A study of the usefulness of implant superstructure production methods using optical impression systems and CAD/CAM techniques - targeting application during home visit dental treatment.

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Abstract

Introduction: According to a survey in 2017, elderly individuals, defined as individuals aged ≥ 65 years, comprised 27.7% of the Japanese population, making Japan the most aged developed nation in the world. Elderly patients admitted to elderly care facilities and patients who are unable to attend clinic visits can be examined by dentists and dental hygienists who perform home visit dental care. Usually, the dentists and dental hygienists must take all examination equipment and materials with them when they visit elderly care facilities during home visit dental care performed in Japan. There are limits on the equipment that can be used during dentistry home visits, and the examination positions that the patient can be placed in are restricted, so the application of digital dentistry, such as optical impression systems and CAD/CAM techniques, may be of greater benefit than conventional techniques.

The objective of this study was to establish a home visit dental care treatment system to enable easy production of intraoral implant superstructures. We performed a clinical investigation to compare implant-supported overdentures (IOD) produced using optical impressions to the old IODs that patients were currently using, in order to determine whether it was possible to use the optical impression IOD production method during home visit dental treatment.

Subjects and Methods: Our subjects were six patients (three men, three women, mean age 71.0 ± 5.9 years) fitted with a mandibular IOD and a maxillary complete denture, selected from among edentulous patients being followed up at the Division of Oral Implantology and Division of Prosthodontics at Fukuoka Dental College Medicine and Dental General Hospital. The IOD was produced using the optical impression method (digital method), which entailed preparing dentures using an optical impression system and 3D printer models, and a questionnaire was administered to evaluate masticatory function using a rubbery substance, with the approximate consistency of hard chewing gum, and to determine the degree of patient satisfaction, among other factors. We also administered a questionnaire to perform similar evaluation of masticatory function using the old IODs produced using the conventional method, which entailed preparing dentures using silicone impression material and gypsum models. We then compared the digital method to the conventional method.

Results: The median values (interquartile range) obtained during the mastication function tests using the rubbery substance were 4.5 points (0.6) and 5.0 points (0.5) for the conventional and digital methods, respectively. The results of the survey to determine the degree of satisfaction with the IOD, measured using a visual analogue scale (VAS), were 7.8 points (2.4) and 7.3 points (1.2), respectively. In addition, the results of the survey to determine the degree of satisfaction with the IOD, measured using the Oral Health Impact Profile (O-HIP), were 18.5 points (16.3) and 16.5 points (11.5), respectively. There were no statistically significant differences observed in any items.

Discussion and Conclusion: We did not observe any statistically significant differences in the results of masticatory function tests and degree of patient satisfaction surveys obtained from patients using old IODs, produced using the conventional method, and IODs produced using the digital method. These findings suggest that the IODs produced using the digital method provide the same degree of restoration of intraoral function as the old IODs produced using silicone impression materials. This outcome suggests that the application of digital dentistry, such as CAD/CAM techniques that enable the production of models using an optical impression system and its impression data during home visit dental treatment, is useful when preparing intraoral implant superstructures for patients who find it difficult to attend clinic visits, or for whom the use of the conventional method is unsuitable.

Key words: dental implants, Optical impression, edentulous, elderly patients
I. Introduction

According to a survey in 2017, elderly individuals, defined as individuals aged ≥65 years, comprised 27.7% of the Japanese population, making Japan the most aged developed nation in the world. Elderly patients admitted to elderly care facilities and patients who struggle to travel to appointments can be examined by dentists and dental hygienists who perform home visit dental care. Usually, the dentists and dental hygienists must take all examination equipment and materials with them when they visit elderly care facilities during home visit dental care performed in Japan. When patients age after intraoral implant treatment, it may become difficult for them to attend hospital visits due to systemic disorders and decreased mobility, and they may not receive adequate implant maintenance. In addition, self-care may become challenging due to upper limb paralysis and dementia after cerebrovascular disorders, and we believe that a system to allow home visit treatment, such as implant maintenance and functional restoration when issues occur in these types of patients, needs to be established as a matter of urgency. According to a report by Wada et al., issues related to intraoral implants during home visit dental treatment include a lack of understanding of intraoral implant care methods by caregivers, the fact that the majority of elderly patients suffer from peri-implantitis, requests for extraction of submerged intraoral implants at other hospitals when the manufacturer is unknown, and the fact that family and caregivers do not recognize the presence of an intraoral implant in the patient. According to a questionnaire survey administered to implantology specialists certified by the Japanese Society of Oral Implantology (924 individuals) and the Society of Prosthodontics and Implant Dentistry (924 individuals), 3% of patients who receive dentistry home visits previously received intraoral implant treatment, and more than half of those patients are in a state in which they are unable to perform self-care. The most common issues related to intraoral implants were difficult cleaning (47%) and peri-implantitis (39%), which were treated by means of drug administration (32%) and follow-up observation (22%). The most common reason for follow-up observation was that 29% of the practitioners performing the dentistry home visits had no experience of intraoral implant treatment, and we believe they had insufficient knowledge of how to produce intraoral implant prosthetics.

