Dimensional Accuracy and Retentive Strength of a Retrievable Cement-retained Implant-supported Prosthesis

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The purpose of this research project was to compare the fit of a retrievable cement-retained implant-supported framework to that of a traditional wax and cast, screw-retained framework and to test the strength of the cemented restoration. Ten telescopic frameworks were luted to gold cylinders with a bis-GMA resin cement. The control group consisted of 10 frameworks fabricated with traditional wax and casting techniques directly to the gold cylinders. Frameworks were analyzed for distortion in the z-axis using scanning electron microscopy and a single screw test. Results demonstrated that the retrievable cement-retained group had a decreased gap distance and improved angular distortion (statistical significance P < .01) compared to the control group. Retentive strength measurements for the cement-retained group with a direct pull-out test revealed a mean pull-out force of 65.7 kg. Three of the 5 samples surpassed the tensile strength of the gold retaining screws (76 kg). Cement-retained restorations demonstrated superior fit in the z-axis and angular distortion compared to traditional wax and cast screw-retained frameworks. Retentive tests support a simplified technique of clinically luting telescopic implant-supported frameworks with adequate retentive strength. (INT J ORAL MAXILLOFAC IMPLANTS 2001;16:547–556)

Key words: *dental cement, dental implants, dental materials, fixed partial denture, implant-supported dental prosthesis, prosthesis fitting*

Numerous authors have addressed the necessity for passive-fitting implant-supported prostheses and their relationship to complications and long-term success. Some of the current literature questions the significance of passive prosthesis fit and its relationship to maintenance of osseointegration.[1–4] However, misfitting prostheses may cause prosthetic complications such as screw loosening, component fracture, or loss of osseointegration.[5–11] Therefore, to maximize preload of retaining screws, it is advantageous to establish passive-fitting implant-supported prostheses.[12]

Generating a passive fit with screw-retained restorations presents limiting factors. Wee and colleagues categorized each prosthetic procedure and resultant inaccuracy in replicating implant or abutment platform location.[13–16] Research to date substantiates limiting factors present in each area of the distortion process.[17–39] Jörnéus and coworkers[12] and Rangert and associates[40] concluded that the closer component stacks are clamped together, the greater the preload that is placed in the screw stem, with resultant decreased screw loosening. Laser videography,[41] photogrammetric analysis,[42,43] strain analysis,[44] and other techniques[45] have demonstrated the inaccuracies in framework fit. Smedberg and colleagues have demonstrated that framework misfit will produce strain on implants.[4] Therefore, one must consider the implication of clinical misfit on implants. In a 5-year study, Jemt and Book[2] demonstrated a lack of marginal bone loss in spite of misfitting frameworks. Animal studies using rabbit tibiae and baboon jaws revealed continued bone

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Fig 1a Simulated metal master cast.

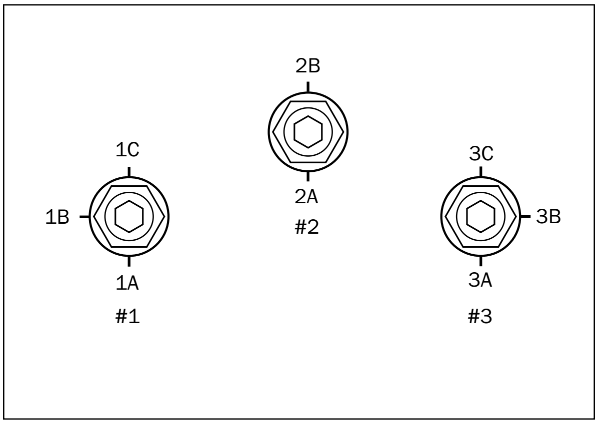

Fig 1b Reference point locations.

