THE EFFECT OF COMPRESSIVE CYCLIC LOADING ON RETENTION OF A TEMPORARY CEMENT USED WITH IMPLANTS

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KEY WORDS

Temporary cement
Retention
Implant
Cyclic loading

Masticatory forces cause fatigue to cement-retained crowns and abutments and may adversely effect retention. The relation between the number of load cycles and the retentive forces is important. This study evaluated the effect of compressive cyclic loading on the retentive forces of a temporary cement used to retain implant crowns and the relationship between load cycles and retentive forces. Ten castings and implant abutments were cemented with zinc oxide-eugenol temporary cement. The retentive force necessary to dislodge the casting from the abutment was determined before and after the application of 2 Hz of vertical off-axis 3-mm sinusoidal-type compressive cyclic loading between 20 and 130 N for 500 000, 1 000 000, and 5 000 000 cycles. These forces were equivalent to approximately 6 months, 1 year, and 5 years of human mastication. Data before and after the applied loading were analyzed with a paired sample t test ($\alpha = 0.05$). The retentive forces of the 3 groups were analyzed by 1-way analysis of variance and post hoc by Scheffé multiple comparison ($\alpha = 0.05$). The relation of the loading and the altered retentive forces were analyzed with the Pearson correlation coefficient. Compressive cyclic loading reduced the retentive forces significantly in all groups ($P = .000$). The retentive forces were reduced 16.75%, 18.73%, and 19.68% during the applied loading cycles of 500 000, 1 000 000, and 5 000 000. All reduced retentive forces were not significantly different ($P = .792$). Although cyclic loading reduced the retentive forces, the increased cycles had little relationship ($R = 0.119$) to the decreased retentive forces of the temporary cement. The relationship between occlusal loading and retentive force can influence the choice of a temporary cement for a particular clinical situation.

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INTRODUCTION

Screws or cement can be used to join implant restorations with their abutments. Screw-retained restorations are retrievable, often at the expense of occlusion or esthetics.[1] The advantages of cement-retained prostheses include passivity, improved esthetics because of the lack of screw access holes, reduced complexity of the components and laboratory procedures, lower cost, and reduced chair time.[2] Retrievability of cement-retained implant restorations can be difficult if permanent cements are used.[3] Implant-retained prostheses cemented with temporary cements are easier to retrieve.[4] Although easy retrieval is important if screw loosening occurs, improved abutment screw connection design can decrease the incidence of screw loosening.[5,6]

Several factors influence the retention of cemented implant prostheses, including convergence angle, height, and surface roughness of the abutment.[7–9] Hebel and Gajjar[1] believe that an ideal abutment taper and longer walls necessitate the use of a temporary cement for long-term retention.

Cement failure can occur with temporary cements. Singer and Serfaty[10] reported that 9.8% of cement washout occurred during the first year of service, with the principal cause attributed to short abutments (3–4 mm in length). Cement failure will occur more often in the posterior region as compared with the anterior region with the same abutments.[11]

The purpose of this investigation was to compare the effect of compressive cyclic loading on the retentive force of a temporary cement used to retain an implant crown and to evaluate the relationship between loading and different retentive forces.

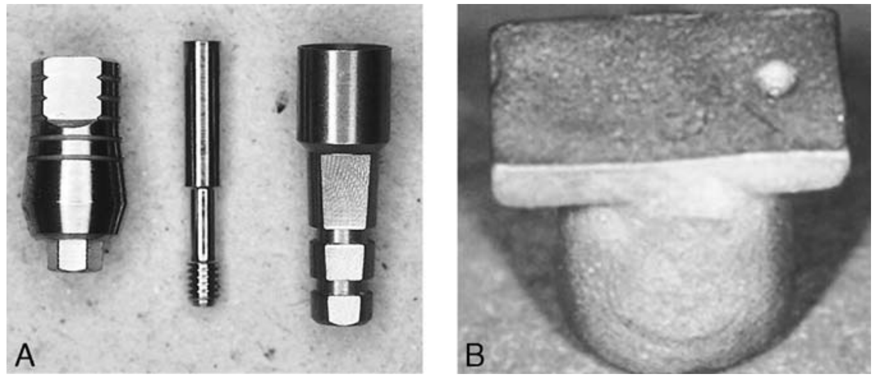

FIGURE 1. (A) Implant abutment (left), abutment screw (middle), and implant analog used in this study (right). (B) Cast crown with a small indentation on the occlusal surface.

