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Calculate the tooth undercut and soft tissue undercut by software, Page 24 Fig. 3

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Journal of Prosthodontics and Implantology

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Editorial

Greetings to the 30th anniversary of the Academy of Prosthetic Dentistry, R.O.C. The glory of self-improvement in efforts, wisdom, and expectations of all prosthodontists, furthermore with strong faith and pride accomplishes tremendous growing developments over the 30 years. As the founder member, I am honored to be the committee member and dedicate my best to the Academy.

There are no short cuts to success. It accumulates in result of preparations, hard work, and learning from failure. Review the past helps one to understand the present. In this volume, two cases and two original studies are deliberated. Within case reports, experiences may improve judgements. In place of studies, findings from experiences can assembled such measures and be attainable to the dental practices. These articles are worth of your reading and I am pleased to share this issue with you. We are also please to share with you all JPI articles with registered DOI can now be found online at Airiti Library worldwide starting March, 2020. At last, great appreciation to all participants and we look forward to more distinct articles may be beneficial to all prosthodontists in the future.

Hsiu - Na Lin

Hsiu-Na Lin
Editor-in-Chief

Original Article

Influence of surface treatment on the color stability of denture teeth

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Abstract

Objective: *Although various surface sealants are available and for use in chairside or laboratory polishing procedures, their effect on the color stability of denture teeth is unclear, as is the effect of denture cleansers on stain removal. The purpose of this study was to evaluate the effect of sealant agents on the color stability of denture teeth and the effect of denture cleanser on stain removal from denture teeth.*

Material and methods: *For each type of denture tooth material (SR Vivodent, PMMA; Vitapan, reinforced-PMMA), 72 specimens were prepared. The specimens were assigned to six groups according to the surface treatment used and cleaning solution used. The surface treatments employed were (1) grinding only (control group); (2) grinding and conventional laboratory polishing; and (3) grinding, conventional laboratory polishing technique and application of surface sealant (Palaseal). After surface treatment, the specimens were immersed in coffee for 14 hours at 37°C and then were rinsed with running water and air-dried. Each surface treatment group was then divided into two subgroups according to the cleaning solution: distilled water or denture cleanser (Polident). The specimens were immersed in cleaning solution for 30 minutes and then in water for 8.5 hours. This cycle was repeated for 6 weeks. CIELab color parameters were measured using a digital spectrophotometer at baseline and after 1st and 6th weeks. Data were statistically analyzed using t-tests and 3-way analysis of variance.*

Results: *The group of teeth to which surface sealant was applied had the lowest color stability. The group of teeth cleaned using denture cleanser had higher color stability.*

Conclusion: *Surface sealant provides an immediate smooth and glossy surface to denture teeth but gives the surface poor color stability. The use of denture cleanser can reduce denture staining.*

Key words: cleanser; denture; staining; surface sealing agent

Introduction

A removable denture consist of a denture base and denture teeth, and the denture teeth are generally made of poly methyl methacrylate (PMMA) or porcelain.[1] Compared with those made of PMMA, porcelain teeth are more aesthetically pleasing and resistant to wear and staining. However, repairing and adjusting porcelain teeth is more difficult than PMMA dentures teeth, which thus become commonly used than porcelain teeth. Inorganic fillers can be added to dentures teeth to enhance their resistance to wear.[2,3] Maintaining the physical appearance of denture teeth at an aesthetically pleasing state for a long period of time can be difficult because daily drinks such as tea, coffee, and red wine all stain denture teeth. Therefore, denture users should select denture teeth that are favorably resistant to staining.[4]

A study [5] demonstrated that tea, coffee, and nicotine (in cigarettes) can cause stains on denture teeth and that the color differences (ΔE) created by these stains can be perceived by the naked eye. The color differences can also be measured using scientific instruments to obtain accurate and objective data. The CIE Lab color system[6,7] developed by the International Commission on Illumination uses color space coordinates to determine color differences. In the system, L, a, and b signify brightness, green–red, and blue–yellow, respectively. In the color space, the distance between two color coordinates is referred to as the color difference. O'Brien (2008)[8] noted that a color change greater than 3.5 can be perceived by the naked eye.

When arranging teeth or adjusting the occlusion of removable dentures, dental technicians must generally grind the dentures teeth to adjust the occlusion and the size of denture teeth. When ground denture teeth lose their smoothness, and the dental technician must then polish and brighten them to restore their texture and decrease the likelihood of staining (because rough surfaces stain more easily). Numerous commercially available surface sealant agents can be applied to the surface of PMMA to reduce its surface roughness and increase luster. Studies[9-11] have demonstrated that surface sealant agents can reduce surface roughness and enhance denture color stability. However, clinical findings revealed that removable dentures coated with surface sealant agents become darker in both their denture base and denture teeth during long-term use, contradicting the findings of previous studies.

Denture cleansers can be employed to clean and sterilize dentures. Kurtulmus-Yilmaz and Deniz[12] discovered that soaking removable dentures in a denture cleanser decreased the severity of stains and enhanced color stability. Nonetheless, some scholars have contended that soaking dentures in denture cleansers for an extended period of time will result in a change to the dentures' base color.

This study investigated whether different surface treatment procedures influence the color stability of denture teeth and whether soaking denture teeth in denture cleansers affects their color stability. The results can serve as a reference for dentists and dental technicians when polish denture surfaces in the future.

Materials and Methods

Two commercially available denture tooth brands—SR Vivodent PE (Ivoclar Vivadent AG, no inorganic filler) and Vitapan (Vita Zahnfabrik, with inorganic filler)—were used. Upper central incisors with color A2 were selected. The tooth models used for the SR Vivodent PE and Vitapan were A17 and T9L, respectively. A total of 144 upper central incisors were selected as the study sample. All the sample were prepared by the same dental technician and the sample was divided into three groups that were differently surface treatment. The first group was the grinding only (G) group; the second, the grinding and conventional polish (G+P) group; and the third, the grinding, conventional polish and sealing with surface sealant agent (G+P+S) group. Each group was further divided into two subgroups; after being soaked in coffee, one subgroup was soaked in denture cleanser, whereas the other was not. Concerning the grinding method, denture tooth luster was removed by operating the Carborundum point HP#13 on the denture teeth surface with low speed. Regarding the conventional polish method, the denture teeth were polished using a silicon point with low speed. The surface sealant agent employed was Palaseal (Heraeus Kulzer GmbH), which was coated uniformly on the denture teeth using a soft brush. The denture teeth were left to dry for 20 seconds before being cured using a curing machine for 90 seconds.

The sample was soaked in coffee and then placed in a water bath (i.e., a constant

Table 1. Color changes (ΔE) at Weeks 1 and 6 for the two denture types, three surface treatment methods, and two cleaning methods

			ΔE from Baseline	
Brand	Surface treatment	Clean	Week 1	Week 6
Vita	Grinding	water	1.62 (±0.65)	2.95 (±0.58)
		cleanser	1.37 (±0.62)	1.54 (±0.54)
	Grinding & Polish	water	1.44 (±0.83)	1.43 (±0.78)
		cleanser	1.11 (±0.42)	1.07 (±0.46)
	Grinding& Polish& Sealing	water	2.29 (±0.78)	10.51 (±1.01)
		cleanser	1.61 (±0.84)	5.39 (±1.47)
Ivoclar	Grinding	water	1.21 (±0.36)	1.81 (±0.47)
		cleanser	1.84 (±0.85)	1.81 (±1.06)
	Grinding & Polish	water	1.50 (±0.49)	1.62 (±0.54)
		cleanser	1.29 (±0.45)	1.10 (±0.66)
	Grinding& Polish& Sealing	water	4.56 (±0.78)	10.10 (±3.33)
		cleanser	3.42 (±1.80)	5.52 (±0.53)

temperature water tank; BU410D) at 37°C for 14 hours. Subsequently, the samples were washed using running water, blow dried, and divided into subgroups; one subgroup was cleaned using distilled water and the other using Polident denture cleaner. All samples were soaked for 30 min before being soaked in tap water for 8.5 hours. The samples were repeatedly soaked in coffee, their respective cleanser, and tap water for 6 weeks.

The colors of the midsections of the denture teeth were then measured using a digital spectrophotometer (Vita Easy-shade; Vita Zahnfabrik).

The length from incisal edge to root portion of the sample (SR Vivodent PE : A17 and Vitapan : T9L) were around 15 mm. The length of the middle part was matched with the diameter of measured cone of the digital spectrophotometer. Additionally, the middle part is the most flat area and the measured cone could touch the teeth surface perpendicularly. The teeth were put into putty block which exposed the measured area of the middle part of the teeth when measurement was performed. The tooth shape of the same brand was consistent and the same measured area were restricted by the putty (Fig.1).

The CIE L*a*b*color parameters of the midsections before the experiment, 1 week after the start of the experiment, and 6 weeks after the start of the experiment were compared, and the color changes were calculated.

The color changes were analyzed using the t-test and 3-way analysis of variance (ANOVA).

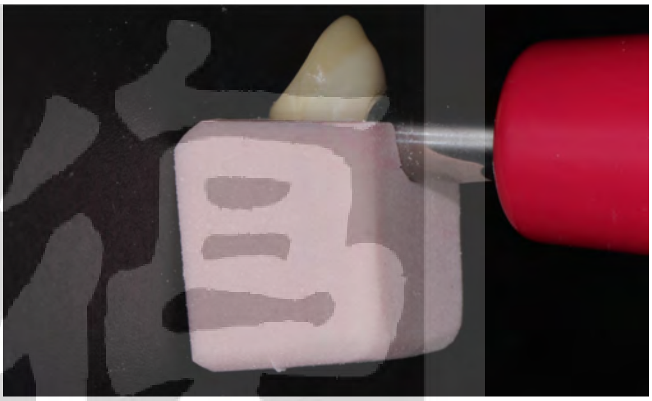

Fig 1: The tooth were put into putty block which exposed the measured area of the middle part when measurement was performed.

Results

In this study, upper central incisors manufactured by two denture tooth brands were used. The surfaces treatments of the denture teeth were processed using one of three methods and cleaned using one of two cleaning methods. The 144 upper central incisors were divided into 12 groups of 12 incisors. The mean and standard deviation color changes (ΔE) of the 12 groups at Weeks 1 and 6 are detailed in Table 1. The color changes were calculated using an equation and the L*a*b* color parameters of the upper central incisors at three time points: before the experiment, 1 week after the start of the experiment, and 6 weeks after the start of the experiment. Clinically, a color change greater than 3.5 (ΔE>3.5) is easily perceived by the naked eye. According to Table 1, the color changes of the Vita denture teeth cleaned by soaking in distilled water at Week 6 were 2.95 (±0.58), 1.43 (±0.78), and 10.51 (±1.01) for the G, G+P, and G+P+S

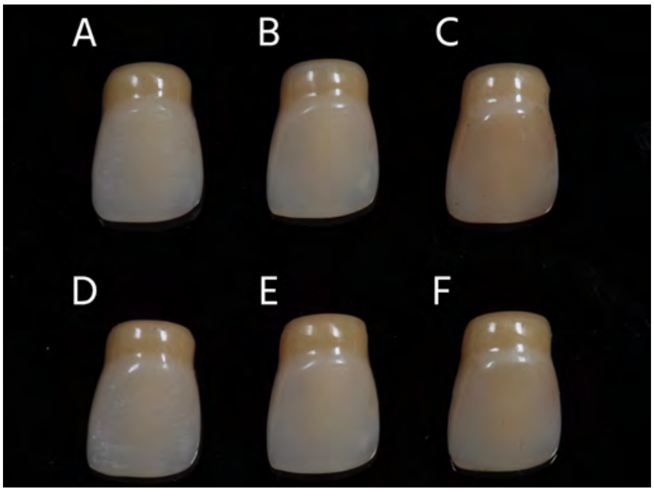

Fig 2: Final result of Ivoclar denture teeth,
A: G group cleaned by distilled water;
B: G+P group cleaned by distilled water;
C: G+P+S group cleaned by distilled water;
D: G group cleaned by denture cleanser;
E: G+P group cleaned by denture cleanser;
F: G+P+S group cleaned by denture cleanser.

groups, respectively. The greatest color change was that of the G+P+S group (ΔE > 3.5), followed by the G(ΔE < 3.5) and G+P groups(ΔE < 3.5). The color changes of the denture teeth cleaned by soaking in denture cleanser were 1.54 (±0.54), 1.07 (±0.46), and 5.39 (±1.47) for the G, G+P, and G+P+S groups, respectively. The greatest color change was that of the G+P+S group (ΔE > 3.5), followed by the G (ΔE < 3.5) and G+P (ΔE < 3.5) groups.

