Role of span length in the adaptation of implant-supported cobalt chromium frameworks fabricated by three techniques

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PURPOSE. This study evaluated the effect of span length on the adaptation of implant-supported cobalt chromium frameworks fabricated by three techniques. **MATERIALS AND METHODS.** Models with two solid abutment analogs at different inter-abutment distances were digitized using a laboratory scanner. Frameworks of two-, three-, and four-unit fixed prostheses were designed by a computer. Six dots with a diameter of 0.2 mm were preset on the surface of each framework. A total of 54 implant-supported cobalt chromium frameworks were fabricated by milling, selective laser melting (SLM), and cast techniques. The frameworks were scanned and exported as Stereolithography files. Distances between two dots in X, Y, and Z coordinates were measured in both the designed and fabricated frameworks. Marginal gaps between the framework and the abutments were also evaluated by impression replica method. **RESULTS.** In terms of distance measurement, significant differences were found between three- and four-unit frameworks, as well as between two- and four-unit frameworks prepared by milling technique ($P<.05$). Significant differences were also noted between two- and three-unit frameworks, as well as between two- and four-unit frameworks prepared by cast technique ($P<.05$). The milling technique presented smaller differences than the SLM technique, and the SLM technique showed smaller differences than the cast technique at any unit prostheses ($P<.05$). Evaluation with the impression replica method indicated significant differences among the span lengths for any fabrication method ($P<.05$), as well as among the fabrication methods at any unit prostheses ($P<.05$). **CONCLUSION.** The adaptation of implant-supported cobalt chromium frameworks was affected by the span length and fabrication method. ***[J Adv Prosthodont 2017;9:124-9]***

KEYWORDS: Milling; SLM; Cast; Span; Adaptation

INTRODUCTION

An accurate implant-supported prosthetic framework is considered to have a simultaneous and circumferential contact between the implant abutment and the framework, without causing strains before functional loading.[1,2] If the gap between the implant abutment and the framework is sufficient for bacterial adherence, inflammatory reactions will occur around the peri-implant soft tissues. Moreover, the accuracy can minimize mechanical complications, decrease the development of strains, and provide long-term results regarding implant dentures.[3-5]

Recently, some novel techniques are advocated to fabricate metal frameworks. Compared with traditional cast technique, the new techniques are operated with machine and not by hand. These novel techniques are characterized as subtraction of raw material, as in milling technique; or addition of raw material, as in selective laser melting (SLM) technique.[6] The marginal accuracy of prosthetic frameworks fabricated by milling, SLM, and cast techniques has been

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extensively studied.[7,8] However, the results are controversial.[9] Nesse compared the precision of the three methods in terms of internal and marginal fit and determined that SLM restorations presented the poorest internal and marginal fit, whereas the milling method was the optimal technique.[10] On the other hand, Xu found that SLM-fabricated cobalt chromium alloy (Co-Cr) crowns exhibited smaller marginal gap widths than those of cast crowns.[11] Furthermore, in most previous reports, the research target was the single crown and not the bridge. Therefore, few studies have focused on the effect of span length on the adaptation of metal frameworks fabricated by different methods.

The present investigation evaluated the adaptation of implant-supported Co-Cr frameworks fabricated by three techniques with different span lengths. Apart from traditional impression replica technique, the frameworks were also evaluated by a new method to determine the overall extent of linear deformation. The null hypothesis was that the span length would not affect the adaptation of implant-supported Co-Cr frameworks fabricated by milling, SLM, and cast techniques.

MATERIALS AND METHODS

Six solid abutment analogs (Straumann 048.5416, Basel, Switzerland) were fixed with plasticene in three standard female mandible molds at their corresponding positions (44 and 45, 43 and 45, 43 and 46). The spaces for pontics (44, 44 and 45) of the two of the molds were also filled with plasticene. Three mandibular models were prepared by pouring type 4 artificial stone into the molds. The models were used to simulate different dentition defects restored by two implants with two-, three-, and four-unit fixed prostheses (Figs. 1A-C). Each model was fabricated with removable dies and scanned by 3Shape D810 laboratory scanner (3Shape, Copenhagen, Denmark) to create a 3D data file. These files were used to design the two-, three-, and four-unit fixed prosthetic frameworks in the virtual realm with the same parameters. Six dots with a diameter of 0.2 mm each were designed randomly by a computer on the abutment surface of each framework for measurement. Two dots were located at the buccogingival region (A1 and A2), two other dots were placed at the bucco-occlusal region (B1

