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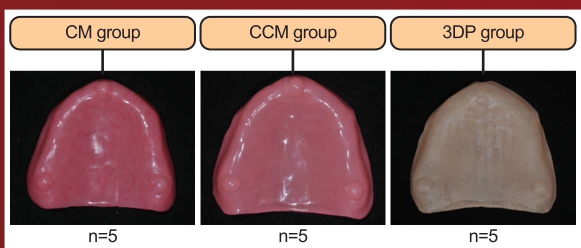

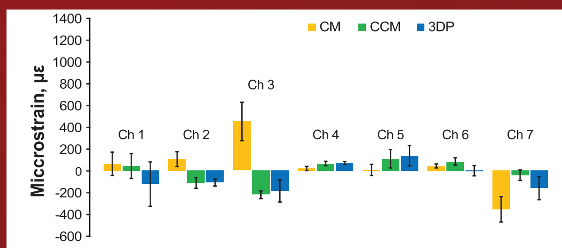

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Table of Contents

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

Comparison of peri-implant bone resorption around tilted and straight implants in edentulous maxilla with All-on-4 rehabilitation

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Abstract

Objective: *Implant supported fixed full-arch prostheses for the severe atrophy edentulous patients is often regarded as a challenge. "All-on-4" concept suggest placing two straight implants in the anterior region combined two tilting implants in the posterior area to overcome anatomical limitations. The purpose of this study was to compare the different peri-implant marginal bone loss between tilted and straight implants of all-on-4 implant-supported fixed prostheses for long-term follow-up.*

Material and Methods: *Patients enrolled in this retrospective study had receive all-on-4 rehabilitations in the Chang Gung Memorial Hospital during February 2016 to February 2020. The peri-implant bone level of tilting and straight implant apart in 0, 3, 12 months after surgery were measured from the panoramic images by using the ruler of a software program. To compensate the radiographic distortion, the marginal bone level measured from panoramic image was divided by the multi-unit abutment height, and used with the real multi-unit abutment height to calculated the corrected marginal bone level. Different peri-implant bone resorption between straight and tilting implants of 3 and 12 months were analyzed with Wilcoxon sign rank test. The initial peri-implant bone level estimated once the implant placement (0 month) was defined as comparison. The statistical significance was defined as $p< 0.05$.*

Results: *This study included 10 patients, 5 male and 5 female, the average age was 51.4 years (range from 36 to 68 years). Total of 40 implants in maxilla were placed, included 20 straight and 20 tilted implants. Wicoxon sign rank test showed Z score – .336 at 3 months follow-up and -.485 in the 12 months follow-up. P= .737 and P= .627 for the 3 months and 12 months respectively.*

Conclusions: *No significant difference was shown in the peri-implant bone resorption between straight and tilting implants of all-on-4 implant rehabilitation for both 3 months and 12 months follow-up time. All-on-4 implant-supported fixed prosthesis was considered as a reliable solution for severe atrophy edentulous ridge.*

Key words: All-on-4 rehabilitation, Peri-implant bone level, Tilting implant, Straight implant

Introduction

The edentulous condition or terminal unrestorable dentition shows poor chewing function and poor esthetics, as well negative impacts on oral health related quality of life. It can be derived from many factors such as extensive dental caries, severe periodontal disease, trauma or tumor. Immediate rehabilitation with implant supported fixed full-arch prostheses for the edentulous patients has been associated with a high level of satisfaction about esthetics, phonetics and functionality[1,2]. However, rehabilitation of severe atrophy maxilla with fixed prosthesis is often complicated due to anatomical limitations, such as maxillary sinus, poor quality and quantity of bone. Bone grafting or other augmentation procedures are used to increase the bone volume for implant placement, though complications occurs, such as increase surgical difficulties and prolong the treatment time. Malo´ P et al used the tilted implants as an alternative approach to treat atrophy edentulous patients and named it the "all-on-4" concept. As suggested, placing two straight implants in the anterior region and two implants, tilted 30 ° to 45 ° relative to the occlusal plane, in the posterior area[3,4,5,6]. Tilting the posterior implants preserves anatomical structures and reduces the need for bone augmentation, which results in reducing surgical invasion, shorter treatment time and lower costs. Tilting allows the placement of longer implants with good cortical anchorage in optimal positions for prosthetic support, it increases the contact area between the implant and the bone, thus enhances the implant primary stability[7]. Tilting the implants in the posterior regions can also reduce the length of cantilever. Previous study showed implants with distal cantilever longer than 15mm lead to higher risk of failure[8]. Tilting increases the distance between anterior and posterior implants, the implant support is more distal, thus the cantilever length was reduced or even eliminated. It provides the better stress distribution and the proper anterior-to-posterior spread of the implants.

In vitro studies showed that unfavorable loading direction may accentuate stresses around implant neck which non axially were placed, as it could cause more marginal bone loss around the implants[9,10]. In all-on-4 concept treatment, the tilted implants and the straight implants are splinted, we supposed that may re-distribute the occlusal forces. The purpose of this study was to compare the different peri-implant marginal bone loss around tilted and straight implants of all-on-4 implant-supported fixed prostheses for long term follow-up.

Materials and methods

Those patients receive all-on-4 rehabilitations in the Chang Gung Memorial Hospital from February 2016 to February 2020 were enrolled in this study. Participants are those who had edentulous or remaining hopeless teeth which planned for extraction, mainly moderate or severe atrophy of the maxillary that bone augmentation was necessary for placing implants in the posterior region. They all received preoperative clinical and radiographic evaluation, panoramic and cone-beam computerized tomography. These subjects were restricted to have good health, no neuromuscular disorder, head and neck cancer history, and nor temporomandibular joint disorders. All participants had proceed all-on-4 implant rehabilitation as inform consent undersigned.

Surgical procedure placed 2 straight implants in the premaxilla area and 2 tilted implants (30 to 45 degree) in the posterior region. The multi-unit abutments were connected to implants during surgical procedure, and an all-acrylic resin with all-on-4 design fixed provisional prostheses were delivered for early loading within 2 weeks after surgery. Surgeon recorded all the implant fixture size and the multi-unit abutment size in the patients. Definitive prosthesis was delivered 6-8 months later until soft and hard tissue heals completely. The prosthesis was designed as hybrid denture and fabricated with the CAD/CAM IBO titanium framework combined with acrylic resin teeth, each denture contained 12 resin teeth from incisor to first molar every quarter.

All participants were closely followed-up every week within the first 2 months, as well each month during 3-12 months period. Panoramic radiograph was taken on the day of surgery as baseline and every month after surgery for regular evaluation. The peri-implant bone level of tilting and straight implant measured in 0, 3, 12 months after surgery were recorded.

The marginal bone level and multi-unit abutment height were measured from the panoramic images by using the ruler of a software program (Dental PACS, version 2.3; GE Healthcare Inc). The marginal bone level was calculated from the first bone to implant contact interface to the tip of the multi-unit abutment. (Fig.1) To compensate

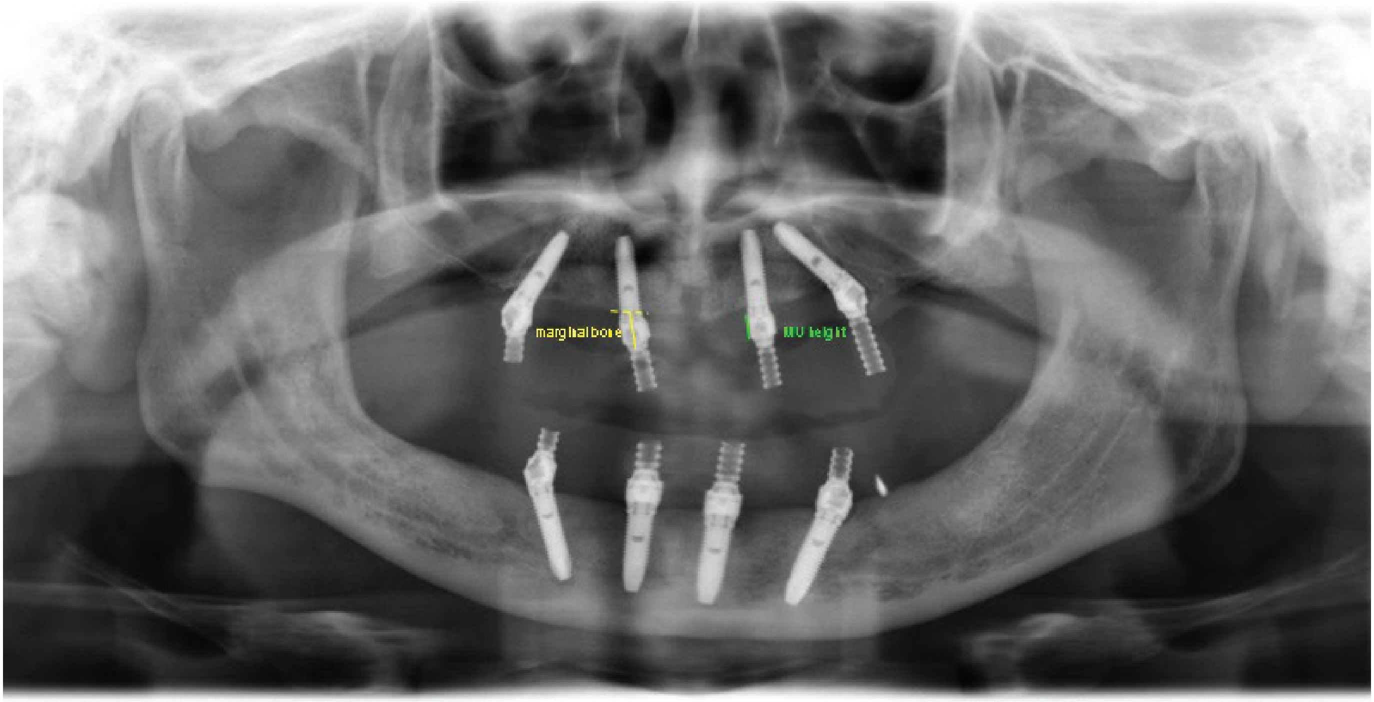

Figure 1. The marginal bone level and MU height were measured from the panoramic image. To compensate for the image distortion of the panoramic radiograph, the marginal bone level was divided by the MU abutment height as a ratio, and the ratio was used with the real MU abutment height to calculated the real marginal bone level. (MU: multi-unit abutment)

for the image distortion of the panoramic radiograph, the marginal bone level was divided by the multi-unit abutment height as a ratio, and the ratio was used along with the real multi-unit abutment height to calculated the real marginal bone level. The altered marginal bone level from 0 to 3 months and 0 to 12 months were defined as peri-implant bone loss. The marginal bone level measured before prosthodontic rehabilitation (0 month) were regarded as comparison.

