Precision of Fit to Implants: A Comparison of Cresco™ and Procera® Implant Bridge Frameworks

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ABSTRACT

Background: The Cresco™ (Astra Tech AB, Mölndal, Sweden) method aims to reduce the inevitable distortions when cast metal frameworks for implant-supported prostheses are fabricated. However, limited data are available for the precision of fit for this method.

Purpose: To measure and compare the precision of fit of Cresco- and computer numeric controlled (CNC)-milled metal frameworks for implant-supported fixed complete prostheses.

Materials and Methods: Two groups of frameworks were fabricated according to the Cresco method, either in titanium (Cresco-Ti, $n = 10$) or in a cobalt-chrome alloy (Cresco-CoCr, $n = 10$). A third group comprised CNC-milled titanium frameworks (Procera® Implant Bridge [PIB], Nobel Biocare AB, Göteborg, Sweden), made from individual model/pattern measurements (PIB, $n = 5$). Measurements of fit were performed by means of a coordinate measuring machine linked to a computer. The collected data on distortions were analyzed.

Results: Overall, a maximal three-dimensional range of center point distortion of 279 μm was observed for measured frameworks. The framework width (x-axis) decreased for Cresco-CoCr, but increased in Cresco-Ti and PIB; Cresco-CoCr compared to Cresco-Ti ($p = .0002$) and Cresco-CoCr compared to PIB ($p < .0001$). In vertical dimension (z-axis), less distortions were present in PIB compared to Cresco-CoCr ($p = .0007$) and in PIB compared to Cresco-Ti ($p < .0001$).

Conclusions: None of the frameworks presented a perfect, completely "passive fit" to the master. Although the direction of distortions varied, the horizontal distortions were of similar magnitudes. However, the PIB frameworks had statistical significant less vertical distortions as compared to the Cresco groups.

KEY WORDS: CNC-milled, complications, dental implants, distortion, frameworks, laser-welded, misfit, screw-retention

It is a challenge for the dentist to choose among the various materials and techniques available for fabricating an implant-supported prosthesis. One of the reasons is the still unknown tolerance of misfit gaps and external preload between the prostheses and the implants. Thus, until quantitative guidelines are presented and generally accepted, it seems wise to choose a framework with as good a fit as possible.

Every single step in fabricating an implant-supported prosthesis influences the fit between the implants and the final prosthesis.[1–4] Conventional casting procedures for metal framework fabrication, for instance, inevitably result in discrepancies between the frameworks and the implants because of distortion in the casting process.[5–7] Despite this, metals and metal alloys are still probably the most frequently used implant

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framework materials, particularly in the complete edentulous jaw. Titanium and gold alloys are commonly used framework materials, and different cobalt-chrome alloys have been presented as alternatives because of low cost and favorable mechanical properties.[8,9] Yet, knowledge of how cobalt-chrome frameworks supported by implants perform clinically, and how the surrounding tissues react to them is limited.

As well as various materials, several alternative framework fabrication techniques have been presented, often aimed at reducing distortion problems. Casting procedures including brazing of separated frameworks, laser welding of prefabricated components, as well as CAD/CAM and milling procedures are among the reported techniques.[10–15] Based on these studies, milled frameworks in commercially pure (CP) titanium have been shown to have a better fit compared to traditional cast gold alloy frameworks.[6,16,17] Örtorp and colleagues[16] thus examined computer numeric controlled (CNC)-milled grade II CP titanium frameworks (Procera® Implant Bridge [PIB], Nobel Biocare AB, Göteborg, Sweden), and concluded that these frameworks, milled from one piece of titanium, have a better fit than traditional, individually cast gold alloy frameworks.[16] However, these titanium frameworks were fabricated from one replica, and variations in fit between frameworks made from different casts were not analyzed. In contrast, Al-Fadda and colleagues[18] studied CNC-milled titanium frameworks, fabricated on individual casts, and compared them to conventional cast frameworks in a silver-palladium alloy.[18] Their observed fit of the CNC-milled titanium frameworks was still better than the cast frameworks, but not as good as the fit of the CNC-milled frameworks described by Örtorp and colleagues[16] The Cresco™ method (Astra Tech AB, Mölndal, Sweden) represents another framework fabrication technique, presented by Hellden and Derand.[19] Several studies have described the experimental and clinical outcomes of the Cresco method,[9,19–24] and a good clinical performance for this technique has been reported when both titanium and cobalt-chrome alloys were used for the frameworks.[9] The Cresco method is, in some ways, based on the same principles as an earlier procedure for fabricating welded titanium frameworks.[11,25,26] However, data on measurements of fit of frameworks fabricated according to this method are limited, but Torsello and colleagues[27] concluded that the misfit micro-gaps observed were comparable with the best values reported in earlier studies of other systems.[27]

