Clinical Report

Application of a Real-Time Three-Dimensional Navigation System to Dental Implant Removal: A Five-Year Single-Institution Experience

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Abstract: Real-time three-dimensional navigation images can facilitate minimally invasive and accurate surgery. The aim of this study was to clarify the usefulness of a real-time three-dimensional navigation system for removal of dental implants. The authors designed a retrospective study and analyzed patients who underwent implant removal surgery with a real-time three-dimensional navigation guide under general anesthesia. Six patients (age, 64.3 ± 8.8 years) were included in this study. The procedures involved the maxilla and the mandible in four and two patients, respectively. The implant bodies were adjacent to the maxillary sinus or nasal cavity in all the maxillary cases, and to the mandibular canal in both mandibular cases. Adjacent implant bodies and adjacent teeth that had to be preserved were noted in 1 and 5 cases, respectively. All cases required elevation of a mucoperiosteal flap for removal of the implant bodies, and five cases required removal of the alveolar bone. No postoperative complications were observed, and the adjacent teeth and implants could be preserved in all cases. This study suggests that a real-time three-dimensional navigation system under general anesthesia is useful for dental implant removal surgery in cases with no absorption of alveolar bone around the implant bodies, cases wherein the implant bodies have migrated into an inappropriate position, and cases with adjacent teeth or implant bodies that have to be preserved intact.

Key words: Real-time three-dimensional navigation image, Dental implant, Removal

Introduction

Technological progress has contributed to innovations in surgical procedures, thereby leading to better treatment outcomes. In particular, technologies such as three-dimensional navigation and image-processing methods have allowed better visualization of surgical fields and the lesions or objects to be removed, and they are useful for avoiding damage to important organs and structures. Real-time three-dimensional navigation images thus facilitate minimally invasive and accurate surgery, and have been applied to the treatment of various diseases.

Dental implants are useful for restoring occlusion and aesthetics and improving masticatory function and are the only effective treatment approach for cases in which conventional prosthetic treatment cannot be applied. Dental implant treatments have been clinically applied for approximately half a century, and studies to improve their success rate have been actively conducted, with the success rates ranging from approximately 90% to 97%.

Materials and Methods

Patients

The authors designed a retrospective study assessing patients who underwent implant removal surgery at the University of Fukui Hospital between April 2013 and April 2018. Only the patients who underwent the surgery under the real-time three-dimensional navigation guide were included in this study.

Surgery under the three-dimensional navigation guide

Preoperative thin-slice (1 mm) computed tomography (CT) scan data were obtained before surgery, and the data were imported to a real-time three-dimensional navigation system (BrainLAB Inc., Heimstetten, Germany). Since a reference point was fixed on the forehead, oral appliances for fixing both jaws were worn during preoperative CT examinations and removal surgery only in the mandibular cases in order to reproduce the relative positions of both jaws. All removal surgeries with...
the navigation guide were performed under general anesthesia. The authors performed each surgery after confirming a match between the navigation image and the patient’s anatomical landmarks.

**Evaluation**

We analyzed the location and number of implant bodies to be removed, the reason for removal, the anatomical structures around the implant bodies, the surgical procedures, the postoperative complications, and the use of analgesics.

This study was approved by the Institutional Research Board (Ethics Committee of the University of Fukui, Faculty of Medical Sciences; No. 20180063).

**Results**

Ten patients underwent dental implant removal surgeries under general anesthesia. Six (four men and two women) of the 10 patients received dental implant removal surgeries under the real-time three-dimensional navigation guide (Table 1 and 2). The youngest and oldest patients were 55 and 76 years old, respectively, and the patients’ mean age ± standard deviation was 64.3 ± 8.8 years. Four patients underwent maxillary surgery, while the other two patients underwent mandibular procedures. Three cases involved the maxillary anterior region, one involved the maxillary molar region, and both mandibular cases involved the molar region. In one of the maxillary cases, one implant body had migrated into the maxillary sinus. One patient required removal of three implant bodies, two others required removal of two implant bodies each, and the remaining three patients each required removal of one implant body (Table 1). The removal was necessitated by surgery for periimplantitis in two cases, fracture of the implant bodies in four cases, and maxillary sinus migration of the implant body in one case. The implant bodies were adjacent to the maxillary sinus or nasal cavity in all of the maxillary cases, and to the mandibular canal in both the mandibular cases. In addition, adjacent implant bodies and adjacent teeth that had to be preserved were noted in one and five cases, respectively. Removal of the implant bodies required elevation of a mucoperiosteal flap in all cases and removal of alveolar bone in five cases. Four patients required oral or intravenous analgesics after surgery. No postoperative complications were observed, and the adjacent teeth and implants could be preserved in all cases.

**Case presentation**

This section presents representative cases of implant removal surgery under the real-time three-dimensional navigation guide.

**Case 4** (Fig. 1)

A 60-year-old woman presented to the authors’ department complaining of swelling and tenderness of the right cheek. Imaging examination revealed a implant body displaced into the maxillary sinus and a implant body with surrounding alveolar bone absorption due to unsatisfactory installation of an abutment. The authors planned to perform dental implant removal surgery under general anesthesia. C: Intraoperative photograph obtained during surgery for removal of a dental implant that had migrated into the maxillary sinus (Navigation pointer (Δ)).