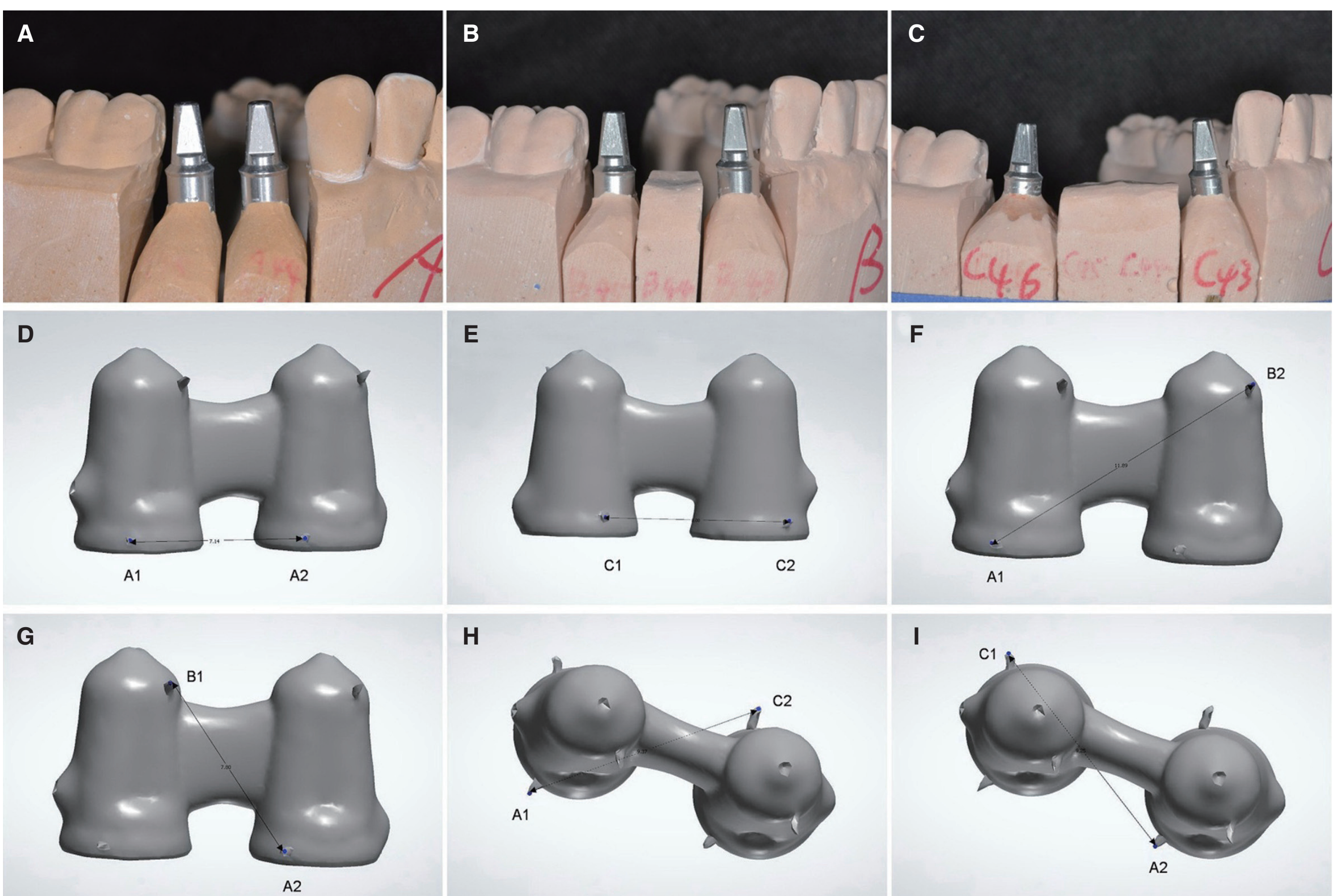

Fig. 1. Models simulating two implants with two-unit (A), three-unit (B), and four-unit (C) fixed prostheses. The standard distance was defined as the distances between six dots along the X, Y, and Z directions on each designed framework (two-unit), named as X1 (D), X2 (E), Y1 (F), Y2 (G), Z1 (H), and Z2 (I).

and B2), and the last two dots were positioned at the linguo-gingival region (C1 and C2).

