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RESEARCH AND EDUCATION

Fit of 3Y-TZP complete-arch implant-supported fixed dental prostheses before and after porcelain veneering

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ABSTRACT

Statement of problem. To minimize technical complications, implant-supported fixed dental prostheses must fit well. The fit of complete-arch veneered zirconia frameworks has not been fully evaluated.

Purpose. The purpose of this in vitro study was to evaluate the fit of screw-retained zirconia implant-supported complete-arch maxillary frameworks for fixed dental prostheses before and after porcelain veneering.

Material and methods. Ten stone casts simulating an edentulous maxilla and provided with 6 abutment analogs were produced. For each stone cast, 1 zirconia framework was fabricated by computer-aided design and computer-aided manufacturing. The fit was analyzed by using a coordinate measuring machine in 3 dimensions (x, y, and z axes) using best fit by virtual matching of center point coordinates before and after porcelain veneering. Also, the horizontal distances between implant position pairs P1–P6, P2–P5, and P3–P4 were measured. Furthermore, an optical microscope was used to evaluate vertical fit at the terminal abutments after porcelain veneering.

Results. Before the porcelain veneering procedure, the frameworks had a mean horizontal misfit of 27.7 μm in the x-axis and 12.0 μm in the y-axis. In the vertical dimension (z-axis), the mean misfit was 2.4 μm and the mean 3D misfit value was 32.3 μm before veneering. Porcelain veneering increased the mean misfit by 0.2 μm in the horizontal plane (x and y axes), 0.4 μm in the vertical plane, and 0.4 μm in 3D; the difference before and after veneering was not statistically significant ($P>.05$). The mean ±standard deviation vertical misfit at the terminal abutments was 9.2 ±2.9 μm, optically recorded after porcelain veneering. The measured horizontal distances between implant position pairs P1–P6, P2–P5, and P3–P4 increased to 0.9 μm, 2.0 μm, and 1.9 μm, respectively, after porcelain veneering. The difference for the implant position pair P2–P5 was statistically significant ($P<.05$).

Conclusions. Screw-retained zirconia implant-supported complete-arch maxillary frameworks for fixed dental prostheses have a fit well within the range of 30 μm in the horizontal plane and 10 μm in the vertical plane. The porcelain veneering procedure did not affect the fit of the frameworks. (J Prosthet Dent 2019;122:137-41)

Complete-arch rehabilitation using implant-supported fixed dental prostheses (FDPs) is a well-documented treatment and has been used extensively since the 1980s. Initially, the FDPs were mainly fabricated from gold alloy and acrylic resin veneers, but also from base metal with acrylic resin or porcelain veneers.[1] With the introduction of computer-aided design and computer-aided manufacturing (CAD-CAM) technology, titanium could be used without the problems inherent in casting the material and with favorable results regarding fit.[2,3]

Yttria-stabilized tetragonal zirconia polycrystalline (Y-TZP) ceramics has mainly been used for fabrication of tooth-supported FDPs and has shown acceptable clinical results.[4,5] However, porcelain-fused-to-zirconia restorations have

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Clinical Implications

Complete-arch veneered zirconia frameworks can be produced with a horizontal and vertical fit well within 30 μm.

been reported to suffer from chipping of the porcelain veneering material, in particular on implant-supported FDPs.[4-7] In implant dentistry, zirconia is used with caution, especially for long-span frameworks.[8]

For implant-supported FDPs, a good fit between the implants or abutments and the FDP has been considered a prerequisite to reduce complications. No misfit or passive fit, without any strain in the FDP or in the implants when seated, is regarded as ideal.[9,10] The acceptable levels of vertical misfit for implant-supported FDPs with metal frameworks have been suggested to be 40-150 μm.[11,12] The technical complications are porcelain chipping or fracture of the veneering material, screw loosening, screw fracture, and framework fracture.[13,14] For screw-retained FDPs, the greatest stress is focused on the prosthetic retaining screw and the surface supporting the screw head. With an increased misfit, the external preload may cause microcracks, fractures, or loosening.[15,16]

