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Original Article

# Dental implant navigation system guide the surgery future

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**Abstract** No study has investigated the effect of learning curves on the accuracy of dental implant navigation systems. This study evaluated the accuracy of the dental implant navigation system and established the learning curve according to operation site and operating time. Each dental model was used for drilling 3 missing tooth positions, and a patient tracking module was created. The same dentist performed the drilling test for 5 sets of dental models. CT back scanning was performed on the dental models. Customized implants based on the drilled holes were inserted. The relative error between the preoperative planning and actual implant was calculated. Using the dental navigation system could help dentists position implants more accurately. Increasing the frequency with which a dentist used the navigation system resulted in shorter operations. Longitudinal and angular deviation were significantly ($P < 0.0001$ and $P = 0.0164$). We found that the same level of accuracy could be obtained for the maxilla and mandible implants. The Student's $t$ test demonstrated that the longitudinal error, but not the total or angular error, differed significantly ($P = 0.0012$). The learning curve for the dental implant navigation system exhibited a learning plateau after 5 tests. The current system exhibited similar accuracy for both maxillary and mandibular dental implants in different dental locations. The one-way ANOVA revealed that the total, longitudinal, and angular errors differed significantly ($P < 0.0001$, $P < 0.0001$ and $P = 0.0153$). In addition, it possesses high potential for future use in dental implant surgery and its learning curve can serve as a reference for dentists.


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## Introduction

Dental implant technology has been widely used for oral reconstruction in recent years. Dental implants provide an alternative solution for patients who are unsatisfied with traditional partial or full mouth dentures. Furthermore, dental implants have yielded satisfactory outcomes in cases where treatment through full mouth reconstruction was previously difficult. A robust dental implant prosthesis restores chewing function, has superior biomechanics and aesthetics, and facilitates efficient long-term care. A well-fabricated dental implant prosthesis is based on the appropriate placement of the implant, a prosthetic-driven concept that highlights the importance of the implant placement, angle, and direction [1,2]. However, because the maxilla and mandible have special anatomical structures, such as the maxillary sinus and the inferior alveolar nerve, adequate information must be obtained before performing implant surgery to plan the implant location and depth, improve the success rate, and reduce possible sequelae from the implant surgery. Several studies have reported that the poor accuracy of these 2-dimensional images fails to provide the information required for dental implantation [3,4]. By contrast, computed tomography (CT) can provide images in different planes and a 3-dimensional space through image database reorganization. Thus, CT has been widely used in preoperative examinations for various dental implant surgeries in recent years [5—7]. After clear images of the maxilla and mandible have been obtained through CT, image analysis with implant-related software and surgical stent analysis can be performed to establish the targeted implantation position and achieve the desired results [8,9].

Dental implant navigation systems are auxiliary systems for implantations; such systems are based on medical imaging technology in combination with optical positioning. They integrate dental implant surgical instruments, medical imaging, and optical positioning devices with preoperative planning software for dental implants. Through a clinically applicable interface that provides real-time display, these systems guide users to drill into the targeted position according to the output of the preoperative planning software [10]. Navigation systems can improve safety during surgery and prevent damage to nerves or critical structures of adjacent teeth [11,12]. By using this system, dentists can develop a precise plan for dental implants according to preoperatively derived data, thereby increasing the accuracy of dental implants and reducing the risk of dental implant failure [12,13]. Clinical experiences have confirmed that dental implant navigation systems are reliable and can be routinely used in dental implant surgery [14].

Regarding the convenience of the dental implant surgery, studies have indicated that performing implant surgery for teeth located in the rear mandibular region is not always easy because the soft tissue in the oral cavity can affect the surgical field of view [15]. In addition, the short interarch distance in this region significantly affects the ability of appropriately placing the surgical drill [16]. Other studies have reported that the degree of accuracy in implant surgeries varies depending on the position of the tooth to be operated on [16]. Furthermore, studies have demonstrated that compared with traditional surgical approaches, dental implant navigation systems can provide more favorable surgical outcomes [17]. Collectively, these studies have suggested that using dental implant navigation systems can assist dentists in offering high-quality and safe medical services to patients.

Since the early 1980s, many researchers have gradually applied learning curve theory to investigate whether the efficacy of medical treatments and consumption of healthcare resources have improved with the number of services offered by providers and the extent of their experience. Although learning curve theory is widely used in medical treatments, related findings have varied in terms of the strength of the relationship among numerical results in different diseases. Studies have reported that establishing learning curves facilitates improving medical care quality [18]. Dental implant installation is widely used and can be combined with cutting-edge technologies. However, no study has investigated the effect of learning curves on the accuracy of dental implant navigation systems. Therefore, through the practical use of a dental implant navigation system, we attempted to establish a learning curve for the operation time and degree of accuracy of dental implants in this study. In addition, using the navigation system, we examined the difference in accuracy according to the operation site and time. We hypothesized that the operator can achieve stable implant installation accuracy through 3 drilling tests.

## Material and methods

This study was approved by the IRB of KMUH-IRB-2013-08-02(1).

### Drilling trial

**Step 1. Preparation of the tooth model**

Nissin upper and lower jaw dental models were used to obtain the desired edentulous conditions (maxillary edentulous positions: 11, 17, and 26; mandibular edentulous positions: 31, 36, and 47). The models were replicated to produce 25 sets of plaster dental molds (each set contained one model for the maxilla and one for the mandible, hereinafter referred to as the dental model). Each dental model was used for drilling 3 missing tooth positions (differences between actual drilling and preoperative planned positions were indicated by markers), and the patient tracking module was created (Fig. 1).

**Step 2. CT scan**

CT was performed for each combination of the dental model and patient tracking module (Asahi AZ3000CT, slice spacing: 0.26 mm), giving a total output of 25 DICOM files with a standard format.

**Step 3. Preoperative planning**

At the beginning of the experiment, imaging data were first imported into the implant preoperative planning software (SmilePlan, TITC Ltd, Taiwan) in the dental navigation system (AQNavi, TITC Ltd, Taiwan) for surgical planning. The planned implant was placed at the desired surgical