Different peri-implant bone resorption between straight and tilting implants in every follow-up period as 3 and 12 months were analyzed with Wilcoxon sign rank test. The statistical significance was defined as $p< 0.05$. A statistical software program (IBM SPSS Statistics version 20) was used for the analysis.

Results

10 patients were selected for this study, 5 male and 5 female, the average age at surgery was 51.4 years (range from 36 to 68 years). Total of 40 implants in maxilla were placed, included 20 straight and 20 tilted implants. At the 3-month follow-up, the mean marginal bone loss of the straight implants was 1.40 ± 2.21 mm (maximum = 8.49 mm and minimum = -2.09 mm), compared with 1.04 ± 0.98 mm for the tilted implants (maximum = 2.67 mm and minimum = -1.62 mm). At the 12-month evaluation, average was 0.97 ±2.63 mm (maximum = 8.26 mm and minimum = -3.74 mm)for straight implants and 1.24 ± 2.45 mm (maximum = 4,58 mm and minimum = -3.41 mm) for tilted implants (Table 1).

As the analyses of Wicoxon sign rank test shown in Table 2, Z score was - .336 at 3 months follow-up and - .485 at 12 months follow-up. P= .737 and P= .627 at 3 months and 12 months respectively. No significant difference in marginal bone loss between straight and tilted implants was detected.

Table 1. The peri-implant bone level of straight and tilting implants estimated in 3month and 12 month after implant surgery compared to 0 month.

Implant an-gulation	Time	Mean	Max	Min	SD
Straight	3 months	1.40	8.49	-2.09	2.21
	12 months	0.97	8.26	-3.74	2.63
Tilting	3 months	1.04	2.67	-1.62	0.98
	12 months	1.24	4.58	-3.41	2.45

Table 2. Wilcoxon sign rank test(P<0.05). [a]tilting<straight, [b]tilting>straight, [c]tilting=straight

	n	Mean rank	Sum of ranks	Z score	P
3 month Straight-tilting					
Negative ranks	10a	11.40	114.0	-.336b	.737
Positive ranks	10b	9.60	96.00		
Ties	0c				
Total	20				
12 month Straight-tilting					
Negative ranks	9a	10.22	92.00	-.485b	.627
Positive ranks	11b	10.73	118.00		
Ties	0c				
Total	20				

Discussion

This study demonstrates no significant differences in peri-implant bone resorption between straight and tilted implants of all-on-4 implant rehabilitation for a long term follow-up. The result was coincidental to the previous studies that all-on-4 concept can be regarded as a feasible treatment for severe atrophy edentulous ridge[11,12].

Previous studies indicated high survival rates for tilted implants[13]. It can be used to reduce cantilever length and give better load distribution on the prosthesis. Past investigation revealed the load concentrate around cervical region of the single tilting implant[14]. During chewing function, the vertical loading is supposed to cause more bone destruction around the tilted implant, the stress concentrated in the marginal area of bone might increase the bone resorption[15]. However, when implants are used in a full-arch fixed prosthesis, the tilted implants and the straight implants are splinted to each other and behavior as a functional unit, not as isolated elements, it might limit implant micro-motion and change the distribution of the loading forces, which may results in reduce stress on the peri-implant bone[16,17]. This is the preliminary study to investigate the different bone resorption of tilting and straight implants in Taiwan, and results were coincidental to multiple previous researches which shows no significant difference of the bone resorption between straight and titling implants[17,18,19]. Hence, the all-on-4 implant rehabilitation is a reliable treatment modality for those who has severe bone defect. Some previous study suggested the definitive prostheses delivered after 3 months of healing time for all-on-4 treatment protocol[20,21], thus many studies follow up the implants up to 12 months as long-term survey. Therefore, this study analyzed the peri-implant bone resorption on 3 months and 12 months after implant placement.

Although the main bone resorption regularly occurs in the first year after implant surgery, long-term follow-up may effectively represent functional loading. Besides, the different angulation degree of the tilted implant and distal cantilever length may influence the marginal bone loss in those who receives all-on-4 treatment. The angulation of distal implants is usually tilted 30 ° to 45 ° and the cantilever length was limited within 15mm, but these up-limitation variables had never been measured in the present study, such interesting issue is worthy of further discuss.

All radiographic methods have been utilized the marginal bone estimation. Although bitewing examination is the first choice of image modality to assess the marginal bone level at premolar region due to excellent reliability, it appeared to be none suitable for estimating the tilting implant of all-on-4 implant system. The past investigation indicated the inter-observer agreement in marginal bone assessment from intraoral and panoramic radiographs and found the same agreement rate methods[22]. The previous study compared the intraoral and panoramic radiography to evaluate the peri-implant marginal bone level and considered the panoramic radiographs were as reliable as the intraoral radiographs, though the calculation methods should be carefully selected[23]. As for the possible existence of panoramic radiograph, a rough estimation of marginal bone level at premolar region is clinically acceptable bearing in mind that bone height of the mandible premolar region might be overestimated as compared to bitewing radiograph[24]. Based on previous study proposed that variables measured from the panoramic radiographs may have been affected by distortion[25], this study utilized the calculation of the MU height to compensate the radiographic distortion for realism increased.

By placing longer implant, posterior tilted implants enlarges the contact area between bone and implants, it could enhance osteointegration and provide better loading distribution. And we supposed the occlusal loading could re-distribute by means of splinting the straight and tilted implants. All maybe the reasons that the peri-implant bone resorption around tilted implants were deceased. Future analysis maybe proceed on the relationship between the length of tilted implant fixture and bone resorption.

Conclusion

All-on-4 implant-supported fixed prosthesis was regarded as a reliable solution for severe atrophy edentulous ridge. No significant difference was observed between straight and tilted implants in peri-implant marginal bone loss.

Acknowledgment

This study was supported by Chang Gung Memorial Hospital, Linkou (CMRPG3L0051).

Conflicts of interest

None.

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Original Article

In vitro evaluation of strain distribution on maxillary denture bases fabricated using compression molding, milling, and printing techniques

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Abstract

Purpose: *This in vitro study aimed to evaluate the strain distribution under static loading conditions on maxillary denture bases fabricated using computer-aided design and computer-aided manufactured CAD-CAM milling (CCM), 3-dimensional (3D)-printing (3DP), and conventional heat-polymerized resin compression molding (CM) methods.*

Materials and methods: *A maxillary edentulous reference model was scanned, and 2-mm-thick denture bases were designed and fabricated using 3 fabrication techniques: CCM, 3DP, and CM. A 45 N load was applied perpendicularly to each denture base, and the experiments were repeated 3 times for each denture base. A total of 7 strain gauges were attached to each denture base, including at the labial and buccal notches, the anterior palatal sites at the midline, the posterior palatal seal, and the ridge crest of tuberosity. Mean strain values (MSVs) recorded from the denture bases were compared. Statistical analyses were performed using the Mann–Whitney U test, Kruskal–Wallis test, and Wilcoxon signed-rank test. P< 0.05 was considered significant.*

Results: *Significantly higher MSVs were observed at the posterior palatal seal, ridge crest of tuberosity, and labial notches for all 3 types of fabricated dentures, especially for the CM technique. The lowest MSVs were recorded for the CCM group from the measurement sites, and the mechanical performance of the CCM and 3DP groups were similar under loading conditions. Additionally, divergent MSVs were observed for the 3DP measurement sites.*

Conclusion: *Within the limitations of the present study, CCM dentures exhibited lower MSVs under loading conditions than 3DP and CM dentures. CCM and 3DP dentures have similar mechanical performaces different from the pattern of CM dentures.*

Key words: Compression molding, CAD-CAM milling, 3D printing, maxillary denture, strain distribution.

Introduction

Although better support and retention can be achieved by using implant-retained overdentures[1], maxillary complete dentures continue to provide esthetic, phonetic, and chewing functions for edentulous patients who are not willing to undergo additional surgical processes[2]. Conventionally, polymethyl methacrylate (PMMA)-based dentures, fabricated using the compression molding (CM) technique, have been the most widely used denture type[3], due to good biocompatibility, easy processing, stability in the oral environment, acceptable aesthetics, and economic characteristics[4]. However, low-mechanical-strength resin bases are vulnerable to deformation during mastication and can crack or fracture when subjected to strong external stress[5]. A higher incidence of damage has been reported for maxillary dentures, according to clinical surveys [5,6]. Additionally, resin polymerization shrinkage can result in linear deformation of 0.4%–0.9% during processing. Denture deformation during processing affects prosthetic occlusion and dimensional accuracy, and denture distortion can increase the vertical dimension of an occlusion, which results in the increased necessity for laboratory and clinical adjustments[7,8].

