Effect of Building Orientation on Marginal Gap and Internal Fit of The Implant-Supported 3D-Printed Provisional Crown

Atittaya Chaowthawee[1] Patcharanun Chaiamornsup[1] Pornpot Jiangkongkho[1] Yosnarong Sirimethawong[1*]

Abstract

Background: With the increasing popularity of immediate implant placement and restoration, precise fabrication methods for provisional restorations have become crucial since it helps preserving the soft tissue around the implant. 3D-printed PMMA provides cost-effective alternatives despite concerns about polymerization shrinkage. Previous studies have shown that building orientation for 3D-printed methods can affect the marginal gap and internal fit of the restoration. This study aims to examine the effect of building orientation on the marginal gap and internal fit of implant-supported provisional prostheses.

Materials and Methods: The implant-supported provisional restoration of the right maxillary central incisor was designed by complete digital workflow using 3shape software. The virtual implant crowns were fabricated with 3D-printer (DLP technology) in three different building orientations (0°, 45°, and 90°) with 10 samples per group. The samples underwent post-processing methods according to the manufacturer's recommendation. Marginal gap and internal fit examination were conducted using a digital silicone replica technique and superimposition method. After digitizing the silicone replica into .stl file, the gap distances were measured at sixteen reference points for each sample using Artec Studio 18 software. The degree of discrepancy was reported in color mapping. The measurements were statistically analyzed using One-way ANOVA .

Results: Statistical analysis revealed significant differences in marginal, cervical, and axial gap across the three groups ($p < 0.05$) except the occlusal gap. The 45° group had a significantly smaller marginal gap (19.1 ± 6.98 μm) than the 0° group (29.78 ± 10.63 μm) and the 90° group (35.68 ± 18.37 μm). Color mapping indicated thicker cement space around the margin of the Ti-base abutment in the 0° and 90° groups compared to the 45° group.

Conclusion: Building orientation in 3D printing significantly affects the marginal gap and internal fit of implant-supported provisional restorations. The 45° orientation produced the best results among the three groups.

Keywords: implant, provisional restoration, 3D printing, marginal gap

Received Date: Jul 30, 2024

Revised Date: Sep 26, 2024

Accepted Date: Oct 09, 2024

[1]*Department of Restorative dentistry, Faculty of Dentistry, Naresuan University, Phitsanulok, 65000, Thailand.*

*(*corresponding author)*

Introduction

Dental implants have gained remarkable popularity for dental substitution. Their distinguished features, such as exceptional strength, reliable retention, stability, and the capacity to support surrounding structures, not only ensure comfort but also contribute to the preservation of alveolar bone. Moreover, their esthetic resemblance to natural teeth enhances patient satisfaction (1). Capitalizing on these advantages, patients now hold higher expectations for swift and uncomplicated surgical protocols. Immediate implant placement simultaneous with restoration has now become a widely accepted protocol, particularly in areas with esthetic significance. This technique involves attaching a prosthetic crown or bridge attached to the dental implant shortly after its surgical placement. This approach offers several benefits in terms of both functional and esthetic outcomes. It provides patients with a continuous dental structure without the need to endure an edentulous phase and less additional surgical procedure from the second stage surgery. Additionally, an immediate restoration aids in the preservation of soft tissue architecture, preventing gingival recession and shaping the soft tissue to achieve a proper emergence profile around the implant (2).

The use of static computer-assisted implant surgery (sCAIS) is widely used in recent implant placement protocols. This technology significantly enhances the accuracy of surgical protocols, even in cases involving immediate implant placement accompanied by the immediate loading of provisional restorations. Consequently, the design and production of a well-crafted provisional restoration can be accomplished prior to the actual surgical appointment (3). Such provisional restorations, when employed in conjunction with immediate implant placement, not only offer patients a temporary substitute for their extracted teeth but also play a crucial role in facilitating soft tissue healing. Through proper restoration contouring, they have the potential to avert gingival recession post-extraction and aid in shaping the soft tissue to achieve a proper emergence profile (4-6). In this scenario, the utilization of immediate provisional restorations becomes even more significant, given their prolonged usage throughout the healing period. Thus, provisional restorations should possess an optimal level of strength, reliable dimensional stability, and a satisfactory esthetic appearance.

