Image-Guided Surgical Navigation for Removal of Foreign Bodies in the Deep Maxillofacial Region

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Purpose: Most trauma surgeons encounter numerous penetrating injuries. Some foreign bodies can cause pain, infection, and discomfort to the patient. Serious functional disorders also are likely to occur. Foreign bodies in critical areas must be removed. This report describes the use of image-guided technology for the removal of foreign bodies deep in the maxillofacial region.

Patients and Methods: From 2008 through 2011, 5 patients with foreign bodies in the maxillofacial area underwent image-guided removal at the authors’ department. The STN navigation system (Stryker-Leibinger, Freiburg, Germany) was used for surgical planning and intraoperative navigation. Preoperatively, computerized tomography and digital subtraction angiography were used to create 3-dimensional views of the region to aid surgeons in more accurately defining the spatial location of the foreign object. During surgery, the foreign objects and surgical instruments were visualized on the screen.

Results: In all 5 cases, the foreign bodies were removed by minimally invasive access without any complications. Surgical time was approximately 40% shorter compared with the conventional technique of not using image-guided navigation. A 1-year postoperative evaluation showed that the patients’ complaints and symptoms had resolved, function was restored, and esthetics were remarkably improved.

Conclusion: Navigation-guided removal of foreign bodies in the complex, deep maxillofacial region in proximity to vital areas can be regarded an ideal and valuable option for these potentially complicated procedures.

Traumas such as car accidents and gunshot wounds can easily lead to foreign bodies penetrating the maxillofacial region. Although many of these foreign objects do not cause a life-threatening risk, they can cause functional disorders, infection, pain, and discomfort. Foreign objects within vital areas often require removal. However, identifying the location of these objects and determining a safe surgical approach are difficult using conventional preoperative radiography. Surgical procedures for removing foreign bodies in an inaccessible
location are challenging, because certain important surrounding structures, such as the nerves and carotid artery, must be protected.

Image-guided navigation technology has been used in preoperative planning and intraoperative visualization and has been used successfully by maxillofacial surgeons for dental implantation, correction of malformations, and excision of tumors, among others.1-3 However, reports on the use of image-guided removal of foreign bodies seem to be limited.4-7 In this report, the authors share their experience using the STN navigation system (Stryker-Leibinger, Freiburg, Germany) for the removal of foreign bodies deep in the maxillofacial region.

**Patients and Methods**

Five patients with foreign bodies retained in the maxillofacial region secondary to accidents underwent image-guided removal of these objects at the authors’ department from 2008 through 2011 (Table 1). Preoperative spiral computed tomography (slice thickness, 0.625 mm; LightSpeed 16, GE Healthcare, Chalfont St Giles, Buckinghamshire, UK) was performed for surgical

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**Table 1. PATIENTS AND FOREIGN BODIES REMOVED USING IMAGE-GUIDED SURGERY**

<table>
<thead>
<tr>
<th>Case</th>
<th>Patient Age (yr)/Gender</th>
<th>Etiology</th>
<th>Duration (mo)</th>
<th>Material</th>
<th>Quantity</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24/M</td>
<td>traffic accident</td>
<td>6</td>
<td>metal</td>
<td>1</td>
<td>masseteric space</td>
</tr>
<tr>
<td>2</td>
<td>41/F</td>
<td>traffic accident</td>
<td>3</td>
<td>metal</td>
<td>1</td>
<td>infratemporal space</td>
</tr>
<tr>
<td>3</td>
<td>23/M</td>
<td>explosive injury</td>
<td>1</td>
<td>metal</td>
<td>1</td>
<td>parapharyngeal space</td>
</tr>
<tr>
<td>4</td>
<td>51/M</td>
<td>traffic accident</td>
<td>1.5</td>
<td>metal</td>
<td>1</td>
<td>periorbital apex</td>
</tr>
<tr>
<td>5</td>
<td>37/F</td>
<td>explosive injury</td>
<td>12</td>
<td>glass</td>
<td>7</td>
<td>parapharyngeal space</td>
</tr>
</tbody>
</table>

Abbreviations: F, female; M, male.

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**FIGURE 1.** Case 3. Preoperative digital subtraction angiogram visualizes the location of the object in relation to the internal carotid artery.
planning. Four of 5 cases were checked for proximity of the object to the carotid artery. Digital subtraction angiographic data were obtained, and 3-dimensional (3D) images were reconstructed preoperatively. The object’s location in relation to the internal carotid artery and surrounding vessels was defined and dynamically displayed on the screen (Fig 1). This research was performed with the consent of the patients and was granted an exemption from the authors’ institutional review board.

In all cases, the STN navigation system was used. The computer workstation was used to achieve an accurate 3D reconstruction of the anatomic structures and obtain a clear view of foreign bodies in the skull (Fig 2). The tracking device was used to track the dynamic reference frame that was rigidly attached to the patient’s forehead to identify the head’s position and the probe. Clamping of the dynamic reference frame allowed the tracking and calibration of any surgical instrument (pincers, tweezers, forceps, etc), and the tip position and orientation of the frame were viewed continuously on the screen (Fig 3).

