

Introduction

Cantilevered prostheses have become a common treatment modality to provide patients with sufficient functional units with reduced number of implants to avoid bone augmentation procedures. It is critical to evaluate newly introduced materials that are indicated for implant-supported prostheses to broaden the knowledge on these materials' applicability and limitations, which clinicians and dental technicians could benefit from.

None of previous studies on cantilevered frameworks investigated strength gradient zirconia or new-generation CAD-CAM polymers, and only one has evaluated additively manufactured resins.

Aim of the study

To evaluate how monolithic implant-supported cantilevered prostheses in 4 different polymer-based materials and a subtractively manufactured strength gradient zirconia perform under cyclic loading, and their adhesion to Ti-base abutments.

Null hypothesis

Material type would not affect the survival of implant-supported cantilevered prostheses during cyclic loading and their adhesion to Ti-base abutments after cyclic loading.

Materials and methods

A master standard tessellation language file (9 mm × 11 mm × 20 mm) with a Ti-base space that represents an implant-supported cantilevered prosthesis was used to fabricate specimens from additively manufactured interim resin (AM), polymethylmethacrylate (SM-PM), nanographene-reinforced polymethylmethacrylate (SM-GR), high impact polymer composite (SM-CR), and strength gradient zirconia (SM-ZR) (n=10). Each specimen was treated in line with respective manufacturer's recommendation and Ti-base abutments were cemented with an autopolymerizing luting composite.

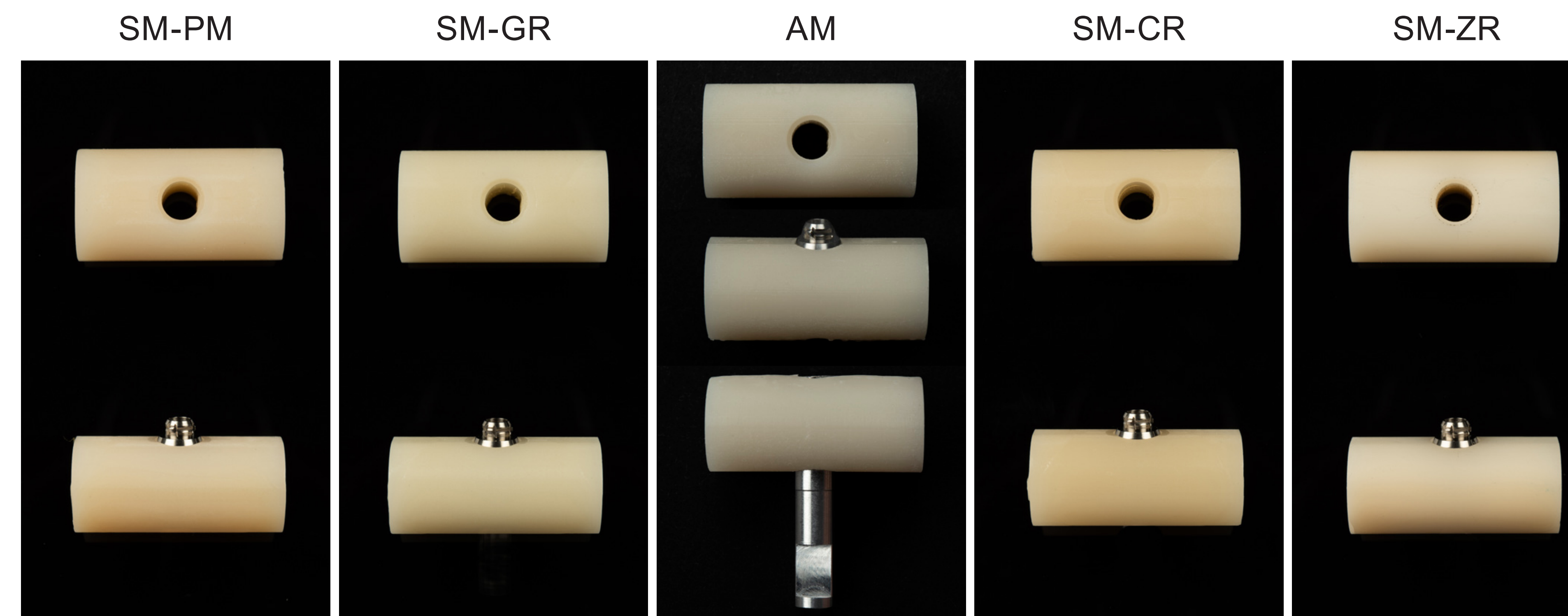


Figure 1. Representative specimens from each group before (top) and after (bottom) the insertion of a titanium base abutment, also when tightened to an analog (middle bottom).