Traditionally, auto-polymerized polymethyl methacrylate (PMMA) has been the material of choice for crafting provisional restorations (7). However, this material does come with certain limitations, including exothermic reactions, polymerization shrinkage, and an unpleasant odor (8-9). The advent of computer-aided design and computer-aided manufacturing (CAD/CAM) technology has revolutionized the field of restorative dentistry, offering enhanced precision and accuracy in the fabrication of dental prostheses.

Provisional restorative materials like auto-polymerized polymethyl methacrylate (PMMA) and bis-acryl resin have been widely used for decades. However, auto-polymerized PMMA can lead to exothermic reactions, polymerization shrinkage, and unpleasant odors, while bis-acryl resin, despite offering good strength and high esthetics, typically requires direct fabrication techniques that demand more clinical chair time and greater clinician skill to achieve flawless outcome(7-9). The advent of computer-aided design and computer-aided manufacturing (CAD/CAM) technology has revolutionized restorative dentistry, offering enhanced precision and accuracy in the fabrication of dental prostheses, with the added benefit of allowing restorations to be prepared in advance of surgery. Although several studies have compared the mechanical and physical properties of conventional PMMA, bis-acryl resin, and 3D-printed resin, the findings remain controversial, indicating the need for further investigation (10).

There are two approaches for producing provisional prosthesis from CAD/CAM PMMA: by milling or 3D-printing. A milled PMMA undergoes complete polymerization under optimal conditions, resulting in reduced residual porosity and monomer content. Thus, milled PMMA presents better mechanical properties compared to conventional PMMA (10-12). Although milled PMMA has greater strength and dimensional stability, it involves higher costs in terms of both material and milling tools. On the other hand, 3D-printed or additive manufacturing is a process that builds objects layer-by-layer. Therefore, 3D-printing generates less waste and proves to be a more cost-effective option. However, a primary concern associated with 3D-printed PMMA is polymerization shrinkage during manufacturing process (13-14). This shrinkage can lead to dimensional alterations, potentially affecting the precision of the restoration's margin and resulting in discrepancies in both the marginal area and the internal gap fit.

The marginal gap and internal fit are two important factors for the long-term success and durability of a fixed prosthesis. Poor marginal fit and clinical unacceptable gap of the fixed prosthesis can lead to cement dissolution, plaque accumulation and microleakage which compromise the surrounding periodontium and may consequences to a marginal bone loss (15). Earlier research indicates that the marginal gap of 3D-printed provisional restorations typically falls within the range of 56–212 µm (14,16-17). Since the properties of printed PMMA are influenced by various factors, including parameter adjustments derived from CAD design, building orientation, as well as the specific post-rinsing and post-curing protocols applied.

Previous studies have shown that building orientation had an influence on marginal gap and internal fit of the tooth-supported 3D-printed provisional tooth-supported crown and bridge (18-19). However, the study about building orientation on marginal gap and internal fit of 3D-printed provisional restoration on implant abutment is insufficient and needs for a further study.

Therefore, this study aims to examine the effect of building orientation on marginal gap and internal fit of the implant-supported provisional prosthesis. The goal is to enhance the precision in fabrication process of provisional implant crowns, ultimately contributing to more favorable treatment outcomes.

Materials and Method

An implant fixture analog (RC analog; Straumann, Basel, Switzerland) was centralized and fixed within 3D-printed acrylic resin block (P Pro Master Model Grey, Straumann, Basel, Switzerland) size 20 x 20 x 20 mm designed from CAD software (3D builder; Microsoft, Redmond, WA, USA). The block was designed with lines across the upper surface to serve as a reference for gap measurement.

An implant scan body was inserted into the implant analog, and then the scan body and the resin base were scanned using an intraoral scanner (Trios3; 3Shape, Copenhagen, Denmark). Computer-aided design (CAD) software (Dental System, 3Shape, Copenhagen, Denmark) was utilized to design the provisional restoration for the right maxillary central incisors through a complete digital workflow. The cement space for the provisional restoration was set at 40 µm. Subsequently, the virtual provisional crown was saved as an STL file for further processing.

