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In vitro evaluation of basal shapes and offset values of artificial teeth for CAD/CAM complete dentures

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ABSTRACT

Statement of Problem. Artificial teeth are bonded onto the recesses of a milled denture base in a complete denture prepared using computer-aided design/computer-aided manufacturing (CAD/CAM). Little is known, however, about the effects of basal shapes and offset values on the accuracy of positions of the bonded artificial teeth.

1. Introduction

Recently, computer-aided design/computer-aided manufacture (CAD/CAM) technologies were applied to the field of complete denture prosthodontics [1,2]. Several fabrication methods for CAD/CAM fabricated complete dentures have been reported [3]. Among these methods, the laboratory procedures are subdivided broadly into 2 categories. One involves fabrication of denture bases using computerized-numerical-control milling [1,4], and the other is a hybrid of rapid prototyping (RP) and conventional laboratory procedures [5]. The abovementioned reports, however, described the fabrication methods and did not mention the accuracy of the finished dentures.

The development of the system for fabricating CAD/CAM fabricated complete dentures was reported previously [6,7]. In this system, artificial teeth are bonded onto the recesses of a milled denture base. The authors previously reported that the polished surface of dentures shows high accuracy, whereas the occlusal surface shows low accuracy [8]. This is because artificial teeth are occasionally not returned to the specified positions during the bonding process, when there is no space between artificial teeth and the recesses. The authors also reported previously that in CAD/CAM fabricated complete dentures, recesses require an offset for precise positioning of teeth [9].

However, in the abovementioned study [9], the displacement of bonded artificial teeth to the buccal surface was observed. This problem is because of the horizontal movement of artificial teeth during the bonding process. Furthermore, the study results showed a wide range of offset values of .10–.25 mm and did not specify the optimal offset value. In addition, cone-beam computed tomography (CBCT) was used for analysis of bonded artificial teeth. In a previous report, Yamashina stated that CBCT is inaccurate [10].

In order to solve these problems, in the present study, basal shapes of artificial teeth were developed from scratch; these shapes are intended to prevent the horizontal movement. Three offset values that were specified in a previous study were selected. A 3-dimensional (3D) laser scanner was used for accurate scanning of the prototype [11]. Thus, our null hypothesis was that, in this preliminary study, among 3 types of basal shape and 3 offset values, there are no differences in positioning of the artificial teeth.

2. Material and methods

2.1. Master data acquisition

The flow chart used in this study is described in Fig. 1. The denture base model was designed in CAD software (FreeForm; Geomagic, Morrisville, NC, USA; Fig. 1a). The standard triangulated language data on artificial teeth (SURPASS G; GC Corp., Tokyo, Japan) were obtained using a non-contact optical 3D scanner (ATOS Triple Scan; GOM, Braunschweig, Germany; Fig. 1b) based on the principle of triangulation. The mandibular left first

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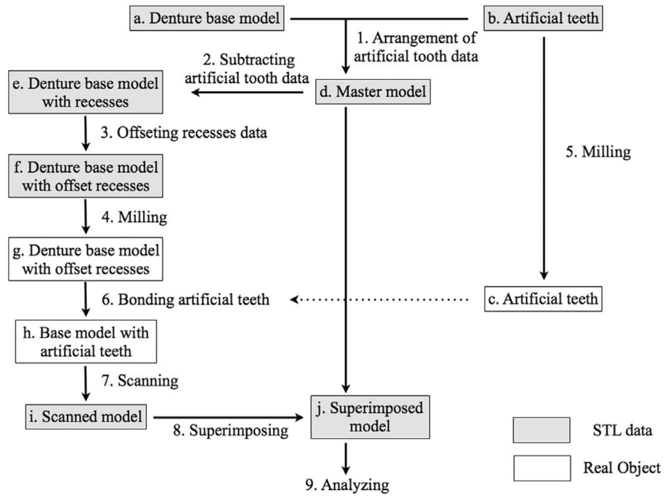

Fig. 1. The flow chart of the study. 1) Artificial teeth were arranged on a denture base model. 2) The parts of the master model related to artificial teeth were subtracted using Boolean logic operations. 3) Recesses were offset using 3 values. 4) A machining center was used to mill a resin block to prepare a denture base prototype. 5) The machining center was used to mill resin blocks to prepare the artificial teeth. 6) The artificial teeth were bonded onto the recesses. 7) A 3D scanner was used to obtain the data in the standard triangulated language (STL). 8) Superimposition based on the flat plane of the denture base model. 9) Analysis in CAD software.

