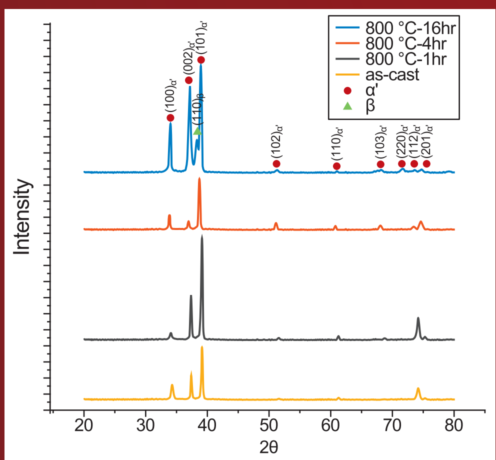
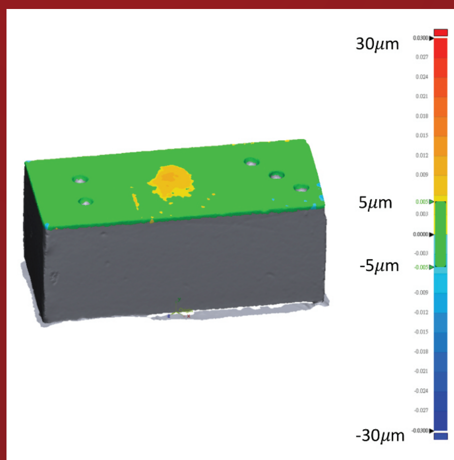
The Academy of Prosthetic Dentistry R.O.C., Taiwan

Journal of Prosthodontics and Implantology





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Editorial

During the pandemic of COVID-19, we sincerely hope everyone is safe and healthy! This March, 2020 issue of ***Journal of Prosthodontics and Implantology*** *discussed comparison between traditional and new technologies. First, comparison of peri-implant bone resorption between the tilted implant and the straight implant in patients treated with All-on-4 rehabilitation system, which provides basic information trying to resolve biomechanical dilemma. Second, with the new applied printing methods, there are also questions raised about the mechanical properties comparison among newly developed for printing, milling and traditionally packed denture base material.*

Hope you will enjoy the academic and clinical discussion of the contents!

Please feel free to extend the reach of the ***Journal of Prosthodontics and Implantology*** *within your community.*

Lih-Jyh Fuh, DDS, PhD
Chief Editor

The Academy of Prosthetic Dentistry R.O.C., Taiwan

Original Article

The Effect of Heat Treatment on the Properties of Titanium-50 Zirconium Alloy

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Abstract

Due to their excellent mechanical properties and biocompatibility, pure titanium and titanium alloys are widely used for clinical purposes. Zirconium, the biocompatible β-stabilizing element of titanium, can be added to titanium to provide a stable β-phase to improve the clinical applicability of titanium. Thereby, β-titanium alloy with a lower Young's modulus can be obtained. However, limited data is currently available on titanium-zirconium alloys. Therefore, in this study, we focused on how heat treatment influences the properties of titanium-50 zirconium alloys. The microstructure of the alloy was analyzed by X-Ray diffraction (XRD) and scanning electron microscopy (SEM), and the Young's modulus was measured. Under the as-cast state, the alloy can obtain a structure as the α'-phase acicular martensite. After high-temperature heat treatment, the alloy becomes wider and plate-like. The XRD data showed that, after long-term heat treatment at 800 °C, β-phase formation could be observed, with the lowest detected Young's modulus of 63.2 GPa. Therefore, compared to commercial materials, titanium-50 zirconium alloy displays less stress shielding effect after the heat treatment, ensuring its high application potential in implantable medical materials.

Key words: Titanium-50 Zirconium, Heat treatment; Young's modulus, Microstructure analysis

Introduction

Various types of metals are used in designing medical devices, with common biomedical materials, including stainless steel, cobalt-chromium alloy, precious metals, or nickel-titanium memory alloy, selected for multi-site applications[1]. Among biomedical metals, titanium and titanium alloys exhibit high specific strength, light weight, good corrosion resistance, and biocompatibility, making them widely popular for various applications in multiple fields. For their use as medical equipment, these characteristics facilitate their use as bone screw nails in orthopedics and metal implants or titanium meshes in dentistry[1–5].

The commonly used titanium variants comprise pure titanium and the alloy titanium-6 aluminum-4 vanadium. However, as the vanadium and aluminum ions released from titanium-6 and aluminum-4 vanadium are reportedly toxic in recent studies, these materials could have adverse effects on human tissues[2,4,5,6]. In addition, the Young's modulus of titanium alloy is significantly higher than that of human bones, potentially resulting in stress shielding and uneven stress distribution of implanted materials on the bone, potentially causing bone atrophy adjacent to the implantation and even operation failure[6–8]. Therefore, to design implantable biomedical titanium alloys that are harmless to the human body, the Young's modulus is reduced by adding β-stabilizing elements, such as niobium, tantalum, molybdenum, and zirconium[7–10]. Binary β-titanium alloy systems, such as titanium-molybdenum, titanium-niobium, and titanium-tantalum alloys, have been extensively studied, although limited research data is available on titanium-zirconium binary alloys.

Y. D. Shi et al[11]. supplemented titanium alloy with a high content of zirconium and water-quenched it after hot rolling treatment above the β transition temperature (735 °C) to obtain a new alloy with a mixed-phase structure of β with a body-centered cubic structure and orthorhombic crystals α": titanium-50 zirconium-5 aluminum-4 vanadium. This alloy exhibits ultra-low Young's modulus (45 GPa), ultra-high tensile strength (1185 MPa), and high elastic strain (2.2 %); this alloy is thus considered to be of particular significance among the implantable materials. When Y. Murayama et al[12]. investigated titanium-chromium-tin-zirconium alloys, alloys of different compositions were quenched, with the microstructure changed from martensite to the β-phase. After these treatments, titanium-5 chromium-9 tin-5 zirconium and titanium-2 chromium-6 tin-45 zirconium alloys adopted an unstable β-phase and generated a two-step yield phenomenon in the stress-strain curve, through the induced transformation of martensite, with the lowest registered Young's modulus of ~41 GPa, measured in the titanium-2 chromium-6 tin-45 zirconium alloy. For instance, compared with multi-element alloys, binary alloys are relatively easy to control the composition and temperature based on the phase stability. Our current focus is on the addition of Zr to obtain Ti-Zr binary alloy, which are the most fundamental to analyze the variation of additional elements.

In this study, based on the premise of obtaining a low Young's modulus and biological safety, we aimed at designing a titanium-50 (wt%) zirconium binary alloy using high zirconium content and pure binary alloy to measure the changes in the Young's modulus through nanoindentation under different heat treatment parameters, with microstructure analysis for structural observation. Based on these results, we investigated the correlation between the change in phase structure and heat treatment temperatures to serve as the process basis for the future development of novel β-titanium alloys.

Methodology

Material preparation

The titanium-50 (wt%) zirconium binary alloy was prepared through a vacuum melting furnace, then hot forged at 1000 °C and cast into a 20 mm thick sheet. After cutting, it was hot forged at 830 °C to form a 3-mm thin plate and finally cut into 10 × 10 × 2 mm test pieces. The material was heat-treated in a small vacuum heat treatment furnace, and solid solution annealing was performed at 800 °C on α+β area for 1, 4, and 16 hours. The same alloy with "as-cast state" was used for comparison.

Microstructure analysis

After grinding and polishing, the test piece was etched in a mixed solution of 15 % nitric acid (HNO_3) + 5 % hydrochloric acid (HCl) + 80 % alcohol for approximately 3 minutes. The test piece was cleaned with ultrasonication and dried. A scanning electron microscope (JEOL JSM-6380, Tokyo, Japan), with an operating voltage of 15kV, was used to observe the microstructure of the material. To explore the structural composition of the different groups, we used an XRD analyzer (Bruker D8, Billerica, MA, USA), with Cu-$K_{\alpha 1}$ rays, a working voltage of 45 kV, and a 2θ range of 20–80°.

The measurement of the Young's Modulus

In this study, we used a nanoindentation measurement system to measure imprints. The principle of the nanoindentation experiment with MTS Nano indenter XP is driving the movement of the indenting probe by a machine, with contact between the probe tip and test material during the probe movement. Throughout the experiment, the machine records the load, displacement, and indentation area on the test material. The downward displacement of the center point of the probe tip is calculated by considering the surface of the test material as the origin. After the experiment, the machine calculated the final Young's modulus of the material based on the input formula.