The virtual crown STL file was assigned into 3 groups according to different building orientation angles. In this context, 0 degrees indicate that the incisal edge of the implant crown was oriented toward the build platform. (Figure 1A)

- Group 1: 3D-printed crown with build orientation 0 degree
- Group 2 : 3D-printed crown with build orientation 45 degree
- Group 3 : 3D-printed crown with build orientation 90 degree

All samples were produced by DLP printer (Straumann® P30; Straumann®, Basel, Switzerland) with printable methacrylate-based resin (P-Pro Crown & Bridge; Straumann®, Basel, Switzerland) with a curing wavelength of 385 nm and the layer thickness of 100 µm. After 3D printing, all specimens underwent the manufacturer's recommended post-processing steps. Upon completion of printing, the samples were removed from the platform and individually wrapped in tissue paper. To eliminate excess uncured resin, the samples were centrifuged in a laboratory centrifuge (EBA 20; Hettich, Tuttlingen, Germany) at 1500 rpm for 2 minutes

Following this, each sample received a secondary exposure using a flash-light curing machine (Straumann® P cure; Straumann®, Basel, Switzerland). Subsequently, the samples were rinsed with isopropanol alcohol using an automated machine (Straumann® P wash; Straumann®, Basel, Switzerland). Then, left to air dry completely for a minimum of 30 minutes. To standardize the procedures, 3D printer, automated curing and washing machine will be calibrated and set the time and temperature according to the manufacturer's recommendations. All procedures will be performed by a single trained researcher.

For marginal gap and internal fit measurement, the digital silicone replica technique adapted from Zeller et al. (20) was used. First, the Ti-base abutment (Straumann Variobase®, Straumann®, Basel, Switzerland) was sandblasted with 50 um Al_2O_3 to reduce reflectivity and need for a coating spray. Then the Ti-base abutment will be scanned as a 'abutment scan' using laboratory scanner (E4, 3Shape, Copenhagen, Denmark). After that, polyvinyl siloxane (Aquasil Ultra, Dentsply Sirona, North Carolina, USA) was loaded into the sample and seated onto the Ti-base abutment. A pressure of approximately 50 N was applied by a specimen positioner (Instron, Massachusetts, USA) and maintained for 5 minutes according to the setting time from the manufacturer's instructions. Then, the crown was removed from the abutment, leaving the PVS replica adhered to the Ti-base abutment. The Ti-base abutment with the PVS replica was scanned using the laboratory scanner (E4, 3Shape, Copenhagen, Denmark). Before repeating all steps for each sample, the silicone replica was removed completely using a dental laboratory steam cleaner to prevent silicone remnants from the previous sample.

All 50 Ti-base abutments with PVS replica scans and reference abutment scans were exported as STL files and imported into engineering software (Artec Studio 18; Artec 3D, Senningerberg, Luxembourg) to analyze the marginal gap and internal fit. The abutment scan and the Ti-base with PVS replica scan were aligned using the "best-fit alignment" function. Once the reference scan and the sample scan were aligned, the scans were sectioned along the labiolingual and mesiodistal directions using a line on the resin block as a reference line.

The discrepancy between the two scans was evaluated at four specific points, covering all four aspects: labial, lingual, mesial, and distal. This evaluation summarized the findings across 16 points for each sample, focusing on two key measurements: (1) the marginal gap (the perpendicular distance of the cement space at the margin of the abutment) and (2) the internal gap, which was averaged from three areas: (a) the cervical gap (1 mm medial to the margin of the abutment), (b) the middle of the engagement area of the abutment, and (c) the middle of the flat surface on the upper half of the abutment. (Figure1B,1C,1D)

