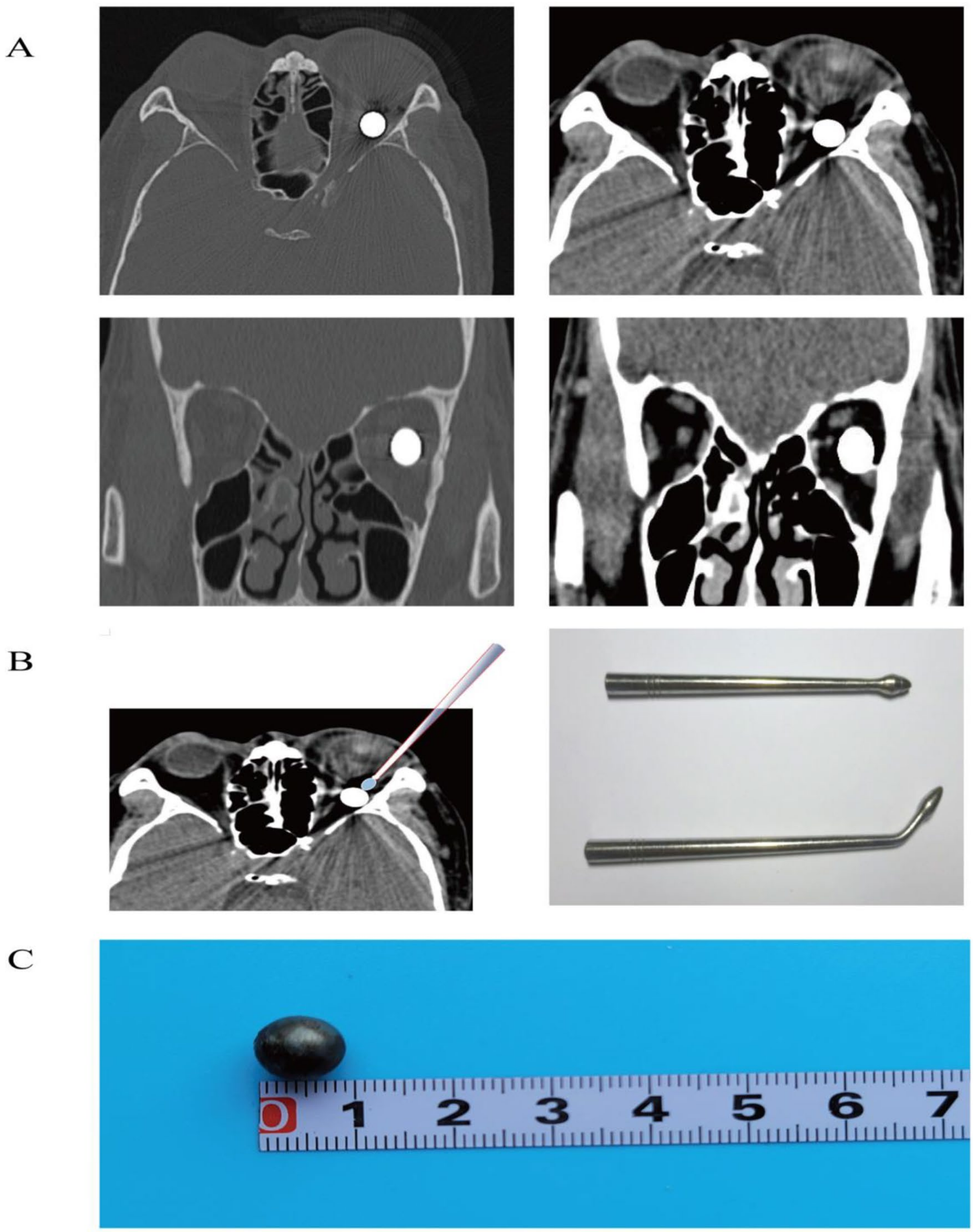


Fig. 2 (**A**) Orbital CT image. (**B**) We used a long, thin magnetic rod to probe for and remove the foreign body directly through the wound channel. (**C**) The diameter of the marble we extracted during the operation was approximately 9 mm

lateral orbitotomy, in which an incision is made at the corner of the outer canthus through the skin into the ligaments, and the foreign body is removed via the artificial opening in the outer wall of the orbit. This method can leave large surgical wounds and affect the appearance of the patient. However, if the surgical criteria are not met, prolonged foreign body retention may cause serious complications, including infection, which can also cause great physical and psychological damage to patients. In such cases, intraorbital magnets have emerged as a superior solution. When the patient presented to the A&E department, he was placed under general anaesthesia.

