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Factors affecting accuracy of implant placement with mucosa-supported stereolithographic surgical guides in edentulous mandibles

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ABSTRACT

This study aimed to evaluate the accuracy of implant placement with mucosa-supported surgical guides in edentulous mandibles and to determine the factors affecting accuracy. Implant placement was simulated on the preoperative CT image and mucosa-supported surgical guides were fabricated for six edentulous mandible models and 15 patients with edentulous mandibles, using CAD/CAM technology. Deviations of the actual implant position from the planned position were calculated by comparing the planned image and the postoperative image. Based on the results, it was concluded that mucosa-supported surgical guides have high accuracy and that bone density and mucosal thickness could affect accuracy.

1. Introduction

Stereolithographic surgical guides can simplify the technique-sensitive and operator-dependent surgical procedures in implant-supported restorations, benefiting both patient and dentist [1]. When stereolithographic surgical guides were used, variations in accuracy of implant placement within surgeons and between surgeons were reduced, compared to surgery using conventional guides [2]. Shorter surgery duration and less discomfort after surgery were recorded when mucosa-supported surgical guides were used [3]. Therefore, the use of mucosa-supported stereolithographic surgical guides in edentulous patients will increase along with the demand for implant-supported restorations in edentulous patients.

Although many researchers have evaluated the accuracy of implant placement with mucosa-supported surgical guides [4–17], few studies have assessed factors affecting the accuracy of mucosa-supported surgical guides. Errors during implant placement have often been explained by instability of the surgical guide [4]. Considering a report that alveolar ridge resorption was associated with denture stability in edentulous mandibles [18], alveolar ridge shape seems to influence surgical guide accuracy, which has not been examined. A previous study reported greater accuracy in the edentulous mandible, which has higher bone density, than in edentulous maxilla [5]. However, in another study, the surgical guide showed higher accuracy in edentulous maxilla because it covered a larger area than the edentulous mandible [6]. There are some reports that thicker supporting mucosa of edentulous maxilla might decrease accuracy [7,8]. Therefore, bone density, mucosal thickness, and area of supporting mucosa seem to affect the accuracy of implant placement with mucosa-supported surgical guides in edentulous mandible. Previous papers have not investigated the influence of these three factors together on accuracy.

In this paper, the authors performed a model study and a clinical study, in which the accuracy of implant placement with mucosa-supported surgical guides was evaluated by matching the images of planned and placed implants and calculating the positional deviations between them. The purpose of the model study was to determine the system-related accuracy using edentulous mandible models and the influence of alveolar ridge shape on accuracy. The purpose of the clinical study was to evaluate the procedure-related accuracy in patients with edentulous mandible and determine the factors affecting accuracy. The null hypothesis for the model study was that there would be no difference between the accuracy of implant placement in two types of models with different alveolar ridge shapes. The null hypothesis for the clinical study was that there would be no correlation between the accuracy and bone density, mucosal thickness, and area of supporting mucosa.

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2. Materials and methods

2.1. Presurgical preparation

The study protocol was approved by the Institutional Ethics Committee of Tokyo Medical and Dental University (#531). For the model study, six edentulous mandible test models were fabricated, which consisted of a stone cast (Zo-Dental Plaster, Shimomura Gypsum, Saitama, Japan) and a 2-mm-thick layer of silicone impression material (Examixfine Regular Type, GC, Tokyo, Japan) as artificial mucosa. They were divided equally into two groups according to the alveolar ridge shape (Absorbed group and Non-absorbed group). The three models in each group were fabricated identically. A radiographic guide was fabricated for each group using multipurpose pourable resin (Procast DSP clear, GC) (Fig. 1a). Eight gutta-percha markers (Temporary Stopping, GC) as radio-paque fiducials were placed in the radiographic guide.

The clinical study population consisted of 15 patients with edentulous mandibles, who were scheduled to be treated with two-implant overdenture at the University Hospital of Dentistry, Tokyo Medical and Dental University, between July 2010 and January 2013. Patients with systemic diseases, poor oral hygiene, uncontrolled diabetes, current irradiation to the head or neck, psychological disorders, or administration of bisphosphonates were excluded. All patients were informed of the study protocol and signed an informed consent form. The patient's complete denture with an optimal shape, occlusion and mucosal fit was used as a radiographic guide (Fig. 1b), and eight gutta-percha markers were placed.