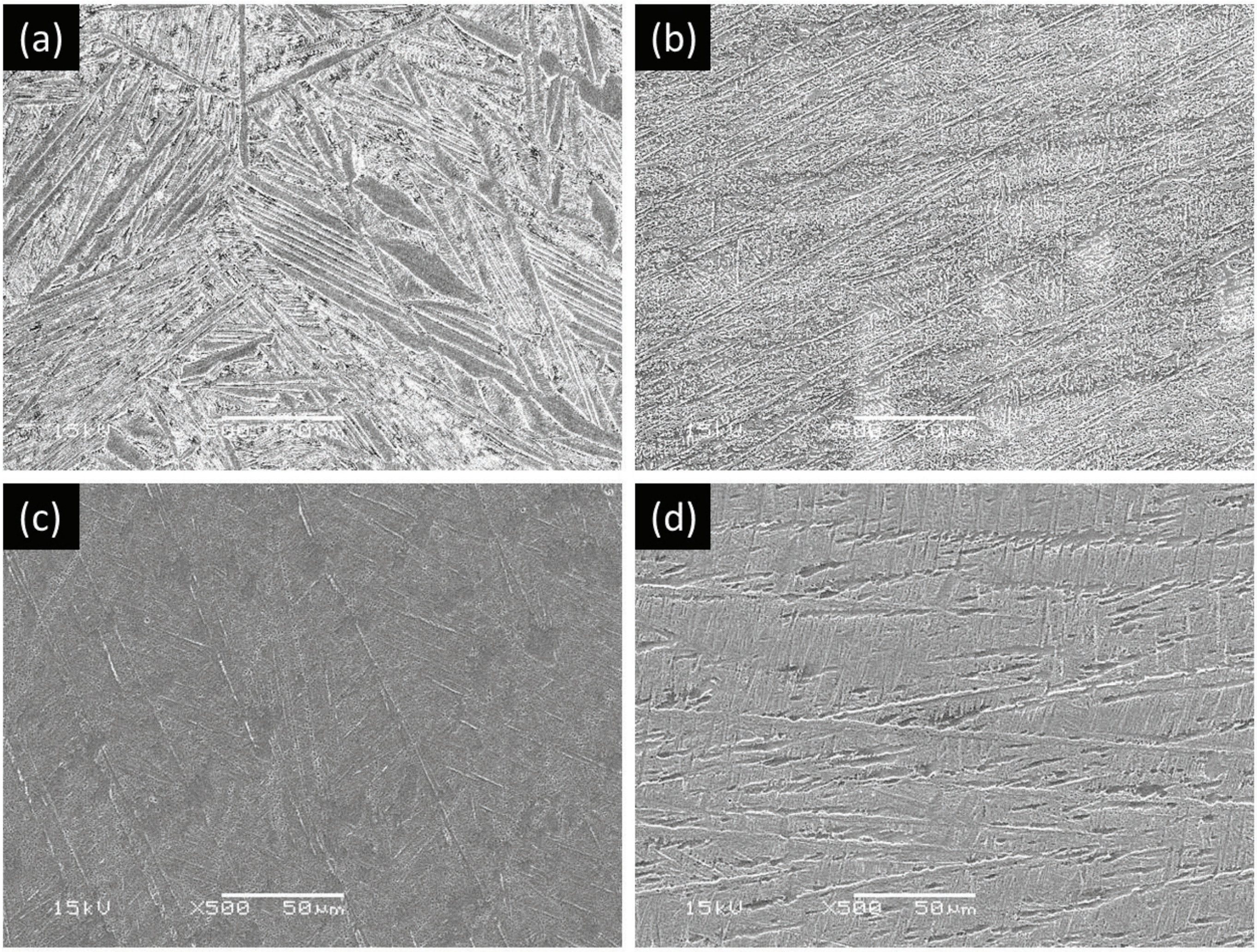

Figure 1. SEM pictures of different titanium-50 zirconium alloy microstructures after different heat treatments
(a) As-cast state (b) 800 °C , 1 h (c) 800 °C , 4 h (d) 800 °C , 16 h

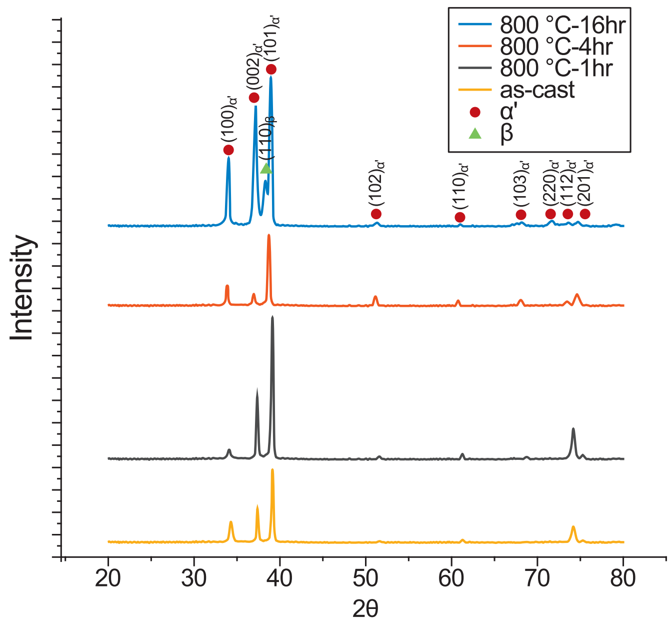

Figure 2. XRD analysis of different titanium-50 zirconium alloy compositions after different heat treatments
(a) As-cast state
(b) 800 °C , 1 h
(c) 800 °C , 4 h
(d) 800 °C , 16 h

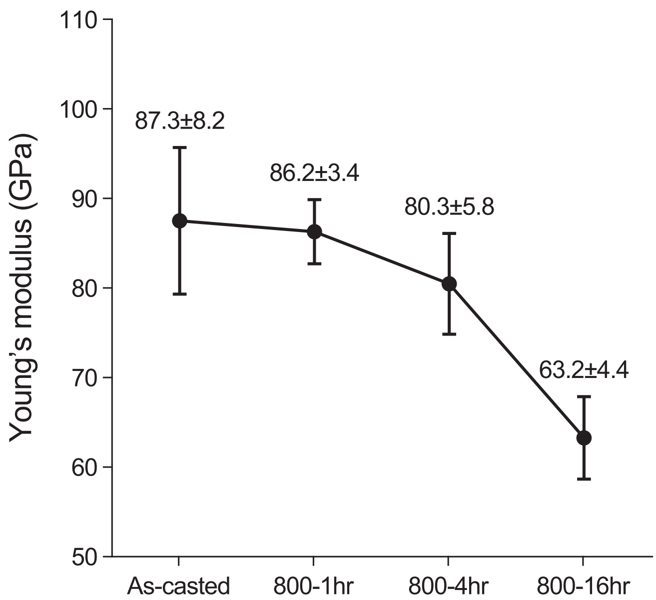

Figure 3. Young's modulus after different heat treatments

Results and Discussion

Microstructure

Under SEM, we could observe that the titanium-50 zirconium alloy is an acicular structure under the as-cast condition, as shown in Figure 1(a). After the high-temperature heat treatment at 800 °C for 1 and 4 hours, the acicular structure began to grow thicker, as shown in Figure 1(b) and (c). As the heat treatment time reached 16 hours, the acicular structure changed to a coarse lath shape, as shown in Figure 1 (d). In addition, the XRD analysis showed that the alloy was in α′ phase after the heat treatment at 800 °C for 1 and 4 hours, while the α′ phase and β-phase peak value were both detected upon heat treatment at 800 °C for 16 hours, as shown in Figure 2.

Young's modulus

The typical values of the Young's modulus for titanium-50 zirconium alloy with different heat treatment are shown in Figure 3. In the as-cast state, the Young's modulus of the titanium-50 zirconium alloy was 87.3 GPa. After heat treatment at 800 °C for 1 hour and 4 hours, the Young's modulus reached 86.2 and 80.3 GPa, respectively. The reason for obtaining a lower Young's modulus of 63.2 GPa at 16 hours could be the appearance of the β-phase in the alloy after the heat treatment at 800 °C for 16 hours, as shown in Figure 1(d); this phenomenon has been reported previously[13]. Different studies reported that a lower Young's modulus would be obtained when the alloy microstructure displays a β-phase, showing that the existence of the β-phase could reduce the overall Young's modulus of the material[7].

Conclusion

On adding high zirconium content (50 wt%), the structure of the titanium-50 zirconium alloy was acicular martensite α′ phase in the as-cast state. After the heat treatment at 800 °C, the alloy adapted a wider and larger lath shape. The Young's modulus of the titanium-50 zirconium alloy decreased to 63.2 GPa from 87.3 GPa as the time of heat treatment increased. The underlying reason for this result is that a small amount of β-phase was formed in the titanium-50 zirconium alloy under the conditions of 800 °C treatment for 16 hours.

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Original Article

Effect of the scanning powder on the accuracy of the digital scanning process

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Abstract

Purpose: *The purpose of this study was to examine the effect of the scanning powder on the scanning accuracy result.*

Materials and methods: *Forty gypsum blocks (size: 6cm x 2cm x 2cm) were scanned by a 3Shape D900 desktop scanner before and after scanning powder sprayed with 3M High-Resolution Sprayer. Powder spraying was performed with different spraying time spans (1 sec, 3 sec, 5 sec, 7 sec). The STL files were then superimposed with analyzing software (Geomagic Control) to compare the thickness and the covering area.*

Results: *The mean thickness of the spraying powder for each spraying time group was 8.9 μm (SD ±1.5 μm) for 1 sec, 10.0 μm (SD ±2.2 μm) for 3 sec, 13.9 μm (SD ±3.5 μm) for 5 sec, and 13.3 μm (SD ±3.1 μm) for 7 sec. As for the mean area proportion for each spraying time group was 2.94% (SD ±1.32%) for 1 sec, 5.07% (SD ±2.76%) for 3 sec, 8.37% (SD ±3.35%) for 5 sec, and 8.65% (SD ±3.01%) for 7 sec.*

Conclusion: *Based on the findings of this investigation, both powder thickness and powder spraying covering area increased with a longer spraying time. The thickness of the powder ranged from 8.9 μm to 13.9 μm under reasonable spraying time, which may influence the scanning accuracy, though it is clinically acceptable.*

Key words: Accuracy, intraoral scanner, scanning powder

Introduction

Computer-aided design (CAD) and computer-aided manufacturing (CAM) has been incorporated into our daily dental works for several years. With the convenience of the CAD/CAM technology, patient's model may compose both examination and final prosthesis designs so as towards the completion of designated treatment plan, such measure may occur through outputting contrasting restorations in result of additive or subtractive manufacturing. The first article related to dental CAD/CAM technology was published by a French dentist Dr. Francois Duret in 1973[1].