With the same data, the frameworks of the two implants with two-, three-, and four-unit fixed prostheses were prepared by milling and SLM techniques (n = 6 for each technique at each unit). The Co-Cr alloy blocks used to mill the framework (Original Multi and Changer 20 RK, Germany) contained 61.1% Co, 32.0% Cr, and 2.5% Mo. The Co-Cr alloy powder used to fabricate the SLM framework (Bego EOS-M280, Germany) contained 63.3% Co, 24.8% Cr, and 5.1% Mo. To cast the framework, the resin patterns of the prostheses (n = 6 for each unit) were first prepared by the milling system. These patterns were then subjected to phosphate-bonded investment (Bego Bellavest SH, Germany) and casted with Co-Cr alloy (63.3% Co, 24.8% Cr, and 5.1% Mo; Germany).

The distances between six dots along the X, Y, and Z directions on each designed framework were measured by 3Shape software. These distances were defined as standard distances and named as X1, X2, Y1, Y2, Z1, and Z2 (Figs. 1D-1I). All frameworks fabricated by the three techniques were scanned by 3Shape D810 laboratory scanner and exported as Stereolithography files with ".stl" as filename extension. The distances on each fabricated framework were also measured with 3Shape software in the same way. They were defined as measured distances. The differences between the standard distances and the measured distances of each framework were calculated and expressed as absolute values. The six distances of each framework were collected and analyzed.

The marginal accuracy was also evaluated using impression replica technique.[12] Briefly, the framework was filled with a light body silicone (Express XT, 3M ESPE) and seated on the corresponding abutment with finger pressure for 2 - 3 minutes. The framework with light body silicone layer was then removed from the abutment and filled with medium-viscosity silicone (Express XT, 3M ESPE). After the material was hardened, the framework and the silicone were separated. The silicone replica was sectioned buccolingually and mesiodistally into four parts (Figs. 2A-2D). Each part was measured twice, and the width of the light body silicone layer represented the gap between the framework and abutment. The measurement was performed using a microscope (Zeiss, Stemi SV11) at ×6.6 magnification (Fig. 2E).

The differences of the distances and gap widths for each framework were collected. They were represented as mean ± standard deviation and analyzed using t-test. A value of $P < .05$ was considered statistically significant.

RESULTS

The differences of the distances and gap widths for each framework are presented in Fig. 3. The differences of the distances in the frameworks made by milling technique were 0.020 ± 0.017, 0.025 ± 0.018, and 0.046 ± 0.043 mm for the two-, three-, and four-unit fixed prostheses, respectively. The corresponding values in the frameworks made by SLM technique were 0.052 ± 0.045, 0.053 ± 0.036, and 0.073 ± 0.048 mm. The values on the cast frameworks were 0.143 ± 0.052, 0.153 ± 0.047, and 0.179 ± 0.085 mm, correspondingly. In terms of span length, a significant difference was found between three- and four-unit frameworks, as well as