The fit of complete-arch CAD-CAM–fabricated implant-supported FDPs fabricated from titanium and cobalt-chromium (Co-Cr) has been analyzed by using a coordinate measuring machine (CMM) and the best fit method. In the horizontal dimension (x and y axes), the misfit was below 13.5 μm, and in the vertical dimension (z-axis), the misfit was below 5.4 μm.[17]

Misfit in the vertical dimension has been evaluated by using traveling microscopes for 3-unit zirconia implant-supported FDPs and compared with other materials. The 1-screw fit test was used to compare zirconia with Co-Cr, with both screws tightened (definitive fit), and the vertical misfit was 107.2 μm for zirconia and 107.5 μm for Co-Cr. The definitive fit was 5.9 μm for zirconia and 1.2 μm for Co-Cr.[18] The same technique was used in another study in which the vertical misfit for zirconia was 37.8 μm and 3.5 μm for Co-Cr. The definitive fit was 14.9 μm for zirconia and 1.9 μm for Co-Cr.[19] Complete-arch zirconia implant–supported FDPs have been compared with milled titanium FDPs using the 1-screw fit test. The vertical misfit of zirconia was 32.7 μm and 15.2 μm for titanium.[20] Additional data are needed on the fit of complete-arch zirconia FDPs, as well as data on the fit before and after the repeated heat treatment associated with porcelain veneering.

The purpose of this in vitro study was to evaluate the fit of screw-retained zirconia implant–supported complete-arch maxillary frameworks for FDPs before and after porcelain veneering. The null hypothesis was that no difference would be found in the fit of the zirconia FDPs before and after the porcelain veneering process.

MATERIAL AND METHOD

A resin master cast of an edentulous maxilla was fitted with 6 implant abutment replicas (Multi-unit Abutment Replica; Nobel Biocare Services AG). Each replica was positioned with its rim at least 1 mm above the gingiva. The master cast was duplicated 10 times by using duplicating silicone (Elite Double 32 Extra Fast; Zhermack SpA), Type IV stone (SHERAHARD-ROCK; SHERA Werkstoff-Technologie GmbH & Co), and abutment-level impression copings (Nobel Biocare Services AG). An acrylic resin pattern with a cut-back design for porcelain veneering was fabricated from a tooth arrangement. The 10 stone casts and the associated resin pattern were scanned in a laboratory scanner (NobelProcera 1G; Nobel Biocare Services AG) and designed by using a CAD software program (NobelProcera Crown & Bridge 4.0.10.5; Nobel Biocare Services AG). The CAD files were then sent to a production center for the manufacturing of zirconia (3Y-TZP) frameworks (Nobel Biocare Services AG).

After delivery of the zirconia frameworks, the frameworks and their corresponding stone cast were sent to an independent measuring laboratory in Sweden (Mylab AB). The fit of the frameworks to the stone casts was measured by using a CMM (ZEISS PRISMO Vast; Carl Zeiss Meditec AG). The contact stylus point was placed on each of the mating surfaces of the abutment replicas, registering x, y, and z coordinates, and thereafter the mating surfaces of the frameworks. The diameter of the stylus point was 0.7 mm. The nominal linear accuracy of the machine was described by the manufacturer to be within 1 μm in all axes as confirmed by Örtorp et al.[2]

From the coordinates, a center point for each mating surface of the stone casts and frameworks was calculated. The distances between the center points of the stone casts and frameworks were calculated by using the least square method as described by Bühler.[21] The center points of the frameworks were superimposed onto the abutment replica center points of the stone casts in a best fit position. The x-, y-, and z-axis directions of displacement of the center points were calculated in μm in real and absolute figures. Also, the angulation displacements of the framework center points were analyzed in the x/z and x/y angles. Furthermore, the x-, y-, and z-axis distances between the center points of the frameworks and the abutment replicas were combined for a 3D value, which was calculated for each individual cylinder by using the formula $3D = \sqrt{x^2+y^2+z^2}$. Also, the intersecting distances between the center points of implants in positions 1 and 6, positions 2 and 5, and positions 3 and 4 were measured and compared with the