For the Ivoclar denture teeth (Fig.2), the color changes of the denture teeth cleaned by soaking in distilled water at Week 6 were 1.81 (±0.47), 1.62 (±0.54), and 10.10 (±3.33) for the G, G+P, and G+P+S groups, respectively. The greatest color change was that of the G+P+S group (ΔE > 3.5), followed by the G group (ΔE < 3.5) and G+P (ΔE < 3.5) group. The color changes of teeth cleaned by soaking in the denture cleanser were 1.81 (±1.06), 1.10 (±0.66), and 5.52 (±0.53) for the G , G+P, and G+P+S groups, respectively. The greatest color change was that of the G+P+S group (ΔE > 3.5), followed by the G (ΔE < 3.5) and G+P (ΔE < 3.5) groups.

Both the Ivoclar (without inorganic filler) and Vita (with inorganic filler) denture teeth were made of PMMA. The color change differences between the two denture tooth brands were obtained using differential analysis [*t*-test]) and displayed in Table 2. The Ivoclar denture teeth exhibited a color change of 3.82 (±3.47), whereas the Ivoclar denture teeth had a color change of 3.66 (±3.33). The *p* value of the *t*-test was 0.782, signifying no significant difference between the two brands in terms of their color changes. The results revealed that the presence of inorganic filler, which is generally believed to improve teeth resistance to wear, had no effect on denture teeth color stability.

Table 2. Differential analysis results of the color changes (ΔE) between denture tooth brands

	Mean	SD	95% CI for Mean Lower Bound	95% CI for Mean Upper Bound	T test *P* Value
Vita	3.82	3.47	-0.963	1.276	0.782
Ivoclar	3.66	3.33			

In this study, denture teeth surfaces treatment were processed using three methods (i.e., G , G+P, and G+P+S). Multiple comparison analysis of the differences in color changes between the three groups is presented in Table 3, with pairwise comparisons being made. The *p* value for all pairs was <.05, signifying the significant effect of surface treatment method on color change and that the color changes were significantly different between the three groups.

Table 3. Multiple comparison analysis of the color changes (ΔE) between the three types of denture tooth surface processing methods

Dependent variable: ΔE LSD (1) Grinding		Average difference	Standard deviation	Significance	95% CI for Mean Lower Bound	95% CI for Mean Upper bound
Grinding	Grinding& Sealing	-5.85*	0.33998	0.000	-6.53	-5.18
	Grinding& Polish	0.73*	0.33998	0.034	0.05	1.40
Grinding& Sealing	Grinding	5.85*	0.33998	0.000	5.18	6.53
	Grinding& Polish	6.58*	0.33998	0.000	5.91	7.25
Grinding& Polish	Grinding	-0.73*	0.33998	0.034	-1.40	-0.05
	Grinding& Sealing	-6.58*	0.33998	0.000	-7.25	-5.91

* A *p*-value of <.05 denotes a significant difference.

The denture teeth soaked in coffee were cleaned using two types of cleaning solution: distilled water and denture cleanser. In this study, whether denture cleanser could remove denture tooth stains and enhance denture tooth color stability was investigated. Table 4 shows the differences in color changes between denture teeth soaked in denture cleanser and those that were not (data were obtained using differential analysis [*t*-test]). The color changes of denture teeth soaked in distilled water and those soaked in denture cleanser were 4.74 (±4.06) and 2.74 (±2.14) ($p < .001$), respectively. The denture teeth soaked in denture cleanser had superior color stability after 6 weeks, whereas those soaked in distilled water were darker ($\Delta E > 3.5$).

Table 5 shows the color changes and 3-way ANOVA results. Significant differences were discovered in the color changes between the teeth subject to different cleaning solutions and different denture surface treatment methods. In addition, the interaction between denture teeth brand and cleaning solution as well as that between denture surface treatment method and cleaning solution had a significant effect on color change.

Discussion

The staining of denture material is a complex process that is affected by factors such as material surface roughness and the interaction between chemical and physical elements. However, surface roughness is generally considered to be the main factor affecting the absorption of stains. Grinding changes the surface roughness of denture teeth, and study[13] have demonstrated that denture teeth polished using surface sealant are smoother than those polished using conventional polishing techniques. Ground denture teeth that do not contain inorganic fillers are smoother than ground denture teeth containing inorganic fillers. Study[12] have shown that smaller color changes were observed in denture teeth processed with surface sealant agent and those without inorganic fillers were after the teeth were soaked in colored solutions. In the present study, denture teeth coated with surface sealant underwent greater color changes, and inorganic filler did not have a significant effect on denture teeth color change; both these findings fail to support the findings of other studies. The difference may be because this study's denture teeth coated with surface sealant agents (i.e., Palaseal), despite having decreased surface roughness caused by grinding, are still stained by the colored solutions for the involved chemical and physical factors. However, this inference must be verified by subsequent studies.

Denture cleansers are believed to diminish denture stains[14] because they contain chemicals such as perborate that can induce oxidation, achieving the effects of bleaching and destaining. Studies [14-16] have demonstrated that denture cleansers enhance denture color stability. In the present study, the denture teeth soaked in denture cleanser and distilled water exhibited an average

Table 4. Differential analysis of the color changes between denture teeth soaked in denture cleanser or distilled water

			95% CI for Mean		T test
	Mean	SD	Lower Bound	Upper Bound	*P* Value
Distilled water	4.74	4.06	0.925	3.070	0.000***
Denture Cleanser	2.74	2.14			

Table 5. Color changes and 3-way ANOVA results

Dependent variable:ΔE

Source	SS	df	MS	F	*P*
Brand	0.886	1	0.886	1.285	0.259
Clean	143.626	1	143.626	208.293	0.000
Surface treatment	1249.426	2	524.7131	905.991	0.000
Brand X Clean	3.162	1	3.162	4.586	0.034
Brand X Surface treatment	1.777	2	0.889	1.289	0.279
Clean X Surface treatment	146.920	2	73.460	106.535	0.000
Brand X Clean X Surface treatment	3.759	2	1.879	2.725	0.069
Error	91.019	132	0.690		

$p < .05$ denotes a significant difference.

color change of 2.74 (±2.14) and 4.74 (±4.04), respectively. The denture teeth soaked in denture cleanser thus had superior color stability, causing a color change that could not be perceived by the naked eye.

Conclusion

The results of this study support the clinical observation that coating the surface of denture teeth with surface sealant agent improves their luster but results in more staining after long-term use. These results can serve as a reference to dentists and dental technicians. In future studies, scholars may employ other surface sealants in discussion of the relationship between surface treatment and color changes. In this study, denture teeth soaked in denture cleanser exhibited superior color stability.

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Original Article

Comparison of Restoration Fit and Operation Time between Clinical Conventional and Digital Impression Methods in Fabricating Fixed Dental Prostheses

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Abstract

Aim: *Dental treatment services have entered the era of digitalization. Relatedly, the operation time required for the digital fabrication and fit of fixed partial prostheses is an important issue. The purpose of this study was to compare the accuracy and time required for fixed partial prosthesis fabrication between a digital fabrication system and conventional fabrication methods.*

Materials and Methods: *The study was conducted at Kaohsiung Municipal Cijin Hospital in Kaohsiung City and included 20 patients for whom a total of 37 prostheses were made. Both digital scanning and conventional operations were performed for the same dental positions by the same senior dentist. Polyvinyl siloxane (Aquasil, Dentsply Caulk, Milford, DE, USA) was the material of choice used in the conventional impression process, while CS3500 (Carestream, USA) was the digital image acquisition machine used in this study. The design software used was Exocad (GmbH, Germany), and the milling machine used was an ARDENTA CNC mill (DT100-4A, Tainan, Taiwan). The composite material used in milling that did not require thermal sintering was crea.lign (Bredent, Germany). The restoration fit was measured by using Fit Checker (GC, Japan) silicone material intra-orally, and each result was assessed using a three-dimensional coordinate measuring instrument (3D CMM , Jingstone Metrology, Taiwan). The operation time and restoration fit data were analyzed by using paired two-sample t-tests (p < .05).*

Results: *This study included 20 patients for whom 37 abutments were made. We measured the operation time and marginal discrepancy of those abutments. On average, the time required for the clinician to obtain dental data using the digital device was 12.73 minutes (standard deviation, SD ± 5.34), while it took 41.81 minutes (±8.50) when performed with the conventional process. In this respect, the data showed a statistically significant difference between the two methods (P<0.001). The total time used in the digital operation was 48.16 minutes (±11.67), while that for the conventional operation was 76.99 minutes (±13.70), which was also a statistically significant difference (p<0.001). A comparison of the marginal discrepancies for the prostheses made by the conventional and digital processes was also performed. The average marginal discrepancy of four buccal, lingual, distal, and mesial points for the digital process was 77.67μm (± 47.88), while that for the conventional process was 111.25 μm (± 52.02), which was also a statistically significant difference (p < 0.001).*

Conclusion: *The analysis showed that the operation time required for the digital process was shorter than that for the conventional one, while the digital process also provided better precision.*

Key words: Digitalization, Conventional, Accuracy, Time, Remote service

Introduction

Digitalization has shown tremendous promise in the dental industry. It is expected to shorten operation times and reduce the number of clinical visits required of patients. The conventional method used in fabricating fixed prostheses uses impression material to obtain a negative imprint of the given patient's abutment teeth. The impression is then sent to a dental laboratory for prosthesis fabrication. Similar to clinical setting, the conventional laboratory procedure also includes multiple time-consuming steps, including die trimming, articulator mounting, etc. Meanwhile, computer-assisted design and computer-assisted manufacturing (CAD-CAM) techniques have been used to produce ceramic restorations since the 1980s.[1] The digital prosthetic treatment process can be divided into two workflows, one of which is performed by the dentist and the other of which is performed by the technician.[2] The advantages of digital optical oral scans include shortened clinical steps and easy data modification. The digitalization process can be used to convert conventional impression models into digital data by using a reference scanner or using the data from an oral scanner directly. Using design software, technicians can remove the need to perform multiple conventional steps, such as die trimming, articulator mounting, and manufacturing of the prosthesis by a milling machine. It is thus anticipated that digitalization will save considerable amounts of human resources and time.