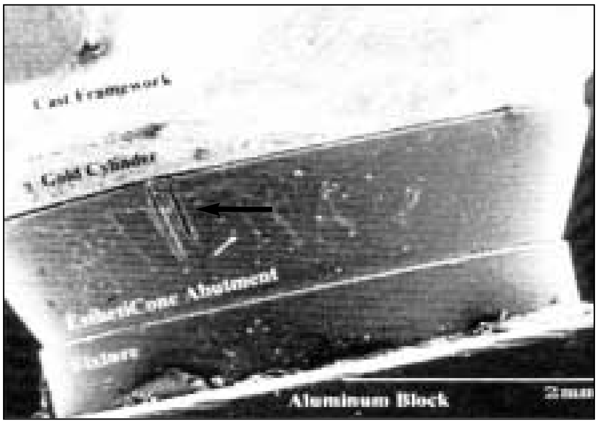

Fig 1c Scanning electron micrograph of reference point IIC *(arrow).*

remodeling around implants with frameworks of varied misfit. Limitations of this research include the fact that the model contained unloaded implants.[1,3] This appears to be in direct controversy with prior authors, who reported that implant loss may be related to non–passive fitting frameworks.[7,46]

Advocates of cement-retained restorations cite improvement in esthetics, passive fit, simplified prosthetic procedures, and lower fabricating cost.[47–49] Proponents of screw-retained prostheses suggest their retrievable nature as a significant advantage and question the degree of retrievability of cement-retained restorations.[50,51]

To achieve passive-fitting screw-retained prostheses, Voitik introduced the Kulzer Abutment Luting (KAL) technique (Attachments International, San Mateo, CA).[52] Luting of a telescopic framework intraorally to the gold cylinders overcomes the inaccuracies of master cast and prosthesis fabrication. By modifying Voitik's KAL technique, Aparicio[53] luted telescopic fixed partial dentures (FPDs) to modified EsthetiCone gold cylinders (Nobel Biocare, Göteborg, Sweden). During a 2-year clinical observation, no decementation of any gold cylinders in 64 prostheses supported by 214 abutments was noted.

The purpose of this laboratory study was to compare the fit of a retrievable, cement-retained, implant-supported FPD with the fit of a conventional wax and cast implant-retained FPD. Second, the retentive strength of a retrievable, cement-retained, implant-supported FPD was also evaluated. The null hypothesis states that the wax, cast, and soldered FPD frameworks demonstrate no difference in fit from the retrievable, cement-retained, FPD frameworks.

MATERIALS AND METHODS

Simulated Master Cast Fabrication

Three 10-mm screw-type implants (SDCA 018, Nobel Biocare, Yorba Linda, CA) were luted in an aluminum block with dual-cure Nexus resin cement (Kerr Company, Romulus, MI) 7 mm apart from center to center (Fig 1a). The middle implant was offset by 2 mm to a straight line through the outermost implants (Fig 1b). EsthetiCone abutments (1 mm, SDCA134, Nobel Biocare) were luted to the implant with dual-cure Nexus resin cement and torqued to 20 Ncm (Torque Controller DEA20, Nobel Biocare). Resin cement was used to lute the abutments and implants to ensure a stable abutment platform throughout the experiment.[23] Eight reference points (1A, 1B, 1C, 2A, 2B, 3A, 3B, and 3C) were marked on the lateral aspect of the abutment cylinders (Fig 1c).

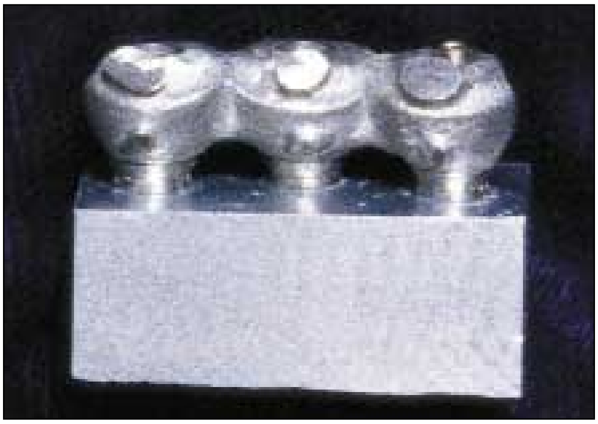

Fig 2a Control group: FPD fabricated using wax and casting technique directly to gold cylinders.