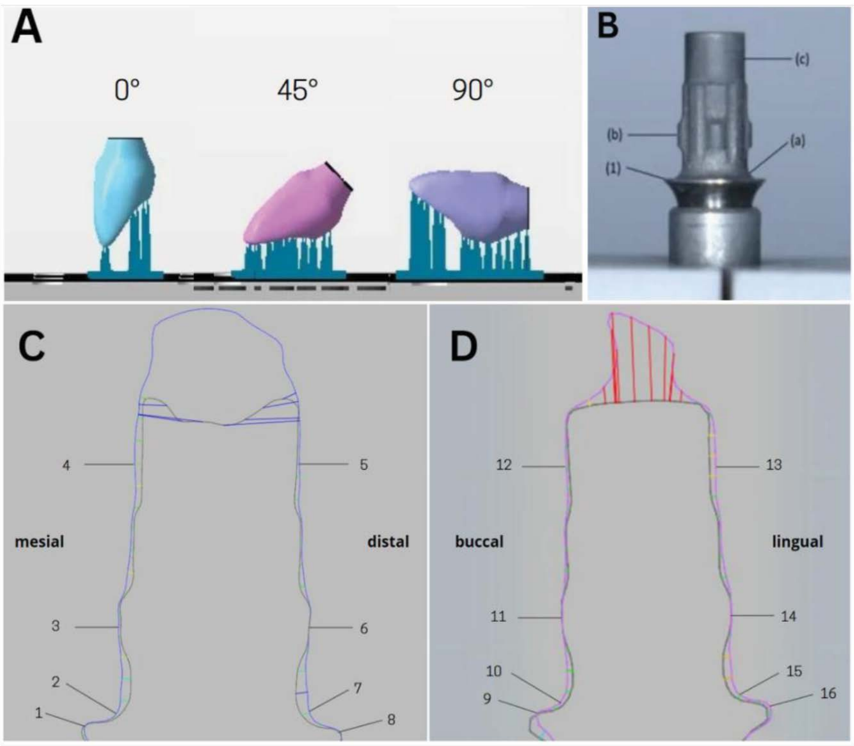

Fig.1 (A) the provisional crowns were built in 3 different orientation (0°, 45°, and 90°) and (B) the four specific points where the gap were measured covering all four aspects of the abutment; (1)marginal gap, (a)cervical gap, (b)axial gap and (c)occlusal gap. (C) and (D) all 16 points measured for gap investigation in each specimen.

Following gap measurement, the sections below the finish line of the abutment, including the base and other components, were deleted. This process resulted in a Ti-base abutment with a silicone replica, which was transformed into a point discrepancy grading represented by color. The program applied a color spectrum ranging from blue to red. Yellow to red hues indicated that the PVS scan had a positive value compared to the Ti-base reference scan, while light blue to navy colors indicated a negative value from the Ti-base reference scan.

The measurement results were statistically analyzed with one-way ANOVA using SPSS for Windows (SPSS v17.0, IBM, Chicago, IL, USA). To further explore any significant differences, multiple comparisons were performed using the Tukey post-hoc test. The chosen level of significance for these analyses was set at $\alpha = 0.05$.

Results

The measurement results of the marginal and internal gaps for different locations (marginal, cervical, axial, and occlusal gaps) and aspects (labial, lingual, mesial, and distal) of implant-supported prostheses at orientations of 0°, 45°, and 90° are presented in Figure 2. One-way ANOVA indicated that building orientation had a significant influence on marginal gap, cervical gap, and axial gap except the occlusal gap.

The Marginal gaps showed significant variation across orientations, especially in the labial and lingual aspects. The mean circumferential of marginal gap of the 45° group had a significantly smaller marginal gap (19.1 ± 6.98 µm) than the 0° group (29.78 ± 10.63 µm)($p = 0.002$) and the 90° group (35.68 ± 18.37 µm) ($p < 0.001$). The post-hoc test suggested that the marginal gap of the labial aspect of the 45° (14.50 ± 8.00 µm) significantly lower than the 0° (32.30 ± 11.42 µm) and 90° (36.90 ± 18.78 µm) orientations group ($p = 0.002$). And the marginal gap of the lingual aspect of the 45° group (19.5 ± 6.35 µm) is significantly smaller than the 90° group (33.70 ± 16.72 µm) with p-value 0.037. The same trends were observed for the mesial and distal aspects regardless of statistical significance.

For the internal fit of the prostheses, Cervical gaps were smaller in 0° group and larger in the 90° orientation for all aspects. The mesial aspect at 90° showed the largest cervical gap with a mean of 112.90 ± 28.31 µm, compared to 55.70 ± 16.41 µm at 0° and 73.70 ± 23.60 µm at 45° ($p < 0.001$). Axial gaps showed significant differences primarily in the lingual aspect where the mean gap is 39.20 ± 16.14 µm, considerably larger than at 0° (17.50 ± 8.36 µm) and 45° (15.50 ± 4.93 µm), with a p-value < 0.001. In contrast, occlusal gaps exhibited no significant differences across orientations. These results suggest that the orientation significantly affects the gap measurements, with the 90° orientation generally presenting the largest gaps, particularly in cervical and marginal locations.

