

Case Report

Oral and Maxillofacial Surgery with Computer-assisted Navigation System

Homare Kawachi, Yasuyuki Kawachi, Chihaya Ikeda, Ryo Takagi, Akira Katakura and Takahiko Shibahara

Department of Oral and Maxillofacial Surgery, Tokyo Dental College, 1-2-2 Masago, Mihama-ku, Chiba 261-8502, Japan

Received 15 May, 2009/Accepted for publication 9 December, 2009

Abstract

Intraoperative computer-assisted navigation has gained acceptance in maxillofacial surgery with applications in an increasing number of indications. We adapted a commercially available wireless passive marker system which allows calibration and tracking of virtually every instrument in maxillofacial surgery. Virtual computer-generated anatomical structures are displayed intraoperatively in a semi-immersive head-up display. Continuous observation of the operating field facilitated by computer assistance enables surgical navigation in accordance with the physician's preoperative plans. This case report documents the potential for augmented visualization concepts in surgical resection of tumors in the oral and maxillofacial region. We report a case of T3N2bM0 carcinoma of the maxillary gingival which was surgically resected with the assistance of the Stryker Navigation Cart System. This system was found to be useful in assisting preoperative planning and intraoperative monitoring.

Key words: Computer-assisted navigation system—Oral and maxillofacial surgery—Squamous cell carcinoma—Noninvasive

Introduction

Accurate, 3-dimensional (3-D) views are essential while performing maxillofacial surgeries, not only because the anatomical structure of the area is complicated, but also because esthetic reconstruction of the facial morphology is a high priority^{4–6}. They are especially important when the surgeon has to depend on tactile sensations through the fingers in performing surgeries in areas that cannot be viewed directly. Furthermore, skilled and experienced operators and sophisticated

equipment are required in performing maxillofacial surgeries³.

We used a computer-assisted navigation system (CAS), also known as image-guided surgery or computer surgery, to perform accurate, safe, and appropriate ablative surgery¹. CAS represents a surgical approach that employs computer technology for preoperative planning and guidance and performance surgical interventions.

The objective of the present report is to describe the application of CAS and evaluate its usefulness in the performance of ablative

surgery of the oral and maxillofacial region.

To the author's knowledge, although application of this system has been reported in the field of neurosurgery, no studies have been published regarding its application in oral surgery. We investigated the efficacy of this system in surgically approaching the superior maxillary palate. The system was found to be effective in approaching the nasal cavity and in ascertaining the actual range of bone excision. We believe that this system will enhance surgical accuracy in the future.

The actual range of bone excision could be confirmed and it was effective. There is no report of approach from the mouth, however, it is expected to be attempted in the future, and there is a possibility that the operation can be conducted with high accuracy *via* this approach. It is thought that this approach is an effective step towards with the future.

Principle of CAS

The CAS system was originally developed for use in neurosurgery. It is a noninvasive system that links a freehand probe tracked by a passive marking sensor system to a virtual computer image space based on the patient's preoperative image data. This system replaces

various imaging modalities, including computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET) during an operation^{3,4)}, and allows images to be changed and displayed. In addition, these images can easily be used to generate 3-D images of target tissues or tumors^{1,2)}.

This system has gained broad recognition. It offers a recognition factor that is 25% greater than that of conventional devices. Information is transmitted to the system using a tracker that reads the position of the patient's head. It has pointers with various shapes on the front edges. We installed digital communication technology into the system, rendering navigation shake to zero. The accuracy of light-emitting diode (LED) recognition also improved. Active spontaneous LEDs with a high recognition rate were used as pointers²⁾.

Case

The patient was a 75-year-old woman with squamous cell carcinoma (T3N2bM0: maximum tumor size, 5 cm; regional lymph nodes, 2 cm) in the middle segment of the upper gingiva.

We performed surgery using the Stryker



Fig. 1 Stryker Navigation Cart System used in surgery (left). Head of patient is immobilized with headband. Registration is then performed using pointer (right).