The intraorbital foreign body was removed after proper debridement and suturing of the wound (Fig. 2, B). Finally, the eyelid was debrided and sutured. We used a long, thin magnetic rod to probe for and pull out the foreign body directly through the wound channel, and the entire procedure was completed within minutes (Fig. 1, B). The diameter of the marble extracted during the surgery was approximately 9 mm (Fig. 2, C). On the day following the operation, the patient's left eye remained unperceptive towards light, while the eyelid and conjunctival wounds were well aligned with the sutures properly in place. Corneal oedema and Descemet's membrane folds were observed, with a large amount of blood present in the anterior chamber. The remaining intraocular tissues were not visible, and the intraocular pressure measured by finger palpation was recorded as T-1. The patient's postoperative indicators were stable, with no signs of infection. The patient underwent a second operation 14 days later, during which pars plana vitrectomy with artificial vitreous balloon placement and silicone oil filling in the left eye was performed. The patient was discharged in a generally good state, with normal eyeball morphology and eye pressure.

Discussion

Intraorbital foreign bodies are caused by foreign bodies lodging in intraorbital structures with penetrating injuries to periorbital tissues. In severe cases, they can cause visual impairment, ocular motility disorders, and damage to the appearance of the eye [4]. Among intraorbital foreign bodies, metallic foreign bodies are relatively common. Prolonged retention of metallic foreign bodies in the eye can lead to metallic toxicity in the eyeball, vascular tissues, and optic nerves, resulting in visual function disorders. Timely removal of the foreign body is therefore essential for the management of this condition [4, 5, 11]. However, there is a lack of satisfactory operational procedures that can effectively remove magnetic foreign bodies stuck in deep intraorbital locations. Lateral orbitotomy is sometimes adopted as an expedient option in these situations [8], where the lateral tissues of the orbit need to be incised and dissected to create access to the foreign body. This procedure is relatively complicated and causes large surgical wounds, in which the lower lateral canthus is often left with obvious surgical scars. Some surgeons resort to nasal endoscopic foreign body removal for limited surgical indications [12, 13]. Another alternative that has emerged in recent years is the use of C-arm X-ray imaging to localize foreign bodies. However, for smaller or migrating foreign bodies, this procedure still falls short of providing a reliable solution to access and gain hold of the foreign body [14]. Therefore, a more advanced method that can remove the foreign body effectively while maintaining intraoperative injuries at a minimum level is needed to avoid serious postoperative complications.

The key to removing intraocular foreign bodies is precise localization, which provides an important reference for the choice of surgical procedure. The current standard of foreign body localization is to use axial and coronal orbital CT scans with sagittal reconstruction to determine the site of the foreign body and its relative position within the eyeball wall and orbital soft tissue, such as the extraocular muscle and optic nerve. Larger metallic foreign bodies have obvious radial artefacts in CT images, and their localization can thus be achieved with image windowing [15]. All patients in this study underwent preoperative CT localization, and the foreign body was successfully removed in 34 of 35 patients, with the exception of one patient in whom the foreign body had been retained in the posterior location of the orbit for nearly 30 years, with organizational encapsulation, and was not removed. These results demonstrated that preoperative localization was accurate and that orbital CT was the key to the diagnosis and treatment of intraorbital magnetic foreign bodies.