The whole CAD/CAM system is composed of three elements, including (1) data acquisition unit (2) designing software

(3) computerized manufacturing device. Data acquisition digitizes patient's dentition or other information into the virtual environment. Dentists and dental technicians can then manipulate such data in a designing software. Actual interior condition of dentation can be simulate by the designing software follow by proper assessment treatment plan. Finally, the design can be performed through the manufacturing device[2].

Optical scanner is one of the data acquisition units used in dentistry, including the intraoral and desktop scanners. Scanning accuracy could vary by surface property of the scanned objects, camera projecting light wavelength and familiarly algorithm calculation data, due to optical scanning characteristics. Powder-free type intraoral scanners are getting popular in recent years, thereby face difficulties in optical properties caused by various oral environment factors (saliva, blood, translucent surfaces, metallic surfaces, etc.), accordingly surface property of the scanned object may affect the light reflected from the surface and cause errors of the scanning results[3,4]. It is suggested that a thin layer of scanning powder, titanium dioxide particles apply to the surface of the scanned object before scanning process can reduce the scanning error and increase the efficiency of the scanning in most cases[3,5]. However, the manufacturer (3M Seefeld, Deutschland) states that the layer should be as thin as possible since application distances and times may result in different thicknesses of the coating layer, which can cause scan errors.

The purpose of this study was to determine the effect of the spraying powder on the accuracy of digital impression and investigate the relationship between spraying time, thickness and covering area of the spraying powder applied.

Materials and methods

Forty type III yellow gypsum blocks (size: 6cm x 2cm x 2cm) were used as the testing samples. A reference scan was proceed with a desktop scanner (3Shape D900; 3Shape A/S) for each testing block before the standardized powder spraying procedure. The testing blocks were divided into four groups according to the spraying time, and each group included 10 testing blocks (n=10). With a spraying machine (3M High-Resolution Sprayer, 3M ESPE, Seefeld, Deutschland), High-Resolution Scanning Spray Powder (3M ESPE, Seefeld, Deutschland) was applied to each testing blocks under a different spraying time (1 sec, 3 sec, 5 sec, 7 sec). A standardized powder spraying procedure was prepared at the distance (2.5 cm) recommended by the manufacturer (Fig.1, Fig.2). A time limit relay was connected to the powder spraying machine to control the different powder spraying time (Fig.3). After the powder spraying, a test scan was performed with the 3Shape D900 desktop scanner for each testing block (Fig.4). The STL files of reference scan and test scan of each testing block were imported into the software (Geomagic Control X, 3D systems, Rock Hill, SC, USA) and superimposed through best fit algorithm, for analyzing the thickness and the percentage of powder covering area (Fig.5, Fig.6). The percentage of powder covering area was calculated by dividing powder covering area by superimposed area. Statistical analyses were performed with descriptive statistics and Pearson correlation.

Results

The mean thickness of the spraying powder for each spraying time group : 8.9 μm (SD ±1.5 μm) for 1 sec, 10.0 μm (SD ±2.2 μm) for 3 sec, 13.9 μm(SD