The aim of this study was to measure and compare the precision of fit of frameworks for implant-supported fixed complete prostheses fabricated according to the Cresco method, made either in titanium (Cresco-Ti) or in a cobalt-chrome alloy (Cresco-CoCr). These two groups of frameworks were also compared to CNC-milled, individually scanned frameworks in titanium (PIB).

MATERIALS AND METHODS

Fabrication of Cresco Frameworks

One master model was fabricated from a randomly selected clinical working cast provided with five Brånemark System® implants (Nobel Biocare AB) in the edentulous mandible. A dental technician with more than 10 years' experience of implant treatment fabricated 20 cast frameworks directly on the implant heads, 10 in grade II CP titanium (Sjödings, Stockholm, Sweden) and 10 in a cobalt-chrome alloy (Wirobond C, BEGO Bremer Goldschlägerei Wilh. Herbst GmbH & Co, Bremen, Germany) according to the routine protocol of the Cresco method.[19,20] In brief, this was performed by shaping a wax pattern (Gator Wax Blue, WhipMix, Louisville, KY, USA). A silicon mold (Zetalabor™, Zhermack, Badia Polesine, Italy) was made for producing the 19 subsequent patterns. The wax patterns were sprued with five to seven pieces of 5-mm wax (Yeti Dental Deton, Engen, Germany). Thereafter, the patterns for the titanium frameworks (Cresco-Ti) were invested in Titavest CB® (Morita, Japan), and those for the cobalt-chrome frameworks (Cresco-CoCr) were invested in GC Fuji Super™ (Leuven, Belgium). The frameworks were cast in one piece in a Bego Nautilus® casting machine (BEGO, Bremen, Germany) and a Cyclark II® casting machine (Morita, Japan), respectively. The frameworks were then inspected. One of the cobalt-chrome frameworks was not accepted because of casting problems, as the melt had not flowed properly. Thus, a new cobalt-chrome framework was produced in the same way as described earlier. After the sprue canals were cut and the frameworks were accepted by the technician, they were sent for precisioning according to the Cresco method.

The Cresco method[19,20] used for precisioning is described briefly in Figure 1. In this study, all the frameworks in the Cresco-Ti and Cresco-CoCr groups were

