Research Article

Quantitative Evaluation of Tissue Surface Adaption of CAD-Designed and 3D Printed Wax Pattern of Maxillary Complete Denture

Hu Chen, Han Wang, Peijun Lv, Yong Wang, and Yuchun Sun

Center of Digital Dentistry, Faculty of Prosthodontics, Peking University School and Hospital of Stomatolgy and National Engineering Laboratory for Digital and Material Technology of Stomatolgy and Research Center of Engineering and Technology for Digital Dentistry of Ministry of Health, 22 Zhongguancun Nandajie, Haidian District, Beijing 100081, China

Correspondence should be addressed to Yong Wang; kqcadc@bjmu.edu.cn and Yuchun Sun; polarshining@163.com

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Objective. To quantitatively evaluate the tissue surface adaption of a maxillary complete denture wax pattern produced by CAD and 3DP. Methods. A standard edentulous maxilla plaster cast model was used, for which a wax pattern of complete denture was designed using CAD software developed in our previous study and printed using a 3D wax printer, while another wax pattern was manufactured by the traditional manual method. The cast model and the two wax patterns were scanned in the 3D scanner as “DataModel,” “DataWaxRP,” and “DataWaxManual.” After setting each wax pattern on the plaster cast, the whole model was scanned for registration. After registration, the deviations of tissue surface between “DataModel” and “DataWaxRP” and between “DataModel” and “DataWaxManual” were measured. The data was analyzed by paired \( t \)-test. Results. For both wax patterns produced by the CAD&RP method and the manual method, scanning data of tissue surface and cast surface showed a good fit in the majority. No statistically significant \( (P > 0.05) \) difference was observed between the CAD&RP method and the manual method. Conclusions. Wax pattern of maxillary complete denture produced by the CAD&3DP method is comparable with traditional manual method in the adaption to the edentulous cast model.

1. Introduction

Before the complete dentures are finally produced and the problems become uncorrectable, a procedure of try-in refers to the wearing of a wax pattern, after the arrangement of artificial teeth, in the mouth of an edentulous patient to identify and fix any problems with denture design. Thus, complete denture try-in is a vital step in the design of complete dentures for restoring edentulous jaws.

Several key points should be confirmed during the try-in [1, 2], including good fit of the completed dentures on the edentulous alveolar ridge and no tilting, twisting, nor stretching of the denture base. Vertical distance, centric relation, occlusion, aesthetics, and phonetic function should also be checked. To best test these dynamic functions of complete denture requires that the dentures be of good retention and stability; that is, each denture must have a snug fit between the denture tissue surface and the edentulous alveolar ridge.

Computer-aided design (CAD) and computer-aided manufacturing (CAM) technology has been widely applied in multiple oral disciplines, especially in the field of fixed denture restoration [3–5]. However, the application of CAD/CAM in the design and development of complete dentures is still being explored. Kawahata et al. and Inokoshi et al. applied the RP technology in the coping of a complete denture [6, 7]. In their studies, a wax copy of old complete denture was produced and used to do try-ins to evaluate the aesthetics, comfort, and stability in patients. However, no studies have quantitatively evaluated the tissue surface adaption of 3D printed dentures in patients, and none have compared this method quantitatively against the traditional manual method. In the previous study we developed the first
generation of complete denture CAD software using a rapid prototyping (RP) process to complete denture production [8]. Systematic study of this entire CAD/RP process, from the acquisition of data to digital design and production, has since been carried out. However, a successful digital try-in methodology for complete denture restoration has not yet been established.

In this study, a wax pattern of maxillary complete denture was made on a standard edentulous plaster cast using high-precision 3D wax-printing technology, and the fit between the wax pattern and the cast was evaluated quantitatively.

2. Materials and Methods

2.1. Complete Denture Wax Pattern CAD. 3D data of the standard edentulous maxilla plaster cast model (DataModel) and its temporal denture base were obtained using a 3D scanner (Activity 880, Smart Optics, Germany). CAD software for complete denture was developed based on a reverse engineering software (Imageware 10.0, Siemens, Germany), where the 3D data of the plaster cast and the temporal denture base were registered, and the wax pattern of complete denture was designed (Figure 1(a)).