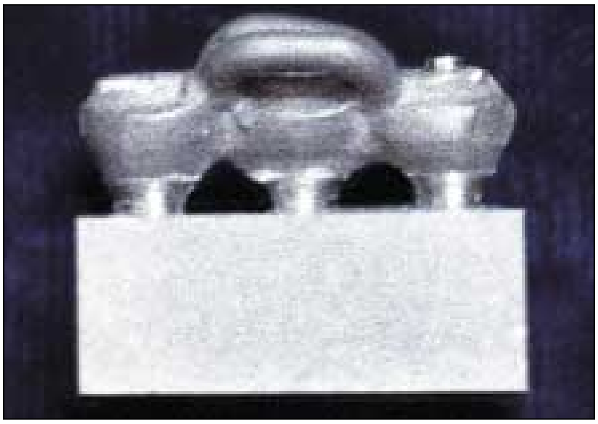

Fig 2b Experimental group: telescopic frameworks luted to EsthetiCone gold cylinders.

Control Group

Ten FPDs were waxed (Jelenko red casting wax, Armong, NY) and cast directly to the gold cylinders (DCB141, Nobel Biocare) with a high-palladium alloy (Cerapall 6, Metalor, North Attleborough, MA). The patterns were invested with a ringless system and cast using an oxygen-propane torch (Fig 2a). A split-mold technique was utilized to reproduce framework dimensions. The passive fit of all 10 frameworks was checked by 4 experienced independent investigators. The single screw test in all 3 positions using 2.75× telescopic lenses was performed to simulate clinical conditions. Fixed partial dentures that were determined to be inaccurate by any one independent investigator were sectioned, soldered (VS1 C, Metalor), or recast until all 4 examiners judged the fit acceptable.

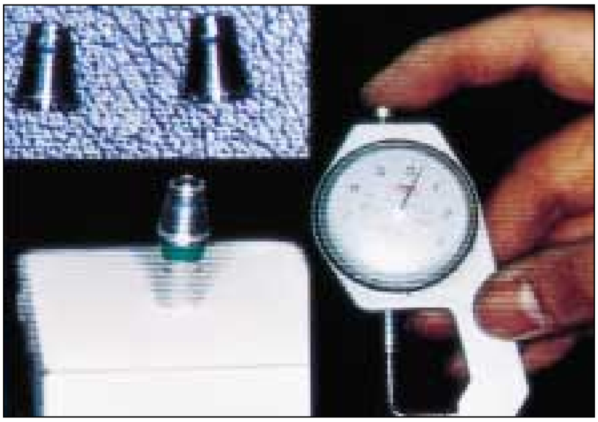

Fig 3 *(Above left)* Modified gold cylinder with retentive groove blocked out, *(below left)* plastic shim on gold cylinder, and *(right)* 0.3-mm shim thickness.

Experimental Group

Ten retrievable telescopic cemented-retained FPDs were fabricated as follows (Fig 2b). Thirty gold cylinders (DCB141, Nobel Biocare) were modified by eliminating the square corners of the coronal retentive element. The remaining neck grooves of these gold cylinders were blocked out by a layer of Stabiloplast (Denerica-Renfert, Renfert, Germany) (Fig 3). Plastic shims were fabricated with .02-inch temporary splint material (Henry Shein, Melville, NY) by using a vacuum-forming machine (Sta-Vac, Buffalo Dental, Syosset, NY) (Fig 3). The thickness of the plastic shims was controlled to 300 µm (Fig 3). The purpose of plastic shims was to create a cement space between modified gold cylinders and telescopic frameworks.