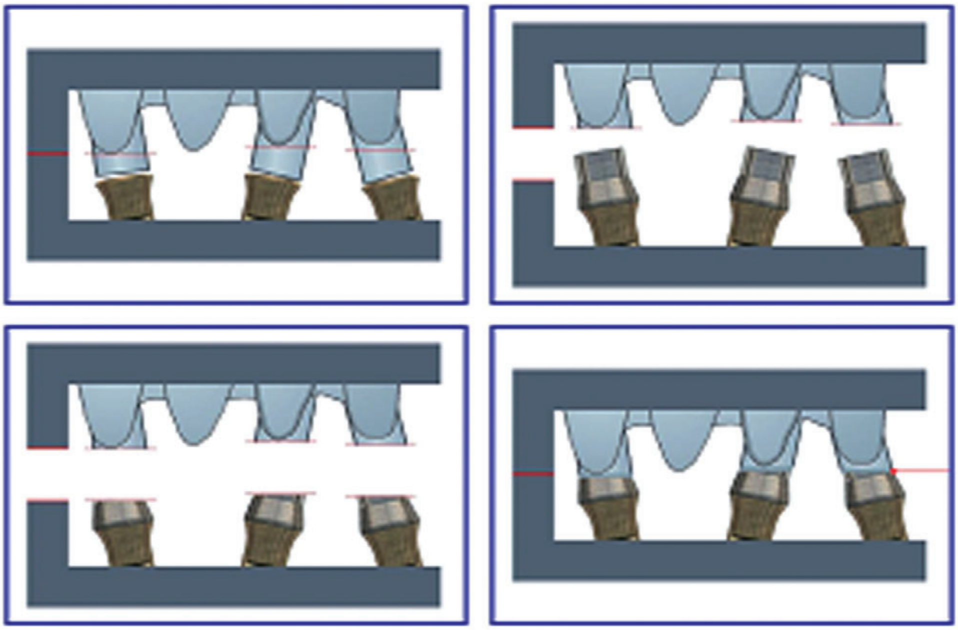

Figure 1 The Cresco method in brief. Upper left: Horizontal cut of a cast framework with misfit to the implants. Upper right: Pre-fabricated or cast cylinders are mounted on a master model. Lower left: The coronal surfaces of the cylinders are cut in the same horizontal plane as the lower surface of the framework. Lower right: The framework is then laser welded to the cylinders. (Reprinted with permission from Astra Tech.)

handled according to the Cresco method in the most experienced Cresco laboratory (Titanbron AB, Kristianstad, Sweden) using prefabricated titanium and cobalt-chrome cylinders (REF 303 and REF 30803, Astra Tech AB), respectively. The laser welding procedures were the same for the two materials except for the duration of the laser pulse and the different welding wires used. The laser pulse lasted for 3.7 ms at each welding point for the Cresco-Ti frameworks, and 7.0 ms for the Cresco-CoCr frameworks. A grade 1 titanium wire, 0.3 mm diameter (DSI Laser-Service GmbH, Maulbronn, Germany) was used for the Cresco-Ti frameworks, and a cobalt-chrome alloy wire, 0.35 mm diameter (Denthouse Amann Girrbach, Pfarzheim, Germany) was used for the Cresco-CoCr frameworks. For each cylinder, 60 to 70 welding points were used. The welding started with one point at the lingual side of implant position 3 (Figure 2), continued at positions 4, 2, 5, and finally position 1. Next, single welding points were made on the mesial and distal surfaces of each cylinder following the same order of implant positions as described before. Thereafter, single welding points were made in the same order as before on the buccal surface of each cylinder. The process continued on the lingual surface by welding points at a quarter of the cylinder circumference in an anticlockwise direction, then at the next quarter of the cylinder circumference in a clockwise direction. Finally, the buccal surfaces were treated in the same way. Through the entire process, the order of the cylinders was the same as mentioned earlier.

Fabrication of PIB Frameworks

In a clinical control group (PIB), five CNC-milled frameworks (PIB, Nobel Biocare) in CP titanium were

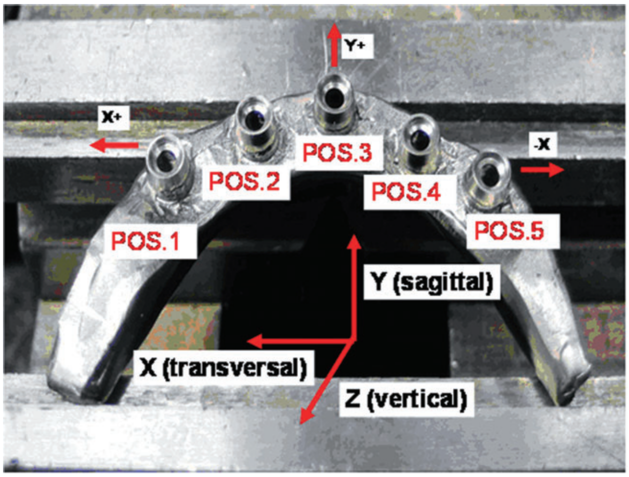

Figure 2 Framework mounted in the mold before measuring in the CMM. Orientation of the coordinates in the x- and y-axes. The vertical axis is oriented with negative values (-z) down toward the master model.

