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Application of Computer-Aided Navigation Technology in the Extraction of Foreign Body From the Face

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Abstract: In the oral and maxillofacial foreign body (FB) extraction surgery, computer-aided navigation technical surgery is minimally invasive and safe, and can improve the accuracy, especially for areas with relatively complex and dangerous anatomical structures. A total of 11 patients, including 8 males and 3 females, who underwent the extraction surgery of FB from oral and maxillofacial regions using computer-aided navigation technical surgery were reviewed. According to the positional relationship between the maxillofacial region and the bone tissue, the FBs were divided into 3 categories: FB in the bone; FB aside the bone; and soft-tissue FB. During the operation, the BrainLab Navigation system was used to observe and guide the operation in real-time to evaluate the effectiveness and accuracy of computer-aided navigation technical surgery in the extraction of FBs from the maxillofacial regions. The FBs were successfully located and removed in 11 patients. No adjacent nerves, blood vessels, and other important anatomical structures were injured during the operation. The postoperative function and shape were not significantly affected.

Key Words: Computer-aided navigation, foreign body, oral and maxillofacial, removal

Foreign bodies (FBs) may get embedded into maxillofacial tissue following trauma or therapeutic intervention. The FBs are frequently missed on initial evaluation and their identification may be difficult. Currently, there are still many controversies on how to treat patients with these types of injuries.[1] The FB may cause further infection, pain, paresthesia, and dysfunctions. Furthermore, long-term retention may cause or aggravate the patient's psychologic disorders.[2] Since maxillofacial region contains important anatomical structures such as nerves and blood vessels, surgical removal of FB from these regions remains big challenge for surgeons.[3] In addition, the design of the surgical approach and incision usually affect the postoperative aesthetics of the patient. Therefore, it is necessary to minimize the related complications, such as nerve injury and bleeding while removing the FBs.[4]

Compared to computer-aided navigation technical surgery (CNTS), traditional surgical procedures in the treatment of complex FBs may cause excessive intraoperative bleeding, prolong operation time, or induce damages to the surrounding tissue.[5] In recent years, the application of digital surgical techniques in oral and maxillofacial surgery has become increasingly popular.[6,7] Using

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CNTS, surgeons can now perform accurate and minimally invasive surgeries profiting from its precise preoperative design, obtaining better postoperative results,[8,9] and thus providing a solution to many problems in the extraction of oral and maxillofacial FBs.[4]

In ever before, soft-tissue FB may be not an indication of CNTS, but in our experience in the CNTS in the extraction of maxillofacial FBs, CNTS plays an important role in this surgery. This article combined the previous patients treated at our hospital to explore the application of CNTS in the extraction of oral and maxillofacial FBs, to evaluate the role and efficacy, and to summarize its indications, technical procedures and clinical routine operations.

CLINICAL REPORT

Patient Source

A total of 11 patients, including 8 males and 3 females, aged 1 to 49 years (mean age was 27 years old) who underwent completed CNTS of FBs at Peking University School and Hospital of Stomatology between June 2011 and August 2017 were enrolled in the study. Among them, there were 5 patients with labor debris damages, 2 patients with blast injury, 1 car accident, 1 gunshot wound, 1 patient swallowed FB, and 1 patient with iatrogenic retained FB. According to the positional relationship between the FB and the adjacent bone tissue, following classification was applied: FBs in the bone, FBs adjacent to the bones and FBs in the soft tissue, where all patients underwent extraction surgery under the guidance of navigation. The general information of all patients is shown in (Supplemental Digital Content, Table 1, http://links.lww.com/SCS/B57.

All patients were informed before surgery, and informed consents for navigation-assisted surgery were obtained. The study has been approved by the institutional ethics committee (no: IRB00001052-11076).

Data Acquisition

All patients were scanned by 16 slice spiral computed tomography (CT) (BrightSpeed 16-slice CT scanner; GE Healthcare, Buckinghamshire, UK) using volumetric scan pattern before surgery; the interlayer spacing was 1.25 mm. In 1 patient, a digital subtraction angiography (digital subtraction angiography [DSA]) examination was performed, and the scan data were transformed to the DICOM format outputs on an engraved disc.