After cementation, specimens were mounted to a chewing simulator, subjected to 1.2 million cycles of loading under 100 N at 1.5 Hz, and surviving specimens were subjected to another 1.2 million cycles under 200 N at 1.5 Hz. The load was applied to the cantilever extension, which was 12 mm away from the clamp of the chewing simulator.

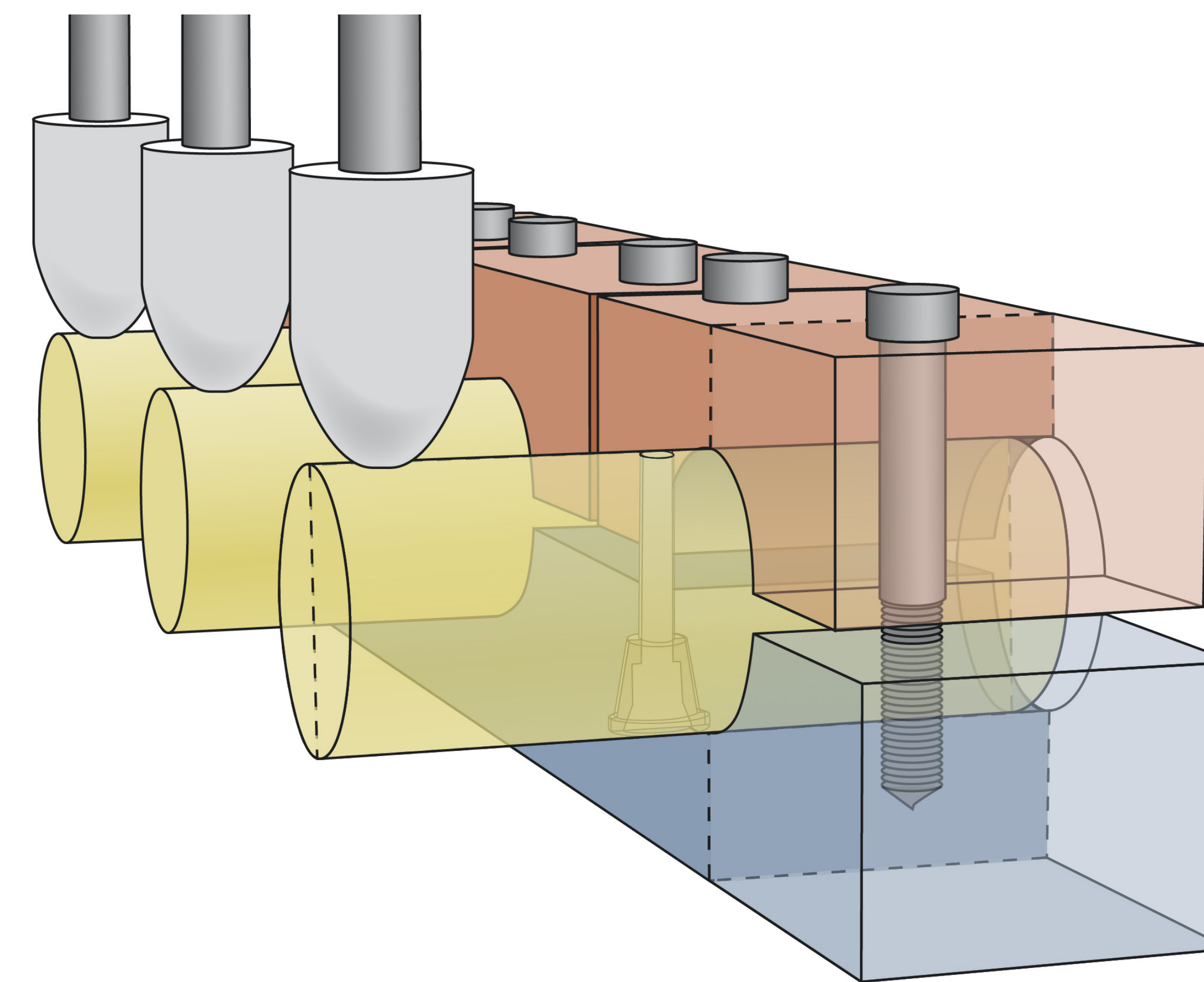


Figure 2. Schematic representation of cyclic loading setup, in which load is applied 12 mm from clamp to simulate a cantilevered prosthesis.