2.2. Wax Denture Manufacturing. The CAD denture data were imported into the supporting software of the 3D wax printer (ProJet CPX 3500, 3D Systems, USA) where, with a print layer thickness of 20 µm, the wax complete denture was printed (Figure 1(b)). A second wax denture was also created on the same plaster cast using the traditional manual method.

2.3. Wax Denture Scanning. The 3D printed wax pattern was scanned to obtain "DataWaxRP." After setting the denture on the plaster cast completely, the entire model was scanned to obtain "DataModel&WaxRP." Similarly, the wax denture made in the traditional manual method was scanned to obtain "DataWaxManual," and the entire model, after setting the denture on the plaster cast, was scanned to obtain "DataModel&WaxManual."

2.4. Data Registration. The above scan data were inputted together into a reverse engineering software (Geomagic Studio/Qualify 2013, Geomagic, USA). Using the multipoint registration and best fit alignment command, "DataWaxRP" was registered to "DataModel&WaxRP" and "DataWaxManual" to "DataModel&WaxManual," where the polished surface of the wax denture was set as the common area. Similarly, "DataModel" was registered to "DataModel&WaxRP" and "DataModel&WaxManual" with the uncovered surface of the plaster model as the common area.

2.5. 3D Deviation Analysis. After registration, using the 3D deviation analysis command, average deviations of the overall area, primary stress-bearing area, secondary stress-bearing area, and border seal area between "DataWaxRP" and "DataModel" (CAD&3DP group) and between "DataWaxManual" and "DataModel" (manual group) were measured (Figure 2).

2.6. Statistical Analysis. 3D deviation analysis data of functional areas (primary stress-bearing area, secondary stress-bearing area, border seal area, and postdam area) were analyzed in statistical analysis software (SPSS 19.0, IBM, USA) using paired t-test where the CAD&3DP group is set as the experimental group and the traditional manual method group as the control group. P value above 0.05 was considered to be not statistically significant.

3. Results

Deviation between the tissue surface of the wax denture and the plaster cast was shown in Figure 2, the green area represents a good fit between them, yellow and red areas indicate a positive deviation (tissue surface locating above the cast surface), and the blue area indicates the presence of a negative deviation (tissue surface locating below the cast surface). For both the experimental group and the control group, scanning data of tissue surface and cast surface showed a good fit with each other in the majority, regardless of some small proportion of positive deviation area. Almost no region has shown negative deviation, since the actual surface
of the denture base cannot invade the surface of the cast model. The very small range of blue region presented on the buccal side of left maxillary tuberosity in control group may be explained as a scanning error by accident. Deviation of the experimental group focused on the right maxillary alveolar crest and buccal edge region, followed by the palate region, with maximum distance below 0.7 mm. Deviation of the control group distributed scattered with distance above 1.0 mm in some regions. The average deviations between the tissue surface of the wax denture and the plaster cast were listed in Table 1. Paired samples t-test between functional areas of CAD&RP group and manual group has shown no significant difference.

4. Discussion
3D printing or 3DP for short was developed by MIT (Massachusetts Institute of Technology) and is based on droplet
This finding demonstrated that the CAD&3DP method, using our complete denture CAD software and the ProJet CPX 3500 printer, can meet the clinically acceptable precision for design and development of complete dentures for try-in for restoring edentulous jaws.

In this study, a wax pattern of complete denture, which allows the evaluation of occlusion, vertical distance, central relationship, aesthetics, and pronunciation, was produced using the digitalized method. Importantly, modifying of the wax pattern could be done during try-in and the improved profile fed back into the design software for further manufacturing.

However, it takes a relatively long time to print the wax pattern of complete denture (14–16 hours) and removing the support material (1-2 hours). The adaption of the tissue surface of wax pattern to the cast for mandibular complete denture should also be evaluated in further study.

5. Conclusion

Compared with the traditional manual method, the adaptation of the maxillary complete denture prepared using the CAD&3DP method for testing teeth arrangement and the edentulous alveolar ridge was not significantly different, meaning that the CAD&3DP method can meet the clinically acceptable precision for design and development of complete dentures for try-in for restoring edentulous jaws.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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