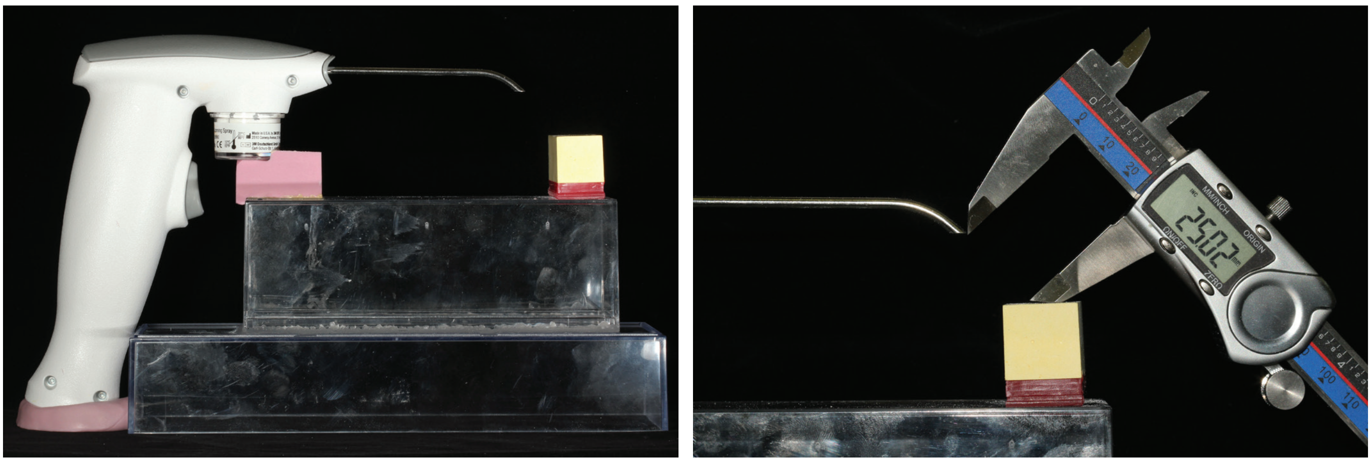

Figure 1. Standardized spraying distance and angle of a powder spraying device

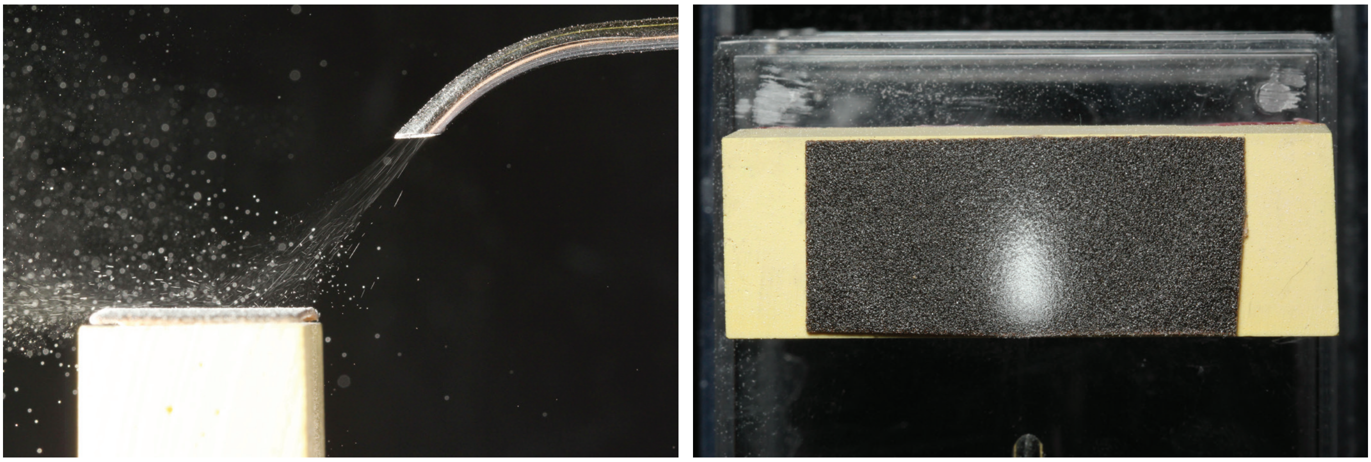

Figure 2. Standardized spraying with a powder spraying device

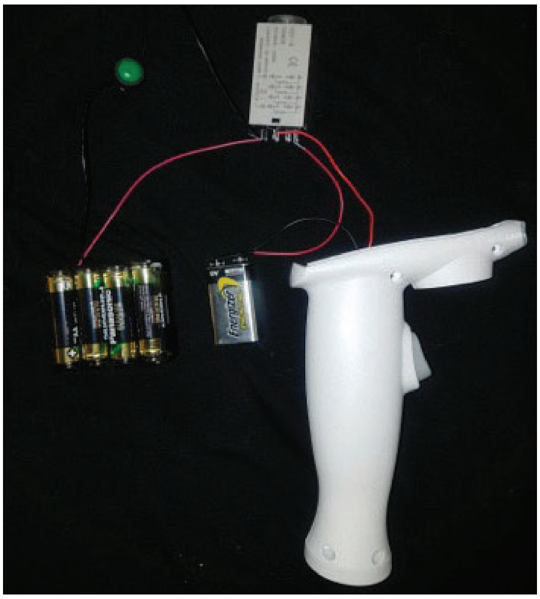

Figure 3. Time limit relay connected to the powder spraying machine

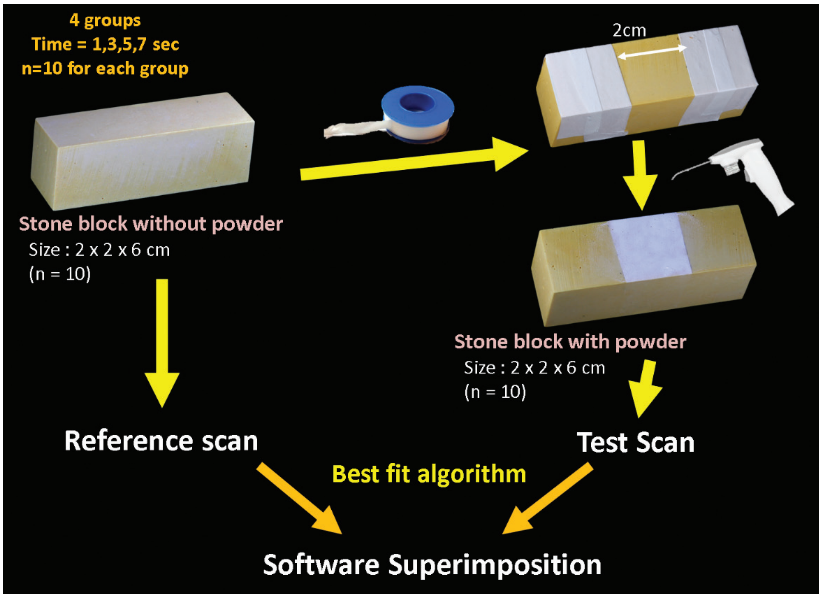

Figure 4. Overview of the experiment workflow

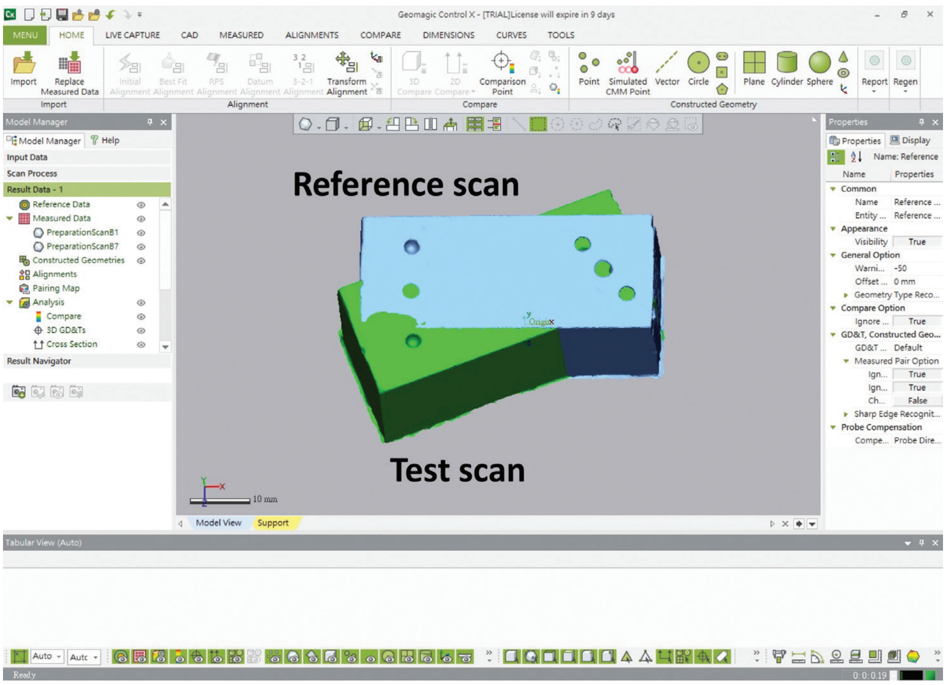

Figure 5. Superimposition of the reference scan and the test scan

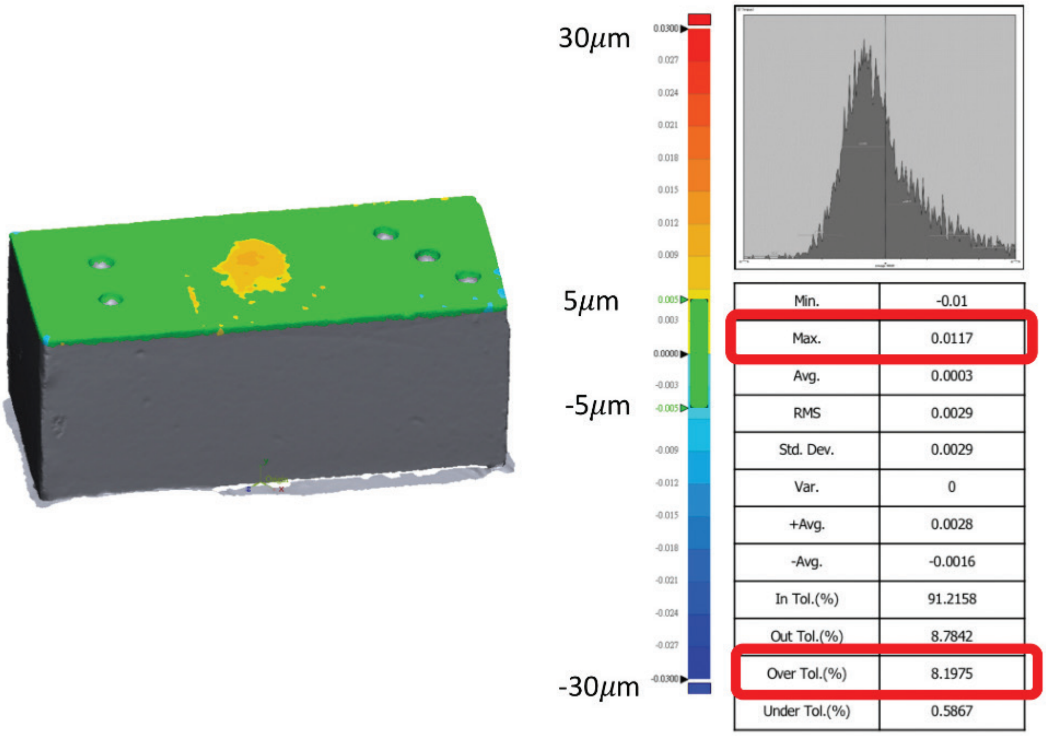

Figure 6. Best fit algorithm performed by the software (Geomagic® Control)

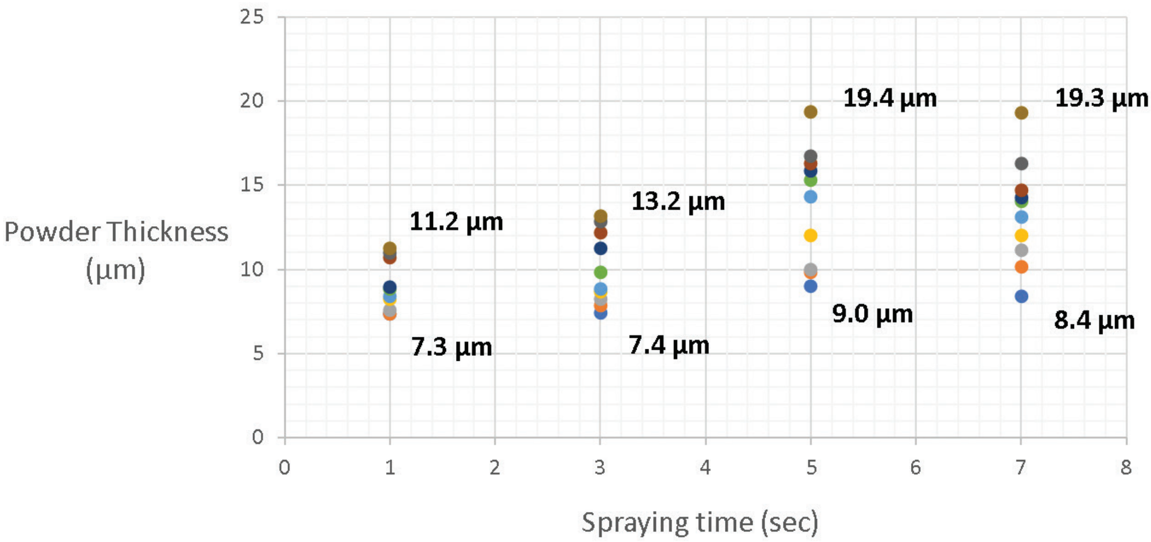

Figure 7. Powder thickness / Spraying time relation char

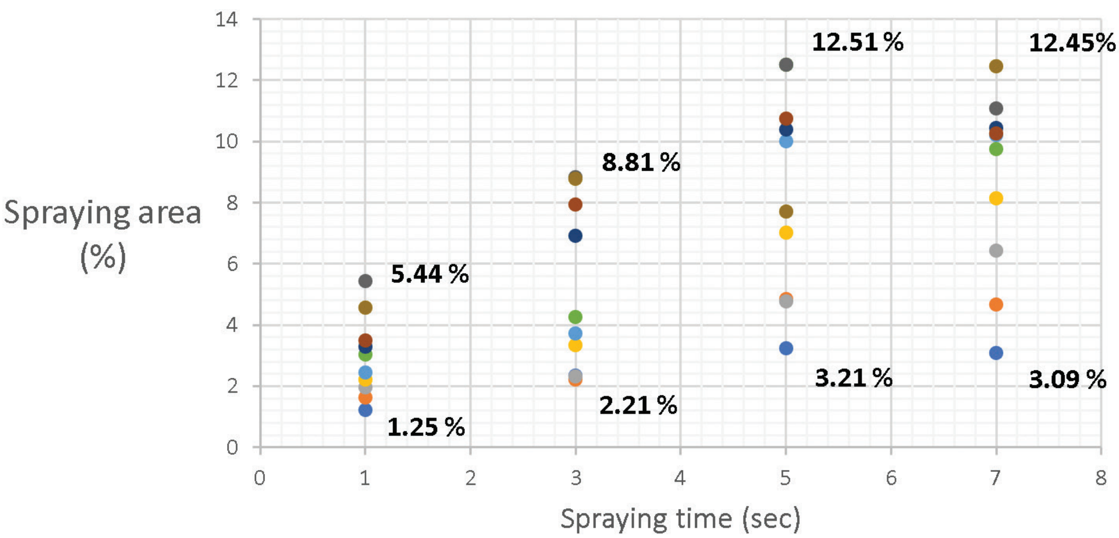

Figure 8. Spraying area/Spraying time relation chart

±3.5 μm) for 5 sec and 13.3 μm (SD ±3.1 μm) for 7 sec. The mean area proportion of the spraying powder for each spraying time group: 2.94% (SD ±1.32%) for 1 sec, 5.07% (SD ±2.76%) for 3 sec, 8.37% (SD ±3.35%) for 5 sec and 8.65% (SD ±3.01%) for 7 sec. (Fig.7, Fig.8). The Pearson correlation coefficient of the spraying time and the powder thickness was 0.576, indicating moderately correlated; The Pearson correlation coefficient of the spraying time and the powder area was 0.651, indicating moderately correlated; The Pearson correlation coefficient of the powder area and the powder thickness was 0.919, indicating highly correlated (Table 1).