The specimens survived the cyclic loading were subjected to pull-off test to calculate the maximum tensile bond strength. The maximum retention force (F_{max}) was recorded in Newton (N) and the maximum bond strength (MPa) was calculated by dividing the F_{max} by the bonding area (mm²). After pull-off tests, intaglio surfaces were inspected for the remaining cement and failure mode classification. Kaplan-Meier survival analysis and Cox proportional hazards model were used to evaluate data ($\alpha=.05$).

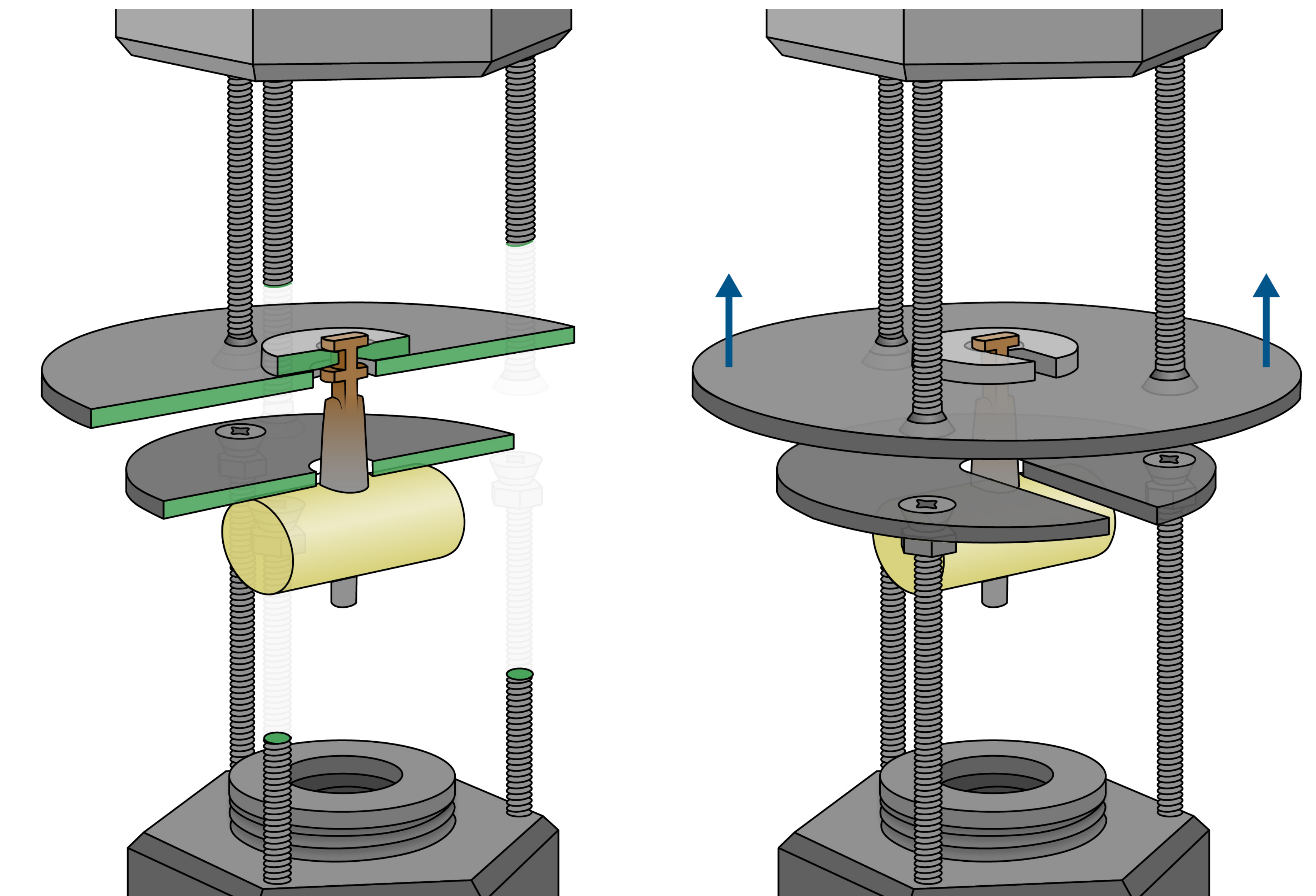


Figure 3. Schematic representation of custom-made device for pull-off test.