In recent years, the use of elastic impression materials in combination with conventional single- or 2-step impression techniques has remained the mainstream approach; however, digital oral scanners are gaining in popularity for the 3-dimensional (3D) capturing and digitization of prepared teeth, and various digital impression systems are now available.[2] Each of these systems operates according to different principles,[3] including the use of the active triangulation technique in combination with optical microscopy [Carestream (CS) 3500], optical triangulation in combination with confocal microscopy (Cerec Omnicam), confocal microscopy in combination with ultrafast optical scanning (Trios 3, Planmeca Planscan), active speed 3D video (CS 3600), the parallel confocal imaging technique (iTero), active wavefront sampling in combination with structured light projection (Lava COS) and "3D-in-motion" video technology (3M True Definition), and video in combination with artificial intelligence (Cerec primescan). Intra-oral scanning machine technology has been greatly improved in recent years while the size of such equipment size has also been reduced, giving dentists more flexibility to scan intra-orally under different circumstances. With the digitization of the design and production process, all data is transmitted over a network, bypassing the distance between a clinic and laboratory office and decreasing the time required for the overall process compared to the conventional workflow.

To fabricate a single crown or fixed partial denture, an accurate cast can be obtained with either digital scanning or a conventional impression. The marginal fit is an important clinical factor used for the quality assessment of fixed partial prostheses. In previous studies, an acceptable crown margin-tooth finishing line discrepancy ranged from 34 to 119 um,[4] and fixed partial prostheses with marginal discrepancies of less than 120 um were considered more likely to be successful.[5] Tsirogiannis et al.[6] conducted a review and meta-analysis and found that no significant differences were observed in the marginal discrepancies of single-unit restorations fabricated using digital or conventional impressions. However, Imburgia et al.[7] found that the precision was higher in a partial edentulous model than in a full arch when using a digital workflow. Lee and Gallucci[8] evaluated the time efficiency of the dental prosthesis impression process in an *in vitro* experiment and found that digital scanning required less time than the conventional technique. Ahrberg et al.[9] compared the time efficiency of digital scan and conventional impressions for the fabrication of tooth-supported restorations in a clinical study and found that optical scanning is significantly less time consuming than making conventional impressions.

Using digital scans for fixed prosthodontics has several advantages compared with using conventional impressions, according to *in vitro* studies.[10,11] However, Benic et al.[12] conducted a clinical *in vivo* study comparing these 2 different techniques and found that conventional impressions were more time-efficient than digital impressions. Given these conflicting findings of past studies, the purpose of the present study was to verify whether a remote process could be used to effectively provide digital prosthetic services. We also sought to compare the time required by digital devices versus conventional procedures, as well as the marginal discrepancies on the same abutments of prostheses made using the digital process versus the conventional process. The null hypothesis was that there would be no statistically significant difference in the operation times and marginal discrepancies for the conventional and the digital workflows.

Materials and Methods

Study setting and participants

This study was approved by the Human Research Ethics Committee of Kaohsiung Medical University Chung-Ho Memorial Hospital IRB, Kaohsiung ROC. (IRB code: KMUHIRB-F(II)-20160090). Informed consent was acquired from all the participating patients. The study followed the CONSORT guidelines for reporting clinical trials.

This research was conducted at Kaohsiung Municipal Cijin Hospital (which is entrusted to Kaohsiung Medical University for its operation) between August 2016 and September 2018 (as approved by the institutional review board). The potential participants were screened and selected by a prosthodontist. Each participant had to be 20~90 years old. The exclusion criteria included any cases that required removable partial denture or complete denture fabrication, as well as any patients with a mouth opening limitation (< 38 mm). In this study, the clinical operator was a senior prosthodontic specialist, and the same laboratory technician was chosen to perform each conventional prosthesis fabrication process. Both the dentist and the laboratory technician achieved the plateau of the learning curve for the optical impression systems and the CAD-CAM training before starting the study. For obtaining acceptable, good results with reduced delivery time, the authors and the technician used the best crown parameters for each patient, which were determined before the study.

Conventional and digital impression (Fig. 1)

After tooth preparation and gingival retraction, the production process after the conventional impression method was as follows:

1. Polyvinyl siloxane (Aquasil, Dentsply) impression material was used to obtain the participant's negative imprint.
2. The negative imprint was sent to the dental technician's office.
3. Gypsum was used to obtain the tooth positive model.
4. The positive model was scanned with a reference scanner (Activity 880 scanner; Smart Optics, Bochum, Germany) to obtain the digitization data for the target tooth [stereolithography(STL) file].
5. Prosthesis design was performed using the CAD software Exocad (GmbH, Germany), and the crown parameters were set using conventional pathway records.
6. An ARDENTA CNC mill (DT100-4A, Tainan, Taiwan) was used in the laboratory office to make the prosthesis.
7. Adjustments to the output tooth were made on the articulator.
8. The prosthesis was sent to the clinical department for delivery by the dentist.

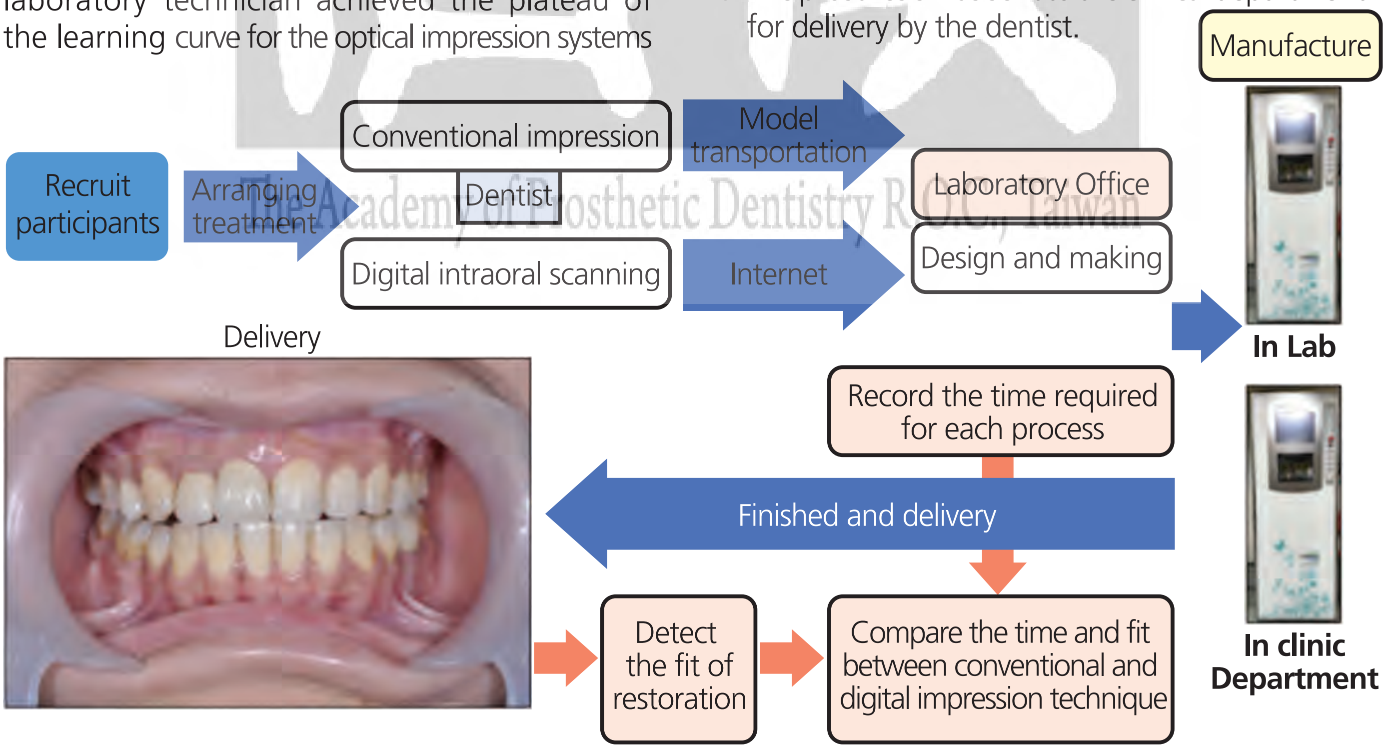

Figure 1. Flowchart of the conventional process and the digital process.

After the tooth preparation and gingival retraction, the production process after the digital optical intra-oral scan was as follows:

1. A photo-type optical digital dental scanner CS3500 (Carestream, USA) was used to obtain the target tooth data (STL file).
2. The dental data was transferred to the laboratory via the Internet.
3. Prosthesis design was performed using the CAD software Exocad (GmbH, Germany), and the crown parameters were set using intraoral scanner pathway records.
4. The data was transferred to the clinical department and an ARDENTA CNC mill (DT100-4A, Tainan, Taiwan) was used to make the prosthesis.
5. The prosthesis was sent to the clinical department for delivery by the dentist.

Critical operation time calculation (Fig. 2)

To determine the time required for the conventional process for each patient, we started the timer after placing the gingival retraction cord in the abutment sulcus and stopped the timer upon completion of the upper and lower occlusion recording.

The laboratory operation time began after the hardening of the working cast, including die preparation with a Di-Lok tray (San Xing, Taiwan), and ended when the cast and tray were mounted on the articulator. After the articulator setting was completed, the second period began with the model being placed in the reference scanner and ended when the storage of the data was completed. After the output was completed, the finishing and polishing of the prosthesis were performed by the same senior dental technician on the articulator.

The starting time for the digital scanning process began with the gingival retraction and ended when the storage of the scan data was completed. The laboratory design time began with the extraction of the data and ended when the design was completed and the data was stored. The 3D tooth milling machine's output time started with the data being transferred to the machine and ended with the machine notification of the completed output. The material used in this study was crea.lign ® (Bredent, Germany), which does not require thermal sintering.

The delivery time began after the patient had been seated in the chair and the relevant pre-delivery preparation had been completed and ended when the patient indicated that there was no problem with occlusion.