METHODS

Ten implant abutments and their implant analogs (Zimmer Dental, Carlsbad, Calif) were used (Figure 1A). Each implant analog was mounted in a 25-mm diameter polyvinyl chloride tube with autopolymerizing acrylic resin (Orthodontic Resin, Harry J. Bosworth Company, Skokie, Ill) with the aid of a dental surveyor. An implant abutment was placed on each analog and torqued to 30 N-cm.

One implant abutment was used to create a master die. All undercuts and the access hole were blocked out with wax, and a poly(vinyl)siloxane impression was made and poured in type IV dental stone (Vel-Mix, KerrLab, Orange, Calif). Three index holes were made on the handle of the die, and 2 coats of die spacer were applied 1 mm above the margin. Eleven silicone impressions were made on the master die and poured in type IV stone to create 11 final dies.

A final die was used to make a T-shaped resin pattern coping with a 1-mm indentation 0.5 mm in depth and 3 mm from the axis of the abutment on the occlusal surface (Figure 1B). A silicone mold of the resin pattern was fabricated, and 10 standardized wax patterns were made and the margins carefully sealed. The patterns were numbered, sprued, invested (High Span II, J. F. Jelenko & Company, Armonk, NY), and cast in a type III gold alloy (Minigold, Ivoclar Vivident, Amherst, NY).

The castings were divested, cleaned in an ultrasonic cleaner, and adjusted with a silicone-disclosing medium (Fit Checker, GC America Inc, Chicago, Ill) before seating. The inner surfaces of the castings were sandblasted with 50 μm of aluminum oxide and the castings randomly paired with the mounted abutments. The lateral walls of the polyvinyl chloride tubes were numbered for identification during the cementation procedures.

Before cementation, the screw access holes were filled with poly(vinyl)siloxane. The 10 samples were used multiple times during the study. For uniformity, each casting was placed in an ultrasonic cleaner for 30 minutes with a cement-removal solution followed by an additional 30 minutes in distilled water.

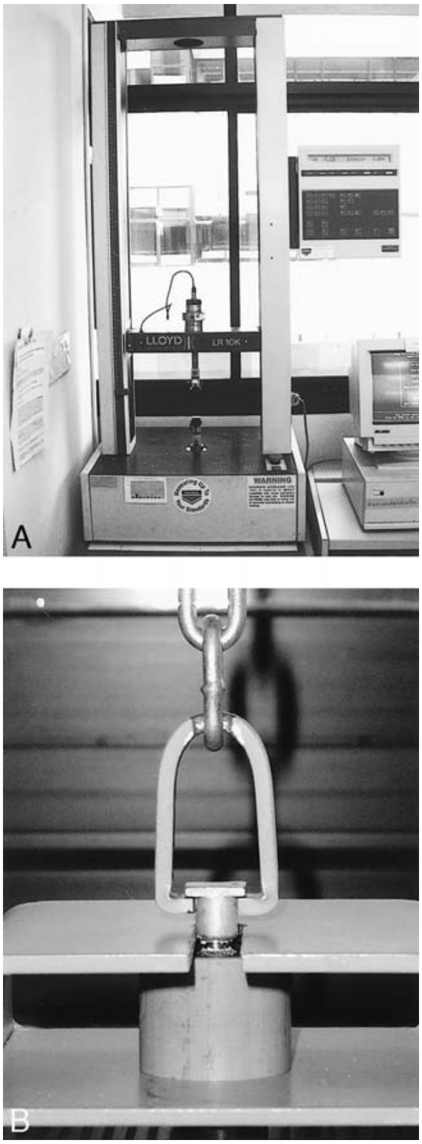

FIGURE 2. (A) Mechanical testing machine. (B) Uniaxial dislodging force was applied to the crown to measure retentive force.