Table 1. Pearson correlation of spraying time / area / heigh

Correlations		Time	Area	Height
Time	Pearson Correlation	1	.651**	.576**
	sig. (2-tailed)		<.001	<.001
	N	40	40	40
Area	Pearson Correlation	.651**	1	.919**
	sig. (2-tailed)	<.001		<.001
	N	40	40	40
Height	Pearson Correlation	.576**	.919**	1
	sig. (2-tailed)	<.001	<.001	
	N	40	40	40

**.Correlation is significant at the 0.01 level (2-tailed).

Discussion

Most of the intraoral scanners do not need powder spraying before intraoral scanning[2,6]. In some special situations, especially scanning the metal or highly polished surface, spraying the scanning powder can homogenize the surface property, therefore the light reflected from the surface can be more easily captured by the camera[7-9]. Some factors might influence the accuracy of the scanning results; e.g. the spraying powder is not evenly distributed, the spraying powder is contaminated by the saliva, and the thickness of the spraying powder may influence the scanning results[3].

According to a previous study, the thickness of the scanning powder may reach from 20 to 40 μm[7]. In our study, the thickness of the scanning powder was ranged from 8.9μm to 13.3μm, under difference spraying time groups. However, our study might underestimate the powder thickness by spraying powder on a flat and dry surface. There was no reference indicated how thick the spraying powder should be applied to achieve an adequate scanning condition, so the dentists can only judge the thickness by the color change of the surface. The powder spraying machine used in this study is driven by a motor, which produced an air-flow through a spraying tube and brought out the spraying powder. The longer the machine sprayed, more amount of spraying powder was out. That can explain the result from our study, the powder thickness was positive correlative to the spraying time.

In our study, the spraying covering area was also positively correlated with the spraying time. The spraying powder may cover more area as the spraying time increased. The standardized spraying device set up in our study target only a spot on the gypsum block to perform the powder spraying, but the powder still could float through the air and extended to the surrounding area, so the spraying covering area increased when the spraying time increased. Dentists usually judge whether scanning powder is adequately sprayed by the change of opacity above the teeth. Thus, we also performed the powder spraying on an artificial tooth with different spraying time, try to imitate the different appearance which may be caused by spraying the powder on a tooth (Fig.9). It was found that the appearances of 1 sec to 3 sec spraying are close to what would be judged as an adequate spray, thus the powder thickness would be around 10 μm according to the observations of this study.

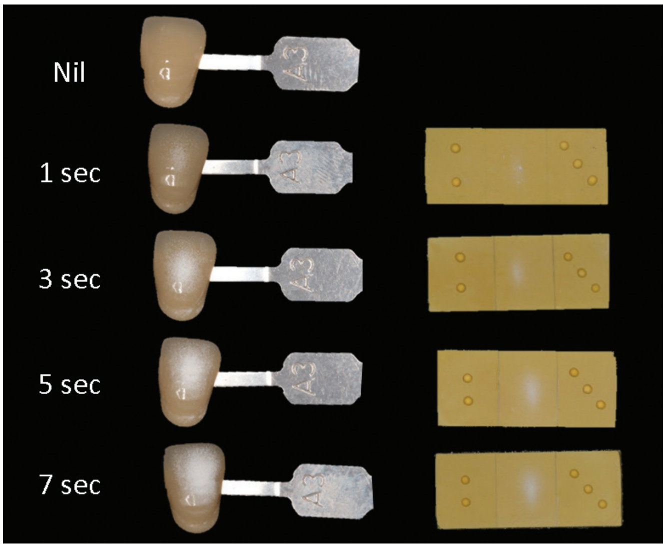

Figure 9. Powder display on artificial teeth and gypsum block for each spraying time group

Conclusions

Based on the finding of this investigation, both powder thickness and powder spraying covering area increased with longer powder spraying time. The thickness of the powder ranged from 8.9 μm to 13.9 μm under reasonable spraying time. The thickness of the powder may influence the scanning accuracy, but it is clinical acceptable.

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Case Report

Interdisciplinary treatment modality for a patient with hypodontia by using orthodontic alignment to avoid adjacent implants in esthetic zone: A clinical report.

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Running title: Orthodontic alignment to avoid adjacent implants

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Abstract

A 20-year-old man with congenitally missing bilateral mandibular second premolars and central incisors presented for treatment. By using orthodontic alignment, redistributing the missing tooth space could avoid adjacent implants to achieve better esthetic outcomes. The prosthodontic treatment consisted placing 4 implants in the mandibular bilateral second premolar and incisor sites.

Introduction

Hypodontia of permanent teeth is fairly common in contemporary populations and is the most common human malformation, the prevalence ranges from about 2% in Taiwanese[1] to 30% in Japanese population[2]. Hypodontia of six or more permanent teeth is defined as oligodontia, which is relatively rare, and the prevalence declines with increasing number of missing teeth[2]. Patients with hypodontia often present with a number of features that require extensive and complex treatment, such as short and retrognathic maxilla, prognathic mandible, and shorter lower anterior facial height[3]. Intra-orally, bimaxillary retroclination of incisors, spacing, centerline discrepancies, microdontia, hypoplastic enamels, ankylosis of the retained primary teeth, over-eruptions, and volume deficiencies of alveolar ridges are also frequently presented[4]. Above all the problems, coordination of a number of specialties might be necessary to idealize the restorative treatment. The options of final prostheses to restore missing teeth of hypodontia could be various, from removable partial dentures, conventional and adhesive fixed dental prostheses (FDPs) to implant-supported prostheses.

Implant-supported prostheses have been introduced for a long history, providing predictable and reliable treatment alternatives. Despite the high success rate, achieving the natural outcomes in the aesthetic zone could still be challenging, especially when it comes to adjacent implants. In many cases, the loss of 2 or more anterior teeth often result in flattening of the inter-proximal bony scallop, resorption of inter-proximal bone crest, and causing long implant restorations with missing or compromised inter-implant papilla[5]. This clinical report describes the rationale and treatment of a patient with hypodontia using implants and orthodontic alignment to solve the dilemma of multiple adjacent anterior implants.

Clinical report

A 20-year-old male patient came to our hospital with a chief complaint that his front teeth were ''small and ugly.'' He asked for restoring mandibular anterior missing teeth. Comprehensive clinical and radiographic examination showed congenital missing of multiple teeth, including mandibular bilateral permanent second premolars, as well as two mandibular central incisors. In the meantime, two primary central incisors were present, as well as the mandibular left primary second molar. (Fig.1 and 2) According to Angle's classification, occlusal analysis revealed the Class III malocclusion. Other dental problems included multiple tooth spacings in the maxilla and mandible, lower dental midline shifting to left side for 2 mm, and deep overbite with vertical overlap of 6mm. Extra-oral examination showed concave lateral profile without gummy smile. The patient did not present with any systemic or genetic disorder that could be associated with hypodontia, and the oral hygiene status was satisfactory.

In order to develop an ideal occlusal intercuspation and to improve lateral profile, space was re-created for mandibular right second premolar by using orthodontic treatment after the model setup and diagnostic wax up to precise the amount of tooth space and position. It was determined that the mandibular left primary second molar should be extracted due to radiographic signs of root resorption (Fig.2). Both mandibular second premolars were restored with tissue level implant (RN Roxolid® SLA® Implants Ø 4.1 mm, Straumann AG). Mandibular left lateral incisor was aligned to substitute left central incisor, leaving two single tooth spaces at mandibular right central incisor and left lateral incisor sites (Fig.3). After the spaces were properly distributed, two narrow implants were placed (Bone level implant - Narrow CrossFit® Ø 3.3 mm; Straumann AG) with the aid of surgical stent. After 3 months of osseointegration, auto-polymerized bisacrylic composite resin (Protemp 3 Garant; 3M ESPE) and titanium temporary abutments (synOcta Temporary Abutment; Straumann

Figure 1. Pretreatment condition. (A) Fontal view. (B) Mandibular occlusal view. (C) Deciduous mandibular central incisors.