The modified gold cylinders were placed on the abutments and torqued to 10 Ncm on the implant cast. Plastic shims were placed on the modified gold cylinders and the telescopic frameworks waxed and cast utilizing the technique mentioned previously. Eight-gauge wax loops were added to the frameworks prior to casting to secure the telescopic frameworks for the retentive test portion of the experiment. Passive fit of the castings was verified with Fit-Checker (GC America, Chicago, IL) and any discrepancies removed to ensure passive seating of the castings.

The inner surface of the telescopic castings and outer surface of the modified gold cylinders were air-abraded with pure 50-µm aluminum oxide particles at 80 psi from a distance of 2 cm for 10 seconds (Micro-air abrader, Danville Engineering, Danville, CA). A simplified technique of luting the telescopic frameworks with a bis-GMA composite luting cement and tin plating or metal priming is proposed. The telescopic frameworks were divided into

2 groups. In Group I, the air-abraded surface was tin plated with a plating unit following the manufacturer's directions (Micro Tin, Danville Engineering) (Fig 4). In Group II, the air-abraded surface was treated with metal primer (Panavia, J. Morita, Tustin, CA). Metal primer was used in group II to compare retentive strength in relation to tin plating.

The modified gold cylinders were placed on the abutments and torqued to 10 Ncm on the implant cast. The telescopic castings were luted to the modified gold cylinders with resin cement (Panavia 21) under constant pressure for 15 minutes.

Data Collection and Analysis

Fit of the as-received gold cylinders was evaluated by measuring the vertical discrepancy (gap distance) between the abutment and gold cylinder platforms under a scanning electron microscope (Type S-Z460N MFG No. 11-06, Hitachi, Tokyo, Japan) by placing 3 gold cylinders on the simulated metal master cast (Fig 1a). Measurements were taken at the reference points (Fig 1b). This procedure was repeated 3 times with new gold cylinders for a total of 24 points of reference. Results demonstrated an average gap distance of 4.99 µm (SD 2.5 µm). Both the control and experimental groups were evaluated with a single-screw test technique. Vertical gap distance between all the fixed partial dentures and abutments was measured at the 8 reference points under scanning electron microscopy (SEM) with one screw tightened to 10 Ncm in abutment position 1 or 3 for both the control and experimental groups. Means were established at each abutment–gold cylinder position by averaging the 3 points of reference at positions 1 or 3 and the 2 points of reference at position 2 (Fig 1b). This was completed for each sample, resulting in an effective sample size of 10 per group. All SEM measurements were performed by one investigator. Vertical gap as described by Holmes and coworkers[54] was determined by the measured distance between the gold cylinder and abutment cylinder platforms. The SEM recordings were printed on a Hewlett-Packard LaserJet printer (Palo Alto, CA) and measurements performed from the hard copies with use of the printed scale (Figs 5 and 6). Groton and colleagues[55,56] demonstrated that a variation in tilt angle caused a projection error of 15%. Results of the present study do not allow a clear statement concerning the accuracy and precision of the SEM measurements. The authors also note a low power of inference because of the limited number of measurement sites at each abutment–gold cylinder connection.

Fig 4 Gold cylinders and telescopic frameworks after air abrading and tin plating.

Mechanical pull-out tests were performed on the experimental group to evaluate the retentive strength of the adhesive system. Each telescopic FPD was subjected to a tensile load at a crosshead speed of 5 mm/min in a 500-kg load cell, and the peak load was recorded. SPSS statistical software (release 9.0 for Windows, SPSS, Chicago, IL) was

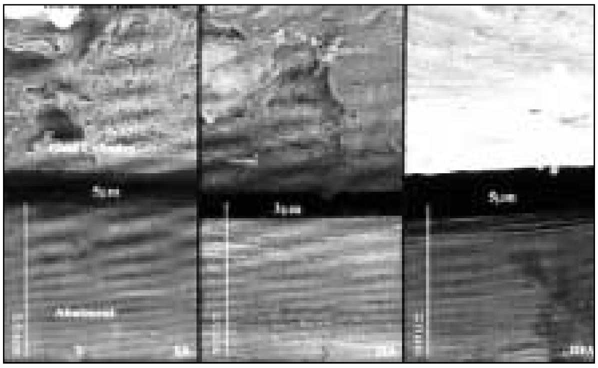

Fig 5 Scanning electron micrographs of experimental group, sample 2, screw in position 1.