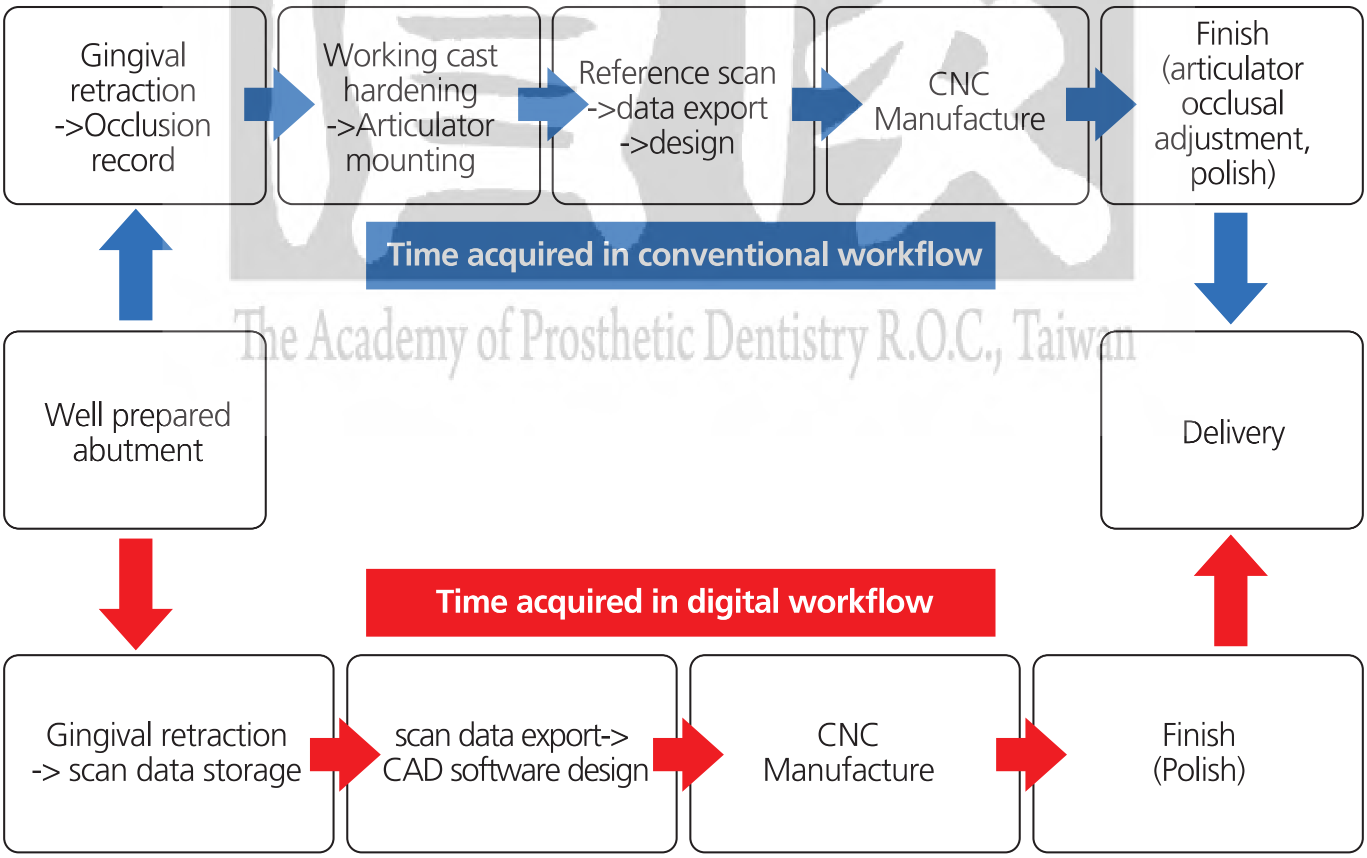

Figure 2 Time required for the conventional workflow and the digital workflow.

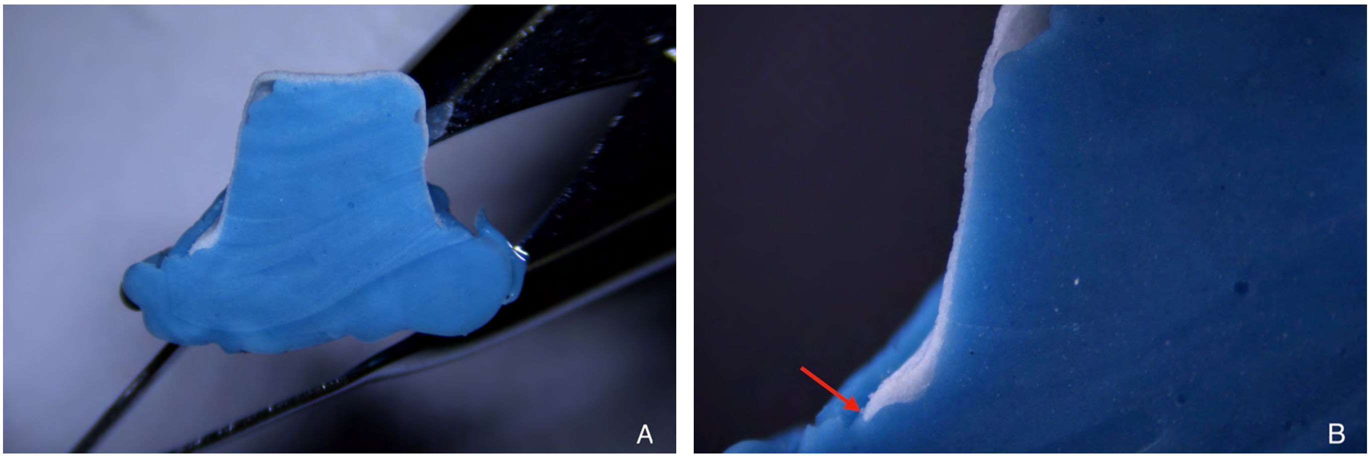

Figure 3. Representative replica cross-section with locations of the measurement points. A, the cross-section of the abutment (original magnification, x0.67). B, the arrow shows the marginal discrepancy from the specimen cross-section (original magnification, x3).

Fit comparison

After the prosthesis delivery-time calculation for the two methods was finished, a replica method was used to evaluate the marginal space between the prostheses and abutment teeth. The intaglio surface of each of the prostheses was filled with Fit Checker (GC, Japan) silicone material. The prosthesis was then placed on the abutment teeth and the patient was asked to bite with normal force for 30 seconds with gauze in between the opposite dentition. Upon removing each prosthesis from the mouth, we injected low-viscosity light-body PVS (Aquasil, Dentsply) into the intaglio surface of the prosthesis to replicate the abutments. Figure 3A shows a layer of the Fit Checker material attached to the surface of the abutment teeth that surrounded by the PVS silicone to fix the Fit Checker layer, which was sectioned mesiodistally and buccolingually with a razor blade. Four points (buccal, lingual, distal, and mesial) for each specimen were then measured one time by the same laboratory staff using a three-dimensional coordinate measuring instrument (3D CMM, Jingstone Metrology, Taiwan) at 0.67X~3X magnification. We selected four reference points, one point per side (mesial, distal, buccal, and lingual), and measured the thickness of the Fit Checker layer to determine the value of the marginal discrepancy (Fig. 3B).

Statistical Analysis

The operation time and fit data obtained as described in the preceding section were analyzed by using paired two-sample t-tests. The statistical significance level was set to $P < 0.05$.

Results

A total of 20 patients participated in the study. There were 15 female and 5 male participants, and they received a total of 8 anterior prostheses and 29 posterior prostheses. There were 29 prostheses placed in their upper jaws and 8 prostheses placed in their lower jaws. A total of 43 abutments was analyzed, including 31 single crowns and 6 crown-and-bridge prostheses. Details of the participants' data and dental condition distribution can be found in Table 1.

Table 1. Participants' basic data and dental condition distribution

Item	n	%
Sex		
Male	5	15.0
Female	15	75.0
Tooth position		
Anterior	8	21.6
Posterior	29	78.4
Jaw		
Maxilla	29	78.4
Mandible	8	21.6
Prosthetic		
Single	31	83.8
Bridge	6	16.2

Total 20 participants, 37 prostheses.

Comparison of key operation time between the conventional and digital processes

In the comparison of operation time, the average time required to complete the digital process was 12.73 minutes (standard deviation, SD ± 5.34), while that required for the conventional process was 41.81 minutes (±8.50). The time spent obtaining dental data showed a statistically significant difference ($P<.001$)

Table 2. Comparison of the time (min) required to fabricate a tooth using the conventional and digital acquisition of dental data

Item	Conventional M	± SD	Digital M	± SD	Diff.	± SD	95%CI	P
Time for obtaining dental data (min)	41.81	± 8.50	12.73	± 5.34	29.08	± 10.88	**(25.28 , 32.87)**	**<0.001**
Clinically acquired dental model	15.99	± 6.95						
Laboratory operation	18.74	± 4.32						
Reference scan	7.07	± 1.09						
Design	3.55	± 1.37	4.11	± 2.21	-0.55	± 1.56	**(-1.10 , -0.00)**	**0.047**
Manufacture	20.30	± 7.07	19.99	± 7.48	0.31	± 3.09	(-0.76 , 1.39)	0.559
Polish	4.40	± 1.74	0.5	± 0.02				
Delivery	6.91	± 3.53	6.32	± 3.44	0.59	± 4.25	(-0.89 , 2.07)	0.422
Total	76.99	± 13.70	43.16	± 11.65	33.83	± 11.84	**(29.69 , 37.96)**	**<0.001**

Paired two-sample t test
Diff. is difference mean
Time unit is minute
Total sample size was 37 prostheses

Table 3. Comparison of the marginal fits of the conventional and digital dental prostheses

	Conventional M	± SD	Digital M	± SD	Diff.	± SD	95%CI	P
Buccal	100.37	± 65.19	64.48	± 47.49	35.88	± 65.84	**(12.26 , 58.50)**	**0.003**
Lingual	111.25	± 55.87	79.31	± 65.63	31.94	± 57.20	**(12.29 , 51.59)**	**0.002**
Mesial	121.37	± 112.07	90.62	± 96.63	30.74	± 138.41	(-16.80 , 78.28)	0.197
Distal	108.00	± 72.42	76.28	± 62.72	31.71	± 78.02	**(4.91 , 58.51)**	**0.022**
Mean	110.25	± 52.02	77.67	± 47.88	32.57	± 46.86	**(16.47 , 48.67)**	**<0.001**

Paired two-sample t test
Diff. is difference mean
Unit of distance [μm]

between the conventional process and the digital process. The average time required for the digital design process was 4.11 minutes (±2.21), while the average time for the conventional design process was 3.55 minutes (±1.37). The time required for the digital design process was thus longer than that required for the conventional design process by 0.55 minutes (±1.56), which was a statistically significant difference (p=.047). The average polish time for the digital group was 0.5±0.02 minutes, while that for the conventional group was 4.4±1.74 minutes, which was much longer than the time required for the digital group. The reason for this difference may have been that the conventional method required the technician to put the specimen back on the gypsum model to make contact area adjustments. From the time when the dental data was obtained to the delivery of the prosthesis, the total time of the digital process was 43.16 minutes on average (±11.65), and the average key operation time for the conventional process was 76.99 minutes (±13.70), which was significantly longer than the total time for the digital process (p<.001). Meanwhile, there was no statistically significant difference between the two methods of modulo in the time used for delivery and milling in the milling machine (p>0.5). For detailed time comparison values, please see Table 2.

Comparison of fit for the conventional and digital prosthesis fabrication processes

Table 3 shows a comparison of the marginal discrepancies for the prostheses made using, respectively, the conventional process and the digital process. For the digital workflow, the mean value obtained for the buccal side of the specimens was 64.48μm (±47.49), while at the same location, the mean value for the conventional workflow was 100.37μm (±65.19), which was a statistically significant difference (p = .003). The mean marginal discrepancy was 79.31μm (±65.63) for the lingual side of the specimens made using the digital workflow, while that for the specimens made using the conventional process was 111.25μm (±55.87), which was also a statistically significant difference (p = .002). For the distal surface, the mean marginal discrepancy for the digital workflow was 76.28μm

(±62.72), while that for the conventional process was 108.00μm (±72.42), which was a statistically significant difference (p =.022). However, there was no statistically significant difference between the two workflows in the measurements for the mesial side of the specimens.

The average marginal discrepancy values of all four points obtained for the digital workflow and the conventional workflow were 77.67μm (± 47.88) and 110.25μm (±52.02), respectively, which were significantly different (p <.001).