fabricated. Five similar mandibular master models were fabricated, each provided with five Brånemark System implants placed in the interforamina area and distributed in a similar way as in the Cresco master model described earlier. These models were sent to three different laboratories for framework fabrication directly on the implant heads. On each model, a plastic replica (PiKu Plast HP36, Bredent, Senden, Germany) was fabricated, matching the outline of the Cresco frameworks described earlier. Thereafter, each replica was laser scanned, and a CNC titanium framework, according to the Procera technique,[25,28] was produced without information to the technician that the frameworks should be used in a study, that is, blinded for the framework manufacture. Measurements were performed after refinement and polishing similar to level "C," as described by Örtorp and colleagues.[16]

Measuring of Master Model and Frameworks

The measurements were performed by an independent laboratory (Mylab AB, Hisings Backa, Sweden). The measuring machine and procedure were similar to those used earlier by Örtorp and colleagues.[16] In brief, the master model was used as the reference for comparing the different frameworks (see Figure 2), and all measurements were performed with a coordinate measuring machine (CMM) (Zeiss Prismo VAST®, Carl Zeiss Industrielle Messtechnik GmbH, Oberkochen, Germany). A scanning head with a 0.5 mm-diameter stylus could be placed in any position within the working space of the CMM. A gentle force was applied to the measuring stylus to facilitate contact between the stylus and the measured component surface. The positions and planes of the fit surfaces of the cylinders were found by stylus contact scanning of the components. The data for each cylinder were condensed to a position of the center point of the cylinder in three dimensions (x, y, z).

To assess whether contraction or expansion of the frameworks was present, the framework width (x-axis), that is, the distance between positions 1 and 5, and the framework curvature (y-axis), that is, the sagittal distortions in position 3 of the frameworks were measured (Figure 3).

Analysis of Fit

The measurements were analyzed for fit between the different frameworks and the master model according to the "least squares method" described by Bühler.[29] This

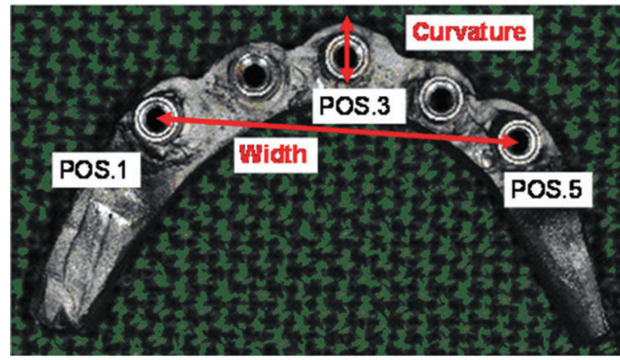

Figure 3 Framework width (x-axis) and curvature (y-axis) distortions. Width distortion as measured from implant 1 to implant 5 in the framework related to the master, curvature as measured as sagittal (y-axis) distortion in implant 3 in the framework related to the master.

was performed when each framework had been placed in the theoretically best possible position, with the shortest center point distance in relation to all the center points of the replicas of the master model at the same time.

For comparison, an alternative fit analytical method, the "orthogonal 3-2-1 method," was used.[16,30,31] This method analyzed the position of the framework cylinders in relation to the master model replicas when each pair of measurements, the framework and the master model, was superimposed in the computer. A software program placed the framework center points in a coordinate system. Thus, the center point of framework cylinder 5 was placed at the origin of the corresponding master replica cylinder for all three coordinates (x, y, z). Cylinder 3 was placed in the x–y plane, and cylinder 1 on the x-axis. Framework distortions were presented in relation to the center points of the remaining cylinders and axes. The distance between the center points of the frameworks and the master model in three dimensions was also calculated for each individual cylinder ($3\text{-D} = \sqrt{x^2 + y^2 + z^2}$).

The distortions were presented in micrometers using absolute and real values.

Precision of Measurement

According to the manufacturer, the precision of the CMM is less than 1 µm. All five components in the master model and in one framework were measured five times. The standard deviation was within ±3 µm for these measurements for all five positions.