Preoperative Design and Simulation

Foreign Bodies Location

The data were imported to a computer graphics workstation BrainLab iPlan CMF 3.0.3 via disc, for 2-dimensional evaluation of sagittal, coronal, and cross-sectional data. The coordinate system was reset, and the 3-dimensional reconstruction data were calculated. Preoperative design determined the anatomical position of the FB, and marked it with different colors. Attention was given to the important adjacent anatomical structures. The surface marker was set at the face projection position of the FB in the soft tissue, and the thickness of the FB was measured from the soft-tissue surface. After the design was completed, BrainLab system outputs generated the navigation files, which were transferred via USB to the operating room BrainLab CMF navigation workstation.

Classification of Foreign Bodies

According to the position of the FB relative to the bone tissue, FBs were divided into 3 categories: FB in the bone, that is, the FB embedded in the bone tissue; FB aside the bone, that is, the FB located at the edge of the bone tissue; soft-tissue FB, that is, the FB completely located in the soft tissue.

Navigation-Guided Surgery (CNTS)

Spatial Registration

After the general anesthesia, intubation and conventional disinfection drape were performed. An invasive navigation fixture was set on the head, with 3 reflective balls on the fixture, which could reflect the infrared light of the optical positioning system on the navigator, thereby realizing real-time track and position of the patient's maxillofacial region and surgical instruments. The contactless infrared registration handle was used to smoothly scan the patient's forehead, nasal root, and orbital margin area for face registration. The navigation probe was used to scan the nasal root point, the inner and outer canthus, and the upper central incisor for accuracy verification.

Surgical Incision Design

Different incisions and surgical approaches were chosen depending on the type of disease and the location of the FB, which were mainly divided into: fresh open wound, the surgical approach is along the original would, extension of the incision is recommended if necessary; small FB, with relatively shallow position, and the wound that was basically or completely closed, mucosal, or small skin incision by the foreign object in the mouth or maxillofacial surface projection position (surface marker); for several FBs, and those accompanied with other maxillofacial fractures, the scalp coronal incision, the extraoral transcutaneous approach, or the intraoral transmucosal approach is advised to expose the fracture line and the location of the FBs.

Real-Time Navigation of Surgery

During the operation, the navigation probe or the registered surgical instrument were used to verify the positional relationship between the operation position and the FB, as well as important anatomical structure in real time. The deviation of the position between the target foreign object and the actual position were corrected according to the 3-dimensional reconstructed image, the coronal, sagittal, and axial cut surface images.

RESULTS

Overall Results

All the 11 patients underwent surgery according to the preoperative design with no obvious surgical complications. During the operation, the positional relationship between the operation position and the FB, and the important anatomical structure were corrected in real-time under the guidance of the navigation, with good surgical results.

Type, Quantity, and Location of Foreign Bodies

The FBs included 8 patients with metal FBs, 1 patient with mercury, 3 patients with glass and other foreign objects. In addition to 3 patients with only 1 single FB, 8 patients had multiple FBs. Among them, 3 patients were intra-bone FBs, 3 patients were bone-side FBs, and the other 5 patients were soft-tissue FBs.

Typical Patients

Patient 1

The FB was found in the bone of a 3-year-old female patient. Facial FB occurred due to gas tank explosion that took place 1 month ago. The swelling of the right zygomaticofacial was obvious, with bruising around the eyes. Spiral CT showed

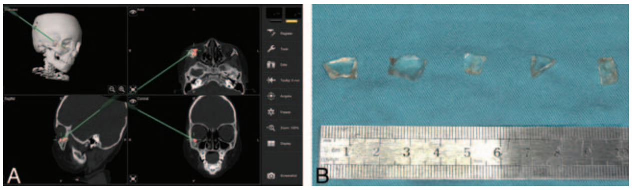

FIGURE 1. (A) Real-time screenshot of the iPlan software accurately during the operation indicating the foreign body (FB; the red part in the medial and posterolateral walls of orbital and right zygoma). (B) The FBs extracted were 5 glass bricks.