Discussion

In recent years, scholars and dentists all over the world have begun to explore the differences between intra-oral digital scanning and conventional impressions. Chochlidakis et al. reviewed and compared *in vitro* studies that measured the marginal fits or internal fits of prostheses made by digital scans and conventional impressions. Carbajal Mejia et al. [13] compared the accuracy of conventional impression and digital scanning methods with a direct intraoral scanner and reference scanner, and the results showed that the highest degree of reproducibility was achieved by intra-oral direct scanning. Park and his coworkers[14] presented a dental technique in which digital data pertaining to a patient's lateral occlusion relationship could be adjusted using software, such that the chair time could be reduced and the anatomic form conserved with the help of CAD software. In this study, the total time required for the digital process significantly differed from the total time required for the conventional process; however, the working time (12.73±5.34 minutes) required to acquire dental data from the images captured by the intraoral scanner (CS 3500) was still longer than the clinician had expected. The benefits provided by other new scanners (Trios, Cerec primescan) might yield better results, and exploring that possibility would be an interesting direction for a future study. However, we strongly recommend that a clinician first achieve the relevant learning curve plateau before using such new cutting-edge devices in order to fully maximize the benefits of their use. Lim et al. [15] investigated the effect of the experience curve on changes in the trueness of full arch scans and mentioned that easy-to-use scanning systems and acceptance training were relevant to such scan results. Relatedly, the present study was performed by a senior prosthodontic specialist who has been well trained and reached the plateau of the learning curve.

Our results showed that the conventional and digital processes did not differ significantly in terms of the time required for obtaining a dental impression (15.99 vs. 12.73 min), designing a prosthesis (3.55 vs. 4.11 min), manufacturing it (20.30 vs. 19.99 min), and delivering it (6.91 vs. 6.32 min). Rather, the excess time required for the conventional process was spent on completing the associated laboratory work. The laboratory procedure involves multiple time-consuming steps, including die trimming, articulator mounting, etc., and any error may necessitate repeating the steps from the start. Therefore, the use of digital impressions can help to reduce the amount of dental material used and lessen the environmental pollution caused by such material.

Matta et al.[16] showed that impression scanning generated more precise models than conventional impression methods. However, impression scanning relies on the use of a special reference scanner such as the NobelProcera 2G scanner (Nobel Biocare), a scanner that can scan the negative imprint, to reduce laboratory working time. In this study, the reference scanner used was the Activity 880, a scanner that can only scan positive models, which resulted in more laboratory time.

Su and Sun[17] compared the internal fits and marginal fits of CAD-CAM, 3-unit ceramic fixed partial dentures and found that the marginal discrepancies of such prostheses made using a digital impression system were smaller than those of such prostheses made using a conventional system. The six fixed partial dentures produced in this *in vivo* study exhibited similar results. Marghalani et al. [18] compared the accuracy of conventional impression and digital scanning systems for partial edentulous arches and reported that the results for all of the investigated impression techniques were within clinically acceptable levels and that there was no statistically significant differences in the results for the different intra-oral scanners used (namely, Omnicam and True Definition scanners). In the present study, a photo-type optical digital dental scanner CS3500 (Carestream, USA) was used to obtain the oral data (STL file). The accuracy of this scanner was similar to that of the True Definition scanner, which allowed for the easy and convenient transfer of data to the CAD-CAM system for further prosthesis fabrication. Tsirogiannis et al. [6] conducted a review and meta-analysis of various *in vitro* studies, finding that the mean marginal discrepancy of a restoration made using a digital impression was 56.1 um (95% CI: 46.3-65.8 um), whereas that of restoration made using a conventional impression was 79.2 μm (95% CU: 59.6-98.9 um). The marginal discrepancy obtained in this paper is 110.25 μm. It is a little bit larger than the Tsirogiannis's review (56.1 μm)[6] or Su's results (71 μm).[17] The main difference was that our study was an *in vivo* study and thus had greater variability in the prostheses produces, in addition to being impacted by the reality of various clinical factors. Moreover, Su's study used the same model with two kinds of polyvinylsiloxane (PVS) used as the replica material, whereas our study used Fit Checker silicone material combined with PVS. The associated binding ability thus might also have been a factor underlying the higher marginal discrepancy value we obtained.

Although no data regarding patient satisfaction was collected in this study, Gallardo and coworkers[11] reviewed the patient outcomes and procedure working times for digital versus conventional impressions and reported that patients are more likely to prefer the digital workflow than the conventional workflow. In a time-comparison study, Benic et al. [12] showed that conventional impressions required less time to produce than digital impressions for single posterior teeth. However, they only calculated the impression/scanning time of the given impression procedure, while the benefits from digital fabrication would also include benefits pertaining to the model pouring, die trimming, and digital occlusal adjustment. Relatedly, Sailer et al. [19] reported that the laboratory working time for a digital workflow was significantly shorter than the laboratory working time for a conventional workflow.

There were only 20 participants for whom 37 prostheses were produced in this *in vivo* study, and the marginal discrepancy and time required were calculated for both the digital and conventional workflows. The limitations of the current study were that the same cement space would possibly not have been created for two groups of FPDs made through two processes of fabrication, the lab technician and dentist were not blind to the study purpose, and the mean marginal gap for the conventional FPD group was slightly bigger than the sizes of such gaps reported in previous studies. To improve upon the present study then, it is expected that larger sample sizes, different scanners, and data regarding patient satisfaction and chewing efficiency can be incorporated in future studies.

Conclusion

Compared with the conventional impression process, the digital scanning process requires fewer operation steps. The results of the analysis showed that photo-based optical digital scanning required less time to obtain dental data than the conventional impression method. Furthermore, digital scanning yielded prostheses with a lower mean marginal discrepancy than that for prostheses produced using conventional impressions, which was consistent with the results of previous studies. For dentists and dental technicians, even those separated by long distances, the digital process can shorten the operation time required, and the precision of the restorations produced by the digital process is not inferior to that of restorations produced using the conventional process.

Acknowledgments

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Conflicts of Interest

The authors declare no conflicts of interest.

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Technique Report

Prosthodontic rehabilitation of patient with prolonged TMJ dislocation reduced by midline mandibulotomy

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Abstract

Prolonged temporomandibular joint (TMJ) dislocations are rare but challenging and result in the impairment of essential functions such as speaking and chewing. The methods used to manage such prolonged dislocations in previous studies have varied widely from manual reduction to numerous surgical methods such as midline mandibulotomy, condylectomy, condylotomy with or without coronoidotomy, and eminectomy. The following case report describes the prosthodontic rehabilitation of a patient with complete dentures and a history of prolonged TMJ dislocation reduced by midline mandibulotomy. Through our multidisciplinary cooperative efforts, the patient's chewing function was restored along with a satisfactory esthetic appearance.

Key words: **complete dentures, midline mandibulotomy, prolonged TMJ dislocation**

Introduction

Temporomandibular joint (TMJ) dislocation is defined as displacement of the condyle from the glenoid fossa and reportedly accounts for 3% of all articular body luxations. TMJ dislocations occur for a variety of reasons, including extreme mouth opening during yawning, trauma to the mandible, dental treatments, and bronchoscopy. Otherwise, an imbalance in the TMJ neuromuscular function or a structural deficit can also induce a TMJ dislocation .

These dislocations can be further subclassified into the acute, chronic recurrent, and long-standing/prolonged types. Acute cases are relatively common events that can be reduced by manipulating the mandibular condyle downward and backward into the glenoid fossa with or without local anesthesia or sedation. Huang et al. [1] reported that prolonged dislocations are rarer, with most resulting from acute dislocations that were left untreated or were inadequately treated for 72 hours or more.

The methods used to manage prolonged TMJ dislocations in previous studies have varied widely. For example, numerous surgical methods have reportedly been used to reduce such dislocations, including midline mandibulotomy, condylectomy, condylotomy with or without coronoidotomy, myotomy, sagittal split mandibular osteotomy, meniscectomy, and eminectomy. [3] Relatedly, because of the rarity of prolonged TMJ dislocations, no standard guidelines for their treatment have been developed thus far. The following report describes the interdisciplinary treatment of a patient with a prolonged TMJ dislocation that was reduced by midline mandibulotomy and then rehabilitated with complete dentures.

Case report

A 71-year-old female patient reported to our hospital with the chief complaint of an inability to close her mouth and chew food due to bilateral joint dislocation after gastroscopy for more than 3 weeks. The patient was completely edentulous and had no prior history of TMJ dislocation. Medically, she reported a history of cataracts and mild mental retardation. She had also received 2 mandibular implants in the regions of teeth 33 and 43 and had had conventional complete dentures fabricated at a dental clinic 1 year ago. On thorough clinical examination, it was found that the patient was experiencing muscle spasms because of a long-standing TMJ dislocation. Examination of the TMJs revealed pain and tenderness on palpation over the bilateral TMJ region.

Manual manipulation was attempted but could not be successfully applied on her first visit to our department, so she was referred to the oral and maxillofacial surgical department for further treatment. Radiographic examinations were taken and showed a bilateral dislocation of the patient's TMJs (Figs. 1-2). Because the patient had experienced considerable pain and was unable to relax her muscles, a further attempt at manual reduction was performed with an injection of local anesthesia, but still to no avail. It was then explained to the patient that reduction under general anesthesia or other more invasive surgical procedures might be necessary. Considering the patient's age and the risks of a surgical intervention, the patient's family decided to transfer her to another hospital for a second opinion. However, they returned 19 days later for further evaluation because the treatments attempted in the meantime, including reduction under general anesthesia, acupuncture, and physical therapy, had all been unsuccessful.

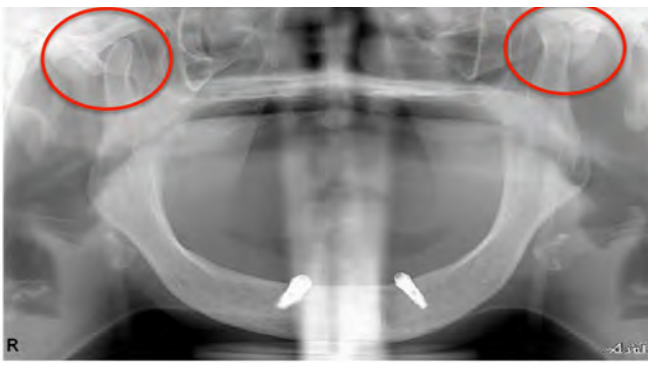

Fig. 1 Initial panoramic x-ray image showing bilateral TMJ dislocation

Fig. 2 CT scan showing bilateral condyles anterior to articular eminence

Various treatment modalities were discussed in detail, and informed consent was obtained from the patient and her family, after which the patient was admitted to our hospital. A variety of surgical techniques were proposed for reducing the prolonged bilateral TMJ dislocation, including pulling downward and backward from both mandibular angles with the help of transosseous wires and the use of a bone hook passed over the sigmoid notch to apply force. Unfortunately, the condyles were still not correctly placed after the application of this technique. Consequently, a midline mandibulotomy was performed, and this allowed the bilateral hemimandibular segments to be easily manipulated such that reduction was finally achieved (Fig. 3). X-rays taken immediately after the surgery with a C-arm x-ray system confirmed that the condyles