Results

Only 2 SM-PM, 2 SM-GR, and all SM-ZR specimens survived 2.4 million cycles of loading.

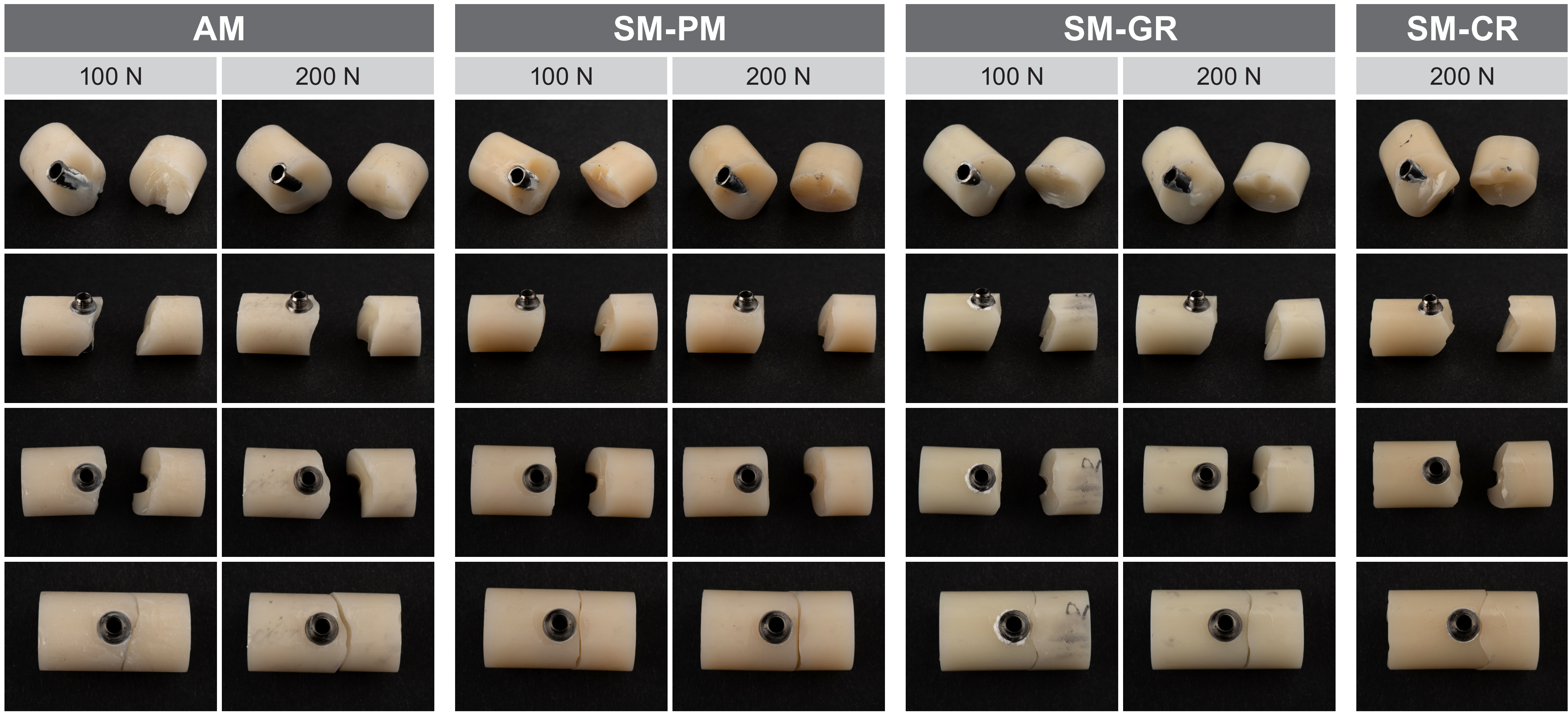


Figure 4. Representative specimens from each group that failed during cyclic loading.