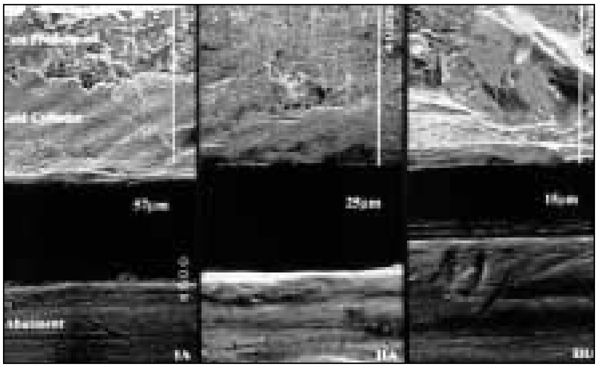

Fig 6 Scanning electron micrographs of control group, sample 5, screw in position 3.

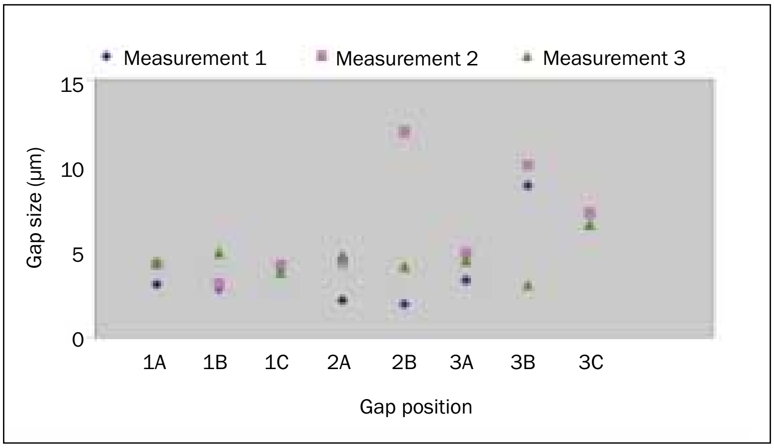

Fig 7 Gold cylinder–abutment cylinder machined tolerance levels. Measurement between abutments and gold cylinders before casting.

used for all statistical procedures. Average measurements were established using the 3 points of reference at positions 1 and 3 and the 2 points of reference at position 2. This was performed for all 10 samples in both the control and experimental groups. Means and standard deviations (SD) for all 10 samples in both groups were calculated for each location with the screw in position 1 or 3. Parametric analysis revealed skewed results. An analysis of the histograms for each group revealed abnormal distribution curves. Therefore, a non-parametric analysis utilizing ranks was substituted to evaluate the results. Vertical discrepancy values and angular distortion were compared for the retrievable telescopic cemented FPDs and conventional FPDs using the Mann-Whitney test at a significance level of $P < .05$.