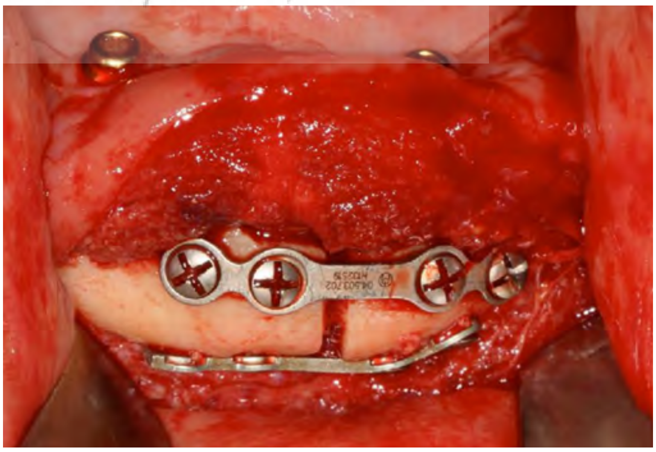

Fig. 3 Photograph showing midline mandibulotomy and fixation with bony plates

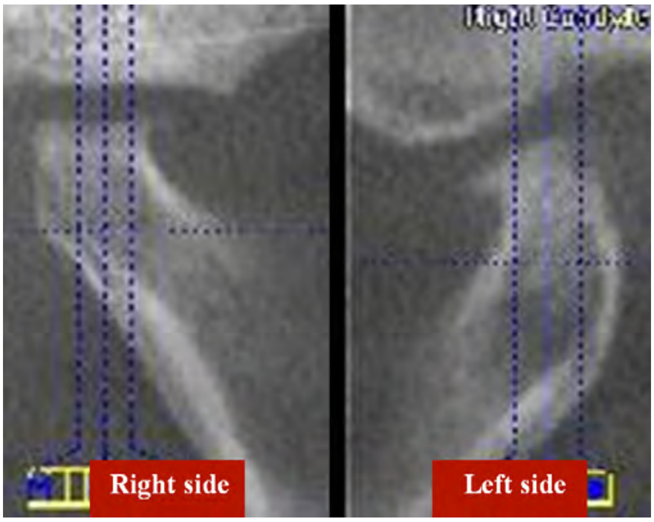

Fig. 4 X-ray images showing osseous changes of bilateral condyles

were placed exactly within the glenoid fossa. The osteotomy site was fixated with bony plates, and a maxillomandibular suspension with miniscrews and wires was then applied with the patient's upper denture and 2 mandibular implants for 12 days. The patient was discharged after being advised to abstain from wide yawning and the chewing of hard foods.

At 3 months after the operation, the patient presented to the department of prosthodontics with the complaint that she was unable to wear her existing complete dentures and found it difficult to eat with them. CBCT and MRI examinations found bilateral condyle osteoarthritis with anterior disc displacement but no mouth opening limitation and no pain or tenderness on palpation over the TMJ region. The condyles were assessed for the presence of osseous changes using lateral images (Fig. 4). An extra-oral examination revealed a concave lateral profile, reduced facial height, relative prognathism, and the collapse of lower facial soft tissue without the old dentures. On intra-oral examination, the residual ridge showed severe bone resorption and flabby gums over the maxillary anterior region. The two implants (4.0x10 mm) with locator abutments (Osstem US II, Osstem Implant Co., Busan, Korea) were properly placed over the severely resorbed mandibular ridge, and no mobility was detected (Fig. 5). However, the gingival tissues around the implants showed slight inflammation, and both old dentures displayed poor esthetics and incorrect occlusal relations.

Fig. 5 Photographs of the intra-oral view of edentulous status

The main objective of the treatment was to achieve esthetic and functional rehabilitation by restoring and reestablishing stable occlusion as soon as possible. Various treatment options were discussed with the patient and her family, including the repair of the old dentures and the fabrication of new dentures. We first checked the old dentures and removed a thin layer from the tissue surface. Then the tissue side was relined with relining material (Flexacryl Hard, Lang Co, USA) and the dentures were inserted into the patient's mouth. After determining the vertical dimension through its association with the rest position, as well through phonetic and esthetic methods, the centric relation was recorded with aluwax (Aluwax Dental Products Co, U.S.A.). The upper and lower dentures were mounted on a semi-adjustable articulator (Artex® CT, Austria) to adjust the occlusion with self-cured acrylic resin (Tokuso Curefast, Tokuyama Dental Co, Japan). Next, relining material (Flexacryl Hard, Lang Co, USA) was applied to the tissue side and the patient was instructed to close her mouth. After complete setting of the material, the dentures were removed, the excess material was trimmed away, and finishing of the dentures was completed. No discomfort was noted during a further 6-month follow-up period, so a primary impression of the maxillary and mandibular edentulous ridges was made using irreversible hydrocolloid impression material and poured with type III dental stone to produce a diagnostic cast on which the custom trays were made. Using the selective-pressure technique, in the upper arch, wax spacer was applied to cover the incisive papilla, rugae, midpalatine raphe, and flabby tissue (Fig. 6); in the lower arch, wax spacer was applied to cover the entire alveolar ridge except at the retromolar pad area. The trays were checked in the patient's mouth and adjusted so that the borders of each tray were uniformly 2 mm short of the vestibules. Border molding was completed with green modeling compounds (Impression Compound Sticks; Kerr Crop, CA, USA). For the final impression, relief holes (Fig. 6) were made and the upper tray was loaded with vinylsiloxanether impression material (Identium, Kettenbach, Germany), and the lower tray was loaded with polyether impression material (Impregum Penta soft, 3M ESPE). Master casts were made with die stone (Fig. 7). In order to prevent recurrent dislocation, the jaw relations were re-evaluated and recorded with a decreased vertical dimension (-3mm), and then a face bow transfer was done and transferred to the semi-adjustable articulator. The teeth

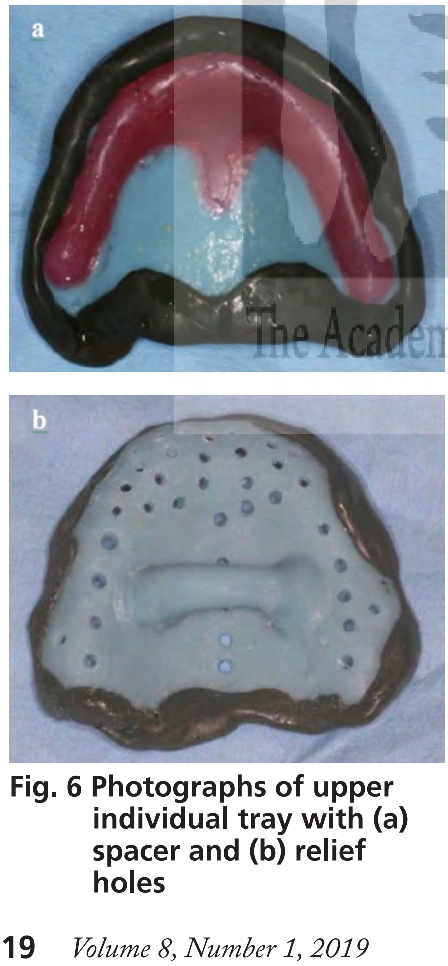

Fig. 6 Photographs of upper individual tray with (a) spacer and (b) relief holes

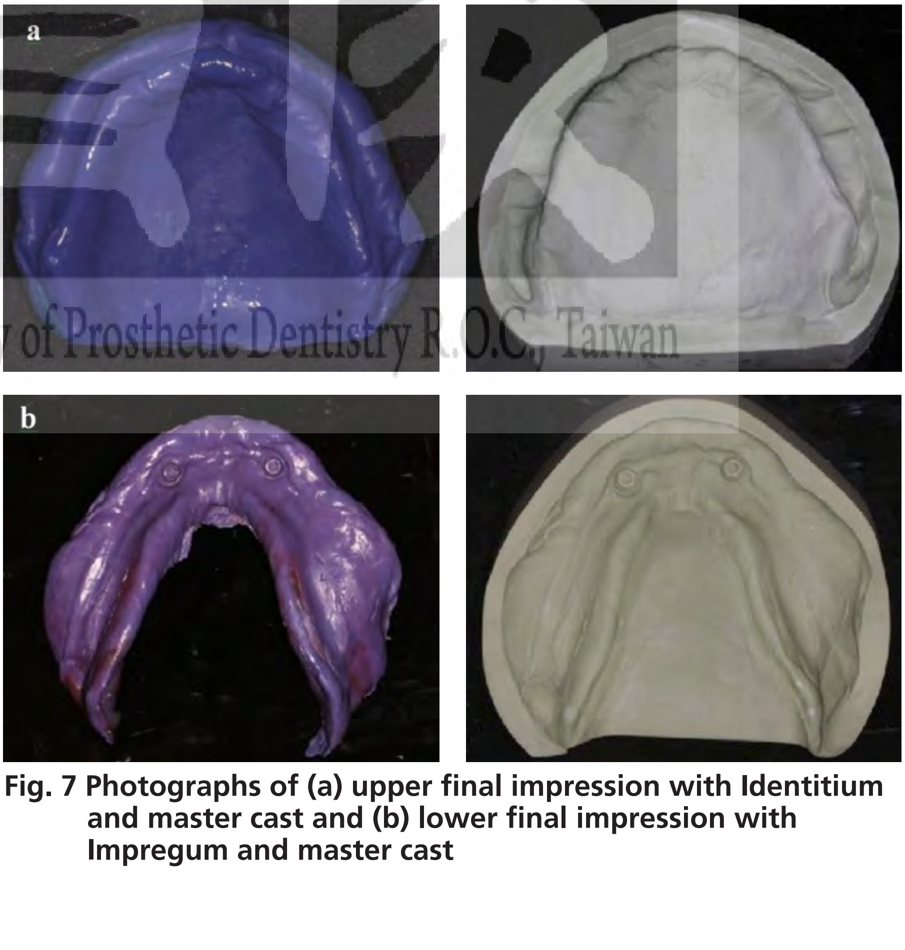

Fig. 7 Photographs of (a) upper final impression with Identitium and master cast and (b) lower final impression with Impregum and master cast

Fig. 8 Image showing inadequate restorative space (3 mm) over the lower buccal side

Fig. 9 Photographs of the definitive prostheses

were set up according to anatomic, functional, and esthetic guidelines, and their setting was accomplished with balanced occlusion. The wax dentures were tried in, and the esthetics and functions were evaluated again.

However, mounted casts with wax dentures showed that there was inadequate restorative space over the lower buccal side for the attachment system (Fig. 8). The definite treatment plan was thus modified to upper and lower conventional complete dentures. The prostheses were processed with the Ivocap injection molding system (Ivoclar Vivadent Inc., Amherst, NY) to decrease packing errors. After deflasking, the occlusion was adjusted, and the prostheses were finished and polished. Through a clinical remount procedure, the finished dentures were delivered with minor tissue side adjustments (Fig. 9). Clinical examination revealed no abnormal clinical signs, and the patient showed good adaptation to the new prostheses and was very pleased with the results. The patient was asked to return every 3 months for an evaluation of the stability of occlusion and the TMJs.