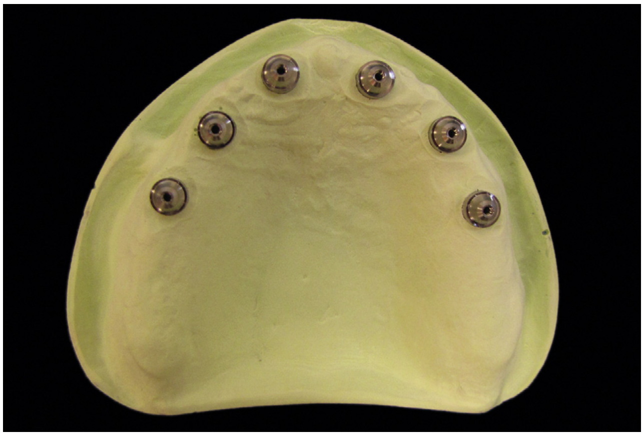

Figure 1. Cast with description of implant positions, measuring points, and distances.

Figure 2. Zirconia frameworks before veneering (back) and after porcelain veneering process (front).

distances from the actual cast before and after porcelain veneering (Fig. 1).

The frameworks were sent to a commercial dental laboratory, and an experienced dental technician placed the veneering porcelain (Fig. 2). The procedures, firing cycles, and materials are presented in Table 1. After the veneering procedure, the mating surfaces on the frameworks were airborne-particle abraded with 50-µm glass beads at 200 kPa (Magma 50 µm; M-Tec Dental AB). The frameworks were then resent to the independent measuring laboratory for fit measurements after the porcelain veneering by using the same scanning procedure as described earlier.

After the fit analysis with the CMM technique, the vertical fit was also measured by using an optical microscope (Nikon SMZ800; Nikon Instruments Europe B.V.) with ×31.5 magnification. The FDPs were seated on their corresponding casts and fixed using 4 prosthetic retaining screws in implant positions P1, P3, P4, and P6. The screws were tightened by using a torque wrench to 15 Ncm in the following sequence: P1, P4, P3, and P6.

Table 1. Firing cycles and materials for zirconia frameworks

n	Program	Material	End Temperature (°C)
1	Liner	IPS e.max Ceram ZirLiner	960
2	Dentin/incisal	IPS e.max Ceram Dentin/Incisal	730
1	Glaze	IPS Ivocolor Glaze Paste	710

n, number of firing cycles.

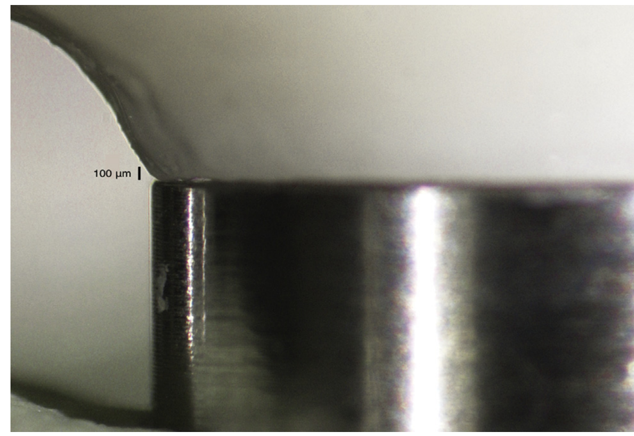

Figure 3. Measurements of vertical distance at implant position P1 between framework and abutment.

The screws in positions P1 and P6 were then loosened. Six measurements per implant position (P1 and P6) were performed, 12 points per FDP in total (Fig. 3).

A statistical software program (IBM SPSS Statistics, v22.0; IBM Corp) was used for statistical analysis. Box plots were used to analyze the distribution, and the parametric paired-sample *t* test was used to analyze differences in fit and the y/z and x/z angles of the frameworks before and after porcelain veneering. Also, differences in the distances between P1 and P6, P2 and P5, and P3 and P4 were analyzed by using the parametric paired-sample *t* test (α=.05).