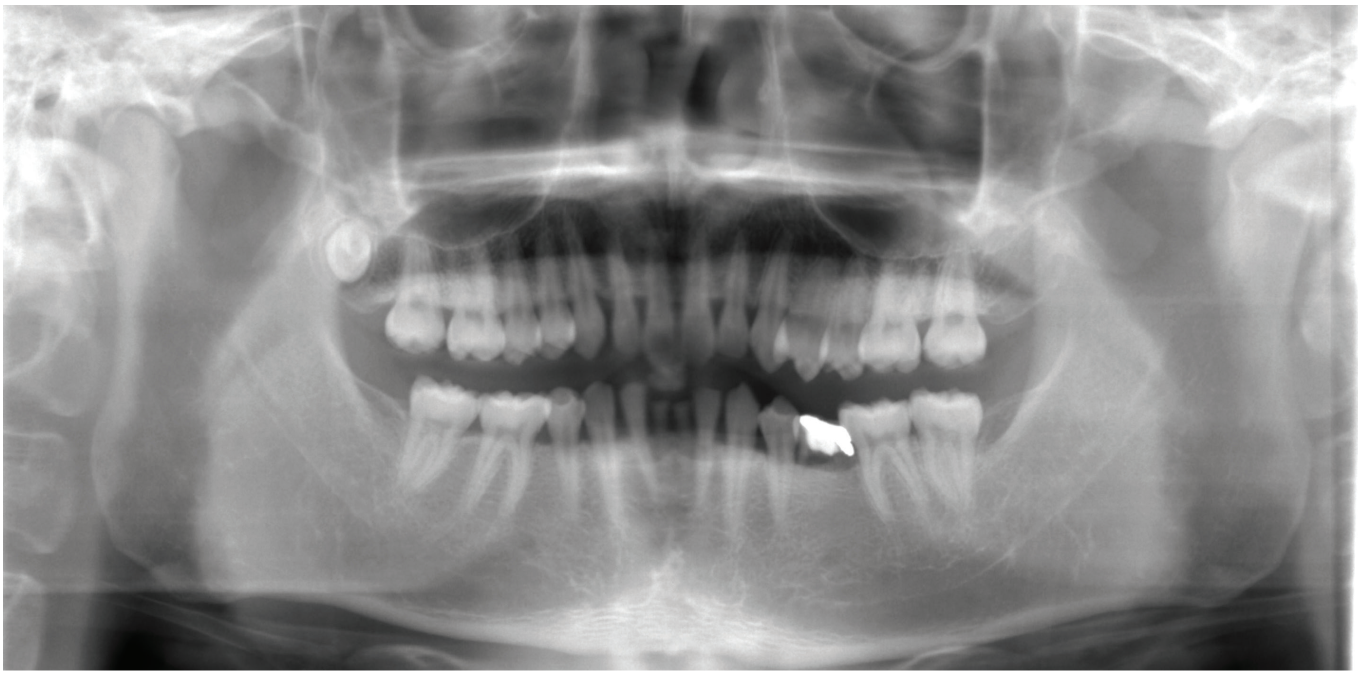

Figure 2. Pretreatment panoramic radiograph.

AG) were used to make the provisional restorations. Six months after orthodontic finishing, an open tray impression was made at implant level using a customized impression coping and polyvinyl siloxane (Aquasil Ultra XLV and Aquasil Soft Putty; Dentsply Caulk). Zirconia framework with labial veneering porcelain design was chosen. The porcelain-fused-to-zirconia copings were bonded to the titanium inserts (Variobase Abutment; Straumann AG) with resin cement (RelyX Unicem; 3M ESPE) to make a 1-piece screw-retained single crown. The definitive crowns were delivered uneventfully after clinical adjustment (Fig.4 and 5). In mandibular anterior esthetic zone, harmonious gingival margin, tooth shape and adequate papilla height were recorded. For the first year of treatment, the patient was given routine hygiene and maintenance therapy every 3 months for long-term outcome assessment. The 3-year-follow-up revealed maintenance of orthodontic treatment, occlusal plane, oral hygiene, esthetics, and stability of bone level (Fig.6). No mechanical (ceramic fracture, screw loosening) and biological complications (peri-implantitis) were recorded. The patient acknowledged having improved function and esthetics, and was satisfied with the results.

Discussion

The successful treatment of patients with hypodontia need the interdisciplinary intervention of number of specialties (orthodontist, implantologist and prosthodontist), where each member contributes

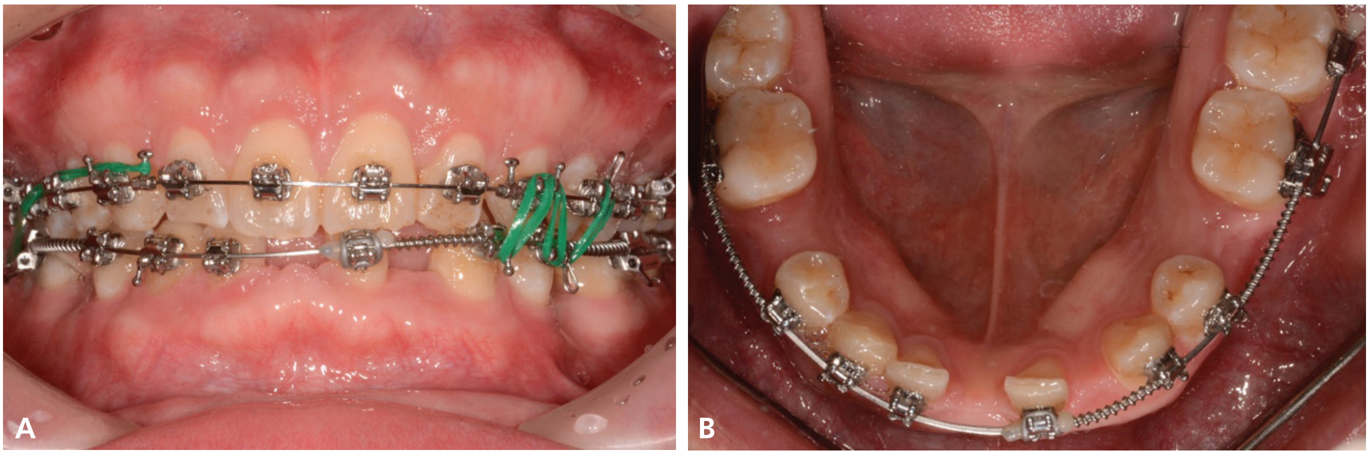

Figure 3. During orthodontic treatment. (A) Fontal view. (B) Mandibular occlusal view

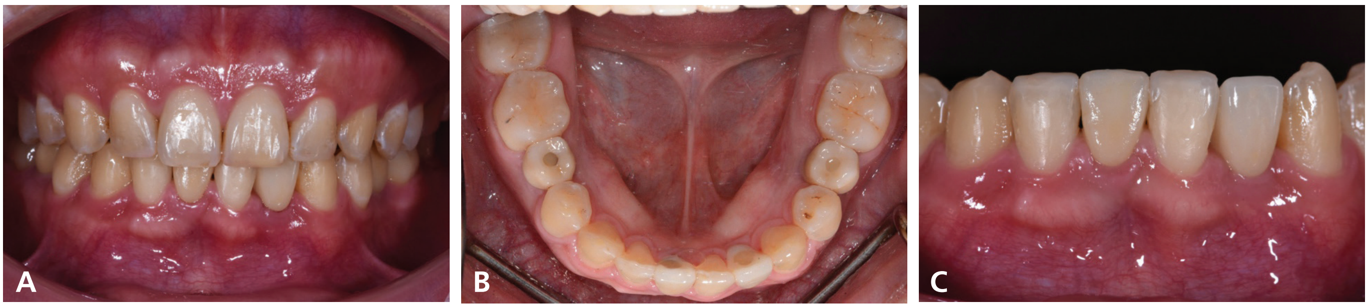

Figure 4. Post-treatment condition. (A) Fontal view. (B) Mandibular occlusal view. (C) Definitive crowns on mandibular right central and left lateral incisor positions.

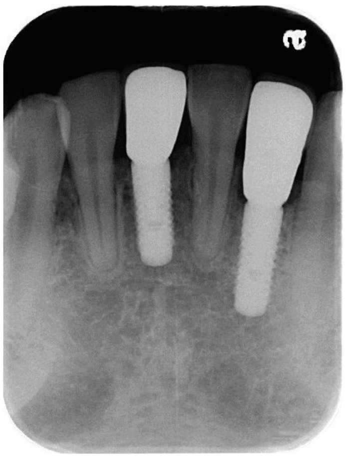

Figure 5. Radiographs after delivery of definitive crowns in mandibular anterior region.