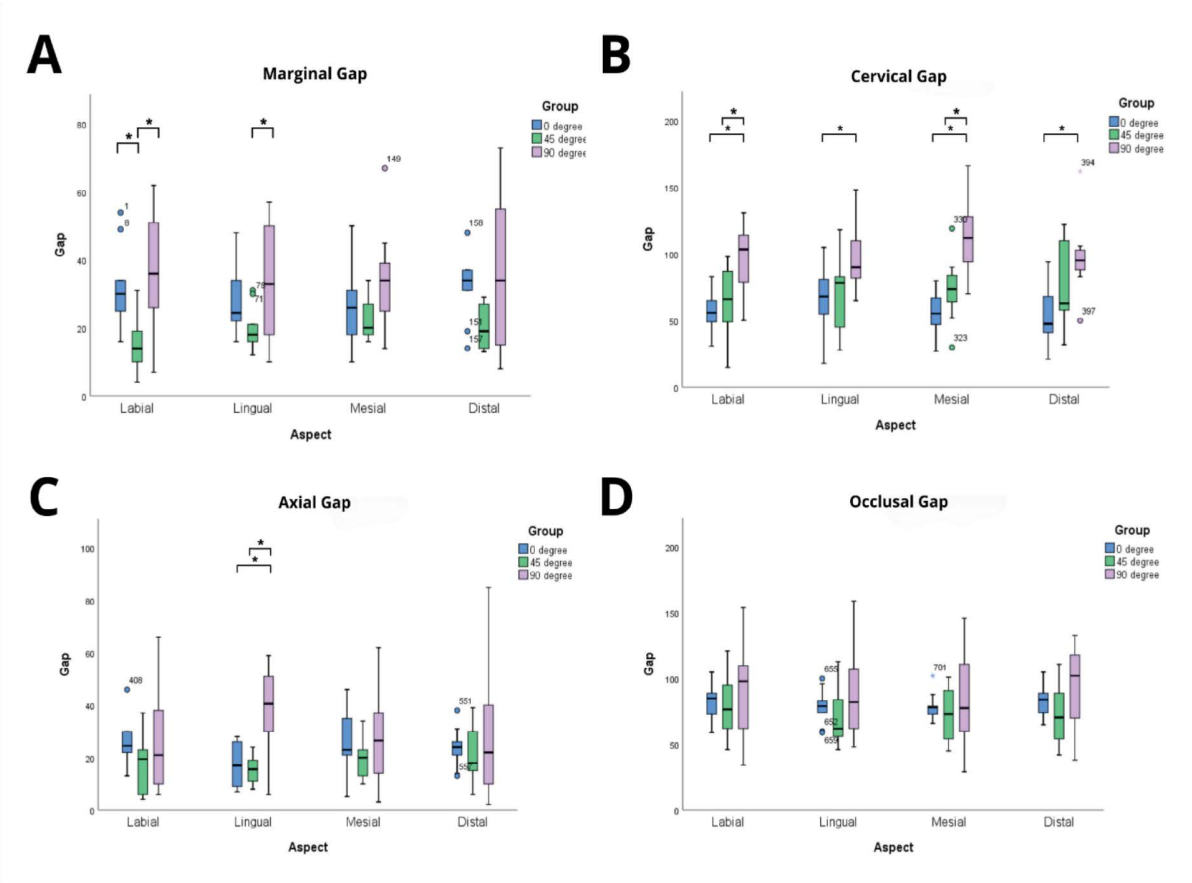

Fig.2 box plot graph of the gap measurement for different locations. (A) marginal gap, (B) cervical gap, (C) axial gap, and (D) occlusal gaps in four aspects (labial, lingual, mesial, and distal) of implant-supported prostheses at orientations of 0°, 45°, and 90°. *indicate statistical significance between groups.