Statistics

Conventional descriptive statistics were used to present the distortion of the frameworks.[32] Analysis of variance

TABLE 1 Horizontal Distortions

	Width Differences Related to Master	Number of Frameworks with Expansion of Width	Number of Frameworks with Contraction of Width	Curvature Differences Related to Master	Number of Frameworks with Curvature Expansion	Number of Frameworks with Curvature Contraction
Cresco-CoCr ($n = 10$)	−12 (19)	2	8	4 (59)	5	5
Cresco-Ti ($n = 10$)	38 (34)	9	1	−10 (62)	5	5
PIB ($n = 5$)	71 (44)	5	0	−1 (27)	1	4

Width differences: difference in mean distance (standard deviation) in μm between positions #1 and #5 of the frameworks compared to the distance between the same positions of the master model. Curvature differences: mean sagittal difference, y-value (standard deviation) in μm between position #3 of the frameworks compared to the same position of the master model. Directions of distortions are related to Figure 3.

and Tukey's post hoc test were used to identify and study differences between the groups. Because normal distribution could not be verified and the observations were rather few, all significant differences were also validated with Fisher's nonparametric permutation test. Contraction in each framework group was examined with Fisher's nonparametric permutation test for paired observations.[33] Comparisons between the least squares method and the orthogonal 3-2-1 method were performed by Wilcoxon's rank sum test. The level of statistical significance was set to 5% ($p < .05$).

RESULTS

An overall distortion of width (x-axis) and curvature (y-axis) of the frameworks (see Figure 3) is presented in Table 1. A statistically significant expansion of framework width compared to the master model was found in the Cresco-Ti group ($p < .05$). The same tendency was found in the PIB, although it was nonsignificant ($p > .05$). On the other hand, the Cresco-CoCr presented a contraction (x-axis), although it was nonsignificant ($p > .05$). Statistically significant differences between the groups could be observed for the width (x-axis), but not for the curvature (y-axis) of the frameworks (Figures 4–6).

The ranges of individual framework center point distortions in three dimensions are presented in Table 2, and statistical comparisons of the measurements are presented in Figures 4–6. Horizontal distortions (x- and y-axes) were found to be greater than vertical distortions (z-axis) for all groups. When maximal values in absolute figures were compared (see Figures 4–6), the PIB group revealed a statistically significant greater range in the x-axis compared to Cresco-CoCr, but a statistically

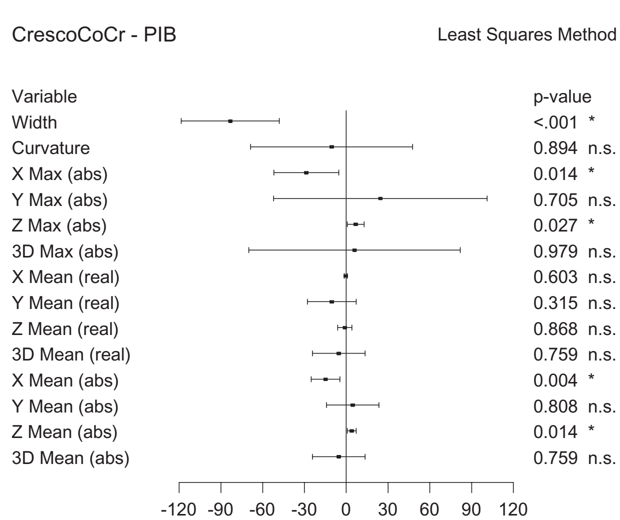

Figure 4 Comparison between Cresco-CoCr and PIB distortions. Means in μm, 95% confidence intervals, and p values. n.s. = nonsignificant. *$p < 0.05$.