Materials					
Specimen number	AM	SM-PM	SM-GR	SM-CR	SM-ZR
1	100 N/80000 cycles	100 N/890000 cycles	100 N/853000 cycles	200 N/80000 cycles	*
2	100 N/870000 cycles	200 N/145000 cycles	100 N/945000 cycles	200 N/50000 cycles	*
3	100 N/870000 cycles	200 N/215000 cycles	100 N/869000 cycles	200 N/120000 cycles	*
4	100 N/95000 cycles	200 N/66000 cycles	200 N/10000 cycles	200 N/180000 cycles	*
5	200 N/120000 cycles	200 N/10000 cycles	200 N/1100000 cycles	200 N/450000 cycles	*
6	200 N/50000 cycles	200 N/216000 cycles	200 N/459000 cycles	200 N/618000 cycles	*
7	200 N/145000 cycles	200 N/120000 cycles	200 N/450000 cycles	200 N/190000 cycles	*
8	200 N/85000 cycles	200 N/106000 cycles	200 N/450000 cycles	200 N/320000 cycles	*
9	200 N/10000 cycles	*	*	200 N/215000 cycles	*
10	200 N/55000 cycles	*	*	200 N/200000 cycles	*

Table 1. Failure analysis of each specimen within each material during cyclic loading. *Did not fail during cyclic loading.

Kaplan-Meier analysis revealed that after 2.4 million cycles, survival rate of SM-ZR was 100% and that of AM was 0%.