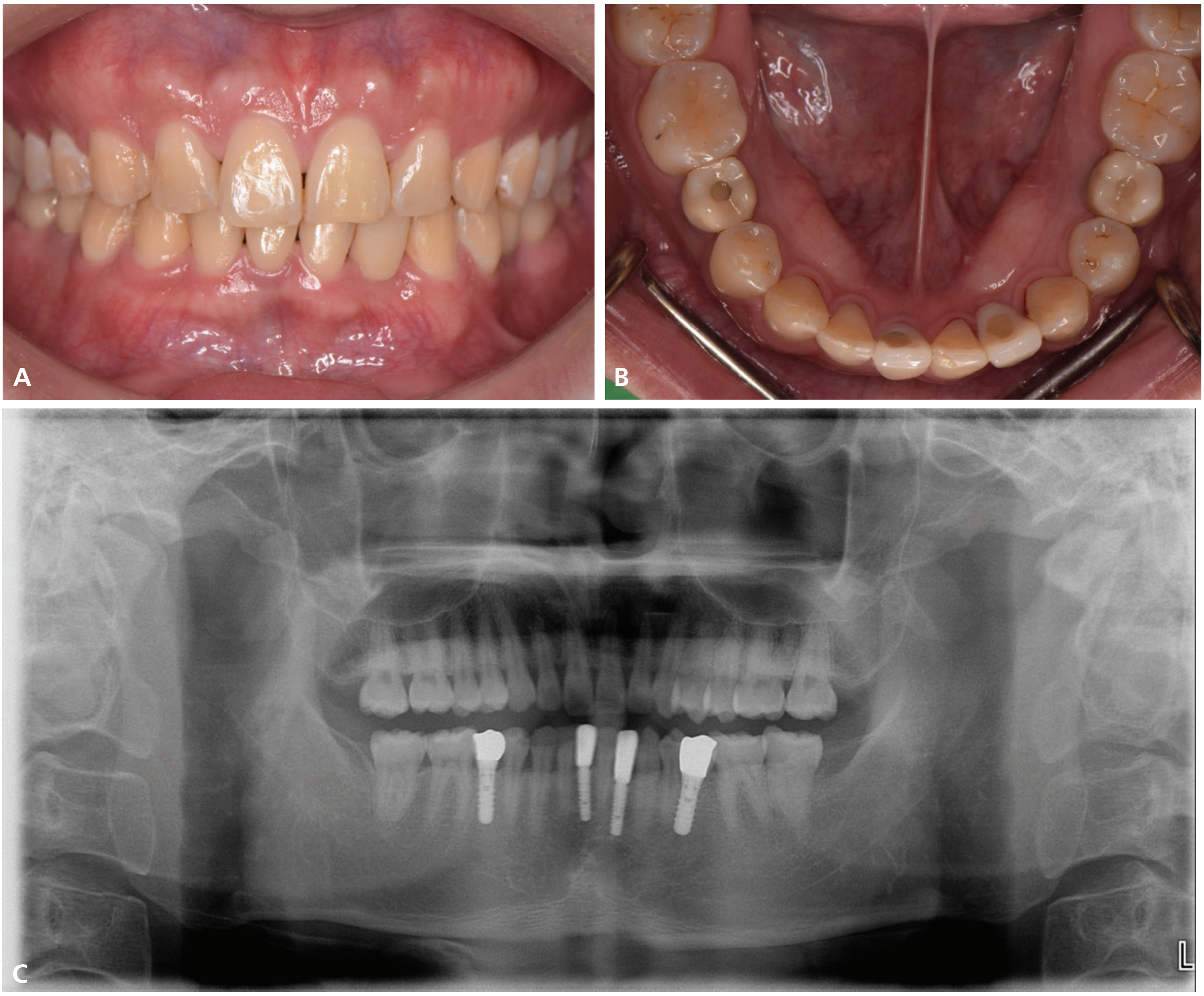

Figure 6. Three years after crown delivery. (A) Fontal view. (B) Mandibular occlusal view. (C) panoramic radiograph.

with a different expertise to achieve an optimal outcome for the patient[2]. Orthodontic treatment allows for the creation or redistribution of spaces for prosthetic rehabilitation, thus, treatment planning could be the most important part, which usually depends on the severity of hypodonita[6]. The treatment options available for these cases are the maintenance of primary teeth[7]; orthodontic space closure; space maintenance; and/or orthodontic space redistribution to facilitate the prosthetic treatment[8]. In this case, the mandibular left primary second molar could not be maintained because root resorption had affected its stability. Instead of closing the space after extraction, the space for mandibular left second premolar had been maintained. In the meantime, space was re-created for mandibular right second premolar. The advantage of space opening include improvement of both function and occlusion, leading to better intercuspation[9]. But its major disadvantage is that it commits the patient to a definitive prosthesis. On the other hand, closing space could be more time-consuming, and tend to retract the lower anterior teeth, which may cause increased overjet or more concave lateral profile, which both are unfavored.

How to restore two missing mandibular central incisors is another issue in this case. There are several treatment options, such as conventional tooth-supported FDPs and implant-supported prostheses. The patient rejected conventional FDPs at the first place due to unwilling to sacrifice the intact tooth structure. The treatment with dental implants maybe the best option, because this procedure is predictable, stable and provides good esthetic results[10]. However, when two adjacent teeth are missing in the aesthetic zone, the presence of the papilla between two implant crowns is determined predominantly by the level of the inter-implant bone crest[11]. Therefore, only a maximum of 3.4 mm of inter-implant papilla height should be expected[12], resulting in black triangle or long contact points of adjacent implant crowns to camouflage these defects. It could be very challenging to reach the esthetic demands. To avoid adjacent implants and the following unfavored esthetic result, mandibular left lateral incisor was aligned to substitute left central incisor, leaving two single space at tooth 41 and 32 for two single implant placements. In case of single-tooth replacements, the presences of the papillae are determined predominantly by the attachment levels of the neighboring teeth[13]. In periodontally healthy patients, neighboring teeth enhance the esthetic outcome by maintaining stability of peri-implant papillae. According to clinical retrospective study conducted by Belser et al,[14] anterior maxillary single-tooth implants with 2~4 years follow-up, regardless of uncontrolled factors including timing of implant placement, implant type and design, and type of surgical access flap, the complete papilla fill could be highly achieved (60% in mesial papilla and 29 % in the distal papilla).

There is one more benefit about above method could be addressed. While lateral incisor was pushed mesially to replace central incisor, the root movement creates adequate alveolar ridge width distal to the lateral incisor through stretching of the periodontal ligament, providing better bone condition for implant placement. This process is so-called "orthodontic site development,"[15] and supposed to be accomplished in any part of alveolar ridge, where a tooth will be moved before implant placement.

Optimal Implant positioning in relation to the adjacent teeth could be crucial, inadequate distance between tooth and implant (less than 1.5mm)[16] may result in exaggerated bone loss and increased distance from proximal contact points to the associated alveolar bone crests. Furthermore, not only adequate space must be created for replacement of the tooth crown, but the roots of adjacent teeth should be parallel or slightly divergent to give adequate space for implant placement. The position of the roots of the adjacent teeth should therefore be evaluated radiographically before the appliances are removed[17].

There are potential risks and complications in orthodontic treatment, including dental caries and root resorptions[18]. In this case, high standard of oral hygiene was requested, and fluoride mouthwashes had been used through the treatment to prevent caries. Although some degree of external root resorption is inevitably associated with fixed appliance treatment, no clinically significant root resorption arose in this case, furthermore, resorption rarely compromises the longevity of the teeth[19].

In short, by carefully planning of tooth space distribution, we manage to improve the patient's occlusion, facial profile, better bone and adequate space for implant placement, and avoid the dilemma of adjacent implants at the same time.

Summary

Interdisciplinary planning is the key to treat a patient with hypodontia, decisions about space management must be made by the interdisciplinary team, taking into account the risks and benefits of all options. Re-distributing two adjacent missing spaces into two single space could be a solution to make a better and more predictable esthetic outcome.

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Case Report

Using 3D-printed duplicate dentures as an impression method in a patient with severely limited mouth opening after tumor excision and graft repair: A clinical report

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Running title: 3D printed duplicate denture as impression tray

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Abstract

Prosthetic management of edentulism can be challenging with the presence of severely limited mouth opening and oral movement, especially in patient with tumor excision and graft repair. Adjusting the current denture and then duplicating it for closed-mouth impressions is one method to effectively record the tissue and polished surfaces, and the vertical dimension. This clinical report describes a method for using 3-D printed duplicate interim dentures as impression trays to reproduce the denture space, including polished surfaces and vertical dimension, in patients with limited oral movement after extensive surgical procedures. Interim complete dentures were placed in the edentulous maxilla and mandible with multiple extensions of the denture base and adjustments of the polished surfaces. After the oral function improved, the interim dentures were duplicated and designed as impression trays to record the form as adapted by the patient during daily use. This method, together with computer-aided design and manufacturing, provides a more efficient method of fabricating removable prostheses. During the 2-year follow-up period, the patient's masticatory function and physical appearance improved.

Key words: Limited mouth opening, 3D printed duplicate denture, close mouth impression

Introduction

Prosthetic management of patients with extensive surgical procedures can be challenging due to the presence of severely limited mouth opening and interocclusal space[1,2]. For the dentist involved in prosthodontic treatment of such patient, restricted maximal opening commonly leads to compromised impressions and prostheses, especially in removable dental prostheses[3]. The conventional fabrication of complete dentures is founded on several anatomical landmarks and reference planes[4,5]. The loaded impression tray is the largest item requiring intraoral placement in this process. However, it is difficulty in patient with restricted opening ability to record the morphology of edentulous ridge properly[2]. To overcome the challenge of clinical variations in edentulous ridges, a method has developed by using the current denture as an impression tray after morphological adjustments to record the tissue and polished surfaces in a duplicate denture[6-8]. The key factor for this method is adjusting the current dentures till it had been adapted physically and then duplicating accurately. With the development of digital approaches, such as optical scanners and computer-aided design and manufacturing, had led to be more precise and easier duplication process [9]. This clinical report describes and evaluates a digital process to duplicate interim dentures for fabrication of the final prostheses in a patient with severely limited mouth opening after extensive surgical procedures.

Case report

A 65-year-old man presented at our department requesting prostheses to improve masticatory function. He had undergone a tumor excision combined with radical neck dissection and graft repair 8 years previously to treat bilateral buccal mucosa and left lateral tongue verrucous carcinoma. Clinical and radiographic evaluations revealed poor oral hygiene, multiple retained roots, and ill-fitting fixed prostheses with marginal dental caries (Figs 1 and 2). The range of tongue movement and mouth opening was limited (maximum mouth opening 10 mm between maxillary and mandibular incisal edges), and the lingual vestibule was shallow due to scar formation and submucosa fibrosis after surgical processes. These factors made it difficult to maintain oral hygiene and even insert an impression tray during prosthetic treatment. After discussion, irreparable teeth were extracted and complete dentures were fabricated during the interim phase (Figs 3 and 4).