The software displayed the deviation of the specimen and reference files in a color range from blue to red. Since the PVS substitutes for the cement space, only positive deviations, shown in green to red hues, were demonstrated. The color mapping results showed larger cement gaps, indicated in yellow, at the marginal area of the abutment in the 0° and 90° groups compared to the 45° group. Additionally, the overall cement space in the 90° group was larger than in the other groups. (Figure 3)

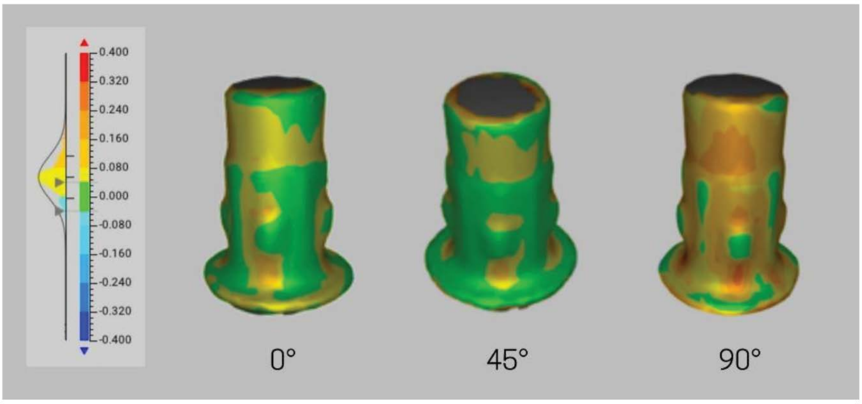

Fig.3 color map of the PVS replica substitute for the cement space in each group. The discrepancy of samples and reference file were demonstrated in color, ranging from green to red, indicating small to large gaps.

Discussion

This study aimed to evaluate the marginal gap and internal fit of the implant-supported provisional crown produced by 3D-printed technology in various building orientations. The results showed that the building orientation had an influence on marginal gap and internal fit of the 3D-printed implant-supported provisional crown especially at marginal and cervical area.

A range of marginal gaps in 3D-printed provisional restorations using DLP technology has been documented in prior research. Ryu et al. reported gaps for 3D-printed crowns between 58-113 µm (19), while Park et al. observed 52-61 µm for implant-supported crowns (21). Although Farag et al. reported a higher fit of marginal gap of the provisional crown printed by SLA printer than those by DLP printer (22). Yet, the results showed that the marginal gap of provisional crown from SLA printer was range between 40-72 µm. This study found marginal gaps ranging from 19-35 µm, which is notably lower than previously reported figures. This may be because this study implied the whole digital workflow and design the provisional crown from the abutment library provided in the CAD software, which can reduce the error of the scanning process of the abutment. McLean and von Fraunhofer analyzed the fit of fixed restorations over five years and concluded that a gap under 80 µm is clinically acceptable (23). Consequently, the marginal gaps identified in this study fall within acceptable clinical parameters.

In this study, the 45° group was found had the lowest marginal gap coincided with the results from Park et al. who studied 3D-printed implant-supported 3-unit bridge in 5 build angles (0°, 30°, 45°, 60°, 90°) and found a significant difference in the marginal and internal fit, in which the optimal build angles were 45° and 60° (24). Similarly, Osman et al. evaluated the accuracy of 3D-printed provisional crowns at various angles, discovering that 135° (corresponding to 45° in this study) and 210° showed the lowest discrepancies (25). However, Chaiamornsup et al. reported significant larger marginal discrepancies in 3-unit fixed partial denture casting patterns printed at a 45° orientation than those in 0° and 30° (18). These differing results may be attributed to variations in prosthesis type and design, including tooth-supported versus implant-supported restorations, the number of crowns involved and cement gap configuration in CAD software.

Several factors elucidate why building orientation influences accuracy, resulting in varying marginal gaps and internal fits of 3D-printed restorations. In this study, the cervical gap was increased in more tilted building orientation in all aspects. This may have occurred because the DLP printer cures the resin layer by layer, alterations in building orientation affect the shape of each cured resin layer. In this study, the specimen featured a cylindrical space in the center for the abutment and the screw access channel. During printing, the shape of the central hole of uncured resin varied across the three groups. In 0° group, this hole is nearly circular; however, it became increasingly elliptical with greater tilt degree and eventually nearly rectangular at the 90° group. This variation resulted in the mesial and distal aspects of the crown being cured separately. Such changes in shape influence the form and degree of polymerization shrinkage, as well as the direction of the shrinkage (19,24). When a polymer layer is repeatedly photopolymerized from one side, the previously cured material contracts to release internal stress, while the newly cured material shrinks within the boundaries of the previous layer (26). This may result in larger gap in 90° group especially at the cervical area and in lingual aspect of the axial area because it is the site where support structure is attached.