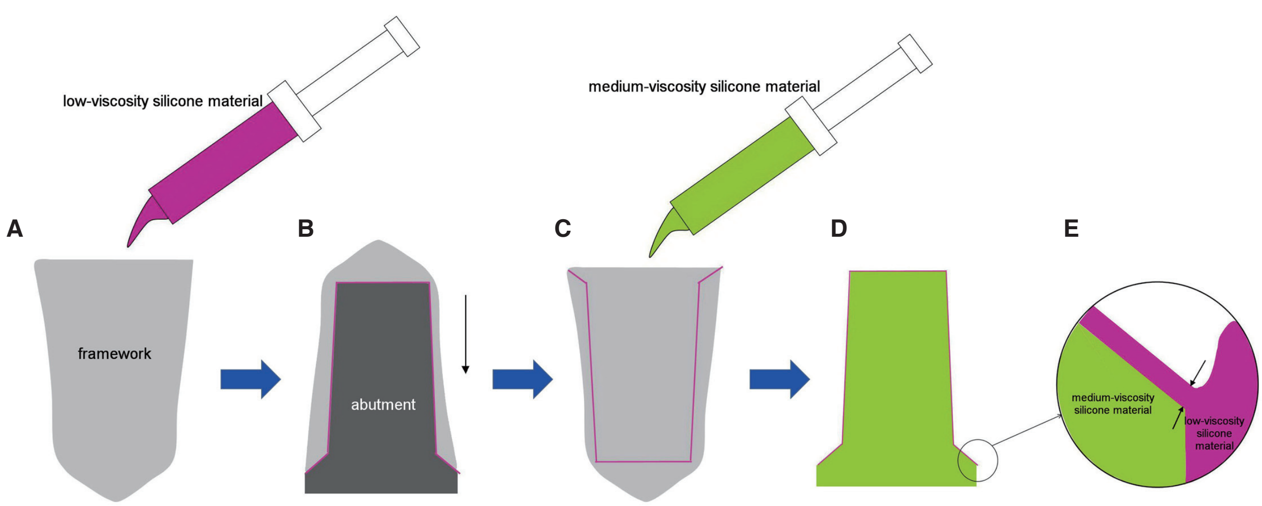

Fig. 2. Schematic diagram of impression replica technique. The framework was filled with a light body silicone (A) and seated on the abutment with pressure for 2 - 3 minutes (B). The framework with light body silicone layer was then removed from the abutment (C) and filled with medium-viscosity silicone (D). After the material was hardened, the silicone was separated and sectioned buccolingually and mesiodistally into four parts (D). The width of the light body silicone layer was measured using a microscope at ×6.6 magnification (E).

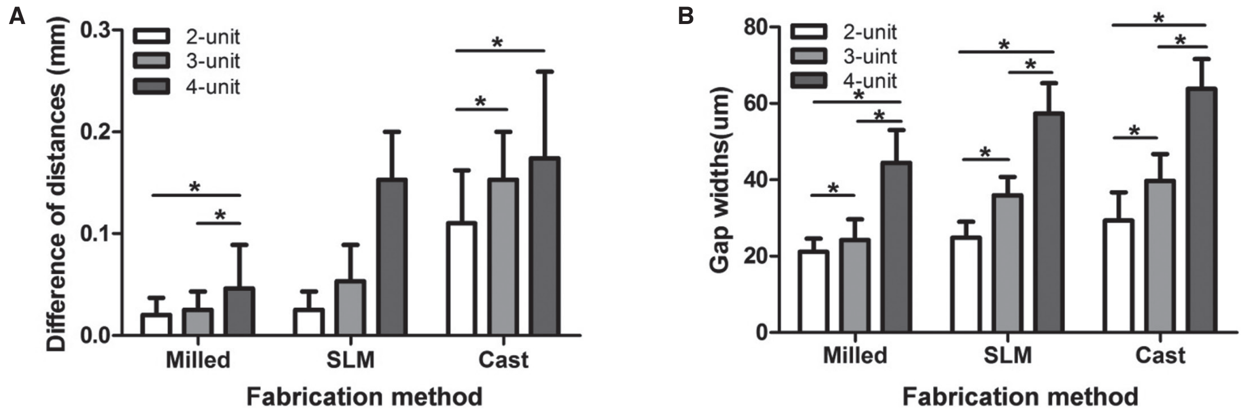

Fig. 3. Differences between standard distances and measured distances, as well as marginal gap widths among milled, SLM, and cast frameworks. (A) Difference of distances; (B) Gap widths. *$P < .05$.

between two- and four-unit frameworks made by milling technique ($P < .05$). A significant difference was also noted between two- and three-unit frameworks, as well as between two- and four-unit frameworks made by cast technique ($P < .05$). In terms of fabrication method, both milling and SLM techniques presented smaller differences than cast technique at any unit prostheses ($P < .05$), but the milling technique exhibited smaller differences than the SLM technique ($P < .05$). Moreover, the impression replica method showed that the average marginal gap widths of the milled frameworks were 21.13 ± 3.47, 24.18 ± 5.45, and 44.44 ± 8.61 μm for the two-, three-, and four-unit fixed prostheses, respectively. The corresponding data for SLM frameworks were 24.85 ± 4.09, 35.89 ± 4.84, and 57.31 ± 7.97 μm; for cast frameworks, the data were 29.30 ± 7.37, 39.72 ± 6.99, and 63.76 ± 7.79 μm, respectively. A significant difference existed among the span lengths for any fabrication method ($P < .05$), as well as among the fabrication methods at any unit prostheses ($P < .05$).

DISCUSSION

The results of this study rejected the null hypothesis as the framework span would affect the adaptation of implant-supported Co-Cr frameworks fabricated by milling, SLM, and cast techniques.