RESULTS

Before the porcelain veneering procedure, the frameworks had a mean horizontal misfit of 27.7 µm in the x-axis and 12.0 µm in the y-axis. In the vertical dimension (z-axis), the mean misfit was 2.4 µm. The mean 3D misfit value was 32.3 µm before veneering. After the porcelain veneering, the misfit in the horizontal dimension was 28.0 µm in the x-axis and 12.2 µm in the y-axis. The z-axis misfit was 2.8 µm. In 3D, the misfit was 32.7 µm. No significant differences were found in the x, y, and z dimensions or 3D before and after veneering (Table 2).

The y/z angle changed from 0.059 degrees to 0.132 degrees, and the x/z changed from 0.064 degrees to 0.117 degrees after porcelain veneering. The changes in both angles were statistically significant (P<.05) (Table 3).

The distances between the center points on the FDPs for implant positions P1–P6, P2–P5, and P3–P4 were 40.629, 29.886, and 12.241 mm, respectively, before

Table 2. Mean distortion ±standard deviation (μm) of framework center points presented with master cast as reference using least square method, in absolute figures

Framework	N	|x|	±SD	|y|	SD	|z|	SD	3D	SD
Zirconia frameworks	10	27.7	±15.1	12.0	±8.4	2.4	±0.7	32.3	±16.0
Zirconia frameworks veneered	10	28.0	±15.6	12.2	±8.6	2.8	±1.6	32.7	±16.1
P		.150		.775		.408		.123	

n, number of frameworks; SD, standard deviation. *Statistically significant (*P*<.05).

Table 3. Mean deviation ±standard deviation in angulation in decimal degrees of framework mating surfaces using least square method in absolute figures

		X/-Z Angle		Y/-Z Angle	
Framework	n	Mean	±SD	Mean	SD
Zirconia frameworks	10	0.059	0.029	0.064	0.030
Zirconia frameworks veneered	10	0.132	0.062	0.117	0.059
P		.016*		.008*	

n, number of frameworks; SD, standard deviation. *Statistically significant (*P*<.05).

Table 4. Distance in mm between center points (1–6, 2–5, 3–4) ±standard deviation of zirconia frameworks compared with center points of implant positions on the casts

		Center Point Positions					
Framework	n	1–6	SD	2–5	SD	3–4	SD
Cast	10	40.709	±0.0183	29.938	±0.0150	12.259	±0.0214
Zirconia frameworks	10	−0.0796	±0.0564	−0.0523	±0.0413	−0.0182	±0.0238
Zirconia frameworks veneered	10	−0.0805	±0.0563	−0.0543	0.0402	−0.0201	±0.0233
P		.343		.047*		.150	

n, number of frameworks; SD, standard deviation. *Statistically significant (*P*<.05).

veneering and increased to 0.9 μm between P1–P6, 2.0 μm between P2–P5, and 1.9 μm between P3–P4. The changes for P1–P6 and P3–P4 were not statistically significant, but for P2–P5, the change was significant (*P*<.05) (Table 4). The mean ±standard deviation vertical misfit (z dimension) in positions P1 and P6 measured after placing the frameworks on their corresponding casts and fixing them with 2 prosthetic retaining screws in position P3 and P4 was 9.2 ±2.9 μm.

DISCUSSION

The purpose of the present investigation was to evaluate and compare the fit of screw-retained zirconia implant–supported complete-arch maxillary frameworks for FDPs before and after porcelain veneering and to compare the results in vertical misfit from 2 different measuring techniques. The results showed no significant differences in fit in any of the 3 dimensions (x, y, or z) or 3D after porcelain veneering of the zirconia FDPs. Also, the FDPs expanded in the horizontal dimension, and the changes in distance between the center point positions of P1–P6, P2–P5, and P3–P4 were within 2 μm. However, only the change for positions P2–P5 was statistically significant. Therefore, the null hypothesis that there would be no difference in fit after the porcelain veneering process was accepted.