Computer-aided design and computer-aided manufacturing (CAD-CAM) technology was first used to fabricate complete dentures in the 1990s,[9] and can currently be used in both subtractive (computerized numerical controlled milling) or additive (rapid prototyping) processes[10]. The CAD-CAM milling (CCM) technique produces dentures by machining a pre-polymerized PMMA block, which possesses the advantages of superior strength, fewer residual monomers, and less porosity than PMMA dentures formed using the CM technique[11-14]. The 3-dimensional (3D) printing (3DP) technique (rapid prototyping) has been rapidly developed during the past decade and has the advantages of less material waste and the ability to include intricate internal geometrical details[15]. However, light polymerization printed resin has lower surface hardness and higher flexural strength than conventional acrylic resin[16]. Information remains lacking in the mechanical properties of denture materials, including the strain distribution of denture bases fabricated using CM, CCM, and 3DP techniques under uniform testing conditions.

The purpose of this *in vitro* study was to compare the strain distribution of maxillary denture bases fabricated using CCM, 3DP, and CM techniques under a static load. The null hypothesis was that no differences in strain distribution would be observed among the different fabrication techniques.

Materials and methods

An edentulous maxillary cobalt-chromium alloy reference model fabricated in our previous study[17] was scanned (E3 3D scanner; 3Shape), and the scanning data were outputted as standard tessellation language (STL) files. Then, a PMMA maxillary edentulous test model (Hygienic resin, Coltene Whaledent) was duplicated from the reference model, with a 2-mm thickness artificial mucosa, using impression material (monopren, Kettenbach)[18].

Next, 2-mm-thickness denture bases were designed with a CAD software (3Shape Dental Designer; 3Shape) using the STL file from the reference model, and the denture bases were fabricated using CCM, 3DP, and CM techniques. Fifteen sets of denture bases were fabricated consisting five sets in each group (Fig. 1). In the CCM group, the denture bases were milled from Yamahachi PMMA blocks (Yamahachi Dental Mfg), using a 5-axis milling machine (CORiTEC

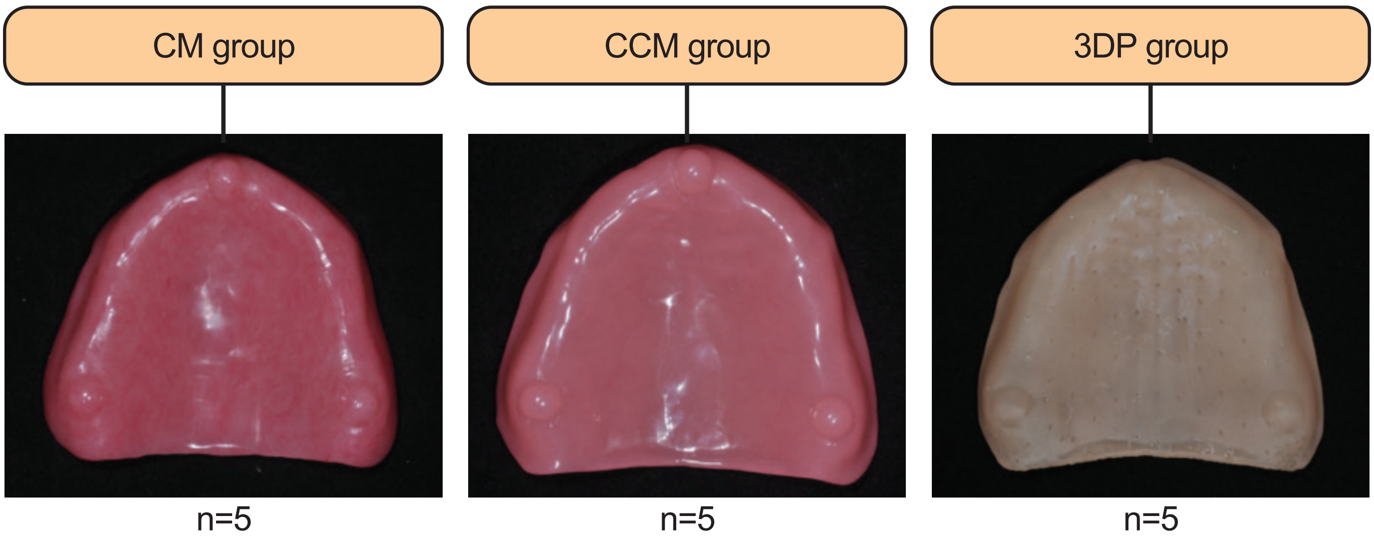

Figure 1. Denture bases fabricated using different techniques. CCM, CAD-CAM milling; 3DP, 3D printing; CM, compression molding.

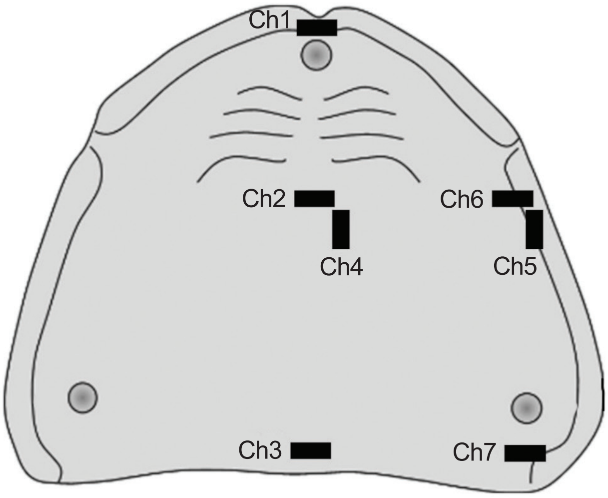

Figure 2. Positions of the strain gauges on the denture base, including Ch 1: labial notch; Ch 2: transvers anterior middle base plate; Ch 3: posterior palatal seal; Ch 4: axial anterior middle base plate; Ch 5: left buccal notch; Ch 6: left anterior ridge crest; and Ch 7: left ridge crest of tuberosity.

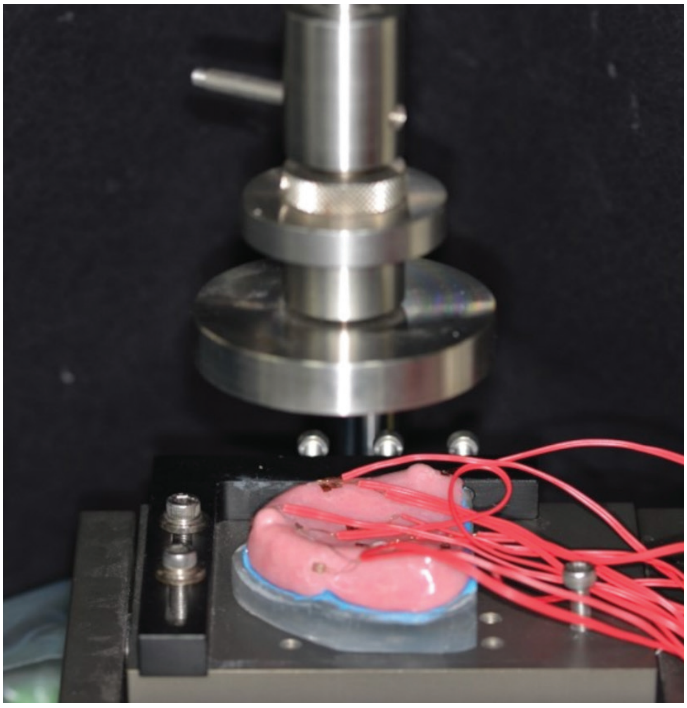

Figure 3. 45 N vertical loading on the denture base.

250i; imes-icore GmbH; Fig. 1). In the 3DP group, denture bases were printed from NextDent Base printable resin (NextDent BV), using a digital light processing (DLP) based printer (NextDent 5100 DLP printer, NextDent). In the CM group, according to pre-scanning data of reference model, the 2-mm thickness spacer for denture base was designed with a CAD doftware (Meshmixer, Autodesk Inc) and printed with printable resin (MiiCraft BV-005, Yong Optics Inc) by using the DLP printer (NextDent 5100). Then the spacer was placed on the reference model for packing procedure. The denture bases were fabricated using heat-polymerized PMMA resin (Luciton 199; Dentsply Sirona).

Seven miniature strain gauges (KFGS-2-120-C1, KFGS-2-120-D16, Kyowa Co) were attached to the polished surface of each denture base using specific cement (CC-33A, Kyowa) to measure the strain under loading, including at the labial notch (Ch 1); transvers anterior middle base plate (Ch 2); posterior palatal seal (Ch 3); axial anterior middle base plate (Ch 4); left buccal notch (Ch 5); left anterior ridge crest (Ch 6); and the ridge crest of left tuberosity (Ch 7) (Fig. 2). Each denture base was placed on the test maxillary model and mounted on a universal testing machine (TD-221; JobHo Technology). A 49-N axial load19 was applied perpendicularly to each denture base three times (Fig. 3). The outputs from the strain gauges were transferred to an analog/digital converter through an amplifier (PCD-300A, Kyowa Co). The mean strain values (MSVs) from strain gauge of each group were collected for comparison.

To determine differences between groups, the Kruskal–Wallis test, followed by Dunn's post hoc test (α =.05), was used to compare the MSVs between the CCM, 3DP, and CM groups. All data were analyzed using statistical software (IBM SPSS Statistics, v21.0; IBM Corp).

Results

Figure 4 shows the MSVs recorded at the various measurement sites for each denture base in the study; the positive and negative values represent tensile and compressive strains under loading, respectively. In general, the largest MSVs were recorded at the posterior palatal seal sites (Ch 3), followed by the anterior middle base plate (Ch 2) and the labial notch (Ch 1), along the middle line from posterior to anterior sites, in all 3 groups. The CCM group demonstrated the lowest tensile MSVs, whereas the CM group showed the largest compressive values at the posterior palatal seal. Additionally, larger MSVs were exhibited at the ridge crest of tuberosity (Ch 7), especially for the CM group. The mechanical performance in terms of tensile or compressive strain was similar between the CCM and 3DP groups but differed from that observed for the CM group. Moreover, the 3DP group showed larger variations in the results obtained from the measurement sites under loading in the study.