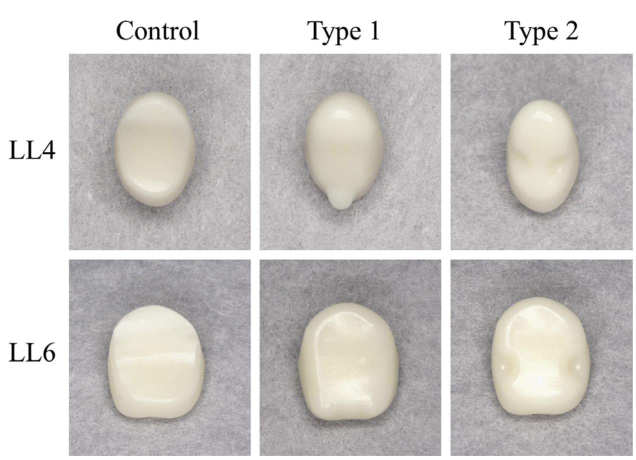

Fig. 2. Three types of artificial teeth seen from the basal area. The mandibular left first premolar (LL4) and mandibular left first molar (LL6) were analyzed. The Type 1 has projections and Type 2 has dimples in the basal areas. Additionally, the Control group had sharp edges, but the Type 1 and 2 groups had margins that were smoothened by CAD software.

premolar (LL4) and mandibular left first molar (LL6) were used for the experiments. The data on artificial teeth served as the Control group. Using the CAD software, the basal shapes of the Control group were changed as follows. The Type 1 group had projections in the lingual area, whereas the Type 2 group had dimples in the basal area on the mesial and distal side (Fig. 2). In both groups (Types 1 and 2), the edges of the basal area were changed to a smooth curve. On the occlusal surface of each tooth model, a reference point ("A" in Fig. 3) was designed. On the basis of these data, a five-axis computerized numerical control machining center (GM-1000; GC Corp., Tokyo, Japan) and a ball-end mill (.5 mm in diameter) were used to mill polymethyl methacrylate (PMMA) disks (Aadva PMMA disc; GC Corp., Tokyo, Japan) to prepare the artificial teeth (Fig. 1c). Three types of artificial teeth were arranged on the denture base model in the CAD software. Each type of artificial teeth for LL4 and LL6 was set at regular intervals on the

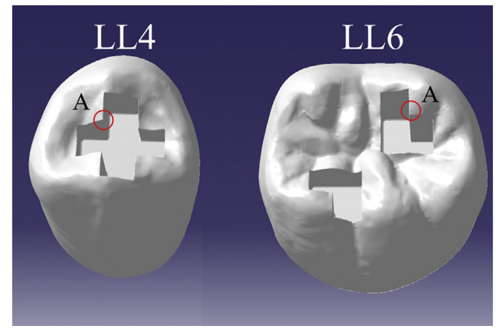

Fig. 3. Reference point A is an intersection of 3 lines that was designed on the mandibular left first premolar (LL4) and mandibular left first molar (LL6). Milling bars crossed at right angles produced the reference point.

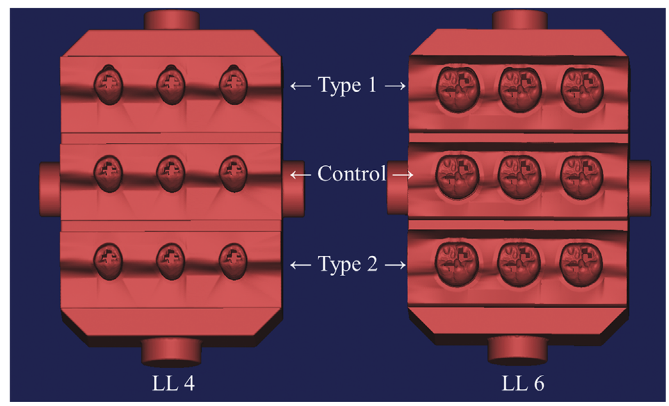

Fig. 4. Master data for the mandibular left first premolar (LL4) and mandibular left first molar (LL6).

denture base model; these data were defined as the master data (Fig. 1d and 4).

2.2. Acquisition of scanned data

The artificial teeth were subtracted from the denture base model by means of Boolean logic operations in order to produce recesses (Fig. 1e). The recesses were then offset with 3 values (Fig. 1f). The offset values were .15, .20, and .25 mm. During this process, offset recesses for the artificial teeth were prepared on the denture base model. According to these data, the machining center was used to mill 3 translucent PMMA disks to prepare denture base prototypes with recesses for LL4 and LL6 (Figs. 1g and 5). A quickly self-polymerizing acrylic resin (UNIFAST III; GC Corp., Tokyo, Japan) was used for bonding the artificial teeth onto the base prototype containing the recesses. An examiner with >5 years of clinical experience in prosthodontics at the Dental Hospital, Tokyo Medical and Dental University, bonded the sample piece (Fig. 1h, Fig. 6). These denture base models with bonded artificial teeth were analyzed using the 3D scanner. These data were defined as the scanned data (Fig. 1i).

2.3. Analysis of accuracy

The scanned data were superimposed on the master data in accordance with the flat plane part of the denture base model using the CAD software (Mimics; Materialise, Leuven, Belgium; Fig. 1j). The deviation comparison between the master data and the scanned data was performed on the artificial teeth. Mean deviations were calculated as absolute values according to the method described previously [9]. However, in the color-coded maps of deviations, positive and negative values were used