Modifications in building orientation also alter the area where the supporting structure attaches to the prosthesis. Since the 90° group had a support structure attached near the margin of the prothesis more than the other groups, this may lead to distortion of the crown margin (19) during removal and post-curing process resulting in larger marginal gap of the implant crown printed in 90° than those in 0° and 45°. (Figure 1)

Unkovskiy et al. investigated the accuracy of rectangular bars printed in various building orientations, finding that Z-axis accuracy decreases as specimen length increases (27). This decreased accuracy in the Z-axis may contribute to the inaccuracy of the margin of the 0° group in this study. Additionally, the 0° group exhibited the lowest cervical gap, potentially leading to an improper seat of the crown on the abutment. These factors together might account for the larger marginal gap in the 0° group compared to the 45° group. Although the low cervical gap in the 0° group could theoretically be compensated for by increasing the cement space setting in CAD software, doing so could result in an improper fit and reduced stability of the entire restoration.

The findings of this study indicated that a 45° building orientation yields the smallest marginal gap and best internal fit. However, these outcomes may not be applicable to all DLP printer configurations. Additionally, various factors, such as the design of the prosthesis, number of the teeth involved, the type of printing material, and post-processing methods, can affect the results. Recognized limitations of this study include the restricted generalizability due to variations in printer specifications and materials.

Conclusion

The 45° orientation demonstrated the smallest marginal gap and superior internal fit, indicating it as the optimal angle for achieving high precision. Therefore, this technique is recommended for implant-supported provisional restorations, particularly in immediate implant placements within esthetic zones, where enhanced precision and tissue compatibility are crucial for promoting soft tissue healing and ensuring favorable clinical outcomes.

Conflict of interest

Non declared.

References

1. Misch, CE. Dental Implant Prosthetics. 2nd ed. Amsterdam: Elsevier; 2014.

2. Javaid MA, Khurshid Z, Zafar MS, Najeeb S. Immediate Implants: Clinical Guidelines for Esthetic Outcomes. Dent J (Basel). 2016;4(2):21. doi: 10.3390/dj4020021.

3. Abduo J, Lau D. Seating accuracy of implant immediate provisional prostheses fabricated by digital workflow prior to implant placement by fully guided static computer-assisted implant surgery: An in vitro study. Clin Oral Implants Res. 2021;32(5):608-18.

4. Amato F, Amato G, Polara G, Spedicato GA. Guided Tissue Preservation: Clinical Application of a New Provisional Restoration Design to Preserve Soft Tissue Contours for Single-Tooth Immediate Implant Restorations in the Esthetic Area. Int J Periodontics Restorative Dent. 2020;40(6):869-79.

5. González-Martín O, Lee E, Weisgold A, Veltri M, Su H. Contour Management of Implant Restorations for Optimal Emergence Profiles: Guidelines for Immediate and Delayed Provisional Restorations. Int J Periodontics Restorative Dent. 2020;40(1):61-70.

6. Wang WCW, Hafez TH, Almufleh AS, Ochoa-Durand D, Manasse M, Froum SJ, et al. A Guideline on Provisional Restorations for Patients Undergoing Implant Treatment. J Oral Bio. 2015; 2(2):1-7

7. Burns DR, Beck DA, Nelson SK; Committee on Research in Fixed Prosthodontics of the Academy of Fixed Prosthodontics. A review of selected dental literature on contemporary provisional fixed prosthodontic treatment: report of the Committee on Research in Fixed Prosthodontics of the Academy of Fixed Prosthodontics. J Prosthet Dent. 2003;90(5):474-97.

8. Gratton DG, Aquilino SA. Interim restorations. Dent Clin North Am. 2004;48(2):487-97.

9. Tom T, Uthappa MA, Sunny K, Begum F, Nautiyal MC, Tamore S. Provisional restorations: An overview of materials used. J Adv Clin Res Insights. 2016;3(6):212-4.

10. Al-Humood H, Alfaraj A, Yang CC, Levon J, Chu TG, Lin WS. Marginal Fit, Mechanical Properties, and Esthetic Outcomes of CAD/CAM Interim Fixed Dental Prostheses (FDPs): A Systematic Review. Materials (Basel). 2023;16(5):1996. doi: 10.3390/ma16051996.

11. Igreţ A, Rotar RN, Ille C, Topală F, Jivănescu A. Marginal fit of milled versus different 3D-printed materials for provisional fixed dental prostheses: an in vitro comparative study. Med Pharm Rep. 2023;96(3):298-304.