comminuted orbital fractures of posterolateral wall, FBs in the medial and posterolateral walls of orbital, and right zygoma. The maximum diameter was about 1.5 cm. Through the 3-dimensional reconstruction before surgery (Fig. 1A), the position of the FB was determined in the navigation workstation, and the relationship with the surrounding important anatomical structures (such as the right eyeball and the optic nerve hole). During the operation, the original wound scar was cut along the right side of the right zygomatico-facial, the zygomatic bone was exposed, 2 large glasses of FBs at the posterior edge of the zygomatic bone were removed, and the additional inferior palpebral conjunctiva incision was placed to expose the inferior orbital margin and the orbital inner surface. Five pieces (Fig. 1B) of larger glass FBs were taken out. There were no visual impairments before and after surgery.

Patient 2

The FB at the side of the bone found in a 33-year-old male who suffered a gunshot wound on the left side of the face for 8 hours. The skull PA and LAT and CT (Fig. 2A) showed that a " bullet " metal FB shadow was found under the left petrosal bone. The DSA examination showed the FB adjacent to the internal carotid artery. In the operation, the positioning needle was inserted along the original wound in the left zygomatic arch (Fig. 2B), navigating the position and depth of the FB, suturing and fixing the position needle on the skin surface. Due to the deep position, a small incision in the left submandibular area was designed, the skin and the subcutaneous layer and the platysma were cut open, the parotid gland was separated, the mandibular branch of the facial nerves was exposed and protected, and the anterior border of the sternocleidomastoid was separated to the inside. On the protruding surface, the positioning needle was placed on the surface of the mastoid to locate the metal (Fig. 2C), and part of the free bone block was removed to

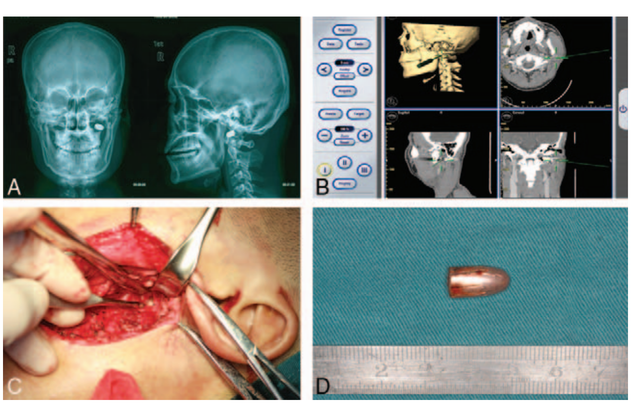

FIGURE 2. (A) The anterioposterior and lateral film indicating a high-density spot under the left petrosal bone. (B) Screen capture of the probe reaching the foreign body (FB) according the preoperation plan. (C) Exposed the FB during the surgery with the help of computer-aided navigation technical surgery. (D) Extracting the bullet.

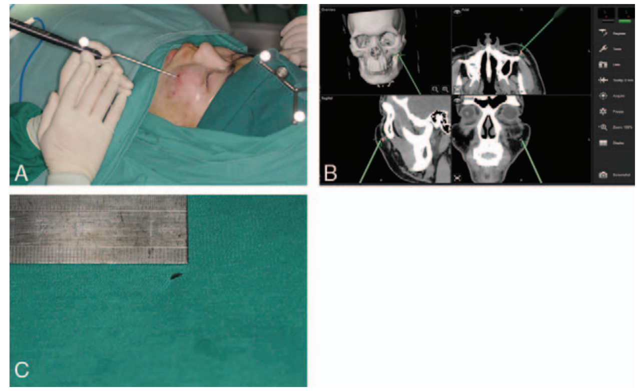

FIGURE 3. (A) Indicating the location and the depth of foreign body (FB) with the assist of probe. (B) Locating the FB with the help of computer-aided navigation technical surgery. Marked the subcutaneous depth of the FB. (C) Extract the FB.

reveal the metal warhead, which was completely removed (Fig. 2D), while the adjacent blood vessels and nerves were not damaged.

Patient 3

Soft-tissue FB was found in a 24-year-old male, who suffered left facial trauma for 5 days. The CT showed a high-density FB shadow with a size of about 3×1 mm, and about 1 cm front the surface of the lower left zygomatic bone. The surface marker was preoperatively made by the FB on the skin surface (Fig. 3A), and the depth of the FB was recorded. During the operation, the incision of about 8 mm was designed along the surface marker in the left zygomatic surface, the specific location of the FB was located with the aid of the navigation indicating the positioning needle (Fig. 3B), and taking it completely out (Fig. 3C).

