Surface attrition of zirconia and hybrid composite resin superstructure during implant therapy

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(Received April 8, 2021; Accepted May 14, 2021)

Abstract

Purpose: The purpose of this study was to examine morphological changes in the superstructure of implants in relation to the degree of attrition of the implant superstructure and its antagonists.

Methods: Thirty-three patients participated. The implant superstructures of the first molar and its antagonists were scanned with an intraoral scanner every 3 months. The amount of attrition was calculated in relation to the various materials used for the superstructure, and differences were analyzed statistically (P < 0.05).

Results: Attrition of the implant superstructure was 110 ± 30 µm for monolithic zirconia and 105 ± 27 µm for resin-veneered metal after 12 months. No statistically significant difference was found between the two groups. In contrast, attrition of the antagonists was 75 ± 25 µm for zirconia and 105 ± 20 µm for resin-veneered metal after 12 months. A statistically significant difference in the attrition levels between the two groups was observed after 9 and 12 months.

Conclusion: During the 12-month observation period, there was no difference in superstructure attrition between zirconia and resin-veneered metal. Attrition of the antagonists was higher for hybrid composite resin-veneered metal than for zirconia, suggesting that surface roughness affected the degree of attrition.

Keywords: attrition, dental implant, implant superstructure, intraoral scanner, zirconia

Introduction

Oral implants are widely used as a highly predictable prosthetic treatment for partially and fully edentulous patients, and in most cases successful long-term functional and esthetic outcomes can be expected [1-5]. Two types of complication can occur after implant treatment: biological and mechanical [6-10]. Peri-implantitis, which is classified as a biological complication, is defined as resorption of the surrounding bone and soft tissue inflammation caused by plaque, and has an incidence rate of approximately 9.7% [11]. In contrast, a study of mechanical complications has indicated that attrition and failure of the superstructure occur at a rate of approximately 33% after 5 years and 66% after 10 years, making this one of the most common complications [12]. Therefore, in implant therapy, superstructure attrition and failure are important factors influencing long-term success of the treatment.

Monolithic zirconia has been widely used as a material for prostheses in recent years. Although zirconia has excellent mechanical properties such as bending strength and hardness, the possibility of causing excessive antagonist attrition cannot be ruled out [13,14]. Nevertheless, with recent developments in digital technology, fabrication of prostheses through the optical impression method using intraoral scanners is becoming widespread in clinical practice [15-17]. The accuracy of the data obtained is equivalent to that of the conventional impression method using silicone impression materials [18-20]. In addition, unlike plaster models, digital data can be stored for long periods, making it effective for observing structural changes over time.

To date, in studies that have examined the degree of attrition, impressions of the occlusal surface were taken and made into a plaster model for comparison [21]. Hence, the conventional measurement method cannot eliminate the possibility of errors caused by deformation of the impression material and expansion of gypsum.

The purpose of the present study was to observe morphological changes in the implant superstructure at the occlusal surface over time, and to examine quantitatively the degree of attrition of the implant superstructure and its antagonists.

Materials and Methods

The study participants were patients who visited the Dental Center of Iwate Medical University Hospital. All provided written informed consent. Based on power analysis conducted prior to the study, the sample size was determined to be 33 (14 males and 19 females with mean age of 58.3 ± 8.9 years). The inclusion criteria for the participants were as follows: having a fixed superstructure delivered on the first molars, healthy antagonist teeth, and superstructures fabricated from monolithic zirconia (n = 20, Lava Plus, 3M, St Paul, MN, USA) or resin-veneered metal (n = 13, Estenia, Kuraray Noritake Dental, Tokyo, Japan). The exclusion criteria were as follows: no occlusal contact with the second molar, use of removable partial dentures, and a history of temporomandibular joint disease. The fixation methods used for the superstructure (screwing, cement fixation) were not stipulated.

Occlusal adjustment was performed by adjusting the occlusal contact of the implant superstructure to make it equivalent to that of natural teeth at maximum bite force. In addition, canine guidance during lateral movement was applied, and discision was applied to ensure no occlusal contact between the molars on the working side and no occlusal interference on the non-working side.

This study was designed as a prospective observational study in which the implant superstructure and its antagonist were scanned with an intraoral scanner every 3 months after final restorations had been delivered. Furthermore, morphological changes caused by attrition were observed for up to 12 months. If large-scale damage requiring repair or refabrication occurred within the observation period, the observation would be terminated at that point. The present study was approved by the Ethics Committee of the Faculty of Dentistry, Iwate Medical University (Ethics Committee No. 12000018, Approval No. 01235).

An intraoral scanner (3M True Definition scanner, 3M) (Fig. 1) was used to observe the occlusal surface, onto which titanium dioxide powder was sprayed to prevent light reflection during scanning. To reduce any error in the data as far as possible, the imaging range was set to include the occlusal surface and the buccolingual maximal convexity from the first premolar to the second molar.