Magnets have proven to be among the most effective tools for the removal of magnetic intraorbital foreign bodies. However, in traditional surgical methods, the incumbent ophthalmic magnet products could not necessarily reach deep intraorbital locations, and the intraorbital tissues and eyeballs in the vicinity could also increase the difficulty of removing the foreign body. The strong intraorbital magnet developed by our team is made of a third-generation rare earth magnetic material, neodymium-iron-boron (Nd-Fe-B), which has strong magnetism. The diameter of the magnetic head is 6 mm, allowing it to easily enter deep orbital areas through the gap between the eyeball and the orbital wall. The product consists of a straight or elbow-shaped rod. The elbow-shaped rod allows the magnet to probe and attract foreign bodies in posterior locations of the orbit along the eyeball wall, and the straight rod can be inserted into the penetrative wound channel to reach foreign bodies. Different incisions should be selected according to different foreign body sites when removing orbital foreign bodies. The incision should be made considering the skin texture and avoid damaging important tissues of the eye, such as the levator palpebrae superioris muscle, pulley, lacrimal apparatus, optic nerve and large blood vessels of the eye. When removing a foreign body, the soft tissue around the foreign body should be separated first, and then the foreign body should be removed. The foreign body should not be removed forcibly to avoid intraorbital haemorrhage and termination of the operation. In this study, foreign body removal was completed within minutes in 34 patients, which may be related to the relatively light adhesion between the tissues and the foreign body. In one patient, the foreign body had been retained in a posterior location of the orbit for nearly 30 years, with organizational encapsulation, and was not removed. Surgery was discontinued to prevent complications.

Common complications of intraorbital foreign body removal include intraorbital haemorrhage, ocular motility disorders, and optic nerve injury, which are commonly caused by direct injury or traction injury in an attempt to clamp the foreign body [16]. The risk of complications increases when a suboptimal surgical approach is employed. For example, selecting an inappropriate route that does not allow direct access to the foreign body—or relying solely on the surgeon's experience or conventional X-ray fluoroscopy to guide the surgical process—can lead to ineffective interventions that significantly increase the risk of permanent iatrogenic damage to orbital tissues [2, 16]. With our product, the foreign body is attracted to the device by magnetism instead of clamping. As a result, probing for and removal of the foreign body is easier, and the risk of injuries commonly associated with the clamping method is minimized, reducing the likelihood of surgical complications. None of the patients in the present study experienced postoperative complications such as decreased visual acuity, excessive intraorbital haemorrhage, aggravated limitation of eye movement, or intraorbital infection as a result of surgery.

In summary, we believe that the use of an intraorbital magnet is a promising method for deep intraorbital magnetic foreign body removal for the following reasons: (1) high success rate: the deep intraorbital foreign body was successfully removed in 34 out of 35 cases in this study, representing a success rate of 97.1%; (2) short procedure: in the 34 cases, the foreign body was removed within minutes; (3) minimal surgical injuries and reduced risk of complications: in the magnet-based procedure, only a conjunctival incision was made, and only slight enlargement of the original wound in extraocular muscles was needed to remove the intraocular foreign body, which caused significantly less surgical injury than lateral orbital surgery would. The extraction procedure using magnetic attraction instead of clamping could also effectively remove the foreign body without the risk of causing direct injuries to the orbital tissues by clamping. Thus, the use of strong magnets is the optimal surgical procedure for removing deep intraorbital metallic foreign bodies.

Conclusion

Extraction using magnetic attraction instead of clamping could effectively remove a foreign body without the risk of causing direct injuries to the orbital tissues by clamping. Thus, the use of strong magnets is the optimal surgical procedure for removing deep intraorbital metallic foreign bodies.

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Author contributions

Shanyu Li, Shaolei Han and Jinchen Jia: completed the operation.Xiaoxuan Wang: drafted the manuscript. Li Li, Rui Niu and Xiujun Liu: statistic analyzed the data, drew charts.Zhang jie: revised the manuscript.All authors read and approved the final manuscript.Thanks to anyone who has contributed to this manuscript, they have agreed to publish it.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This clinical trial was conducted following the Declaration of Helsinki and was approved by the Ethics Committee of Hebei Eye Hospital (Ethics Approval Number: 2024LW06). Before the implantation procedures, the patients and their families were informed about the operation in detail and signed informed consent forms.

Consent for publication

Not applicable in this study.

Competing interests

The authors declare no competing interests.

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