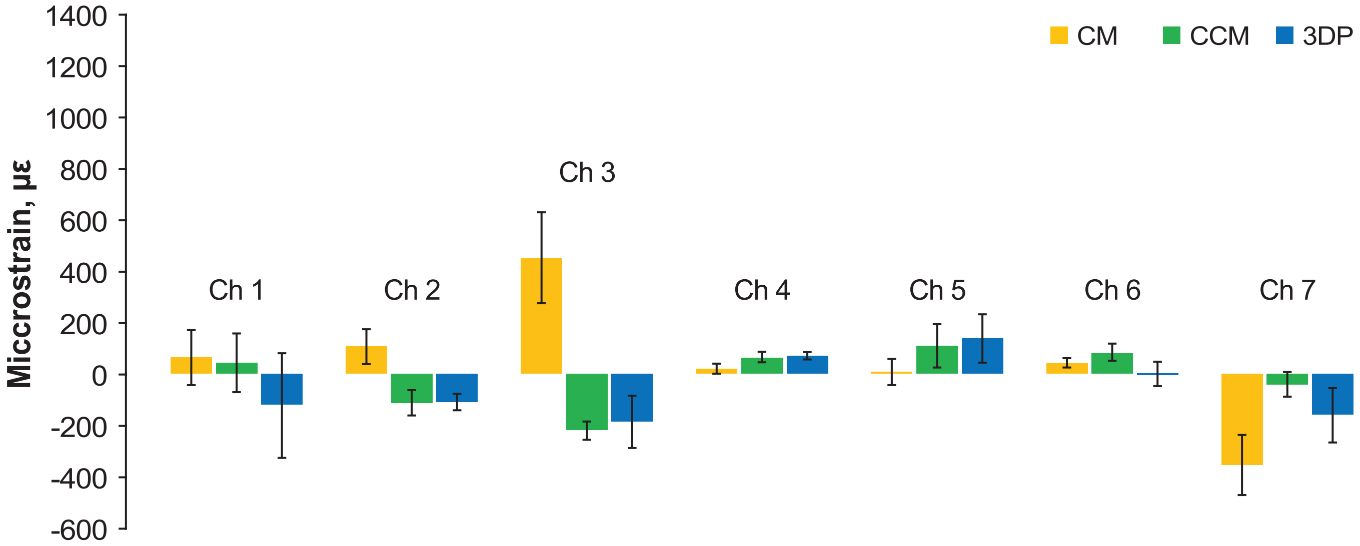

Figure 4. Strain distributions (με) in the CCM, 3DP, and CM groups. Data are expressed as the mean strain value (MSV) and standard deviation. CCM, CAD-CAM milling; 3DP, 3D printing; CM, compression molding.

Discussion

According to the results of the present study, the strain distribution on denture bases varies depending on the fabrication technique used. Therefore, the null hypothesis was rejected. Heat-polymerized PMMA resin CM techniques have long been used to generate denture bases due to acceptable aesthetics, ease of construction, and stable biocompatibility[2,3]. However, deformations during processing, lower mechanical strength, and poor fracture resistance can influence the treatment outcome[16,20]. According to a 3-year clinical survey, Tomita et al[5]. indicated that 70% of the patients experience denture fracture, especially at the midline of the maxillary denture. Several methods have been developed to improve the mechanical properties of dentures, such as the addition of a metal or fiberglass mesh framework to the denture base materials, which can improve the resistance to fractures [6,20]. With advances in CAD-CAM technology, prostheses fabricated by milling from pre-polymerization PMMA resin blocks have been reported to demonstrate increased fracture resistance and tensile strength[11-14]. Additionally, Hsu et al[17]. indicated that dentures fabricated using the CCM technique had higher adaption than those fabricated using other techniques, based on an *in vitro* evaluation.

In the present study, larger MSVs were measured at the posterior palatal seal, buccal notch, and ridge crest of tuberosity regions under loading conditions for denture bases fabricated using 3 different techniques. Significantly lower MSVs were recorded from CCM fabricated dentures, whereas the highest values were observed in those fabricated using the CM technique. Based on these findings, the pre-polymerized denture base material fabricated using the CCM process has higher mechanical strength than dentures fabricated using other techniques, similar to the findings reported by previous studies[11-14,17]. Similar mechanical performances in terms of tensile and compressive strain were observed for CCM and 3DP dentures, which differed from the pattern observed for CM dentures in the study. In addition, more divergent measurements were obtained in the 3DP group under loading conditions. Various factors can affect the outcomes of 3DP technology, such as the material properties of the printable resin, printing method, number of layers used, build angle, and postprocessing procedures[21]. Therefore, additional studies remain necessary to evaluate the impacts of these factors on the 3DP process.

To simplify the clinical conditions, 2-mm-thick, homogeneous denture bases were used in the present study, and a limited number of areas were measured using strain gauges, which allowed for the strain measurements at selected sites and the assessment of dimensional changes when loading forces were applied to the denture base. These may present limitations in the study. Additional studies remain necessary to evaluate the full stress/strain distribution across the complete denture area under clinical conditions, such as dentures containing teeth, containing supportive frameworks, or the use of different materials for CCM fabrication.

Conclusions

Within the limitations of this in vitro study, the following conclusions were drawn:

1. When a maxillary denture is placed under loading conditions, larger strain values were measured at the posterior palatal seal, labial notch, and ridge crest of tuberosity. The dentures fabricated using the CCM technique had the lowest MSVs under loading conditions compared with dentures fabricated using 3DP and CM processes.
2. Similar mechanical performances in terms of tensile and compressive strains were present for CCM and 3DP denrures under loading conditions, which differed from the pattern shown in CM dentures.

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Case Report

A modified matrix impression technique

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Abstract

Clinicians have been looking for an ideal impression technique for decades, which demands to be painless, fast, and predictable. The matrix impression system, published in 1998, is a painless and predictable impression technique. However, the limitation of this impression technique is clinical time-consuming. Also, there is a potential problem with the delamination between impression materials. Therefore, PVS adhesive, which might negatively affect the impression outcome, is still in need.

This article introduces a modification based on the matrix impression system, including the clinical procedures, material selection, and rationale. The new technique attempts to preserve the advantages of the original technique, reduce the chair-side time, and avoid material delamination.

Key words: **cordless, gingiva retraction, matrix impression, Polyvinyl Siloxane, painless**

Introduction

TMaking an impression is a crucial procedure during the fabrication of dental prostheses. An ideal impression should be quick, painless, atraumatic, accurate, and with a highly predictable success rate[1].

However, even though there are many different impression techniques and impression materials available, people are still looking for better clinical performance in the impression procedure.

The most challenging task during impression for fixed prostheses is dealing with subgingival margins[2] along with multiple abutment teeth[3].

Retracting gingiva with retraction cords is the fundamental technique. However, this technique is time-consuming and also uncomfortable for the patients.

Another difficulty of the retraction cord technique for multiple teeth impression would be the material working time being insufficient to make an adequate impression[3].

Many impression techniques do not require a retraction cord, for example, Copper band[4,5], Matrix system[6,7], Retraction Paste[1], Magicfoam cord[1], and Centrix GingiTrac[1]. Amount these techniques, Copper band, Matrix system, and Magicfoam cord can maintain the retraction results without gingival collapse due to the retraction item itself being included in the impression material.

Matrix impression system, proposed by Livaditis in 1998[6,7], is a painless and highly predictable technique. This technique only requires occlusal registration material and impression material, which are both available in every clinic.

This technique uses the semirigid occlusal registration material for the first impression and then trim the first impression into the proper shape to serve as the matrix. The matrix functions as a small custom tray, fitting onto the prepared tooth margins. Then make the second impression with this matrix, high viscosity impression material, and a pick-up impression with stock tray and medium body impression material.

The advantages of this impression technique are[1,6,7]:

1. An atraumatic and painless technique
2. Delivers impression material in the gingival sulcus accurately
3. Holds the sulcus open during the impression procedure.

The limitations of this impression technique are[1,6,7]:

1. Increased chairside time.
2. Impression material delamination
3. The PVS adhesive might affect the quality of the impression on the margin areas.
4. Higher risk to fracture the die.

This article describes a modification of the original technique to make it more straightforward and timesaving. According to the author's clinical experience, this modified technique performed well clinically. Our pilot study reveals the amount of gingival displacement achieved by this technique is about 300 μm on average, affected by the location of the margin and the gingival biotype, also the chosen materials. Further study outcomes will be polished in the following articles.

Technique

1. Site preparation (Fig 1a)

After tooth preparation, place a lip retractor to hold the lip, clean the tooth surface, and dry it. It is unnecessary to over-dry the teeth.

2. Matrix forming (Fig 1b, 1c, 1d)

Load the bite registration material onto the impression, adapt the mixing tip and impression tip. Cut off 1 to 2mm of the impression tip to facilitate the injection. Discard some of the first-mixing material to ensure all the material is well-mixed. Position the impression tip into the margin and sulcus area, apply the bite registration material just as applying impression material. Ensure the material covers all the margin areas. Then apply the material to cover all the abutment teeth. There is no need to apply too much material onto the abutment teeth; except the margin area, it is acceptable to left it not fully covered.