RESULTS

Figure 7 plots the data for vertical gap distances between the gold cylinder and abutment cylinder platforms. As-received vertical gaps averaged 4.99 ± 2.5 µm. Figures 8 and 9 and Table 1 show the results of the vertical discrepancy in the experimental and control groups with gold screws in position 1 or 3. Control group specimens clamped in position 1 demonstrated average vertical discrepancy values at abutments 1, 2, and 3 of 5.6 ± 2.4 µm, 19.3 ± 6.7 µm, and 29.7 ± 14.5 µm, respectively. In the experimental group clamped in position 1, the average vertical discrepancy values at abutments 1, 2, and 3 were 4.0 ± 1.1 µm, 5.2 ± 1.6 µm, and 8.4 ± 2.5 µm (Fig 5). These data demonstrate that vertical discrepancy of the experimental FPDs at abutments 2 and 3 was smaller than that of the control FPDs ($P < .01$). When the gold screw was tightened at abutment position 3, the vertical discrepancy values of the experimental group at abutment positions 1, 2, and 3 were 11.4 ± 7.0 µm, 5.6 ± 3.4 µm, and 4.5 ± 0.5 µm, respectively. In the control group tightened in position 3, the average vertical discrepancy values for abutments 1, 2, and 3 were 32.9 ± 13.9 µm, 20.9 ± 6.4 µm, and 7.5 ± 2.9 µm, respectively (Fig 6). These data demonstrate that the average vertical gap of the experimental group at abutments 1 and 2 was smaller than that of the control group ($P < .01$).

Angular distortion results revealed no statistically significant difference between the control group and experimental group at the clamped ends (position 1 or 3, $P = 1$ and $P > .5$, respectively). At the unclamped ends, a statistically significant difference in angular distortion was noted (position 1 or position 3, $P < .01$; Table 2).

Samples used for retentive strength measurements were divided into 2 groups (Table 3). Group I used tin-plating techniques and group II used Panavia metal primer. The primary purpose of the investigation was to evaluate the dimensional accuracy between the experimental and control groups. Samples were neither stored in water nor subjected to thermocycling to eliminate the effect of hydrating and dehydrating the samples during the SEM measurement period (60 days). The authors are aware of the limited value of the retentive data in the absence

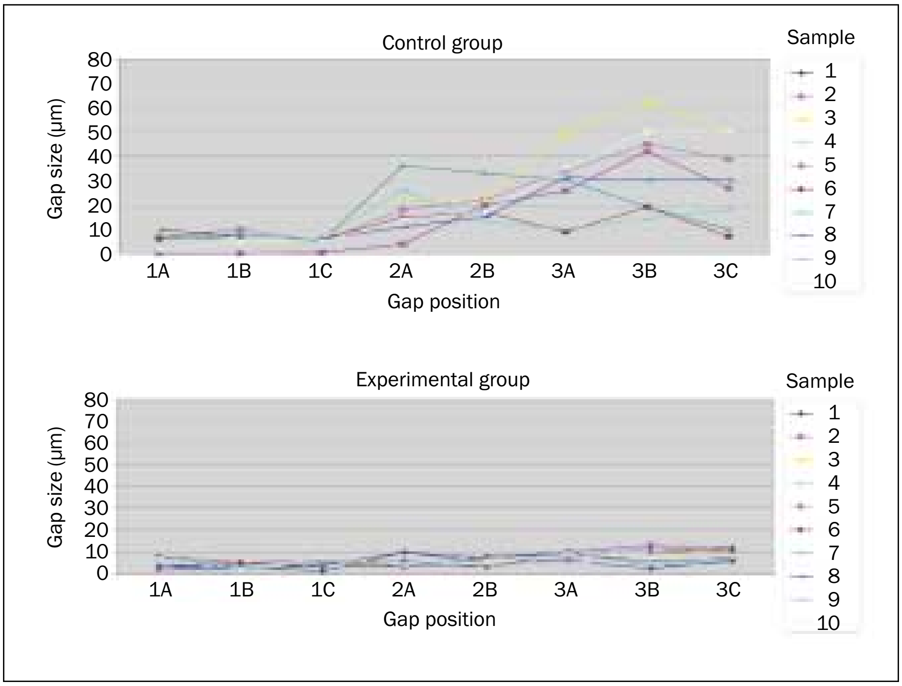

Fig 8 Size of gold cylinder–abutment gap in control and experimental groups with screw in position 1.