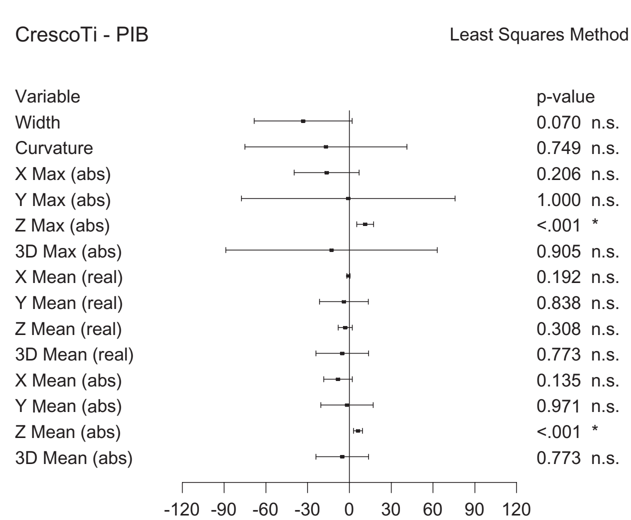

Figure 5 Comparison between Cresco-Ti and PIB distortions. Means in μm, 95% confidence intervals, and p values. n.s. = nonsignificant. *$p < 0.05$.

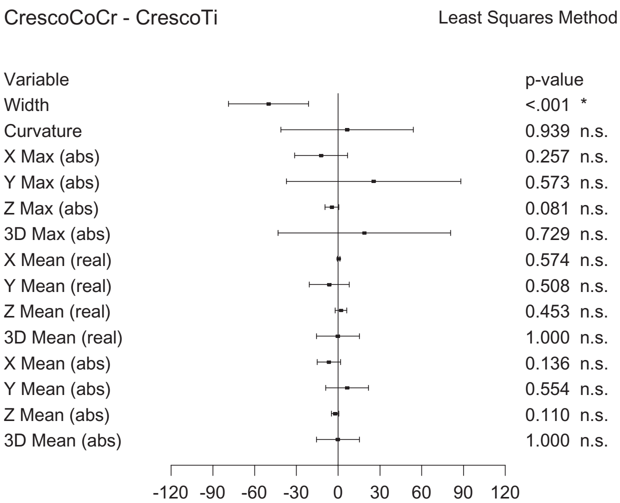

Figure 6 Comparison between Cresco-CoCr and Cresco-Ti. Means in µm, 95% confidence intervals, and p values. n.s. = nonsignificant. $^{*}p < 0.05$.

significant smaller range in the z-axis in relation to the two Cresco groups ($p < .05$).

Analysis of the direction of distortions (ie, in real values) revealed no statistically significant differences in any direction. However, trends of mean expansion of the frameworks at the terminal implants (Table 3; x-axis in position #1 compared to position #5) could be observed for both Cresco-Ti and PIB groups, respectively. On the other hand, when distortions regardless of direction (ie, in absolute figures) were analyzed, statistically significant transversal (x-axis) differences between Cresco-CoCr and PIB, and differences in vertical dimensions (z-axis) between Cresco-CoCr and PIB, as well as between Cresco-Ti and PIB (Table 4, Figures 4–7), were revealed ($p < .05$).

In Figure 7, results from the analyses using the least squares and the orthogonal 3-2-1 methods are presented. Significantly greater displacements ($p < .05$) were found with the orthogonal 3-2-1 method in the x-axis (Cresco-Ti), z-axis (Cresco-CoCr), and in three dimensions (Cresco-Ti). On the other hand, a significantly smaller displacement was found with the orthogonal 3-2-1 method in the z-axis for the Cresco-Ti group. No statistically significant differences between the two fit analytical methods were found for the PIB group.

DISCUSSION

The present study revealed horizontal displacements (x- and y-axes) in various directions for the different materials and fabrication methods. The Cresco-CoCr frameworks showed a contraction analogous to earlier reports on conventional cast frameworks,[18,34] then referred to as contraction distortions related to the investing and casting processes.[34] Similar horizontal contraction of the frameworks was also reported for the "second generation of welded titanium framework," by Jemt and colleagues.[11,25,26] In contrast, the present Cresco-Ti and the PIB frameworks expanded in accordance with the CNC-milled CP titanium frameworks, reported by Al-Fadda and colleagues.[18] On the other hand, Eliasson[30] studied another brand of CNC-milled CP titanium frameworks (I-bridge®, Biomain AB, Helsingborg, Sweden) showing contradictory results of horizontal expansion of the metal frameworks. The differences in contraction and expansion of various fabrication techniques indicate that the production of frameworks is a delicate and precise procedure and that a seemingly small variation in techniques nevertheless results in contradictory distortion patterns.