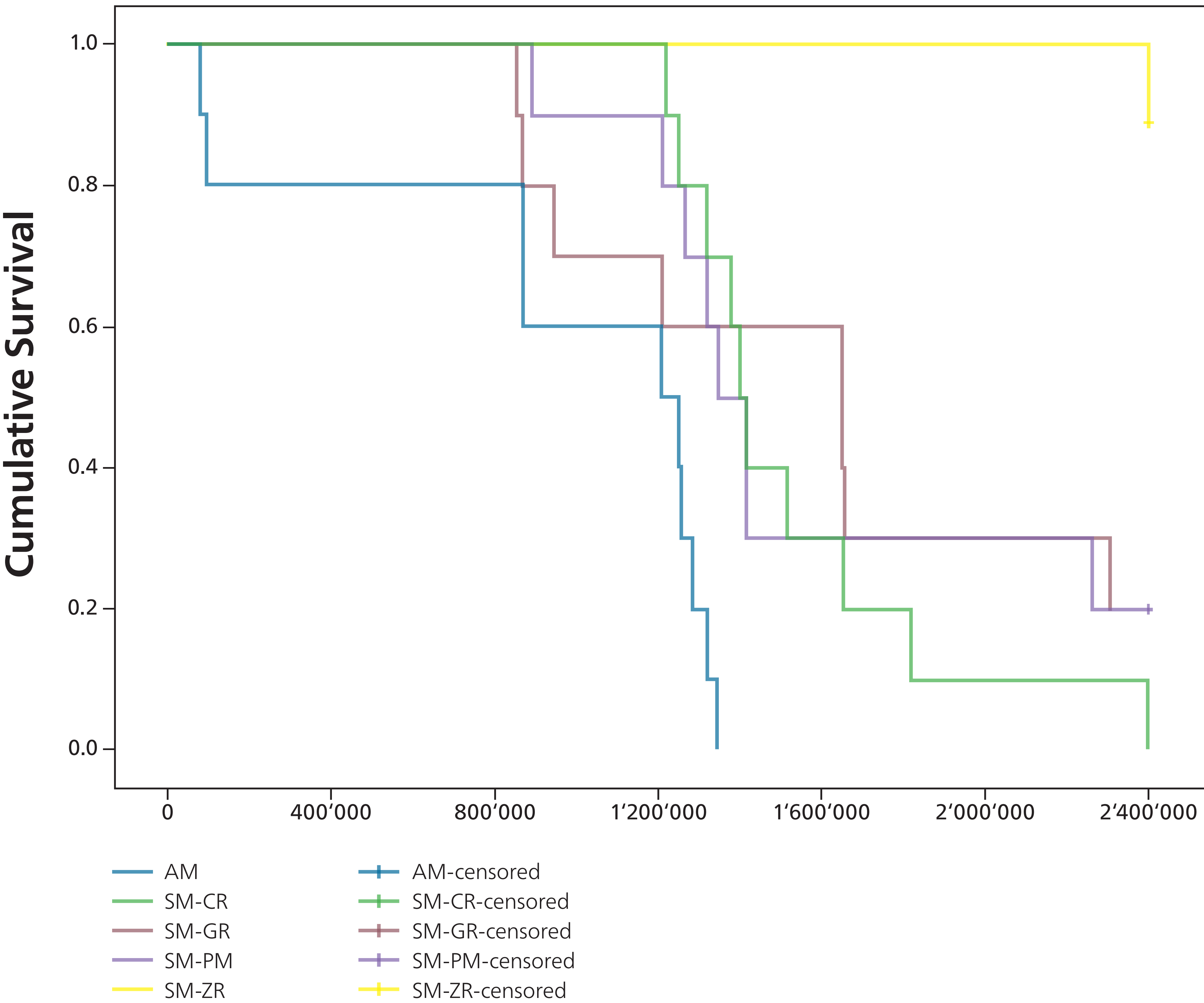


Figure 5. Cumulative survival curves of tested materials after cyclic loading.

The log-rank test revealed a difference among test groups ($P<.001$). SM-ZR had the highest survival rate ($P\leq.013$).

AM had significantly lower survival rate than SM-CR ($P=.031$). Every other pairwise comparison was nonsignificant ($P\geq.167$).

Materials	Number of Events	Survival	95% Confidence Interval	
			Lower	Upper
AM	10	0 %	0%	36.5%
SM-PM	8	20.0 %	5.8%	69.1%
SM-GR	8	20.0 %	5.8%	69.1%
SM-CR	10	0 %	0%	44.6%
SM-ZR	0	100 %	88.6%	100.0%

Table 2.. Results of Kaplan-Meier survival analysis after 2.4 million cycles.

The Cox regression analysis revealed significant differences in hazard ratio (HR) among test groups (P<.001)