Preoperative planning and manufacturing of the surgical guide (NobelGuide, Nobel Biocare, Gothenburg, Sweden) were performed by the double scanning technique [19]. For every CT scan, cone-beam CT (CBCT) (Finecube, Yoshida, Tokyo, Japan; voxel size 0.157 mm, slice thickness 0.146 mm, acquisition time 19 s, FOV 82 mm × 75.1 mm, 90 kV, 4 mA) was used. In the model study, the radiographic guide and the test model were connected using rubber bands and were scanned for the first CT scan. In the clinical study, the patient was instructed to clench the radiographic guide with maximal bite force and the first CT scan was performed. The radiographic guide alone was then scanned for the second CT scan. After a virtual 3D image of the combined radiographic guide and the model or bone was created by the planning software (Procera, Nobel Biocare), two implants were virtually located at their optimal position in the intraforaminal area (Fig. 2a and b). Individually customized surgical guides which contained two guided sleeves and three anchor pin sleeves were manufactured by rapid prototyping (Fig. 3a and b).

2.2. Surgical procedure

The implant placement in the model study was performed by a prosthodontist with ≥7 years of experience in implant-placement surgery. During surgery, the surgical guide was attached to the model using rubber bands. The implant placement in the clinical study was performed under intravenous sedation and local anesthesia, by an implantologist with ≥12 years of experience in implant-placement surgery at the University Hospital of Dentistry, Tokyo Medical and Dental University. The local anesthetic injection was administered via the sleeves, with the surgical guide strongly compressed against the ridge so that mucosa swelled by the anesthetic would not disturb the stability of the surgical guide. Until the implant insertion was over, the surgical guide was kept in place by strongly compressing its bilateral molar regions. The implant (Nobel Speedy Groovy RP φ4 × 11.5–18 mm^2, Nobel Biocare) was inserted according to the manufacturer's protocol for a flapless surgical procedure (Fig. 4a and b) [9].

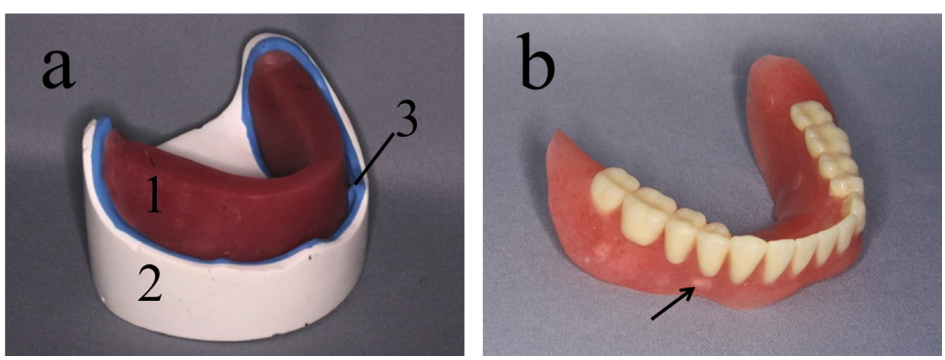

Fig. 1. Radiographic guides for the (a) model study and (b) clinical study. (a) Radiographic guide (1) was fabricated on stone cast (2) with artificial mucosa (3). (b) The patient's complete denture made of acrylic resin was used as a radiographic guide, in which gutta-percha markers were placed as reference points (arrow).

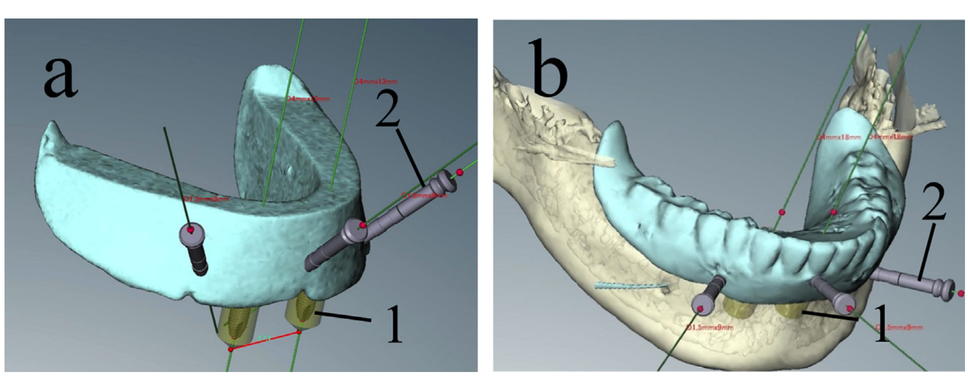

Fig. 2. Planning on the Procera software in the (a) model study and (b) clinical study. Placement of two implants (1) and three anchor pins (2) was planned presurgically, according to anatomy and prosthetic design.