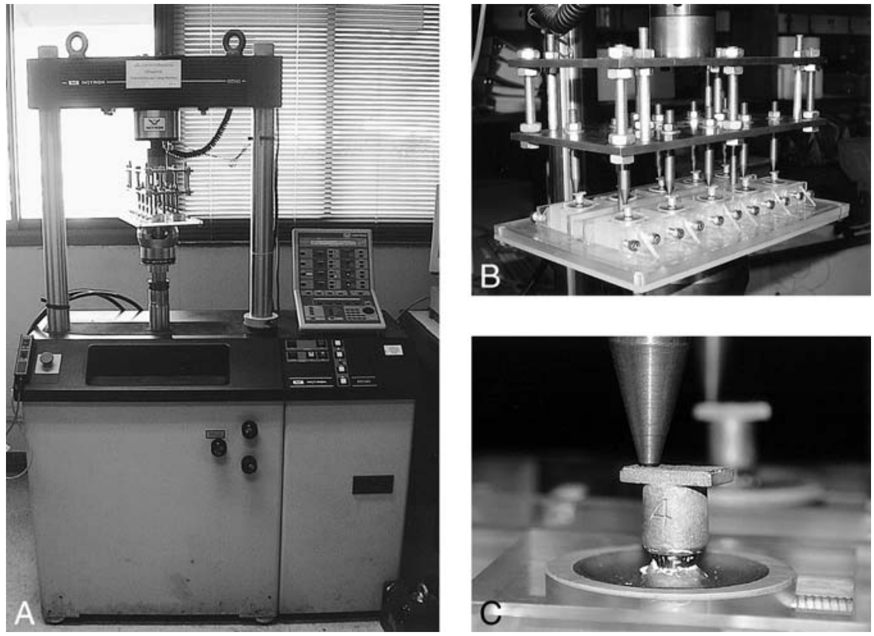

FIGURE 3. (A) Instron servohydraulic machine. (B) Ten specimens were simultaneously loaded. (C) Stylus on the indentation of the crown.

The authors' pilot study indicated that the retentive forces were not significantly different after repeated cementation by this cleaning method, but the retention reusing the loaded crown was unknown. Hence, the retentive forces were measured before and after cyclic loading and were measured again in the unloaded condition to confirm the unchanged retentive forces. The last and the initial retentive forces were compared with a paired sample *t* test ($\alpha = 0.05$). If they were significantly different, the castings that were inadequate to be reused in the next group were remade.

The castings were cemented to the abutments with a zinc oxide-eugenol cement (Temp-Bond, KerrLab) under a 6-kg load for 10 minutes[4] and were then stored at 37°C in an atmosphere of 100% humidity for 24 hours before testing. A load cell of 1000 N on a mechanical testing machine (LR 10K, Lloyd Instruments Ltd, Fareham, Hants, UK) with a crosshead speed of 0.5 mm/min was used to apply a uniaxial dislodging force to each specimen at room temperature (Figure 2).

The servohydraulic machine (Model 8516, Instron Corporation, Canton, Mass) with 10 calibrated identical stations was used as the cyclic testing apparatus. Compressive cyclic loading was applied at room temperature to the prepared recess in each crown by a vertical force (Figure 3). A sinusoidal waveform at 2 cycles per second of compressive loading was applied with cycling between 20 and 130 N to each crown for 500 000, 1 000 000, and 5 000 000 cycles in each group.[12–14] This is equivalent to approximately 6 months, 1 year, and 5 years of in vivo mastication.[15]

Retentive forces before and after loading in each group were analyzed with a paired sample *t* test ($\alpha = 0.05$), and the retentive forces of each group were analyzed by 1-way analysis of variance and Scheffé multiple comparison ($\alpha = 0.05$) if differences were detected. The relation of the loading and the retentive forces were analyzed with the Pearson correlation coefficient.

RESULTS

The results before and after compressive cyclic loading are presented in Tables 1 through 3. Table 4 compares the groups and

TABLE 1
Retentive forces before and after applied 500 000 load cycles

Specimen No.	Retentive Forces (N)		
	Before	After	Before − After
1	230.8	175.2	55.6
2	227.5	201.9	25.6
3	210.5	177.2	33.3
4	255.1	219.4	35.7
5	218.2	173.2	45.0
6	228.0	199.9	28.1
7	225.8	203.5	22.3
8	257.0	171.7	85.3
9	259.0	235.3	23.7
10	272.1	227.3	44.8
Mean ± SD			39.94 ± 19.25

TABLE 2
Retentive forces before and after applied 1 000 000 load cycles

Specimen No.	Retentive Forces (N)		
	Before	After	Before − After
1	232.4	221.7	10.7
2	219.3	195.8	23.5
3	210.0	176.8	33.2
4	257.9	221.9	36.0
5	209.7	153.6	56.1
6	258.6	167.3	91.3
7	229.2	194.6	34.6
8	221.9	170.8	51.1
9	242.6	222.0	20.6
10	255.3	174.7	80.6
Mean ± SD			43.77 ± 26.07