Navigation Cart System (Figs. 1, 2). The patient's head is immobilized using a head-band. Registration is then performed using a pointer. If the extent of the tumor is preset on the system, the actual position of the tip of the instrument can be displayed on the screen during surgery, enabling the operator to decide the extent of resection and to directly treat areas that can not be directly viewed, without damaging important organs. The maxilla and soft tissues can be segmented by simply clicking the bone area on the CT image (Fig. 3). Tissues are automatically recognized 3-dimensionally from the images, and tumor sections can be easily extracted (Fig. 4). We can insert a pointer into areas that are directly visible, and confirm the 3-dimensional position of the pointer on the screen (Fig. 5). In this manner, the required direction and depth for the insertion of a bone saw can be planned (Fig. 6). In addition,

if the bone saw is calibrated, it can function as a pointer to visualize and guide real-time intraoperative movements on a screen.

In this case, the tumor was resected with no signs of recurrence for over 24 months. The patient is now being reviewed annually (Fig. 7).

Discussion

CAS has numerous areas that need further evaluation and improvement. Reducing high costs associated with the system and the time needed to become accustomed to this complex system are areas for improvement. Moreover, there are issues with the marker and other bugs, the system is prone to freeze, human-computer interaction needs improvement, and recognition flaws also exist.

It is possible that deviations in position between the geometric center and the position actually detected from sterilization and reuse of markers could be the cause of lower accuracy levels. Such deviations are likely to cause excessive margins of error.

Reconfiguration, rebooting, and aborting navigation were reported as some methods used to solve the flaws in the system's equipment; however, the correlation between these problems and model-type has not yet been investigated.

In addition, intraoperative steps to increase accuracy that do not rely on navigation include pins or bands that restrict head movement of

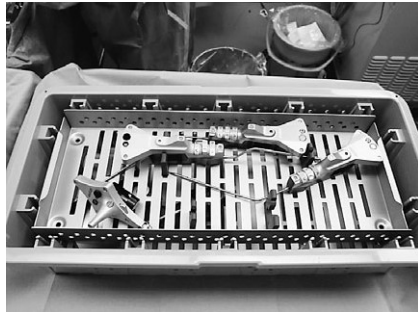


Fig. 2 Various pointers. Pointer fixed with headband and used to project.



Fig. 3 Preoperative remarks: tumor observed in region of front teeth.

patients to prevent markers from shifting. Furthermore, rapid configuration can be achieved through presentations and demonstrations by medical equipment suppliers being frequently accessible to clinical engineering technologists actively participating in such events.

Recently, technological advancements in tumor ablative surgery in the oral and maxillofacial region, allow for a minimally invasive endoscopic approach. Anatomical markers are not sufficient for proper intraoperative assessment of normal and pathological areas^{1,3,5}.

Surgeons have relied on experience and mental images of surgical sites to remove tumors. We believe that surgical accuracy could be enhanced with image guidance systems.

Intraoperative navigation systems were initially developed for neurosurgical applications, and are now also commonly used for endoscopic sinus surgeries⁴. These systems allow surgeons to determine the location of an instrument or bony anatomic landmark and are precise to within 1–2 mm².

The Stryker Navigation Cart System uses an optical platform to spatially localize the patient.

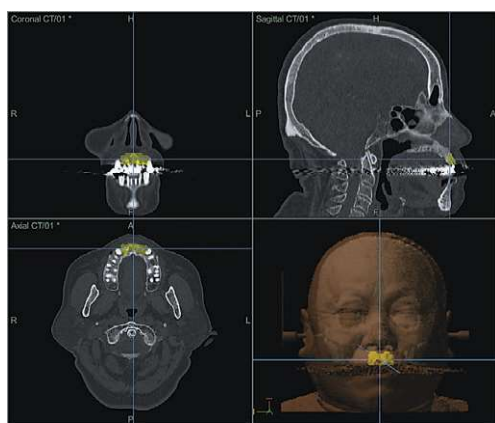


Fig. 4 Tissues are automatically recognized 3-dimensionally from images, allowing easy resection of tumor.

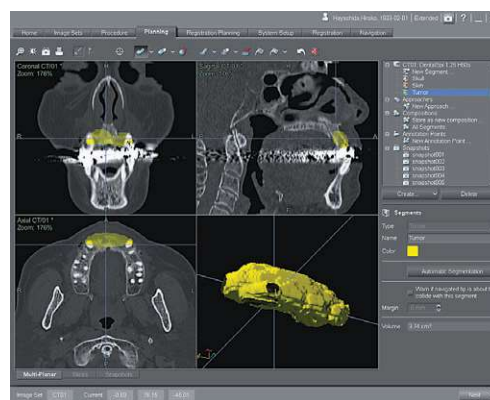


Fig. 5 During navigation, indicated points are tracked and can be confirmed on real-time basis.