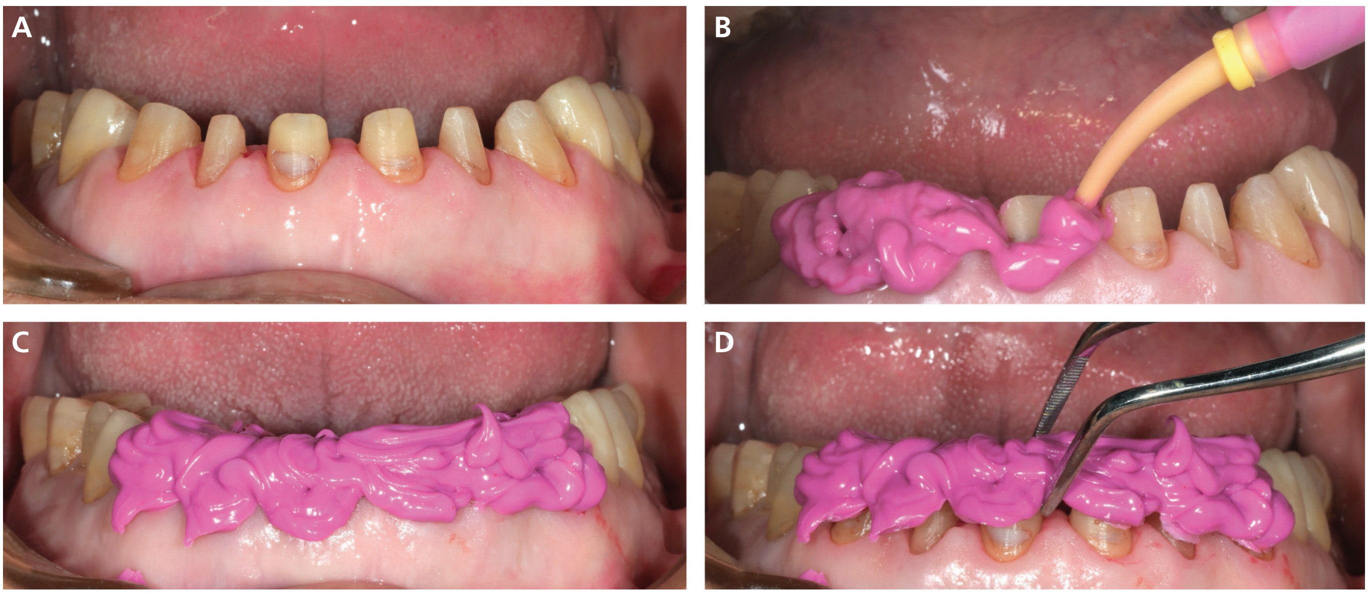

Figure 1. (a) Tooth surface after final preparation. Clean the tooth surface and ready for impression. (b)(c) Cut off 1 to 2mm of the impression tip to apply bite registration material to fill the margin area and cover the teeth. (d) Wait until the bite registration material setting, remove it carefully.

3, Matrix trimming (Fig 1d, Fig 2)

Wait until the bite registration material setting, remove it carefully. Start to trim the matrix in the dust collector. Diamond burs are the most suitable solution for trimming the hard bite registration material properly.

There are three important features of trimming.

1. The margin area: Trim off any material outside the gingival crest
2. Internal relief: Make space for further impression material, but left the most coronal portion as the stop, and left the margin area for support.
3. Perforation: This provides mechanical retention for the new impression material.

4. Try-in and cleaning the matrix (Fig 3)

Wash the matrix thoroughly. Try-in the matrix and confirm this matrix can fit appropriately on the prepared teeth. The margin area of the matrix should be intact, and any defect can be easily relined with new bite registration material. After relining, redo the trimming in the relining area.

5, Loading impression material (Fig 5a, 5b, 5c)

Dry the matrix and the prepared teeth thoroughly, apply light body or medium body impression material onto teeth, and inside the matrix. Place the matrix onto the abutment teeth and ensure the matrix seating properly.

6. Pick-up impression (Fig 5d, Fig 6)

Use a stock tray containing medium or heavy body, perform a pick-up impression over the matrix impression system. Wait until the material becomes fully setting. Remove the impression tray carefully, check the integrity of the margin and the whole impression.

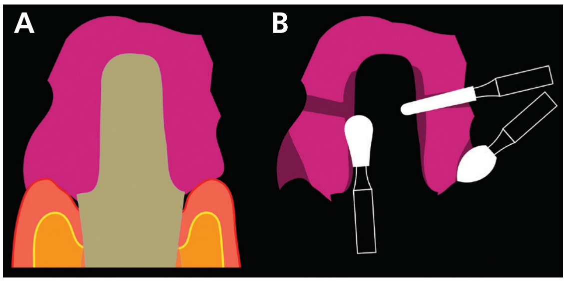

Figure 2. (a) The figure shows how dose the bite registration material adapts on the tooth and fills the gingival margin.
(b) There are three critical features while trimming the matrix.

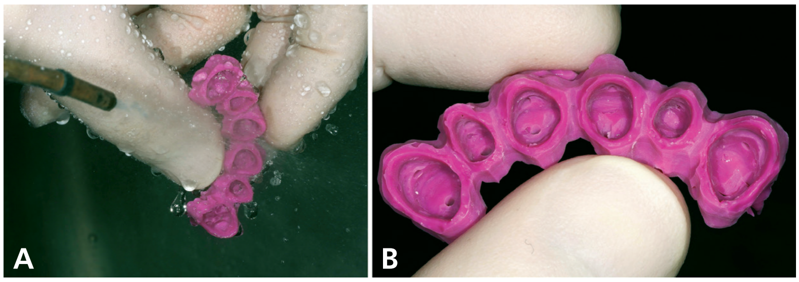

Figure 3. (a) After trimming the matrix, use the air-water spray to clean the dust off.
(b) This figure shows the appearance of the finished matrix.

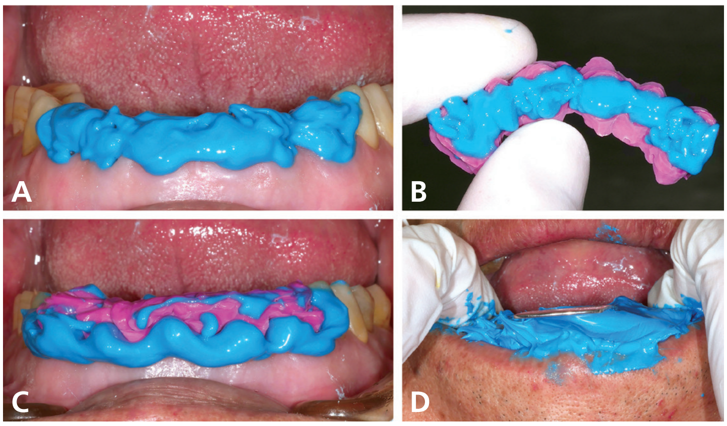

Figure 4. (a)(b) Apply light body or medium body impression material onto teeth and inside the matrix.
(c) Place the matrix onto the abutment teeth.
(d) Pick-up impression with stock tray and medium body PVS.

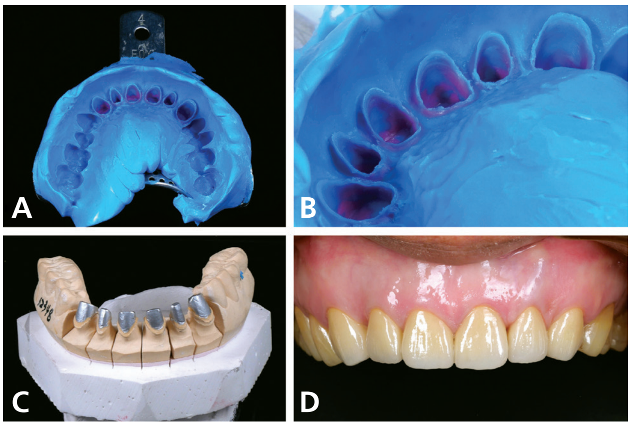

Figure 5. (a)(b) The final impression result and close-up view.
(c) The working cast and die.
(d) The final result of the anterior six crowns.

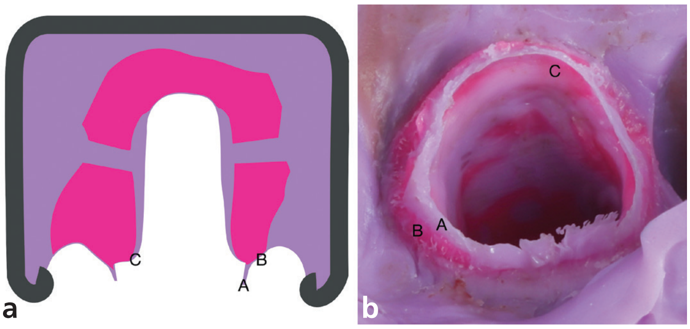

Figure 6. (a) Side-by-side comparison of drawing. (b) and actual impression image.

A. The PVS impression material "fin," which records the subgingival morphology.
B. The outer marginal surface of the matrix.
C. The inner marginal surface of the matrix.

There is a thin layer of PVS light body coating on B and C surfaces. This thin PVS layer is smooth in the C area representing the prepared tooth surface. The PVS layer in the B area represents the surface of intrasulcular epithelium.

Figure 7. The modified matrix impression technique can be used in combination with different impression techniques.

(a) Combine with triple tray impression; the matrix should be made without occlusal interference.
(b) Combine with RPD soft tissue impression; a custom tray with border modeling been used together with the matrix.
(c) Combine with the open tray implant impression; the matrix should be made without interfering the impression coping.

Discussion

Material selection:

This modified matrix impression chooses PVS rigid bite registration material to form the matrix; the hardness is about 90 Shore A.

A relatively rigid material can provide rigidity with less bulk of the material. The high viscosity of the bite registration material also works well in displacing the marginal gingiva. The author had tested heavy body, medium body, and light body to work with both perforated and non-perforated matrix design. Perforated matrix combined medium or light body work better. Light body group shows better detail and less chance of losing the subgingival information.

We select light body PVS as the final impression material to apply inside the matrix and around the prepared teeth. Considering the gingiva has been displaced by the matrix, the final impression material will focus on capturing details and filling the gingival sulcus well. At the same time, the material should be able to adhere to the matrix. (Fig 6) The characteristics of light body PVS is suitable for those requirements.

Saving the clinical time:

The modified matrix impression technique does not require a prefabricated tray to form the matrix. This bite registration material can be directly applied to the sulcus, margin, and abutment surfaces.