Another major issue during home visit dental care to patients who have received implant treatment is the difficulty of repairing or reproducing superstructures. One report has indicated that abutments and attachments became exposed when superstructures were damaged, and were left in that state for some time, which injured the opposing mucosa and caused an eating disorder. One reason it is difficult to reproduce or repair superstructures during home visit dental treatment is that it is difficult to obtain impressions. Taking impressions from elderly patients in need and from patients with dysphagia poses the risk of aspiration or accidental ingestion if the conventional method is employed, i.e. taking impressions using alginate or silicone.

We believe that the information above indicates that the application of digital dentistry, such as CAD/CAM techniques that enable the production of models using an optical impression system and its impression data during home visit dental treatment, is useful when preparing intraoral implant superstructures.

For this reason, during this study, our objective was to establish a home visit dental treatment system to enable easy production of intraoral implant superstructures. Our subjects were patients who had been treated with implant overdentures (IOD). We established a method for preparing superstructures that entailed using an optical impression system to digitize patient models, which we then printed out using a 3D printer. We also compared the IODs produced using the optical impression system to the old IODs and performed a clinical evaluation to determine the usefulness for dentistry home visits.

II. Subjects and Methods

Our subjects were six patients (three men, three women, mean age 71.0 ± 5.9 years) fitted with a maxillary complete denture and a mandibular IOD, selected from among edentulous patients at the Division of Oral Implantology and Division of Prosthodontics at Fukuoka Dental College Medicine and Dental General Hospital. The IOD was produced using the optical impression method (digital method), which entailed preparing dentures using an optical impression system and 3D printer models, and a questionnaire was administered to evaluate masticatory function using a rubbery substance and to determine the degree of patient satisfaction, among other factors. We also administered a questionnaire to perform similar evaluation of masticatory function using the old IODs produced using the conventional method, which entailed preparing dentures using silicone impression material and gypsum models. We then compared the digital method to the conventional method (Fig. 1).

![Diagram showing comparison between conventional and digital methods](Fig.1). We performed a comparative evaluation of old IODs produced using the conventional method (silicone impression material and gypsum models) and IOD is produced using the digital system by means of evaluation of masticatory function (masticatory function tests using a rubbery substance) and questionnaire surveys (O-HIP, VAS scores) one year after fitting new dentures.
1) Evaluation of masticatory function: The rubbery substance used during the tests (approximately 2 cm x approximately 2 cm x 1 cm, UHA Mikakuto) was chewed 30 times, then the degree of pulverization was calculated using a scoring method for masticatory function, which gave the mastication score value. The higher the numerical value of the mastication score, the higher the masticatory function.

2) Questionnaire survey: To create a visual analogue scale (VAS), we requested that patients indicate the degree of satisfaction with the IOD by making a marking above a 100-mm straight line. We measured the length thereof and digitized the value to obtain the degree of satisfaction. This was evaluated as a value out of 10, and the higher the numerical value, the higher the degree of satisfaction. The Oral Health Impact Profile (O-HIP-EDENT-J Ver.2, a quality of life scale related to dental health) was used to survey the degree patient of satisfaction, and the lower the score, the higher the degree of patient satisfaction.

We compared the evaluations of masticatory function when the conventional and digital methods were used, as well as the degree of patient satisfaction measured using the VAS and O-HIP-EDENT-J Ver.2, using the Wilcoxon signed rank test. During statistical analysis, an α =0.05 was considered the level of significance, and statistical calculation was performed using SPSS version 25 (Japan IBM, Tokyo). This study was approved by the Fukuoka Gakuen institutional research ethics committee (approval number: 395).

III. Results

1) Status of submerged implants and attachment type in subjects
The number of implants between the mental foramina were four in five subjects (83%), and two in one subject (70%). The attachment types were as follows: locator attachment in two subjects (33%), bar attachment in two subjects (33%), ball attachment in one subject (17%), and magnet attachment in one subject (17%).

2) 3D printer models and superstructure production
We used an optical scanner (CREC Omnicam, Sirona, USA) to scan the attachments of the mandibular implant and the intraoral mucosa. Scanning one jaw took approximately five minutes. Based on the scan data, we used a 3D printer (Varseo 3D Printing System BEGO, Germany) to produce a 3D model (photopolymer), then produced an IOD using the usual technical operations. The IOD was directly mounted on the attachment clasp within the intraoral cavity (Fig. 2a-g).
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The median values (interquartile range) for the degree of satisfaction with the IOD measured using the O-HIP-EDENT-J Ver.2 were 18.5 points (16.3) and 7.3 points (1.2) for the conventional and digital methods, respectively. We did not observe any statistically significant differences in the results obtained using the conventional method and the digital method (Table1).