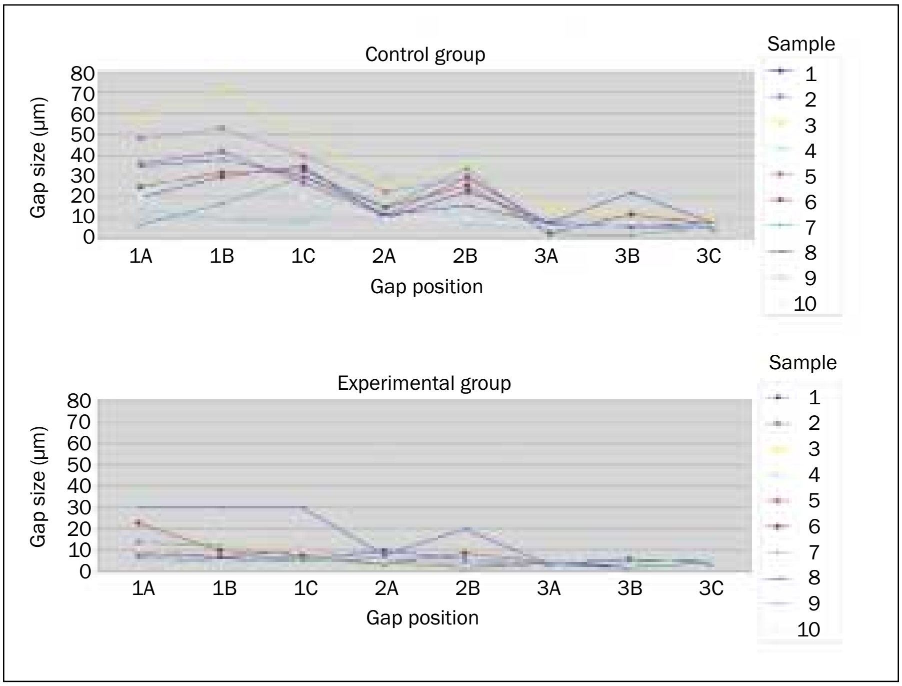

Fig 9 Size of gold cylinder–abutment gap in control and experimental groups with screw in position 3.

Table 1 Comparison of Gaps (Mean ± SD) in Control and Experimental FPDs

Screw/torque	Abutment	Control gap (µm)	Experimental gap (µm)	*P* value*
Position 1, 10 Ncm	1	5.6 ± 2.4	4.0 ± 1.1	< .03
Position 1, 10 Ncm	2	19.3 ± 6.7	5.2 ± 1.6	< .01
Position 1, 10 Ncm	3	29.7 ± 14.5	8.4 ± 2.5	< .01
Position 3, 10 Ncm	1	32.9 ± 13.9	11.4 ± 7.0	< .01
Position 3, 10 Ncm	2	20.9 ± 6.4	5.6 ± 3.4	< .01
Position 3, 10 Ncm	3	7.5 ± 2.9	4.5 ± 0.5	< .01

*Mann-Whitney test.

Table 2 Means and Standard Deviations of Angular Distortion ($d\theta_z$ Comparison)

Screw	Abutment	Control (10^{-3} deg)	Experimental (10^{-3} deg)	*P* value*
Position 1	1	0.97 ± 0.65	0.96 ± 0.44	1
Position 1	3	3.87 ± 1.89	1.01 ± 0.53	< .01
Position 3	1	4.34 ± 2.27	1.21 ± 1.08	< .01
Position 3	3	1.61 ± 1.63	0.87 ± .039	> .5

*Mann-Whitney test.

Table 3 Direct Pull-out Test Data

Sample	Pull-out strength (kg)	Surface treatment	Separation	*P* value†
1*	192.6	Tin plated	Two screws fractured	
2	43.65	Tin plated	Debond	
3	76.05	Tin plated	Screw fractured	
4	65.7	Tin plated	Debond	
5	75.375	Tin plated	Screw fractured	
Mean (2–5)	65.2 ± 15.1	Tin plated	—	
6	0	Metal primer	Debond	
7	25.74	Metal primer	Debond	
8	35.505	Metal primer	Debond	
9	58.005	Metal primer	Debond	
10	46.395	Metal primer	Debond	
Mean (6–10)	33.1 ± 22	Metal primer	—	
Comparison of means				> .06

*All 3 gold screws were torqued to 10 Ncm.
†Mann-Whitney test.