A small but statistically significant change occurred in both the y/z angle and the x/z angle after porcelain veneering. The reason for the recorded changes may depend on minor flexing of the framework, a small amount of veneering porcelain being caught on the buccal side of the mating surface of the framework, or a combination of the two. If there is an actual change in angulation, this may decrease the surface area, taking up the load from the prosthetic retaining screw, which may result in screw loosening or fracture of the zirconia where the screw head rests.

The authors are unaware of a previous study measuring the misfit of zirconia FDPs using the CMM technique and the best fit assessment, preventing comparisons with earlier studies. Results from a best fit assessment should only be compared with other best fit assessments due to the potential underestimation of the vertical misfit (z-axis).[22,23] Because the positions of the center points are virtually matched, the physical limitations of the FDPs and implant analogs are disregarded.[22,23] The vertical misfit of the zirconia FDPs recorded with the CMM technique was below 3.0 μm, which is comparable with results on similar FDPs in titanium and Co-Cr, where the vertical misfit was below 5.4 μm.[17] However, the vertical misfit was also measured by using an optical microscope with the frameworks placed on the corresponding casts. The FDPs were tightened in a clinically relevant manner, leaving the prosthetic retaining screws tightened in implant positions P3 and P4 and misfit measured at the end abutments (position P1 and P6). This procedure was used to measure misfit as far away from where the frameworks were secured to the definitive cast but still with the frameworks placed in a best fit model, thereby simulating both the best fit used by the CMM and the clinical placement of the prosthesis. Other studies on implant-supported FDPs have used the 1-screw fit test, where 1 screw is tightened on the FDP and the gaps are measured at the other implant positions or the other terminal implant.[12] Some have used the term definitive fit when measuring the gap in implant-supported prostheses with both terminal implant prosthetic screws tightened.[18,19] Two studies using the 1-screw fit test for 3-unit FDPs reported a vertical misfit of 107.2 and 37.8 μm, and with both screws tightened on the same FDPs, the definitive fit was 5.9 and 14.9 μm, respectively.[18,19] For complete-arch implant-supported zirconia, the mean vertical misfit was 32.7 μm (1-screw fit test).[20]

In the present investigation, the mean vertical misfit at the terminal abutments using optical measurement was 9.2 μm, which suggests that the potential underestimation in vertical misfit when using the CMM technique was not as pronounced as earlier and still small enough not to be detected without a microscope. If the definitive fit had been analyzed, the vertical misfit could have been even smaller. Compared with earlier results, the vertical misfit of the zirconia FDPs in the present investigation was smaller, even when misfit measurements were performed by using an optical microscope.

The small recorded increase in the horizontal distance between pairs of implants (P1-P6, P2-P5, and P3-P4) was not statistically significant and almost within the measuring tolerances of the CMM. Hence, the zirconia frameworks were judged to be almost unaffected by the veneering process. Whether there is tension within frameworks after veneering that may reduce long-term service or cause porcelain chipping in the future cannot be answered by this study.

The importance of passive fit and acceptable levels of misfit have been discussed without consensus.[22,24] Clinically acceptable levels of misfit for implant-supported metal FDPs have been suggested for vertical (z-axis) distortion to range from 40 μm up to 150 μm.[25]

Porcelain veneering of zirconia is technique-sensitive, and there have been developments over the years to reduce the chipping problems of the veneering porcelains. The porcelain veneering process of metal frameworks has, in most studies, influenced the fit of the prostheses, resulting in an increased misfit, but diverging results have been reported.[17] Furthermore, with the introduction of more esthetic translucent zirconia, omitting the veneering may solve the problem of the chipping of porcelain-fused-to-zirconia restorations.

CONCLUSIONS

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

1. Screw-retained zirconia implant-supported complete-arch maxillary frameworks for FDPs have a fit well within the range of 30 μm in the horizontal plane and 10 μm in the vertical plane.
2. The porcelain veneering procedure did not affect the fit of the frameworks.

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