The captured data were exported as STL (stereolithography) files to the image measurement software (GOM Inspect, GOM, Brunswick, Germany) (Fig. 2). The 3D models at 3, 6, 9, and 12 months were superimposed onto the baseline data using the best-fit algorithm, allowing wear sites on the superimposed images to be identified by the software. Maximum height differences in the functional cusp on the first molar were calculated and compared for each material of the superstructures and antagonist teeth.
Statistical analysis was performed using a statistical analysis software package (IBM SPSS, IBM, Armonk, NY, USA), and the Mann-Whitney test was used for comparison between the two groups ($P < 0.05$).

Results

No abnormalities were visible in the peri-implant tissue during the observation period; the periodontal tissue of the antagonist was in good condition, and the periodontal pocket was always within 3 mm. Additionally, no temporomandibular joint disorders occurred before and after treatment. The zirconia superstructure of one subject (female) fractured after 3 to 6 months during the observation period, and was thus excluded from the comparison.

The degree of attrition of the implant superstructure made of monolithic zirconia was $110 \pm 30 \mu m$ and that of the resin-veneered metal was $105 \pm 27 \mu m$ after 12 months of observation (Fig. 3). No significant difference was found in the amount of attrition between the two groups every 3 months. However, the amount of attrition of the antagonist after 12 months was $75 \pm 25 \mu m$ for zirconia and $105 \pm 20 \mu m$ for resin-veneered metal (Fig. 4). A significant difference was observed in the amount of attrition between the two groups at 9 ($P < 0.05$) and 12 months ($P < 0.05$).

Discussion

In the present study, implant superstructures were observed every 3 months after their delivery. The amount of attrition of the superstructures increased until 6 months after delivery and reached a plateau at 12 months. Stober et al. reported that the occlusal surface morphology of zirconia crowns changed during the first six months following delivery [22], and these results were consistent with those obtained in the present study. However, further structural changes may have occurred during a longer observation period.

The attrition of the antagonist of the zirconia superstructure in this study was $75 \mu m$ after 12 months. Hartkamp et al. reported that the attritions of the antagonists were $86 \pm 23 \mu m$ for enamel and $107 \pm 22 \mu m$ for zirconia superstructures after 12 months, which are similar to the values obtained in the present study [23].

Evaluation of the attrition of the antagonists for zirconia and resin-veneered metal superstructures revealed that after 9 months, attrition for the zirconia superstructure was negligible; however, the attrition of the antagonists for the resin-veneered metal superstructures did not decrease. In a previous study [14] to evaluate the enamel attrition of antagonists for zirconia and lithium disilicate crowns in vitro, the antagonist attrition of a fully polished zirconia crown was smaller. As described above, characteristics such as bending strength and hardness do not always influence the amount of attrition. Zhi et al. have investigated the amount of attrition of the antagonists for ceramic crowns and suggested that the surface texture of crowns could be one of the factors influencing the attrition [24]. The microstructure of zirconia is dense and uniform, resulting in less attrition of the antagonist even after long-term use [25]. When resin-veneered metal is used for a long period, the substrate becomes abraded and the filler is exposed, resulting in the formation of a rough surface. Indeed, in the present study, it was found that antagonist attrition of the resin-veneered metal occurred continuously even after 6 months.

Use of an intraoral scanner helped us eliminate and correct errors resulting from shrinkage of the impression material and expansion of the plaster. The 3M intraoral scanner used in this study has the same distance accuracy as that of the conventional method used for impression-taking [18-20], and has one of the highest accuracy levels among all available intraoral scanners.

Generally, as an intraoral scanner captures images directly, the time required for data acquisition can be shortened compared to the use of a desktop scanner. However, the accuracy of intraoral scanners is ambiguous because the measured data are stitched together to create the image data.
In previous studies that examined the reproducibility of the entire dental arch using an intraoral scanner, image distortions were recognized [28,29]. Thus, to minimize such scanning errors in the present study, the scanning area was limited up to the buccolingual maximum convexity of the target teeth and superstructures.

Another systematic review has concluded that bruxism is not a risk factor for peri-implant biological complications, but may be a risk factor for mechanical complications [30]. Therefore, parafunctions such as bruxism may affect the amount of attrition. Consequently, the influence of bruxism on mechanical and biological peri-implant complications must be analyzed in future studies.

In order to prevent fracture of the implant superstructure and maintain occlusion, it is desirable to use a high-strength material such as zirconia. However, in such a case, there is a risk that the load on the implant might become excessive after long-term use. Therefore, it is necessary to carefully observe the occlusal load on the implant superstructure.

**Conflict of interest**

The authors have no conflicts of interest to declare.