Prosthetic treatment began with plastic stock trays (COE space tray; GC Corp, Tokyo Japan) were adjusted to be able to place in the mouth and cover the edentulous ridges as much as possible. And preliminary impressions were taken by alginate impression material (Jeltrate; Dentsply Sirona, York, US). Then border molding and functional impressions of the maxilla and mandible within the available range of motion using standardized portion of low viscosity polyvinyl siloxane impression material (Panasil Initial Contact Light; Kettenbach GmbH & Co KG, Eschenburg, Germany). The vertical dimension and interocclusal record were transferred to a semi-adjustable articulator (Artex CPR; Koblach, Austria). Anterior resin teeth were placed in the wax rim, with adequate horizontal and

Figure 1. Frontal view of the patient.

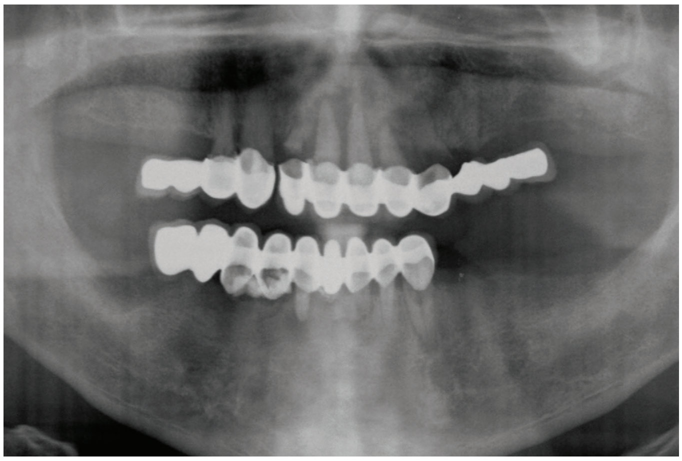

Figure 2. Panoramic radiograph of the patient.

Figure 3. Occlusal view of the maxillary arch after irreparable teeth were extracted.

Figure 4. Occlusal view of the Mandibular arch after irreparable teeth were extracted.

Figure 5. Interim dentures with extension of the denture bases and adjustment of the polished surfaces.

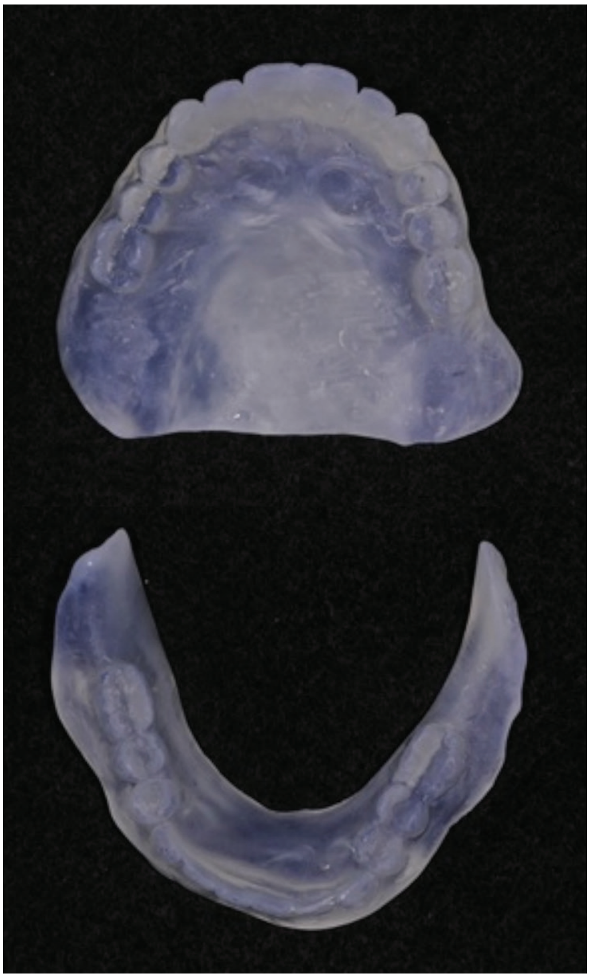

Figure 6. 3D printed duplicate dentures.

vertical overlap and the central fossa of the posterior teeth placed on the crest of the alveolar ridge. The occlusal contacts were adjusted for maximal intercuspation and group function on the working side with balanced contacts on non-working side to improve the stability of prostheses[10]. Due to the limited mouth opening, the morphology of the polished surfaces and extensions of the denture base were evaluated by applying tissue conditioner (Tissue Conditioner II; Shofu Inc, Kyoto, Japan) and self-curing polymethyl methacrylate (PMMA) resin (Unifast II; GC Corp, Tokyo, Japan) several times (Fig 5) After 2 months of regular maintenance, masticatory function was improved.

Regarding the process of definitive prostheses, the interim dentures were scanned with an optical scanner (E3 scanner; 3Shape, Copenhagen, Denmark) and processed with Meshmixer software (Autodesk Inc, California, US). The duplications were printed from NextDent Ortho Clear printable resin (NextDent BV, Soesterberg, Netherlands) using a digital light processing (DLP)-based printer (NextDent 5100; NextDent BV) (Fig 6), serving as a tray for closed-mouth impressions and bite registration (Fig 7). For fabrication of the definitive prostheses, the tooth shape, incisal display, and occlusal plane for tooth arrangement were based on the morphology of the duplication. After trial of the wax dentures, dentures were fabricated by packing with heat-polymerized PMMA resin (Lucitone 199; Dentsply Sirona, Charlotte, US), laboratory remounting, and polishing. Finally, the tissue, occlusal and polished surfaces of the dentures were adjusted several times to maximize oral function (Figs 8,9 and 10). The patient was satisfied with the prostheses and returned for regular 3-monthly follow-ups. No complications occurred during the 2-year follow-up period.

Discussion

Restricted mouth opening ability, oral movement and limited interocclusal space are often encountered in patients who have extensive surgical procedures[1,2]. This situation is a challenge for clinicians due to difficulty in impression during prosthetic treatment. Additionally, poor stability of

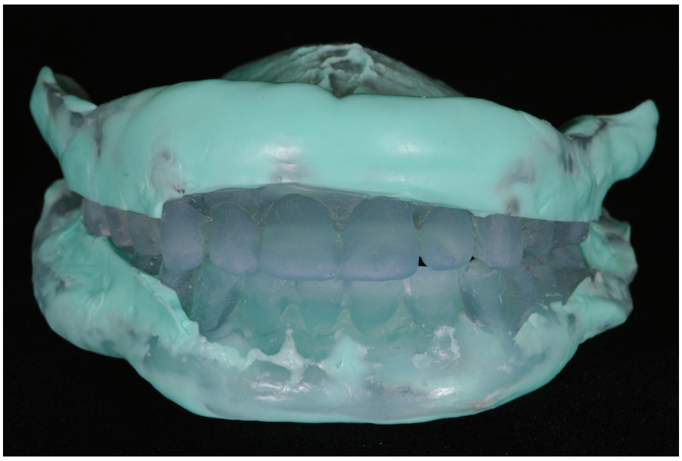

Figure 7. Duplicate dentures as trays for the final impressions and jaw registration.

Figure 8. Frontal view of the patient with final prostheses.

Figure 9. Maxillary view of the patient with final prostheses.

Figure 10. Mandibular view of the patient with final prostheses.

removable dental prosthesis is generally associated with restricted oral movement. Soft tissues form the internal and external boundaries of the denture space, and dentures are more likely to be stable when they are located in a space in which the forces exerted by muscles tend to stabilize the denture[4,5,10,11]. Adjusting the current denture of tissue and polished surfaces till it became stable in the oral cavity, and then duplicating it for closed-mouth impressions is one method to effectively record the tissue and polished surfaces and the vertical dimension[6-8]. In this clinical report with limited mouth opening and oral movement, replicating the interim dentures as impression trays preserves valuable information for fabrication of new prostheses on tooth position, polished surfaces and vertical dimension, as a result of such economized clinical time during fabrication of complete denture was applied. However, the quality of the interim prosthesis influenced the clinical outcome using close mouth impression process with replicated interim denture. If the tooth position, occlusal plane or vertical dimension is obviously inadequate, the conventional process with custom tray to take function impression and occlusal rim to register the jaw relation is more effective.

The duplicate denture technique is not a single technique but a variety of concepts designed to replicate the complete denture. With advances in digital technology, effective and accurate duplications can be achieved with an optical scanner to recode the form, design software to adjust the configuration, and 3D printing technique to produce the shape in minimal time. About different fabrication techniques, Hsu et al[12] compared the adaption of denture bases fabricated by CAD-CAM milled, 3D printed, injection molded and compression molded techniques, and reported the divergent results in 3D printed denture bases both at maxillary and mandibular arches. Additionally, 3D printed denture bases were found to have higher flexibility under loading in this in vitro study[12]. Therefore, the accuracy of 3D printed technique and dimension stability of the materials need to be evaluated furtherly in the future study.

In this clinical report, duplicating the denture space by digital process not only reduced the clinical treatment time, but also provided important information for the fabrication of the definitive prostheses.

Summary

This clinical report describes the use of 3D printing technique to duplicate interim denture as trays for closed-mouth impressions. In this case with limited mouth opening and oral movement after surgery, definitive prostheses were fabricated effectively according to the form that had been adapted physically using a digital approach.

Acknowledgements

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Introduction for authors

The Journal of Prosthodontics and Implantology is an official publication of the Academy of Prosthetic Dentistry, R.O.C., Taiwan, published semiannually in March and September. Articles related to clinical and basic prosthodontics, implantology, implant-related peridontology, periodontology and surgery as well as biological and material sciences related to prosthodontics and implantology are welcome. Article categories include original paper, case report, technical reports, and literature review related to future research. Invited review articles are written by representative scholars on important topics that this journal wishes to emphasize.

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