12. Suwannasing A, Chaoklaiwong B, Banthitkhunanon P. Materials for provisional crowns, CAD/CAM polymethyl methacrylate: literature review. CM Dent J. 2020;41(2):25-35.

13. Ishida Y, Miyasaka T. Dimensional accuracy of dental casting patterns created by 3D printers. Dent Mater J. 2016;35(2):250-6.

14. Wu J, Xie H, Sadr A, Chung KH. Evaluation of Internal Fit and Marginal Adaptation of Provisional Crowns Fabricated with Three Different Techniques. Sensors (Basel). 2021;21(3): 740. doi: 10.3390/s21030740.

15. Srimaneepong V, Heboyan A, Zafar MS, Khurshid Z, Marya A, Fernandes GVO, et al. Fixed Prosthetic Restorations and Periodontal Health: A Narrative Review. J Funct Biomater. 2022;13(1):15. doi: 10.3390/jfb13010015.

16. Deeb LA, Ahdal KA, Alotaibi GN, Alshehri A, Alotaibi B, Alabdulwahab F, et al. Marginal integrity, internal adaptation and compressive strength of 3D printed, computer aided design and computer aided manufacture and conventional interim fixed partial dentures. J Biomater Tissue Eng. 2019;9(12):1745-50.

17. Aldahian N, Khan R, Mustafa M, Vohra F, Alrahlah A. Influence of Conventional, CAD-CAM, and 3D Printing Fabrication Techniques on the Marginal Integrity and Surface Roughness and Wear of Interim Crowns. Appl Sci. 2021;11(19): 8964. doi.org/10.3390/app11198964.

18. Chaiamornsup P, Iwasaki N, Tsuchida Y, Takahashi H. Effects of build orientation on adaptation of casting patterns for three-unit partial fixed dental prostheses fabricated by using digital light projection. J Prosthet Dent. 2022;128(5):1047-54.

19. Ryu JE, Kim YL, Kong HJ, Chang HS, Jung JH. Marginal and internal fit of 3D printed provisional crowns according to build directions. J Adv Prosthodont. 2020;12(4):225-32.

20. Zeller S, Guichet D, Kontogiorgos E, Nagy WW. Accuracy of three digital workflows for implant abutment and crown fabrication using a digital measuring technique. J Prosthet Dent. 2019;121(2):276-84.

21. Park JY, Jeong ID, Lee JJ, Bae SY, Kim JH, Kim WC. In vitro assessment of the marginal and internal fits of interim implant restorations fabricated with different methods. J Prosthet Dent. 2016;116(4):536-42.

22. Farag E, Sabet A, Ebeid K, El Sergany O. Build angle effect on 3D-printed dental crowns marginal fit using digital light-processing and stereo-lithography technology: an in vitro study. BMC Oral Health. 2024;24(1):73. doi:10.1186/s12903-024-03851-4.

23. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. Br Dent J. 1971;131(3):107-11.

24. Park GS, Kim SK, Heo SJ, Koak JY, Seo DG. Effects of Printing Parameters on the Fit of Implant-Supported 3D Printing Resin Prosthetics. Materials (Basel). 2019;12(16):2533. doi:10.3390/ma12162533.

25. Osman RB, Alharbi N, Wismeijer D. Build Angle: Does It Influence the Accuracy of 3D-Printed Dental Restorations Using Digital Light-Processing Technology?. Int J Prosthodont. 2017;30(2):182-8.

26. Zhao Z, Wu J, Mu X, Chen H, Qi HJ, Fang D. Origami by frontal photopolymerization. Sci Adv. 2017;3(4):e1602326. doi: 10.1126/sciadv.1602326.

27. Unkovskiy A, Bui PH, Schille C, Geis-Gerstorfer J, Huettig F, Spintzyk S. Objects build orientation, positioning, and curing influence dimensional accuracy and flexural properties of stereolithographically printed resin. Dent Mater. 2018;34(12):e324-e333.

Corresponding author:
Dr. Yosnarong Sirimethawong
Department of Restorative dentistry, Faculty of Dentistry, Naresuan University, Phitsanulok, 65000, Thailand.
Tel: (668) 9891 7112
E-mail: yosnarong@gmail.com