DISCUSSION

The duration of a TMJ dislocation plays an important role in its prognosis, as delayed treatment can lead to spasms of the masticatory muscles as well as fibrosis of the retro- and peri-discal tissue, which will increase the difficulty of treatment and necessiatate more complex procedures. According to a study by Huang et al., any attempts to reduce such luxations with closed manipulation in patients who had had the luxation for more than 4 weeks were unsuccessful, and either direct or indirect open reduction was suggested instead.[1] In the present case, a series of treatments were performed, starting with a minimally invasive conservative technique and progressing to more invasive surgical procedures.[3] A midline mandibulotomy eliminated the structural resistance, which allowed for the reduction of each joint individually without direct exposure as Lee et al. showed in their case.[2,4] Still, as an invasive approach, this technique entails potential complications including lingual hematoma, malocclusion, damage to the root apex, and nonunion. However, healing of the segmented mandible is more predictable than healing following joint exposure, and jaw function recovered uneventfully in nearly all of the cases in the reviewed literature.

Temporomandibular disorder is a disease with multiple causal factors. In hindsight, it was unclear whether the long-standing TMJ dislocation or the surgery induced osteoarthritis in the patient in the present case; however, for this fully edentulous patient, it was imperative to limit the patient's movement through a reduced vertical dimension, control the patient's diet, and schedule regular follow-up appointments before proceeding to the definitive stage. Furthermore, joint replacements may be considered when all other conservative treatments fail, especially in cases involving associated degenerative joint problems.

With severe ridge resorption patients, dentists are challenged to improve the support, retention, and stability for dentures. In general, the mean denture-bearing area for an edentulous mandible is 14 cm,[2] whereas the mean denture-bearing area for an edentulous maxilla is 24 cm.[2 5] In this case, extension into the deeper retromylohyoid area to gain further retention without interfering with the supporting tissues (2 implants) or causing pain seemed to improve the outcomes. In patients with flabby tissues, the force exerted when making impressions and during mastication can displace or distort the flabby tissues, resulting in compromised denture retention as a consequence of the loss of the peripheral seal. Many techniques have been proposed to help overcome this problem, such as various techniques relating to tray design and the use of different impression materials. Lynch et al. suggested the use of additional relief space or relief holes over flabby tissue, and in the proposed approach, the impression is made in one step. [6-7] Watson et al. proposed the window technique to minimize the movement of flabby ridges during function; however, its controlled application is still a matter of concern.[8] In this case, the use of relief spacer and relief holes combined with low viscosity impression material seemed to provide acceptable final results.

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Technique Report

CAD-CAM generated mouth preparation guide for a removable partial denture: a technique report

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Running title: CAD-CAM preparation guided for RPD

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Conflict

These authors declare no conflicts of interest.

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Abstract

Fabricating preparation guides using computer-aided design-computer-aided manufacturing (known as CAD-CAM), a practical technique was performed to ensure the precise intraoral transfer of guiding planes. By using this particular guiding template, such clinical technique described the oral preparation on different axial abutments to create a placement and removal path for removable partial dentures. The guiding template was designed to simultaneously indicate the position of parallel guiding planes and examine the volume calculation for pulp protection.

Key words: CAD-CAM, parallel guiding planes, removable partial denture

Introduction

Major connector, rests, direct retainer, minor connector, guiding plane, and indirect retainer are the main components of a removable dental prosthesis (RPD).[1] In terms of prosthodontic, it is to be defined as guiding plane of two or more vertically parallel surfaces on abutment teeth and/or fixed dental prostheses oriented as well as to contribute the path of placement direction, the removal of RPD, a maxillofacial prosthesis, and an overdenture,[2] which implies two or more vertical parallel surfaces of abutment teeth should be shaped according to the path of placement and set in parallel to each other, preferably in contrast to the long axis of abutment teeth. The following functions have been attributed to guiding plane in providing path of insertion, improving retention through frictional contact, stabilizing or bracing the prosthesis against horizontal forces, providing reciprocation, stabilizing the individual tooth, minimizing the space between the denture and the tooth to reduce the number of gross food traps, facilitating daily denture wear, eliminating detrimental strain on abutment teeth and prosthesis framework components while inserting and removing the prosthesis, as well as minimizing wedging stresses on abutment teeth.

Guiding planes may present in natural crown contours or may be formed by selective grinding of the natural crown contours or contouring of surveyed crowns. However, they are mostly formed by selective grinding when a natural tooth is selected. Dental surveyor[3] is a reliable method for analyzing and acknowledge parallel planes after preparation; though

Figure 1. A. Maxillary occlusal view B. Mandibular occlusal view

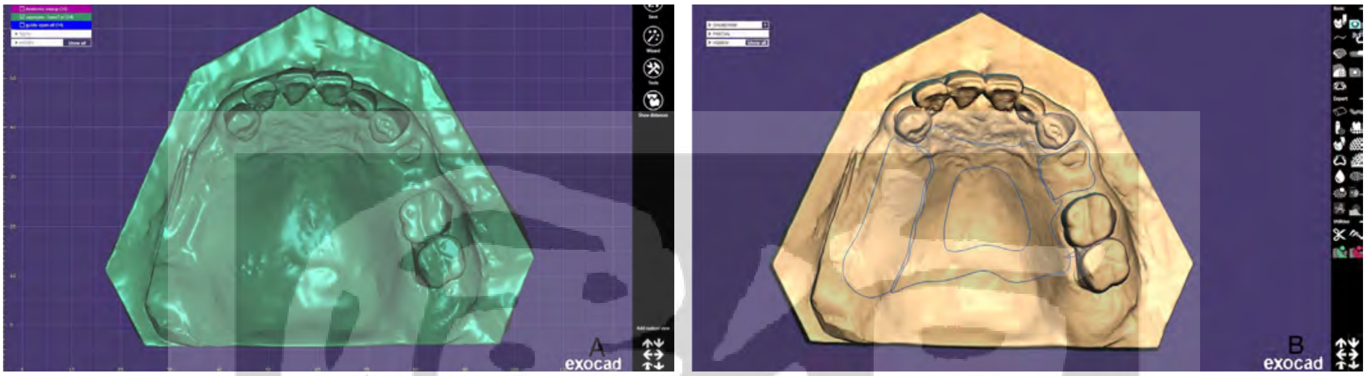

Figure 2. (A) The digital model was constructed using reference scanner and CAD software. (B) Initial survey and framework designs were shown in the software.

verification is a time-consuming process and the parallelism of guiding plane may exhibit divergence when multiple abutments are prepared freehandedly. Several tools are available for the intraoral transfer of a guiding plane, such as resin caps with a parallel pin,[4] rods on the modeling-plastic index,[5] thermoformed matrix,[6] silicone transfer index,[7] acrylic resin jigs,[8] and parallel intraoral device.[9] All techniques are used to fabricate devices for the intraoral transfer as the path of insertion from the surveying instrument.

Digitalized clinical dentistry by using advanced methods, such as CAD-CAM dental products,[10] digital scanners[11] and implant navigation system[12] are becoming popular in the recent dentistry. Moreover, digital assistance simplifies procedures, reduces operating time and increases accuracy. This study introduces a preparation guide manufactured using CAD-CAM for accurate intraoral transfer of the guiding plane; the guide is expected to improve the quality of RPD and shorten necessary clinical chair times.

Methods

A 73-year-old man presented to the Prosthodontic Clinic Department for restoring oral function by using RPD. Figure 1 A and 1 B shown the condition of this patient who had undergone dental extraction due to secondary caries and periodontitis. After full-mouth evaluation, results revealed mouth opening without clicking sound, deviation, and obstruction; an even occlusal plane; six occlusal pairs from canine to canine; and lack of tooth mobility and bleeding on probing. The patient had former lower Kennedy Class 2, modification 1 RPD fabricated 10 years ago; the denture was passively fitted on the surveying crown without displacement during insertion and removal.

Owing to financial constraints, the patient preferred to proceed conventional RPD without dental implant along with the option of installing an RPD without surveying crowns, which may compromise denture retention and stability. As the result, mouth preparation became the vital procedure for our RPD design and fabrication. The greatest challenge in this option was the precise intraoral transfer of the guiding plane. Therefore, a CAD-CAM preparation guide was designed for the transfer. The technique procedure is as following:

Sequence of design by clicking" Virtual Waxup Bottom→ Gingiva Design→ Gingival Parts→ Antagonist→ More Freely→ ADAPT Occlusal→ Cut Intersections-→ Free-Form Scan Data.

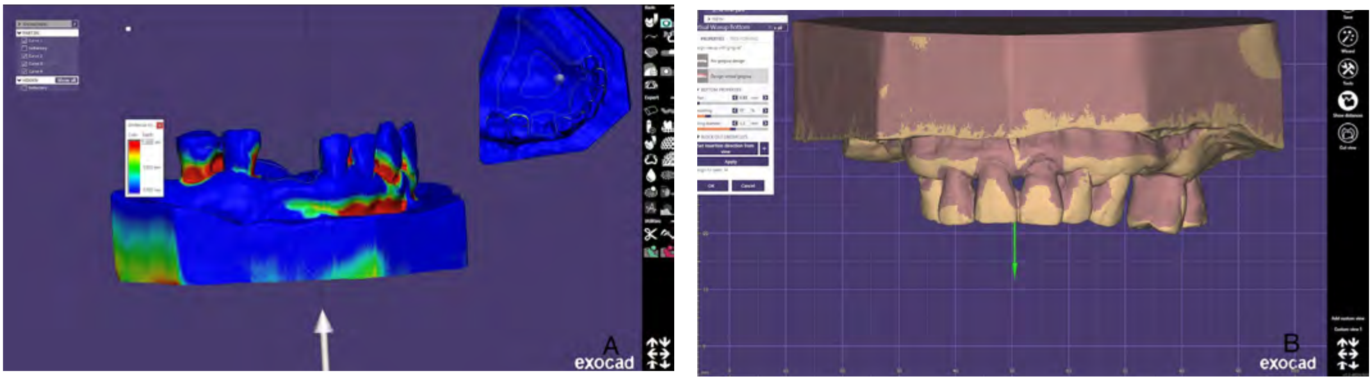

Figure 3. Software analysis for tooth angulation and correction of the final path of insertion.
(A) Undercut evaluation with different color scale.
(B) Calculate the tooth undercut and soft tissue undercut by software.

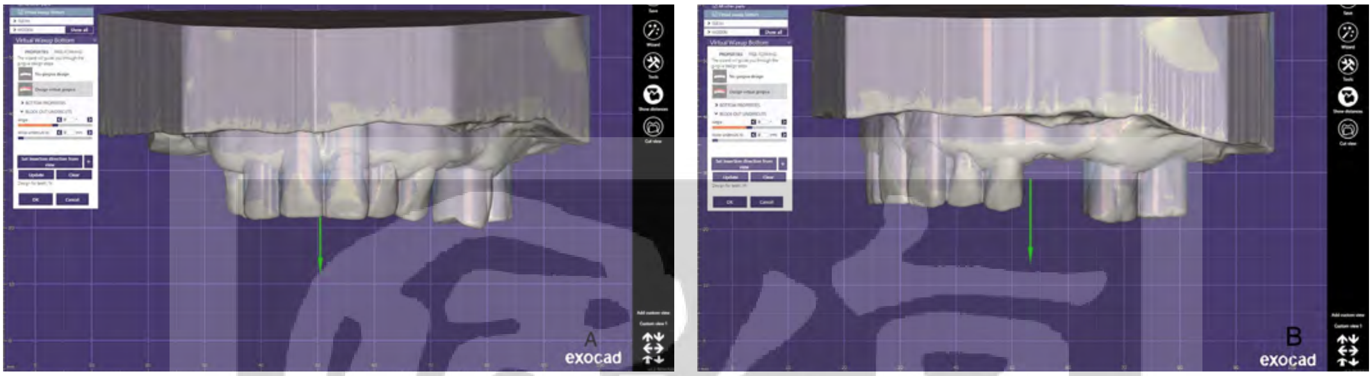

Figure 4. Virtue parallel blockout done by the CAD software. (A) Frontal view (B) Lateral view.