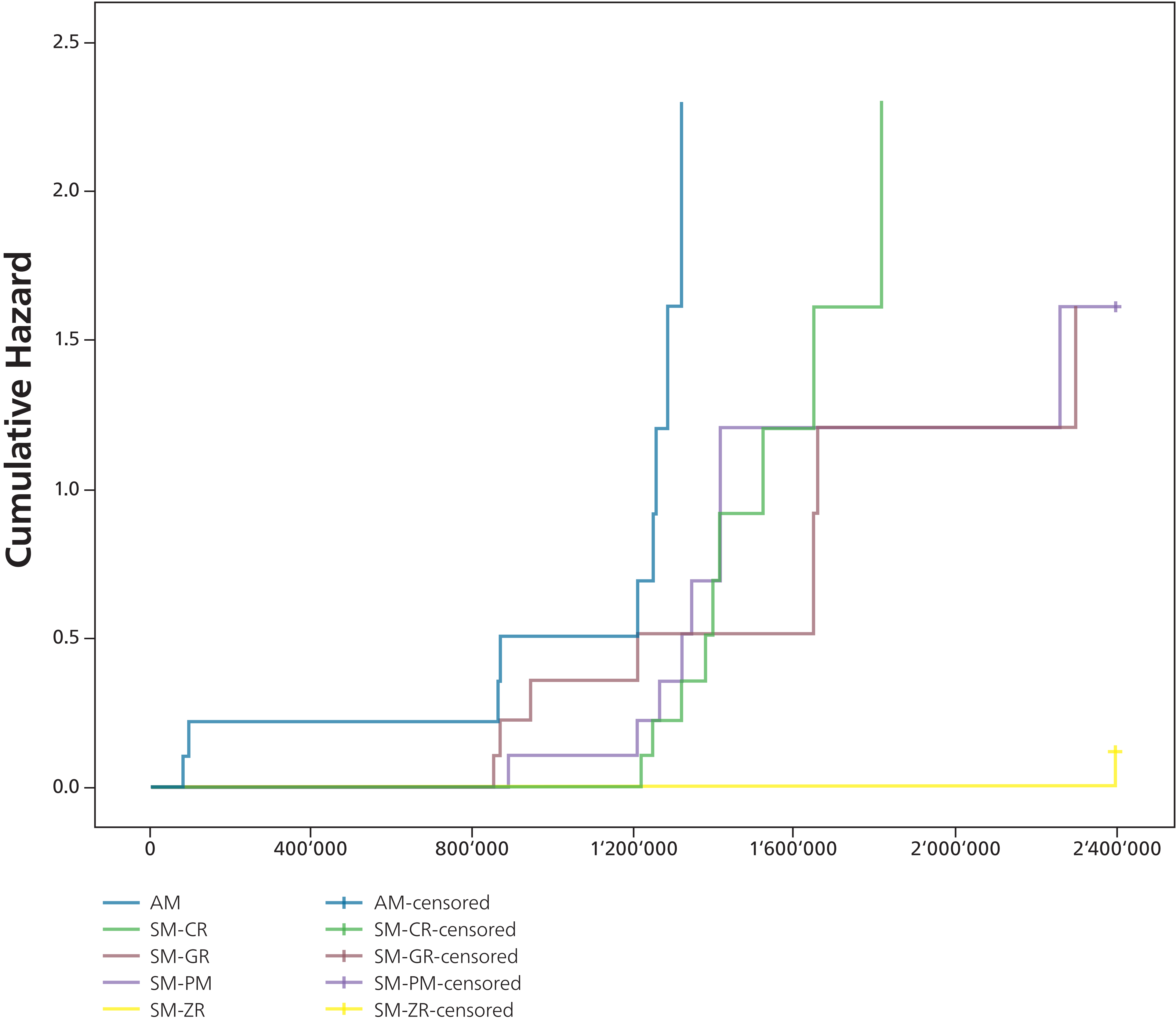


Figure 6. Cumulative hazard curves of tested materials after cyclic loading.

Materials	Hazard ratio	95% Confidence Interval	
		Lower	Upper
AM	85.08	9.76	608.55
SM-PM	17.26	2.01	140.48
SM-GR	15.55	2.17	125.35
SM-CR	23.60	2.91	189.56
SM-ZR	-	-	-

Table 3. Results of Cox regression analysis after 2.4 million cycles

All SM-ZR specimens had adhesive failure, while SM-PM and SM-GR specimens had mixed failure. In addition, two specimens from SM-PM and one specimen from SM-GR had chipping of the prosthetic material during pull-off test along with the mixed failure.

Specimen number	Materials				
	AM	SM-PM	SM-GR	SM-CR	SM-ZR
1	*	*	*	*	352.1 N/3.5 MPa
2	*	*	*	*	535.9 N/5.4 MPa
3	*	*	*	*	252.4 N/2.5 MPa
4	*	*	*	*	282.9 N/2.8 MPa
5	*	*	*	*	327.2 N/3.2 MPa
6	*	*	*	*	740.3 N/7.4 MPa
7	*	*	*	*	356.1 N/3.6 MPa
8	*	*	*	*	263.5 N/2.6 MPa
9	*	493.2 N/4.9 MPa	271.2 N/2.7 MPa	*	611.9 N/6.1 MPa
10	*	503.4 N/5.0 MPa	438.5 N/4.4 MPa	*	919.5 N/9.2 MPa

Table 4. Maximum retention (N) and tensile bond strength (MPa) values

*Failed during cyclic loading

After 2.4 million cycles, all materials had significantly higher HR than SM-ZR (P≤.010) with AM having the highest HR.

Conclusions

Material type affected the survival and hazard ratio of tested materials in a simulated cantilevered implant-supported fixed prosthesis situation.

Strength gradient zirconia had the highest survival rate with no failed specimens during cyclic loading.

Even though most of the tested polymer-based materials failed during cyclic loading, these failures were commonly observed during the second 1.2 million cycles with 200 N.

Tested polymer-based materials had significantly higher hazard ratio than strength gradient zirconia, additively manufactured resin having the highest ratio. Nevertheless, survival possibility may increase with increased cross-sectional prosthesis dimensions.

The tensile bond strength of zirconia specimens ranged between 2.6 MPa and 9.2 MPa, and those of SM-PM and SM-GR specimens were within this range.

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