IV. Discussion

The maintenance of occlusal support is an important factor in elderly individuals with dysphagia and when planning functional restoration through swallowing training in patients with dementia. Accordingly, dentures play a major role in the management of patients who are edentulous or have multiple missing teeth. There are limitations in terms of the materials that can be used when impressions are taken from these patients to produce dentures in a home visit setting, and moreover, the position in which the patient is examined is not ideal under these conditions. The risk of aspiration or accidental ingestion in these patients is therefore high when conventional methods are used, i.e. taking impressions using alginate or silicone. In order to resolve this issue, we believe that digital dentistry, such as CAD/CAM techniques that enable the production of models using an optical impression system and its impression data, can be applied during dentistry home visits to safely take impressions from elderly individuals and produce dentures. Taking impressions using conventional impression coping and silicone impression materials further complicates the process in a home visit setting when patients have existing intraoral implants. This is the reason why the ongoing management of implants is frequently neglected. Optical impressions not only make it easy to take impressions of implants in a home visit setting, but also enable the use of the implant as a standardized point and may improve precision.

During this study, we used an optical scanner to scan the attachments to the mandibular implant and the intraoral mucosa, then produced a 3D model from the scan data using a 3D printer and produced the IOD.
method provide the same degree of restoration of intraoral function as the old IODs produced using silicone impression materials.

There have been reports to date documenting the use of an optical scanner to produce complete maxillary or mandibular dentures for edentulous patients, although it is difficult to determine the functional position of the margin of the edentulous alveolar crest. Due to this difficulty, there have also been reports documenting the production of models from repeated superimposition of optical scan data and silicone impressions, after intraoral muscle trimming, to determine the morphology of the margin of the denture base. 12-14 The IODs produced using the digital method in this study were not complete dentures that required marginal closure, but instead implant-supported overdentures that facilitated maintenance, support and bracing of the implant region. After an alveolar ridge cast has been produced using an optical impression and 3D printer, a surgeon can therefore use the anatomical morphology as a reference to determine the position of the margin objectively. The scan duration for one jaw was a mean period of approximately five minutes. The optical scanner camera portion may become cloudy due to the moist intraoral environment, so we noted that suction may be required to ensure that the intraoral cavity remains as dry as possible. In addition, if a bar or locker attachment was used, the metal inadvertently reflected the light from the optical source, which in turn prolonged the scan time. Accordingly, this suggests the need to use specialized optical scanner powder to minimize light reflection when using materials that reflect light. 15 3D printer models produced from scan data are anatomical models that do not require additional border molding or pressure impressions, so the position of the margin of the IOD base produced in this way differed from that of the old IOD, although the congruence of the IOD and the occlusal morphology were both favorable. During the one-month observation period during the study, the IODs were adjusted three times. In terms of the adjustments performed to the IODs, the length of the margin of the denture base was reduced in the majority of cases. None of the subjects required relining, and in terms of occlusal adjustments, the occlusal facets were repaired.

Payne et al. 16 used the success of implant overdentures as a standard, and showed that the three conditions for success are ① less than two repairs of the clasp within the first year after fitting the overdentures, ② up to five clasp repairs within five years, and ③ up to one relining within five years. The old IODs produced using the conventional method for the subjects in this study fulfilled all success criteria for implant overdentures, and the results of the masticatory function tests and degree of patient satisfaction surveys performed during the study were also high. These findings suggest that the IODs produced using the digital method provide the same degree of restoration of intraoral function as the old IODs, which fulfilled the success criteria for implant overdentures. Therefore, this suggests that the optical impression method is an effective method for managing elderly patients for whom the use of the conventional method is unsuitable, or patients with dysphagia. The present study was a pilot study, with a short observation period for the IODs produced from optical impressions, so we believe that we need to increase the patient population and extend the survey period. We also plan to employ this method in practice for elderly patients and patients with dysphagia during home visit dental treatment going forward.

We believe that the outcomes of the study are particularly beneficial for patients who struggle to travel to the hospital, and primarily need intraoral dentures to practice swallowing during the recovery period. By doing so, we plan to maintain cognitive function in these patients by maintaining or improving intraoral function, which we anticipate will prevent them from becoming dependent on caregivers, prevent aspiration pneumonia and contribute to the achievement of a high quality of life.

V. Conclusion

Despite the small sample size and short observation period during the study, similar results were obtained during masticatory function tests and degree of patient satisfaction surveys on patients using old IODs, produced using the conventional method, and IODs produced using the digital method. These findings suggest that the IODs produced using the digital method provide the same degree of restoration of intraoral function as the old IODs.

This outcome suggests that the application of digital dentistry, such as CAD/CAM techniques that enable the production of models using an optical impression system and its impression data during dentistry home visits, is useful when preparing intraoral implant superstructures for patients who find it difficult to attend hospital visits, or for whom the use of the conventional method is unsuitable.

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