Our results showed that, for all techniques, the differences of distances increased from two-unit to four-unit frameworks. When evaluated with the impression replica method, the average marginal gap widths also increased from two-unit to four-unit frameworks. These findings showed that a longer span indicated larger manufacturing error with less adaptation. The current results were consistent with those of previous studies on zirconia. For instance, Lee evaluated the effect of span length on the fit of zirconia framework fabricated by CAD/CAM system and pointed out that the increase of span length might decrease the marginal and internal fit.[13] Anunmana compared the marginal and internal gaps of zirconia substructure of single crowns with those of three-unit fixed dental prostheses; significant differences were found between the elements under study.[14] Tiossi also discovered that longer-span one-piece zirconia frameworks showed an increased microgap.[15] Although Co-Cr was different from zirconia, which demonstrated shrinkage compensation mechanism for the expected linear shrinkage, the Co-Cr frameworks exhibited the same trend as the span length increased. This finding implied that, in contrast to crowns or short-span frameworks, the more complicated shape and larger size affected the adaptation of long-span Co-Cr frameworks.

With regard to the manufacturing method, the present study revealed that both milling and SLM techniques displayed better adaptation than cast technique regardless of the span length of the frameworks. This result was different from that of Nesse, who reported that SLM restorations achieved the poorest internal and marginal fit.[10] The reason might be attributed to the specimens in Nesse's experiment, which were delivered directly from production without internal airborne-particle abrasion, external polishing, or final adjustments. However, the intaglio surfaces of the specimens in our study were sandblasted with aluminum oxide prior to fit assessment so as to remove the obstacles influencing optimal seating. Furthermore, our result was consistent with some other reports. For instance, Witkowski compared the marginal accuracy of titanium copings fabricated by three different CAD/CAM systems and found that the marginal accuracy was significantly improved by the CAD/CAM system.[16] Moreover, Sundar compared the marginal fit and microleakage of metal laser-sintered Co-Cr alloy copings and conventional cast Ni-Cr alloy copings by using a stereomicroscope and found that the copings fabricated by SLM technique achieved better marginal fit and decreased microleakage in contrast to that of cast method.[17] However, although both milling and SLM techniques were operated by machine, the SLM frameworks presented larger difference in distance and greater marginal gap than the milled frameworks. This finding may be related to their specific manufacturing method. Generally, the milling technique was characterized as subtraction of raw material and manufacturing under recrystallization temperature. Therefore, the process slightly affected the deformation of the framework.[18,19] By contrast, the SLM technique was characterized as addition of raw material, which selectively irradiated the metal powder material into a thin layer at high temperature.[20,21] Hence, the SLM frameworks might suffer from a greater deformation than the milled ones.

Finally, the adaptation evaluation showed that the results of both methods were not totally matched. More differences were observed upon evaluation with the impression replica method. This finding might be related to the larger standard deviations of the new method in contrast to those of impression replica method. Given that the smallest diameter of the dots on the surfaces of the frameworks was 0.2 mm, the distances were difficult to measure with an accuracy of 0.01 mm. Therefore, the large standard deviation of the measurements compromised the precision of the assessment. For more accurate analyses, more specimens are needed when using the new method. Nevertheless, the two methods assessed the adaptation from different aspects. The new method investigated the linear deformation of the whole framework. The adaptation was evaluated by analyzing the differences of corresponding distances on the designed and fabricated frameworks in the X, Y, and Z directions. A smaller difference meant higher adaptation. However, the traditional impression replica method placed more emphasis on the accuracy of the prostheses individually. It measured the gap between the framework and the abutment. A smaller gap indicated better adaptation. Therefore, for more effective and comprehensive analysis on the adaptation of the frameworks, a combination of the new evaluation method and the impression replica method should be considered. Nonetheless, some limitations were identified in this study. The differences of six distances on the designed and manufactured frameworks were not analyzed along the X, Y, and Z directions, but as only the sum of the values. As a result, some detailed information on each direction might be missing. To guarantee the comparability of the three techniques, the resin patterns of the cast technique were prepared by milling technique. Hence, the adaptation of the cast technique should eliminate the error from the milling technique. Finally, the number of specimens used in the experiment was limited, which might compromise the results of the new method.

CONCLUSION

With the limitations of this study, both span length and fabrication method affected the adaptation of the implant-supported cobalt chromium frameworks.

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