Owing to its small amount of material, it does not require much effort and time to trim it properly. Coarse diamond burs are the most suitable tool to do the trimming, which provides accurate outcomes and causes no tearing of the material. The surfaces cut by coarse diamond burs give the roughness for the PVS light body to adhere to it. The rough surface combing with the perforated areas, provide sufficient retention to prevent material delamination. Thus, the original procedure of applying adhesive can be omitted.

Comparison and future application:

According to the original publication of the matrix impression technique, a semirigid polyether bite registration material works well and no need for adhesive. However, nowadays, PVS bite registration material has become the mainstream; materials with different hardness are available in the market. It becomes easy for each clinician to find the most suitable materials for himself to apply this modified matrix impression technique.

The original technique was to force the impression to flow into the gingival sulcus. On the other hand, the modified technique focuses on holding the cervical gingiva away from the tooth surface, creating a space for more flowable PVS to flow into it, but not aim to fill the whole gingival sulcus.

The new technique advocates trimming the matrix with coarse diamond burs. This approach will produce much tiny silicon dust and need to perform in a dust collector to protect human health. If the operator makes a vast and bulky matrix, low-speed carbide bur can be used to trim the bulk faster. However, while trimming the essential detail areas, coarse diamond burs work better.

This modified technique also has the potential to combine with the removable partial denture impression and the triple tray impression. (Fig 7)

Summary

This article introduces a modified matrix impression technique. This new technique inherent previous advantages, which is painless, economical, and highly predictable. Furthermore, it works faster and effectively prevent impression material delamination.

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Case Report

restoration with the "parallel workflow" - A novel technique for multiple restorations

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Abstract

Digital dentistry has been popular in recent years due to increased accuracy and relatively friendly prices. Among all specialties, prosthetic dentistry was affected by the digital dentistry the most. Digitalization brings not only an increase in efficiency of making impressions, but also a change in the entire workflow. Especially in chair-side computer-aided design and computer-aided manufacturing (CAD/CAM), the clinical collaboration between dentists and technicians can significantly improve the predictability and efficiency of treatment. The aim of this clinical case report was to demonstrate a novel technique "parallel workflow", which allows the dentist to work in sync with the technician for multiple restorations.

Key words: Chair-side CAD/CAM, Digital dentistry, Full mouth rehabilitation, Parallel workflow

Introduction

Intra-oral scanning acquires a digital representation of the patient's oral and dental conditions. It is not only faster than traditional impressions[1,2,3,4,5,] but also eliminates the need for gypsum models and transportation[6]. Furthermore, digital scans of the original dental morphology can be used as reference during restoration design. Chairside computer-aided design and computer-aided manufacturing (CAD/CAM) has the additional advantage of allowing the clinicians full control of the final restoration, making changes and adjustments when needed[7].

Further, digital workflow dramatically shortens the distance between the dentist and the technician, and even in-office technicians are possible. In this case, while the doctor performs clinical treatment, the technician may process required prostheses of such patient simultaneously. This process is known as the "parallel workflow".

For multiple restorations, the parallel workflow is an indispensable tool for reliable and systematic design of the prostheses. By making use of manipulation of digital files, parallel workflow streamlines the digital workflow for maximal efficiency. This case report will demonstrate this parallel workflow.

Case report

Patient was a 73-year-old male. The chief complaint was poor chewing function and sensitivity of multiple teeth. Upon intraoral examination, this patient showed full-mouth severe wear with

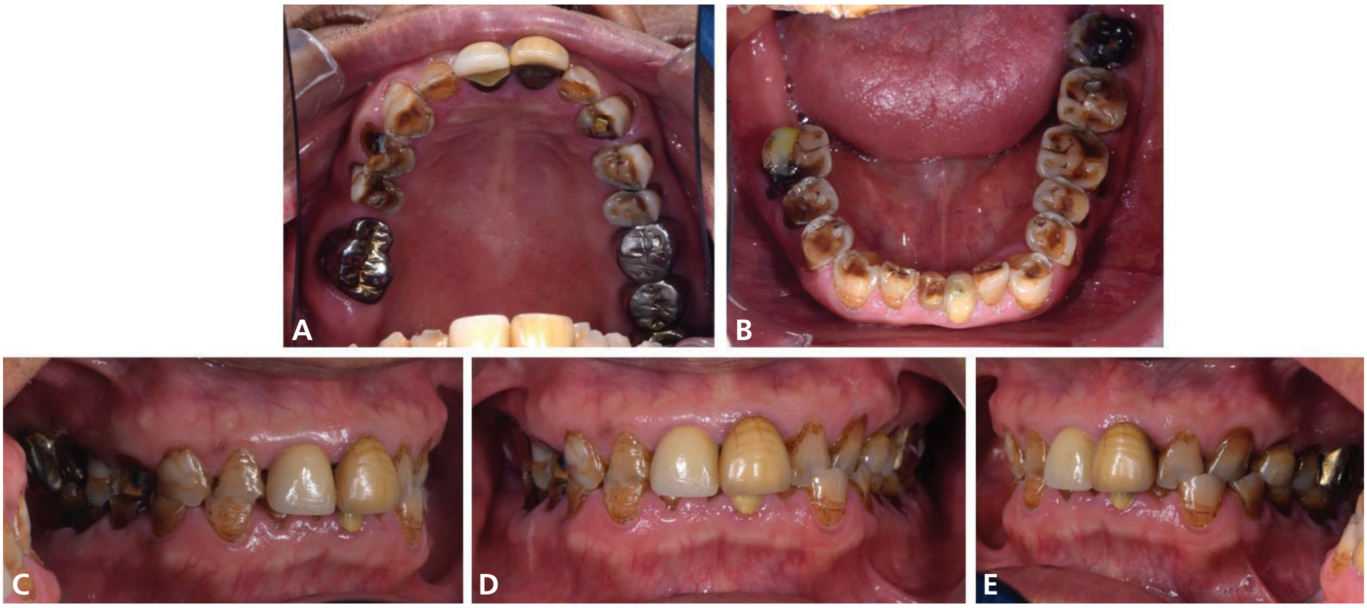

Figure 1. Initial intraoral photographs, which shows full mouth severe worn down and multiple erosion lesions with dentin exposure.

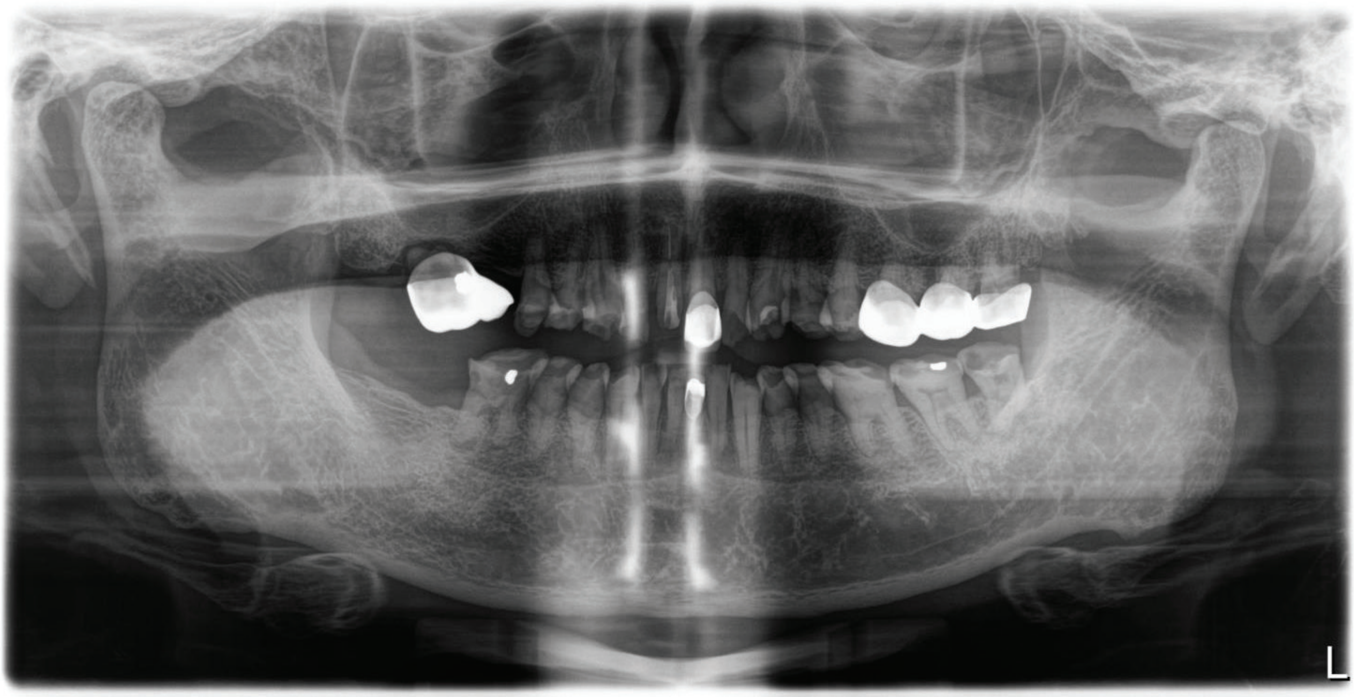

Figure 2. Panoramic film shows 17 severe bony destruction with ill-fitting prosthesis, 11 prior root canal treatment with crown dislodged, ill-fitting crown on 21, 26, 27 and 28, periapical lesion on 46 distal root.

lots of matched facet and multiple erosion lesions with cupping dentin exposure (Figure 1). X-ray showed 17 severe bony destruction with ill-fitting prostheses, 11 prior root canal treatment with crown dislodged, ill-fitting crown on 21, 26, 27 and 28, periapical lesion on 46 distal root (Figure 2).

After discussion, the tentative treatment plan is: 17 extraction, removal of all ill-fitting crowns and provisional restorations on 15-27 and 37-46 as shorten dental arch, which is restored in the new vertical dimension. After provisional prostheses is made, 11 root canal retreatment and 46 root canal treatment should be performed. After 3-month follow-up of new occlusal relationship and all infection control is done, final prostheses can be made.