One such variation in the fabrication process could be the welding of the Cresco frameworks, because welding procedures unavoidably lead to an increase in temperature within the frameworks. The duration of the laser pulse was nearly twice as long for the Cresco-CoCr compared to the Cresco-Ti, and a higher energy was

TABLE 2 Individual Center Points Against Master Model Distortions in µm for the Frameworks (Minimum Values, Maximum Values, and Ranges)

	Minimum	Maximum	Range
Cresco-CoCr ($n = 10$)			
x-axis	−34	26	60
y-axis	−281	44	325
z-axis	−17	18	35
Three dimensions	2	281	279
Cresco-Ti ($n = 10$)			
x-axis	−66	58	134
y-axis	−125	58	183
z-axis	−19	24	43
Three dimensions	5	130	125
PIB ($n = 5$)			
x-axis	−91	55	146
y-axis	−52	60	112
z-axis	−9	6	15
Three dimensions	8	105	113

TABLE 3 Real Mean Distortions (Standard Deviation) in μm Between Frameworks and Master Model for Comparison of Individual Sites

Position	x	y	z	Three Dimensions
Cresco-CoCr ($n = 10$)				
# 1	−6 (14)	−2 (16)	4 (2)	20 (7)
# 2	−9 (7)	−4 (23)	−10 (6)	26 (9)
# 3	−2 (14)	−4 (46)	10 (8)	38 (30)
# 4	7 (17)	−9 (96)	−6 (5)	54 (80)
# 5	6 (14)	−13 (16)	1 (2)	22 (13)
Mean	0 (14)	−6 (48)	0 (9)	32 (40)
Cresco-Ti ($n = 10$)				
# 1	13 (27)	8 (24)	1 (3)	32 (21)
# 2	−3 (23)	−8 (14)	−6 (5)	26 (10)
# 3	−8 (18)	−10 (46)	14 (4)	40 (33)
# 4	7 (13)	18 (20)	−15 (3)	31 (13)
# 5	−23 (22)	−7 (16)	5 (2)	33 (14)
Mean	0 (24)	0 (28)	0 (11)	32 (20)
PIB ($n = 5$)				
# 1	23 (11)	16 (22)	0 (2)	33 (14)
# 2	8 (19)	−13 (15)	0 (4)	24 (13)
# 3	−6 (20)	7 (17)	2 (4)	25 (6)
# 4	25 (29)	13 (36)	−2 (5)	45 (24)
# 5	−48 (34)	−2 (38)	0 (1)	61 (29)
Mean	0 (35)	4 (27)	0 (3)	37 (22)

thereby achieved within the Cresco-CoCr frameworks. These differences, in addition to the inferior thermal conductivity of titanium compared to cobalt-chrome, may also have an impact on the different distortion patterns.

The frameworks in the present study had a greater maximal distortion range of individual center points in the horizontal plane compared to the vertical plane, similar to observations in previous studies.[16,18,30] This could be explained by the fit assessment procedure, disregarding the physical extension of the hardware components and minimizing the vertical gaps that could be found in clinical situations. Yet, on a theoretical basis, it could be suggested that as long as implants are placed in parallel, horizontal displacements can be compensated for to some degree by the machining tolerance of the implant components.[26]

It has been reported that vertical discrepancies may lead to higher stress levels than those obtained by horizontal distortions.[35,36] Consequently, an interesting finding in this study was the significant ($p < .05$) vertical differences between the Cresco groups and the clinical controls (PIB). Whether the magnitude of these vertical differences has any clinical impact or not needs to be confirmed by clinical studies. However, the few animal studies available that have focused on the biological

TABLE 4 Mean Distortions (Standard Deviation) in μm Between Frameworks and Master Model for Comparison of the Three Groups in Absolute Figures

	x	y	z	Three Dimensions
Cresco-CoCr ($n = 10$)	12 (8)	26 (41)	6 (5)	32 (40)
Cresco-Ti ($n = 10$)	18 (15)	19 (20)	9 (6)	33 (21)
PIB ($n = 5$)	27 (22)	21 (17)	3 (2)	37 (22)