Fig 10 Retentive test on sample 1 showing fractured gold screws.

of thermocycling. Three of the 5 tin-plated samples demonstrated retentive strength beyond the pull-out strength of the gold retaining screws. Mean pull-out force was 65.19 kg for the tin-plated group (does not include sample 1) and 33.12 kg for the metal primer group. Gold screws fractured at 76 kg of pull-out force. The remaining 2 specimens in Group I separated at 43.65 and 65.7 kg of pull-out force. Group II (metal primer) specimens separated at an average of 33.12 kg of pull-out force. No statistically significant difference was noted ($P > .06$) between the 2 groups.

DISCUSSION

The current results demonstrate a minor effect of the polymerization shrinkage of the resin cement on 3-dimensional positioning of the gold cylinder platform. Improved results in gap distances in the experimental group existed in a linear relationship from the clamped to the unclamped end of the prosthesis. Also, an improvement in angular distortion ($d\theta_z$) of the gold cylinders between the experimental group and the control group was demonstrated at the unclamped ends (Table 2). This demonstrated an improvement in the "moment arm" effect. Vector analysis of the linear distortion of the control groups validates Jemt's finding of gap distances in excess of 100 µm in large, implant-supported frameworks.[43]

The current research project eliminated all sources of error from impressioning and machined tolerance level of components. Therefore, misfit in the control group was limited to waxing, investing, and casting errors. One could assume greater magnitudes of distortion if impressioning and veneer application had been introduced into fabrication of the control group samples.

As a result of the relatively small surface area of an EsthetiCone gold cylinder, it was necessary to evaluate retentive strength to validate the clinical application of the prosthetic protocol. The first sample in the tin-plated group had all 3 gold screws torqued to 10 Ncm. At 192.6 kg of pull-out force, the sample separated from the test model. Gold screw fracture was noted in positions 1 and 3, and the abutment in position 3 revealed a bent abutment screw (Fig 10). To salvage the test specimen for the duration of the study, only 1 screw was used in position 2 and torqued to 10 Ncm. The mean pull-out force of 65.19 kg for the tin-plated group approached the fatigue failure of the gold screw. Sample 1 (3 screws placed) was not included with samples 2 through 5 (1 screw each placed) in the statistical analysis because of variation in retaining screw number. The specimens in the metal primer group revealed a lower mean retentive value of 33.12 kg of pull-out force.

A bis-GMA resin with tin plating was used to eliminate the technical difficulties and added expense of silicoating the frameworks and gold cylinders.[53,57] Panavia 21 has demonstrated high retentive values in numerous studies.[57–60] Triolo and associates[60] demonstrated a significant increase in retentive bond strength with air abrasion and tin plating. Results of the present study revealed high retentive strength values in spite of the 300-µm film thickness and high palladium content of the telescopic frameworks.[58]

Prostheses connected directly to implants allow for increased torque values to retaining screws. Any degree of prosthesis misfit will increase stress on the implants. The technique may offer a significant improvement in the stress relationship of prostheses directly connected to implants. Assuming access to the retaining screws, a passive-fitting retrievable prosthesis may be fabricated that can be retained with a high degree of clamping force.

CONCLUSION

The results of this project demonstrated a statistically significant improvement in passive fit of retrievable cement-retained prostheses versus traditional wax, cast, and soldered implant-supported frameworks in the z-axis and angular distortion. Retentive strength measurements revealed that the technique can be applied to intraoral situations with a high degree of confidence. The telescopically cemented technique eliminates errors encountered in the distortion process and allows fabrication of passive-fitting retrievable prostheses. Further research of the dimensional accuracy in the x-y planes needs to be evaluated, along with the retentive strength of cantilever restorations.

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