After we reached an agreement with the patient, primary intraoral scanning (CEREC Primescan; Dentsply Sirona, USA) of upper and lower jaw with buccal scan bite registration in a new vertical dimension was done (Figure 3). The new occlusal vertical dimension (OVD) was determined by assessment of freeway space[8], with the aid of a calliper and a leaf gauge. As I exported this file to

Figure 3. Primary intraoral scan models, with buccal scan bite registration in a new vertical dimension.

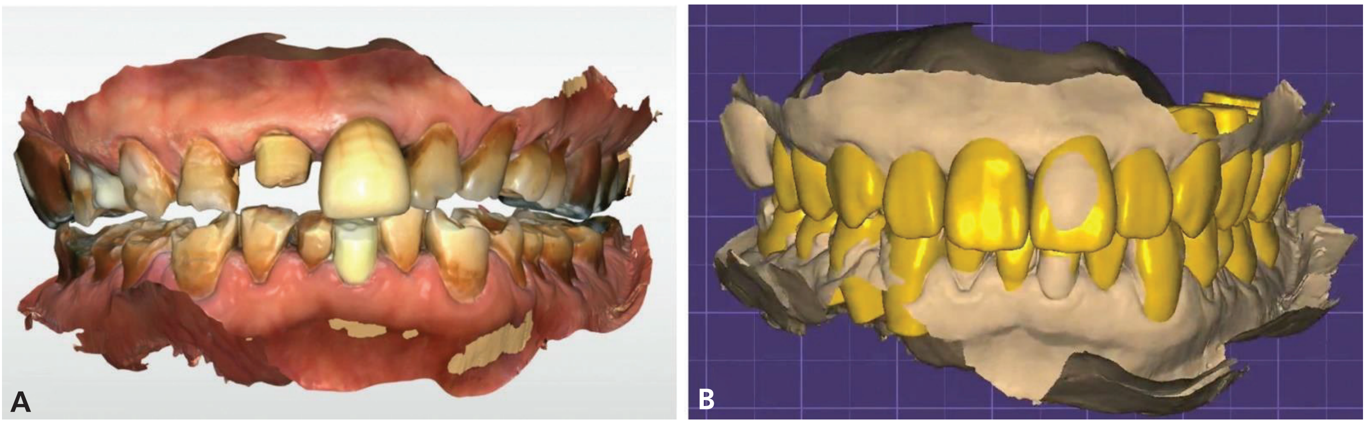

Figure 4. Diagnostic design with new vertical dimension.

Figure 5. Transfer diagnostic design into mouth with the silicon key made from 3D printed model.

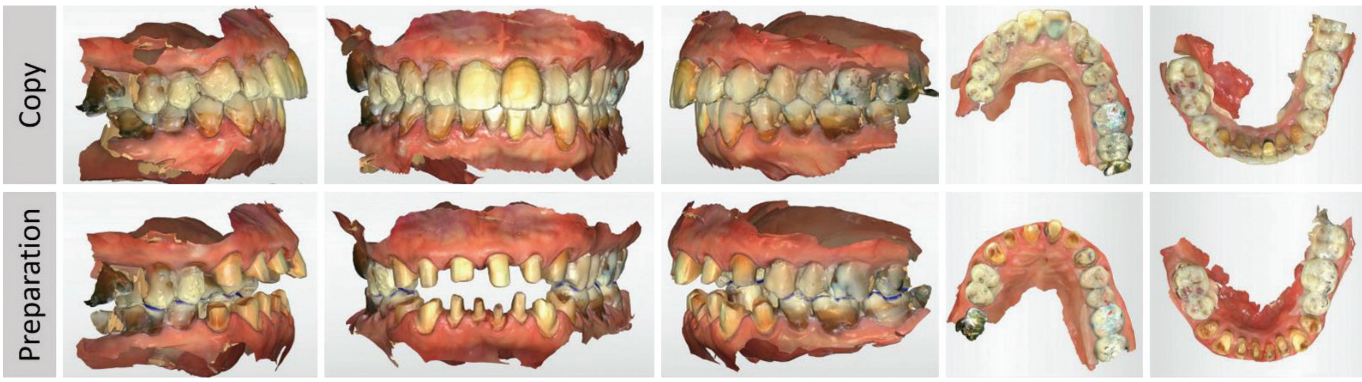

Figure 6. The "file 1", which combined the mock-up scan as copy and anterior preparation scan.

CAD software (exocad 2.3; exocad, Germany). In the software, I have designed the ideal prostheses design with mutually protected occlusion concept[9] (Figure 4) and upper anterior-six combine with extraoral photos in exocad Smile Creator module. Then I exported the design as .stl file, 3D printed it with 3D printer (Form2; Formlab, USA). This 3D printed prototype serves as the diagnostic model.

In the appointment of the provisional prostheses fabrication, before teeth preparation, the intra-oral mock-up was done by the silicon key (Aquasil; Dentsply Sirona, USA) made from the diagnostic model (Figure 5). After clinical occlusal adjustment of mock-up, patient felt comfortable with the new occlusal design and facial aesthetic. From here on, it is the "parallel workflow". The process is divided into several stages and is described as following.

Stage 1. The mock-up was scanned as the copy.

Stage 2. 13 to 23 and 34 to 44 were prepared and scanned with buccal scan bite registration. This file combined with mock-up scan and preparation scan, we called it "file 1" (Figure 6). Then "file 1" was

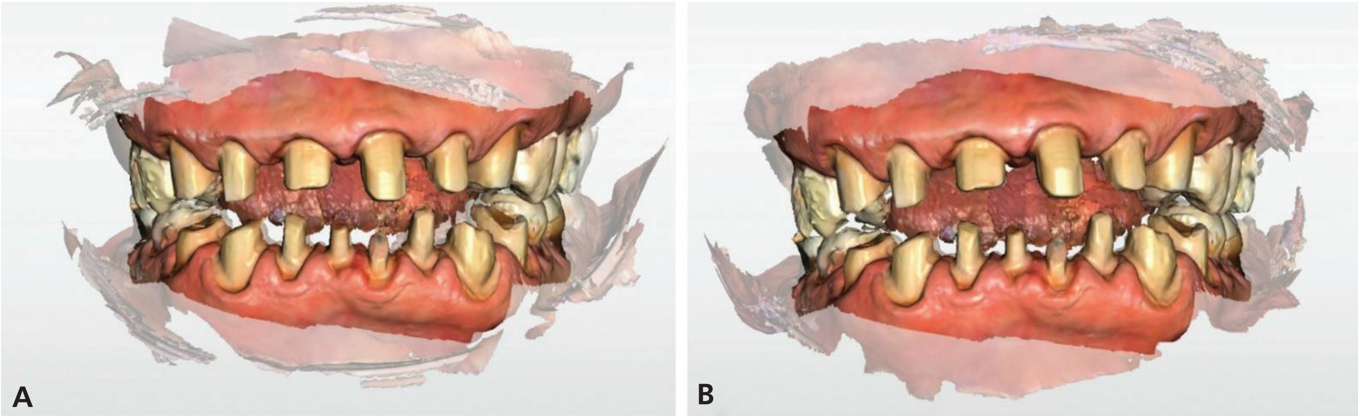

Figure 7. The "same" buccal scan bite registration can be used in 2 different treatment stages.

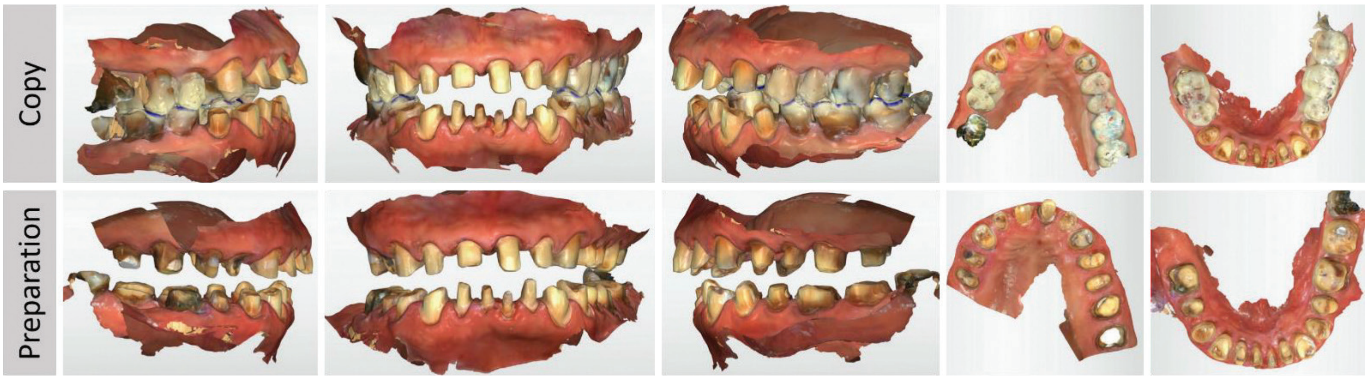

Figure 8. The "file 1", which combined the mock-up scan as copy and anterior preparation scan.