TABLE 3
Retentive forces before and after applied 5 000 000 load cycles

Specimen No.	Retentive Forces (N)		
	Before	After	Before − After
1	266.4	205.0	61.4
2	223.8	170.1	53.7
3	229.6	211.6	18.0
4	242.4	234.1	8.3
5	242.0	194.9	47.1
6	255.7	187.4	68.3
7	254.0	176.1	77.9
8	209.8	204.3	5.5
9	254.1	175.9	78.2
10	234.4	178.1	56.3
Mean ± SD			47.47 ± 27.45

shows a significant reduction in all groups (P = .000). The mean retentive forces before and after compressive cyclic loading were 238.40 ± 20.58 N and 198.46 ± 23.60 N in the applied loading group of 500 000 cycles (reduced 39.94 ± 19.24 N, or about 16.75%), 233.69 ± 19.02 N and 189.92 ± 25.20 N in the applied loading group of 1 000 000 cycles (reduced 43.77 ± 26.07 N, or about 18.73%), and 241.22 ± 17.15 N and 193.75 ± 20.16 N in the applied loading group of 5 000 000 cycles (reduced 47.47 ± 27.44 N, or about 19.68%). The reduced retentive forces of the 3 groups were not significantly different (P = .792) (Table 5, Figure 4). The Pearson correlation coefficient (Table 6) indicated that the increased load cycles had little relation to the decreased retentive forces ($R = 0.119$).

DISCUSSION

Within the severe conditions of the oral environment, the fatigue strength of materials tends to be reduced to a greater extent as compared with that of in vitro studies.[16] The retentive forces of the zinc oxide-eugenol cement evaluated in this study were found to be reduced in 100% humidity because of its high solubility with direct contact with water.[17,18] The extent of the microspace at the margin between the crown and the implant abutment is a significant retentive factor.

The mean retentive forces of the unloaded groups in this study ranged from 230 to 240 N, whereas other investigations using the same temporary cement but different implant systems ranged from 67.13 to 138.87 N.[19–22] The size and contour of the implant abutment should play a major role in its retention. The height of the implant abutments used in this study was 7 mm, with 5 lateral grooves around the surface of the abutment and one third of the wall height being parallel. Most of the abutments from the other studies were CeraOne (Nobel Biocare, Yorba Linda, Calif), which were at most 5 mm in height and had smooth surfaces.[19–21] If the retentive forces of cemented implant crowns in the oral cavity are as high as those observed in this study, implant restorations cemented with temporary zinc oxide-eugenol cements would

TABLE 4
Summary of paired sample t test

	Paired Differences							
				95% CI of the Difference				
	Mean	SD	SEM	Lower	Upper	t	df	P Value (2-tailed)
Before 500 000 − after 500 000	39.9400	19.2492	6.0871	26.1700	53.7100	6.561	9	.000
Before 1 000 000 − after 1 000 000	43.7700	26.0743	8.2454	25.1175	62.4225	5.308	9	.000
Before 5 000 000 − after 5 000 000	47.4700	27.4457	8.6791	27.8365	67.1035	5.469	9	.000

TABLE 5
One-way analysis of variance results for decreased retentive forces comparing of 3 groups

	Sum of Squares	df	Mean Square	F	P Value
Between groups	283.533	2	141.766	.236	.792
Within groups	16233.046	27	601.224		
Total	16516.579	29			

TABLE 6
Summary of the Pearson correlation coefficient for increased load cycles

	Decreased Retentive Forces (N)
Pearson correlation	0.119
P value (2-tailed)	.531
N	30

be difficult to retrieve. With large implant abutments with parallel walls, weaker cements are indicated.

The authors' pilot study indicated that recementation did not affect retentive forces, and it was the load cycle that decreased these forces after cyclic loading. Retentive forces were reduced 16.75% as compared with the unloaded condition at 500 000 cycles. Retention decreased 1.98% with 1 000 000 cycles and 2.93% at 5 000 000 cycles. The greatest reduction of retentive forces occurred during the initial loading (500 000 cycles). Singer and Serfaty[10] reported that the greatest loss of retention between a cemented crown and an implant abutment occurred during the first year in function.

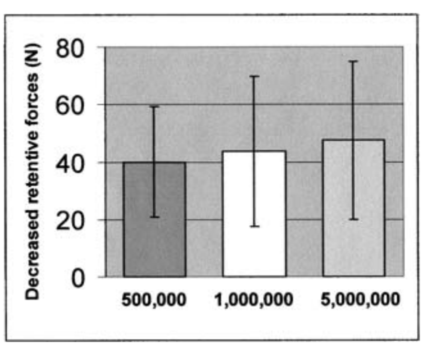

FIGURE 4. Altered retentive forces after different load cycles.

CONCLUSIONS

The results of this investigation suggest (1) vertical off-axis loading can significantly reduce the retentive force of zinc oxide-eugenol temporary cement to retain crowns on implant abutments, (2) retentive forces are not significantly different at different time cycles, and (3) increased loading cycles have little correlation to decreased retentive forces.

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