DISCUSSION

The 1st step in the removal surgery of FBs is accurate positioning. At present, there are many methods for inspecting and locating foreign objects. For metal FBs and most nonmetallic FBs, CT, cone-beam CT, magnetic resonance imaging (MRI)[4,10] can accurately determine the position, volume and density of those objects. However, due to similar CT values or MRI signal values with soft tissues, the other nonmetallic FB can only be located combined with ultrasound.[11,12] The DSA can accurately observe the relationship between FBs and surrounding blood vessels. The eventual need for surgery, as well as a direct, reasonable, and minimally invasive surgical approaches, is decided according to the overall condition of the patient.[13] Intraoperative surgical navigation system, which mainly has a guiding role, assists in real-time guidance of the actual distance between the surgical area and FBs to remove foreign objects. In general, the overall accuracy of intraoperative use of CNTS (BrainLab) is <1.5 mm,[14] and the error is mainly due to the reference positioning deviation generated by registration space registration. Compared with traditional surgery, navigation-assisted surgery can reduce bleeding, reduce the incidence of intraoperative and postoperative complications, and make surgery safer, more precise, and minimally invasive.[6,15]

According to surgical indications for assisted maxillofacial FB removal surgery, the maxillofacial FB can be divided into 3 situations according to the foreign object position:

1. FB in the bone, where the FB has relatively constant position during the surgical removal process. It does not shift easily, and it is the absolute indication of the application of navigation system.
2. FB asides the bone, where FBs may be displaced during the operation, so it is necessary to design the surgical removal

approaches that are mainly dependent on the distance between FB and skin surface or oral mucosa around anatomical structures, including the original wound and new skin or oral mucosal incisions, or an extension incision in the original wound if necessary. It is the relative indication of the application of navigation systems.

3. FB in soft tissue, where FBs may drift during the operation. In the past, this was not considered an indication for the navigation system. However, from our experience, while the position of the operation area can be marked before the incision, or the soft tissue can be avoided as the navigation marker point to reduce the error made by the drift phenomenon; the navigation system can help in detecting the position of FB projection on the skin surface, the depth of the wound, especially when adjacent to the important nerves and vessels, it is of great significance to protect the surrounding tissues, but of limited importance to guide in real-time positioning of surgery.

Regardless of the use of surgical navigation system, the surgical approach is important in the maxillofacial FB removal surgery. The factors that determine the surgical approach include injury time, depth of the injury, location of the FB, surrounding anatomic structures, distance from the skin surface and oral mucosa, and the nature of the FB. Some alternative approaches include: original or extended incisions, skin or oral mucosal projection position incisions, and coronary incisions. Yet, the choice of the overall surgical approach needs to include direct, minimally invasive approach that does not lead to the intraoperative shift of FBs, which in fact can be achieved by CNTS.

Under the CNTS, the surgical approach should be determined before surgery. With the FB in the mandibular bone or aside the bone, the preoperative radiologic data collection should be completed under the intermaxillary ligation, the same as the surgical-navigation-aided surgery process. For intra- and extrabone FBs, it is necessary to use the navigation probe or the registered surgical instrument to indicate the real-time distance between the surgical position and the FB, gradually revealing the FB, and finally taking it out. For the FBs in the soft tissue close to the skin, after the registration is completed, the surgical incision entry point and the relative distance of FBs can be indicated under the navigation guidance, and then separated and taken out.

In short, CNTS can help with the localization of intraoperative FBs during the removal proceeding of FBs in the oral and maxillofacial region, thus reducing the damage and bleeding of surrounding anatomical structures, improving the accuracy and safety of operation, and reducing the invasiveness and postoperative complications.

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Single-Stage Reconstruction of Full-Thickness Nasal Alar Defect Using Bilobed and Turnover Flaps

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Abstract: Skin cancer of the nose remains a common challenge for the reconstructive surgeon with full-thickness defects being

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