**Case 6** (Fig. 2)

A 64-year-old man visited the authors’ department for dental prob-
Computer-assisted surgery is performed for the treatment of various diseases and maxillofacial lesions such as oral cancer, temporomandibular ankylosis, and trauma\(^6\)\(^7\). Computer assistance before and during the surgery can facilitate more precise and safer surgery\(^6\)\(^7\). In particular, computer analysis and assistance are indispensable for dental implant insertion surgery. In this study, the three-dimensional navigation system was useful for objectively evaluating the surgical field. Moreover, the three-dimensional navigation guide could facilitate minimally invasive surgery in cases involving implant body migration into the maxillary sinus, implant body migration below the gingiva as a result of fractures, or implant body without significant bone resorption. Furthermore, in all of the cases in this study, it was possible to remove dental implants without surgical complications such as perforation into the nasal cavity, damage to the mandibular canal, and damage to adjacent teeth and implants. Two previous articles reported transnasal or transoral endoscope-assisted surgery for removal of migrated dental implants into maxillary sinus\(^6\)\(^7\). The advantage of our method was that it allowed us to objectively confirm the position of the bone to be resected and thereby allow easy removal of the implant body without causing damage to adjacent structures.

Oral surgeons must employ the appropriate insertion technique while using dental implants and should also use an appropriate removal technique for failed cases. Dental implants integrated with the surrounding alveolar bone may be difficult to remove. Stajić et al. reported five different techniques for removal of dental implants, and these methods required elevation of a mucoperiosteal flap and removal of alveolar bone or the use of a dedicated removal kit\(^3\). Although removal techniques involving mucoperiosteal flap elevation and bone removal are accompanied by the drilling noise and force, they are reliable, versatile, and predictable\(^3\). Stajić et al. also pointed out that dental implant removal using these methods will involve long operation times\(^3\). Thus, surgeries performed under general anesthesia are recommended for cases of dental implant migration or cases wherein large amounts of bone have to be removed before removal of dental implants.

The main components of the three-dimensional navigation system are a navigation camera, an infrared scanner, a reference point, a navigation pointer, and a monitor\(^10\). Before performing surgeries, surgeons must confirm a match between the navigation image and the patient’s anatomical landmarks using an infrared scanner under general anesthesia\(^10\). The unpredictable movement of an anesthetized patient and the deviation of a reference arc from the confirmed position can affect the accuracy of the navigation image\(^11\). In order to prevent these movements and deviations, neurosurgeons usually adopt a three-point rigid cranial fixation device with a reference point mounted on a rigid arm when they use a navigation system\(^11\). That method provides them a clear surgical field without interference by the reference point. Similarly, oral and maxillofacial surgeons can obtain accurate navigation images during surgery by placing a reference point on the forehead in case of surgery in the maxillary region\(^10\). On the other hand, surgeries in the mandibular region may involve mismatches between the navigation image and the patient’s anatomical landmarks because of mouth opening. Thus, the authors used oral appliances for fixing both jaws only in the mandibular cases, and they were used for both preoperative CT examinations and the removal surgeries. Even in the mandibular cases, this method provided accurate navigation images with the forehead reference point during surgery.

The disadvantages of this method are the extended operation times, radiation exposure, and the additional costs incurred by the patient and the medical institution. Therefore, oral surgeons should carefully select the cases in which this method can be applied while considering the above-mentioned benefits and disadvantages of this system.

In conclusion, this study suggested that a real-time three-dimensional navigation system under general anesthesia is useful for dental implant removal surgery in cases without absorption of alveolar bone around the implant bodies, cases wherein the implant bodies have migrated into inappropriate positions, and cases involving adjacent teeth or implant bodies that need to be preserved intact.

### Table 2. Details of the dental implant removal surgeries performed with the real-time three-dimensional navigation guide

| Case | Age | Sex | Locations                      | Number of implant bodies | Presence of adjacent teeth | Presence of adjacent implant bodies | Reasons for removal | Alveolar bone removal | Use of analgesics |
|------|-----|-----|--------------------------------|--------------------------|---------------------------|------------------------------------|---------------------|---------------------|-------------------|
| 1    | 74  | M   | Maxillary anterior region      | 2                        | +                         |                                    | Periimplantitis      | +                   | +                 |
| 2    | 55  | M   | Maxillary anterior region      | 1                        | +                         |                                    | Fracture            | +                   | +                 |
| 3    | 57  | F   | Maxillary anterior region      | 1                        | +                         |                                    | Fracture            | +                   | +                 |
| 4    | 60  | F   | Maxillary molar region and maxillary sinus | 2                       | +                         | Periimplantitis and migration into the maxillary sinus | +                   | +                   | +                 |
| 5    | 76  | M   | Mandibular molar region        | 3                        | +                         |                                    | Fracture            | +                   | +                 |
| 6    | 64  | M   | Mandibular molar region        | 1                        | +                         |                                    | Fracture            | +                   | +                 |
| Mean | 64.3| 1.7 |                                |                          |                           |                                    |                     |                     |                   |

Mean 64.3 1.7

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Mean 64.3 1.7
Conflict of Interest
The authors declare no conflict of interest.

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