After the registration procedure, pinpointing “screws markers” implanted in the upper alveolar bone before computed tomographic data acquisition achieved an accurate match between the virtual and physical spaces. The precise spatial location of the foreign object was seen on the screen, and the accuracy was checked by repeatedly pinpointing the anatomic landmarks. The probe could be inserted through a small intraoral or extraoral incision. Once the probe reached the retained object (Fig 4A, B), the object could be removed easily with the use of calibrated surgical forceps (Fig 4C, D).

**Results**

Preoperative dynamic 3D digital subtraction angiographic data were obtained to define an object’s location in relation to the internal carotid artery in 4 cases.
The accuracy of the STN navigation system was less than 0.8 mm. Using the STN navigation system, the probe made it easier to detect the exact anatomic site of the retained foreign bodies and enabled the calibrated surgical instruments to remove the objects in a minimally invasive manner without damaging important surrounding structures. Eventually, the foreign bodies were removed safely and successfully (Fig 5A, B). The approximate duration for the removal of each foreign body, after installation of the system, was an average of 15 minutes. After a 1-year follow up, the patients’ complaints and symptoms had resolved, function was restored, and esthetics improved significantly without complications.

Discussion

The incidence of foreign bodies retained deep in the complex maxillofacial region has increased greatly in recent years. The timing and method of removing these foreign objects are controversial.

The first consideration is whether the foreign object should be removed. Based on a review of the present 5 cases, 4 manifested complications, such as discomfort, pain, and infection. Although case 3 did not present any symptoms, the patient underwent surgery because of the object’s high-risk location. Therefore, the authors suggest that all foreign fragments that are symptomatic and those that are located near vital structures be removed to prevent further complications.

The second consideration is to determine the most acceptable time to remove the fragment. One potential problem is the tendency for a fragment to move within the soft tissues, which has not been discussed thoroughly in the literature. This tendency can prove difficult during surgery because the location of the foreign body might instantly change. Thus, preoperative imaging is no longer reliable. For all 5 cases, the procedure for removing the foreign objects was not performed during the first stage of surgery, for various reasons. The fragments had remained in the patients’ bodies from at least 1 month to 1 year. In
FIGURE 2 (cont’d).

FIGURE 4. Case 3. A, C, Navigation probe and calibrated forceps-clamped dynamic reference frame inserted through a small surgical incision. B, D, Real-time screenshots of instruments reaching the object. (Fig 4 continued on next page.)

FIGURE 4 (cont’d).

consequence, a fibrous connective tissue mass had developed around each foreign body. This condition is advantageous for the surgeon because it helps limit the movement of the foreign body. During the operation, the precise position of the object could be determined and the object could be removed safely. Therefore, the authors recommend a duration of at least 1 month before surgical removal.

The third consideration is safe removal of the foreign body. Several methods have been used to detect and localize foreign bodies. Plain radiographs, computed tomograms, magnetic resonance images, and ultrasound may be used,\(^9\)\(^{10}\) depending on the site and composition of the object. However, even if the object is perceived from the imaging data, an accurate determination of its position in the head can be difficult, especially if the foreign body is not adjacent to a fixed anatomic landmark. For those foreign objects deep in the maxillofacial region, it is necessary to determine preoperatively the spatial location with reference to the important surrounding blood vessels. This is a limitation of conventional radiographs. In the present 4 cases of objects deep in the maxillofacial region, digital subtraction angiographic data were obtained and reconstructed preoperatively. The localization of objects in relation to the internal carotid artery was displayed dynamically in the 3D view.

In the conventional technique, foreign bodies retained in a crowded anatomic zone with delicate structures are difficult to extract. Detecting a foreign body in a narrow deep area with poor visibility undoubtedly increases the risk of damage to adjacent structures. An image-guided navigation system allows for preoperative planning and intraoperative visualization and has been described as an effective treatment modality for improving surgical outcome; it plays an ever-increasing role in craniofacial surgical procedures, as described in a previous article.\(^3\) Grobe et al\(^ {11}\) reviewed their navigated cases and confirmed that there was a significant correlation between navigated surgery versus non-navigated surgery and complication rate, including major bleeding, soft tissue infections, and nerve damage, and between operating time and postoperative complications. It is essential to use navigation technology in the removal of foreign bodies deep in the maxillofacial region. The authors’ experience showed that the use of image-guided techniques is of great benefit for surgeons in removing these foreign bodies because of 1) improved surgical accuracy, 2) shortened operating time, and 3) minimally invasive access.

In conclusion, the following conditions are recommended indications for the use of the navigation system for the removal of foreign bodies: 1) fragments that could cause complications, 2) presence of multiple foreign bodies, 3) use of minimally invasive procedures, 4) objects located within vital areas, and 5) failure of previous attempts using conventional techniques.

References


FIGURE 5. A, Metal object in case 3 and B, glass object in case 5 removed from the deep maxillofacial region.