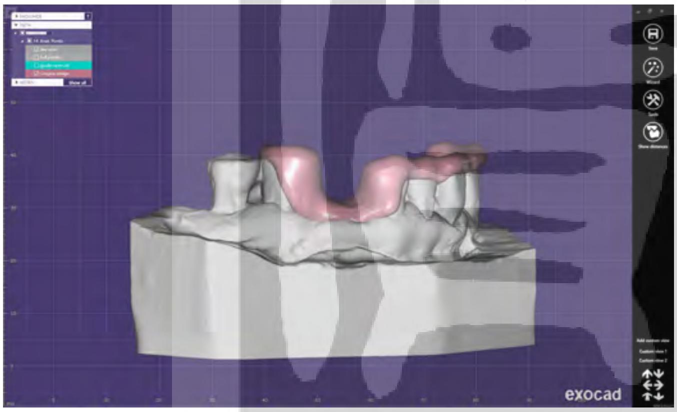

Figure 5. The outline of initial CAD-CAM preparation guiding stent was designed on the blocked-out model.

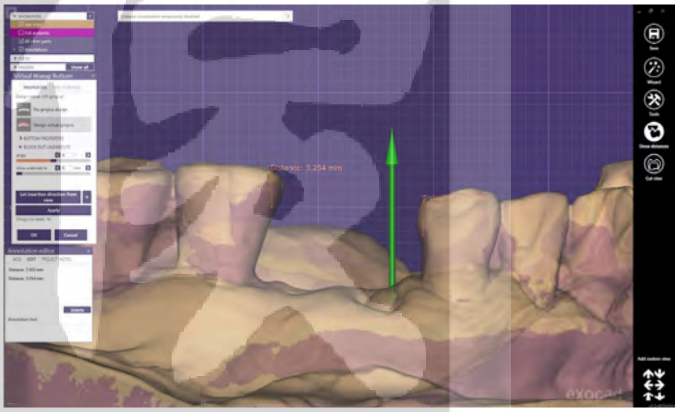

Figure 6. According the RPD design, the amount of preparation for ideal path insertion and preservation of tooth structure for each abutment was measured and calculated by CAD software.

1. Diagnostic casts were fabricated using ISO type III gypsum (Yoshino Gypsum Co., Ltd., Japan). The digital model was constructed by scanning the diagnostic cast with reference scanner (Smart Optics, Activity 880, Bochum, Germany) (Fig. 2A). We used CAD software (Exocad, Exocad GmbH, Darmstadt, Germany) for the following steps, including RPD framework design (Fig. 2B).
2. The model was digitally surveyed (Fig. 3A) via "Virtual Waxup Bottom" in software (Fig. 3B) to decide the ideal path of insertion.
3. Undercut areas were blocked out (Fig. 4A and 4B).
4. The outline of the stent was designed on the blocked-out model via "Gingiva Design" in software (Fig. 5).
5. Each abutment was measured for preparing the guiding plane according to the RPD design. The prepared guide plane, following Krol's concept,[22] was prepared on the abutment occlusal 1/3 with 3.5 mm width of buccal-lingual dimension and 2 mm height (Fig. 6).

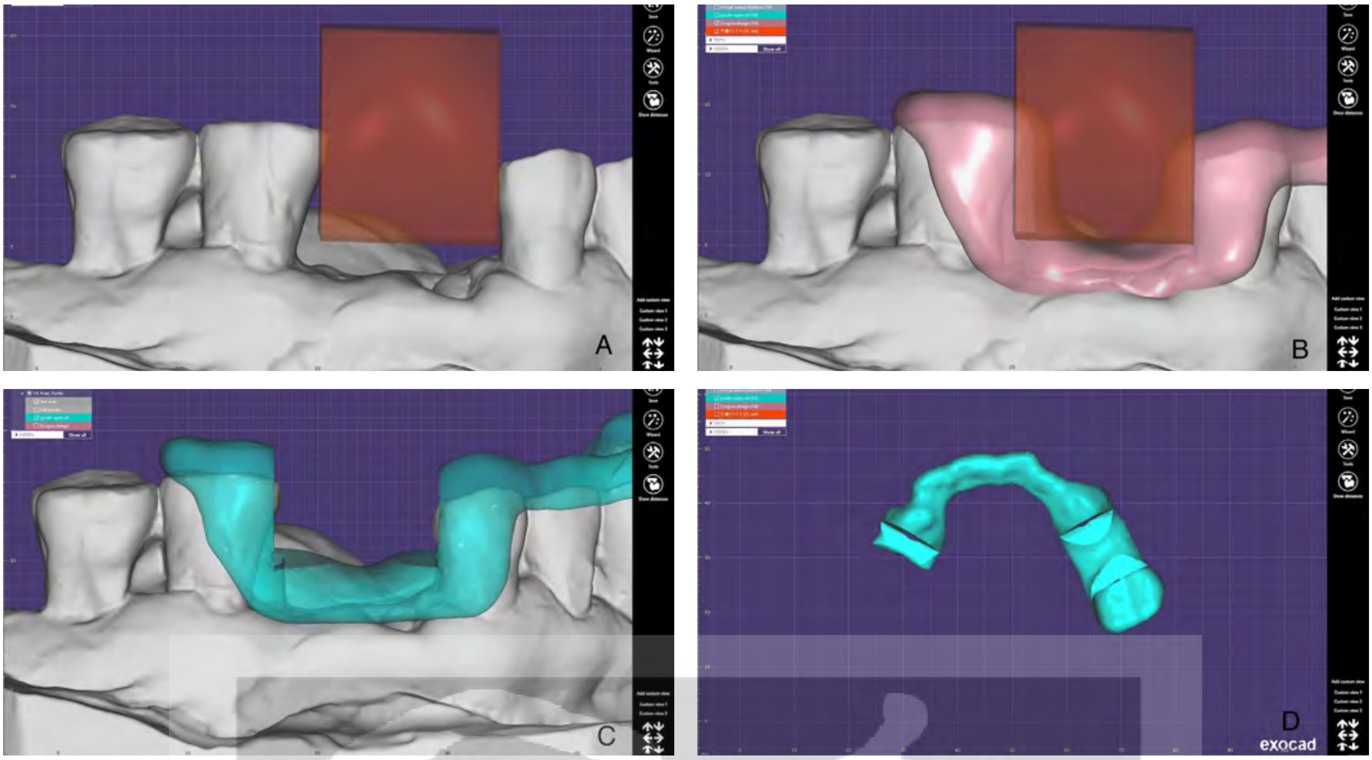

Figure 7. The open window design of preparation guide was achieved by using (A) cubic templet, (B) overlapping the stent, (C) exposing the teeth. (D) Export the design to CAM software and manufacture the guide stent.

Figure 8. (A) CAD–CAM preparation guide with three open windows for proximal plane preparation. (B) Intraoral guide template try-in and the preparation area. (C) Preparing the guiding plane with a diamond bur and finish bur.

Figure 9. (A) After using CAD-CAM guide stent, the parallel of abutment and path of insertion of RPD was checked again by CAD software. (B) (C) Final major connector, minor connector, rest, direct and indirect retainers was designed in this final model.

6. A cubic templet was used to define window area of the stent via click the procedure "Gingival Parts→ Antagonist→ More Freely→ ADAPT Occlusal→ Cut Intersections→ Free-Form Scan Data" (Fig. 7A~7D).
7. CAD-CAM preparation guide with three open windows for proximal plane preparation (Fig. 8A). Guiding template during intraoral try-in (Fig. 8B). Preparing the guiding plane with a diamond bur and finish bur (Fig. 8C).
8. The guiding plane was achieved and following our original design (Fig. 9A~9C).

Figure 10 After framework try in and wax denture try in, maxillary removable partial denture delivery.

The standard removable partial denture-fabrication process was followed, and the RPD with great retention and stability was fabricated (Fig. 10). The patient continues to routine follow ups at Prosthetic Clinic Department until now as no further deteriorative change in each abutment was required

Discussion

Krikos[5] reported that guiding planes created using the free-hand method with index are likely to exhibit divergence. As more teeth required to be shaped according to the path, the higher collective error may occur. In order to accurately transfer the orientation of guiding planes from the cast to abutment teeth, several devices and techniques such as verification devices,[8, 9, 13] matrices,[6] indexes,[5, 7] reciprocating dental handpieces,[14] intraoral surveyors[15, 16] and parallel devices,[9, 17] are being described. All methods were designed to enable clinicians to obtain precise final results. One of the advantages with this present method is the dental surveyor results outputted by CAD software which helps to verify pulp position by reviewing the integrated data of dental surveyor results and radiographic images.

The second advantage of the guiding plane is for the template to be milled using a polymethylmethacrylate disc with a standard diameter of 98 mm; it has a clear appearance and rigid. The disc is used in CAD–CAM systems for implanting surgical stents and occlusal devices extensively. Due to the rigidity of the material, the template could be placed on the neighboring tooth and edentulous ridge firmly. The reduction orientation and volume were precisely limited by window areas. Interproximal space was ultimately examined before milling and with the help of our guiding template, the preparation procedure was unaffected by the clinician's experience and required relatively less time.

The disadvantage of this method was the required traditional impression steps, stone pouring, and survey. Although excellent accuracy in single-unit scans has been demonstrated, the accuracy of a full-arch scan by using an intraoral scanner should be validated under clinical conditions.[18, 19, 20, 21] In the future, this technique can be combined with a digital intraoral scanning to simplify the procedure. Without the steps of impression and stone pouring, the deviation between the image and real conditions can be reduced. Guiding plane preparation can become an objectively replicable procedure.

Summary

In this technique report, CAD-CAM preparation guide enabled us to achieve parallel planes on the axial surface of RPD abutment teeth. The patient was satisfied with the high retention and stability of RPD and with no complain regarding food trapping.

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Introductions for authors

The Journal of Prosthodontics and Implantology is an official publication of the Academy of Prosthetic Dentistry, R.O.C., published quarterly in April, July, November and January. Articles related to clinical and basic prosthodontics, implantology, implant related periodontology, periodontology and surgery as well as biological and material sciences related to prosthodontics ad implantology are welcome. Articles may be categorized as original paper, case report, technical reports and literature review related to future research. Invited review articles are written by representative scholars on some important topics this journal wishes to emphasize.

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      (2) Online journal article: Yavuz MS, Aras MH, Büyükkurt MC, Tozoglu S. Impacted mandibular canines. J Contemp Dent Pract 2007; 8: 78-85. Available at: http://www.thejedp.com/issue036/index.htm. Accessed November 20, 2007.
   B. Book reference style:
      (1) Complete book: McDonald RE, Avery DR. Dentistry for child and adolescent. 5th ed, Mosby Co, St Louis, 1988; pp339-41.
      (2) Chapter in book: Moore BK, Avery DR. Dental materials. In: McDonald RE, Avery DR (ed). Dentistry for child and adolescent. 6th ed., Mosby Co., St. Louis, 1994; pp349-72.
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      (4) 討論 (discussion)：強調重要結果與論點，與前人論述作比較等。
      (5) 結論 (conclusion)：結論要簡要明確。
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