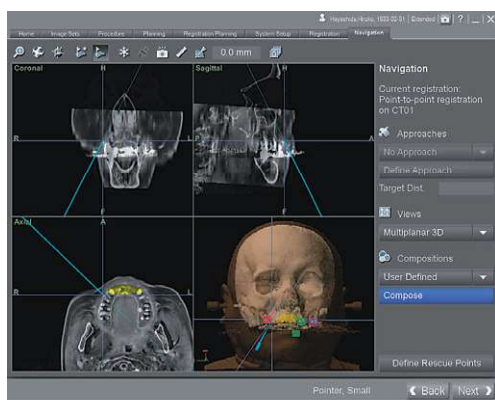


Fig. 6 Maxilla and soft tissues can be segmented by clicking bone area on CT image.



Fig. 7 Postoperative remarks: course of recovery was excellent.

Optical systems use infrared-emitting diodes or reflectors between the patient and the surgical probe. Optical systems are quite versatile, and accuracy is not compromised by the presence of ferrous materials. The primary disadvantage is the need to maintain a direct line of sight between the infrared-emitting diodes on the patient or instrumentation and the infrared sensor^{2,3)}.

The most important factor in CAS is the development of accurate models of patients. This can be achieved using a number of medical imaging techniques, including CT, MRI, and X-ray. To generate this model, the anatomical region to be operated on has to be scanned and uploaded into the system. Specialized software then renders the data as a virtual 3-D model of the patient, which can easily be manipulated by a surgeon to provide views from any angle and at any depth within the volume⁵⁾. These improvements in assessment can help establish more accurate diagnoses. Furthermore, surgical intervention can be planned and simulated before surgery actually takes place^{2,6)}.

There are also a number of adaptors available for this system. In this case, a band was fastened to the patient's head for immobilization. Since the system had universal attachments and calibration tools, it was possible to use any object with sharp, tapered front edges as a marker. Computer modeling and intraoperative navigation is a relatively new device to assist surgeons with resection of the oral and maxillofacial region.

Furthermore, intraoperative navigation helped determine the position of foreign bodies during imaging, making it easier to locate the tumor during the operation.

Also, CAS training and courses for cadaveric dissection give less-experienced surgeons a better understanding of the anatomy involved, by allowing for controlled simulations of individual steps, and giving them the ability to look ahead.

This system could help young surgeons safely and accurately perform minimally invasive

surgery, even in cases that have long been heavily dependent on the judgment and skill of experienced surgeons. Future developments should bring further improvements in imaging definition and the amount of information that can be obtained through this type of examination. The demand will be for further advances in visualization of the operating field and the ability to determine areas of tactile sensation. As virtual-reality technology progresses, more support should become available for precision surgeries that utilize these systems.

References

- 1) Annette MP, Amir AR, Marc CM, Amir J, Bradley S (2007) Computer modeling and intraoperative navigation in maxillofacial surgery. *Otolaryngol Head Neck Surg* 137:624–631.
- 2) Foley KT, Simon DA, Rampersaud YR (2001) Virtual fluoroscopy: computer-assisted fluoroscopic navigation. *Spine* 26:347–351.
- 3) Heiland M, Habermann CR, Schmelzle R (2004) Indications and limitations of intraoperative navigation in maxillofacial surgery. *J Oral Maxillofac Surg* 62:1059–1063.
- 4) Heiland M, Pohlenz P, Blessmann M, Werle H, Fraederich M, Schmelzle R, Blake FAS (2008) Navigated implantation after microsurgical bone transfer using intraoperatively acquired cone-beam computed tomography data sets. *Int J Oral Maxillofac Surg* 37:70–75.
- 5) Marc CM, Amir AR, Bettina HM, Annette MP, Brad S (2007) Comparison of 4 registration strategies for computer-aided maxillofacial surgery. *Otolaryngol Head Neck Surg* 137:93–99.
- 6) Postec F, Bossard D, Disant F, Froehlich P (2002) Computer-assisted navigation system in pediatric intranasal surgery. *Arch Otolaryngol Head Neck Surg* 128:797–800.

Reprint requests to:

Prof. Takahiko Shibahara
Department of Oral and
Maxillofacial Surgery,
Tokyo Dental College,
1-2-2 Masago, Mihama-ku,
Chiba 261-8502, Japan
E-mail: sibahara@tdc.ac.jp