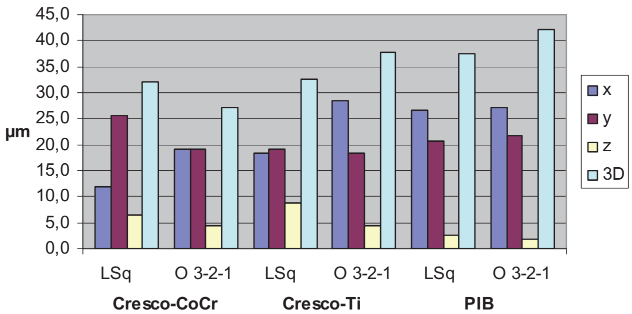

Figure 7 Mean distortions (µm) of the center points of the frameworks with the master model as a reference in absolute figures, using the least square (LSq) and orthogonal 3-2-1 (O 3-2-1) analytical methods for the three groups.

impact of vertical misfit indicate that misfit preload seems to have more impact on bone response than magnitude of the vertical gap.[37–39] Considering these observations, it could be more crucial to reduce vertical gaps in the present frameworks connected directly to the implants, where higher preload forces could be anticipated. Thus, compared to prostheses made on the abutment level, the screwdriver torque recommended for prostheses made according to the present study is much higher (35 Ncm compared to 10–15 Ncm). Earlier studies demonstrated the possibility of decreasing a vertical misfit by increasing the tightening force.[40] As a result, increasing the applied preload can reduce to some degree an existing misfit between prosthesis and implant, but the consequence is the introduction of higher stress levels in the screw joint and the peri-implant tissues. Furthermore, new materials such as titanium for prosthesis retention screws and cobalt-chrome for framework fabrication are less flexible compared to the earlier, more commonly used gold alloys. As a consequence, an even higher stress level could be introduced. Although studies presenting short-term results of frameworks made on the implant level report few complications and no increase in bone loss compared to frameworks made on the abutment level, long-term effects are unknown.[21,22]

The two analytical least squares and the orthogonal 3-2-1 methods are commonly used techniques.[41] As could be expected considering the nature of the two techniques, slightly lower levels of distortion for the least squares method were observed, in accordance with an earlier publication.[30] Thus, precision of fit seems to be a relative observation, dependant on what mathematical logarithms used in the computer. As a consequence, it would be difficult to compare precision of fit of different frameworks when using dissimilar fit assessment techniques. However, in view of the fact that both analytical methods, orthogonal 3-2-1 and least squares, work in a virtual world and ignore the physical limits of reality by permitting negative vertical (z-axis) values, they also underestimate the vertical distortions.

The test groups, Cresco-CoCr and Cresco-Ti, presented similar distortion ranges as the clinical controls, PIB. The standard deviations for the center point distortions in the three groups were generally greater than presented in the study by Örtorp and colleagues,[16] where one single scanning procedure was used for all frameworks. Because the present variations are in accordance with the observations reported by Al-Fadda and colleagues,[18] who also used individual pairs of models or frames as in the present study, it could be assumed that the difference in fabrication or scanning procedures will have an impact on variations in center point distortions.

Because different fabrication techniques can influence the precision of fit for implant-supported frameworks on implants, an increased use of computer support in the fabrication process could be expected to decrease the level of misfit. Örtorp and colleagues[16] found some support for this assumption in their results. Thus, CNC-milled frameworks could be expected to present a higher precision of fit than the Cresco method because the latter includes several demanding technical steps which can all be crucial for the outcome. However, the present study revealed only minor differences between the two methods, which are of unknown clinical importance.

CONCLUSIONS

1. Neither the Cresco nor the PIB frameworks presented a “perfect” or completely “passive” fit.
2. Using different methods of fit assessments revealed significant differences of framework precision.
3. Although the direction of distortions varied, the horizontal distortions were of similar magnitudes in the Cresco frameworks compared to the PIB frameworks.
4. Statistically significant smaller vertical distortions were found among the PIB frameworks compared to the Cresco groups.
5. Clinical studies are needed to examine the clinical significance of the results presented in this study.

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