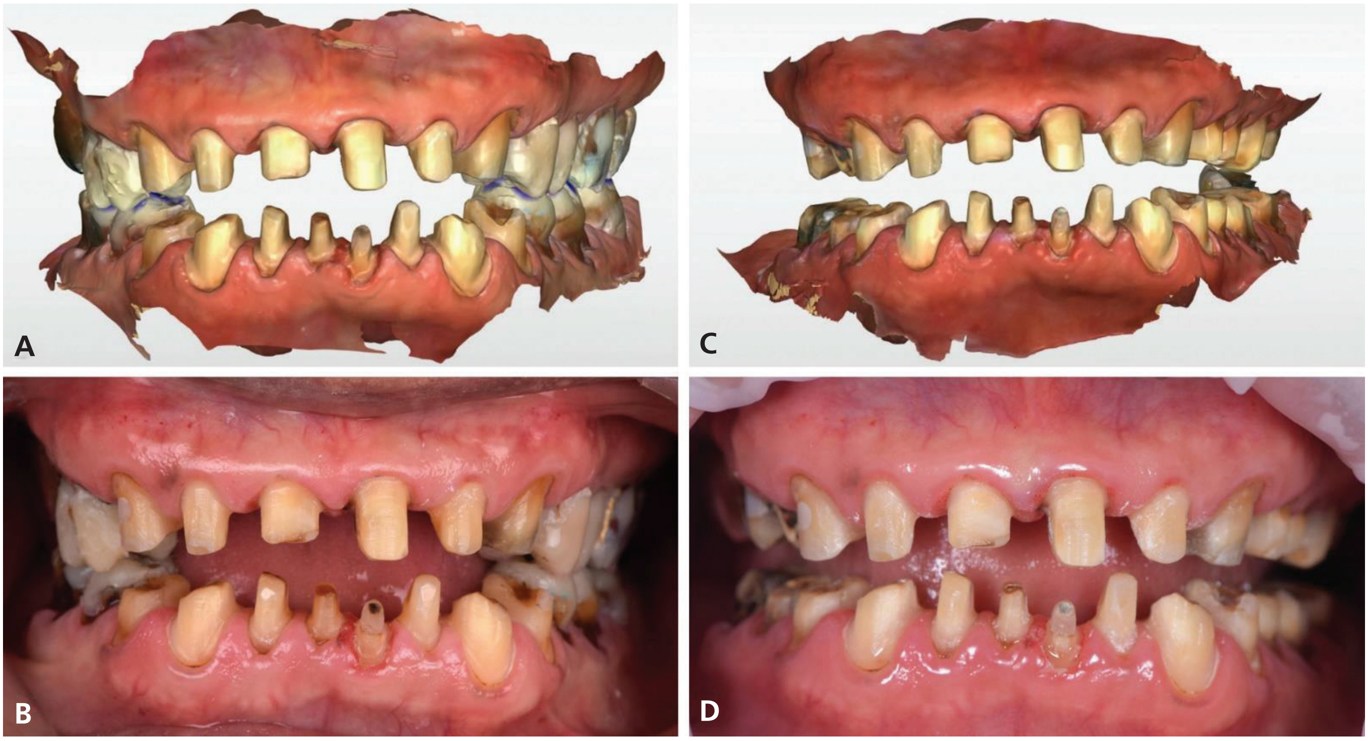

Figure 9. The "same" buccal scan bite registration can be used in 2 different treatment stages.

sent to the in-office laboratory. By using the mock-up copy as reference, the provisional restorations for 13 to 23 and 34 to 44 can be designed and fabricated.

Stage 3. During technician design (CEREC 4.6; Dentsply Sirona, USA) and mill (MCXL; Dentsply Sirona, USA) anterior provisional prostheses, I started to prepare rest of teeth. After I finished all posterior preparation, I copied the "file 1" as the new copy file first. Then scanned full upper and lower jaw, but kept previous buccal scan bite registration, which still work in matching upper and lower jaw (Figure 7). Now, this file combined with "file 1" and posterior teeth preparation, listed as

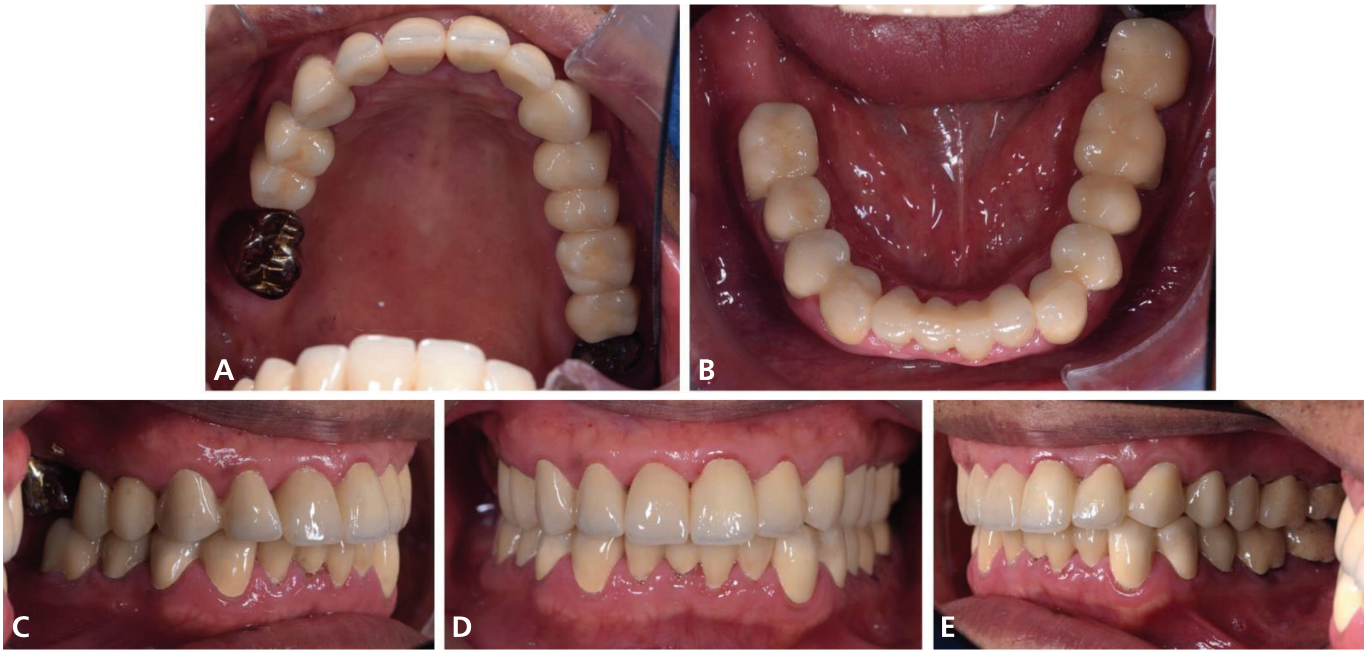

Figure 10. Full-mouth provisionals after delivery. The mock-up with diagnostic design was precisely transferred.

Figure 11. Extraoral comparison.

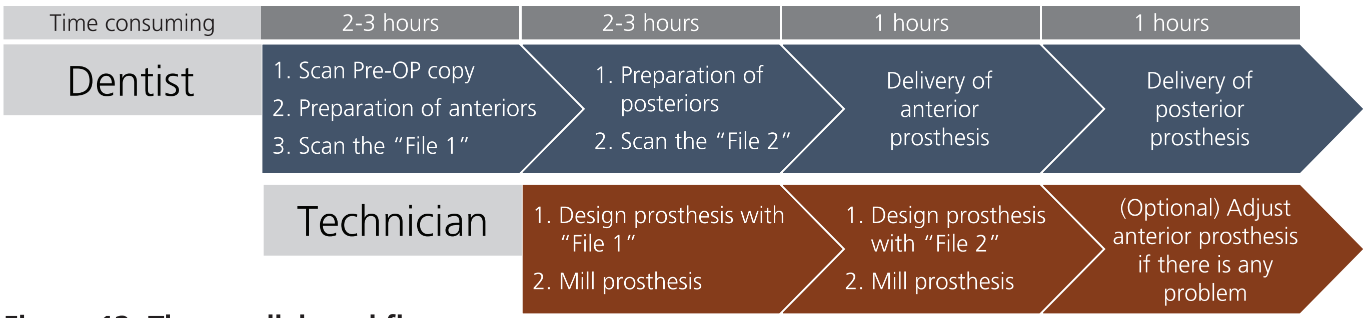

Figure 12. The parallel workflow.

"file 2" (Figure 8). Again, "file 2" was transferred to the in-office laboratory for the remaining provisional prostheses.

Stage 4. The anterior provisional prostheses were delivered after its completion around the same period of time. As the anterior teeth were cemented, the provisional prostheses of the posterior teeth were almost finished.

Stage 5. The posterior provisional prostheses were cemented. The parallel workflow finished (Figure 10,11).

After this appointment, this patient is undergoing infection control and occlusal adaptation now.

Discussion

With "parallel workflow", dentists can work with technicians synchronously (Figure 12), which contains several benefits. First, this can greatly improve efficiency and eliminate time consuming procedures which allows the dentist to concentrate on teeth preparation and cementation. The dentist can start delivery immediately after completing the preparation. This process can be used not only in provisional prostheses, but also in single-visit final prostheses.

Second, under such segmentation procedure, the occlusion relationship between the upper and lower jaws can be controlled well. Suppose we have a full-mouth scan and bite record after all the teeth prepared, one is that the upper and lower buccal scan for bite registration lacks a stable support and is prone to error; the other is that this model will be very difficult in mapping with the preoperative mock-up model. Because the difference is too large. This will result in the inability to accurately replicate the patient's occlusal design that has been adjusted.

Third, because the technician's design is to copy the dentist's mock-up, and this mock-up has been occlusal adjusted at the very beginning, as long as we can control the precision of the intraoral scanning and milling procedure, the finished prostheses will be very predictable. For example, this patient did not need any occlusal adjustment during these provisional prostheses delivery.

But in the implementation of this process, there is a point that must be paid attention to, that is, the contact of the adjacent teeth at the segment point (e.g. 13 and 14 in this case) must be perfectly copied in the design. Otherwise, because this is designed in two separate files, it is not possible to see the contact area directly of these two tooth designs during designing.

This case report demonstrates the clinical efficacy and reliability of parallel workflow for multiple restorations. This workflow can be used to accurately transfer our prosthetic designs to provisional prostheses or final restorations, which also shows the dramatic changes in the clinical prosthetic workflow of chair-side CAD/CAM and digital dentistry.

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