Table I. Materials used in this study

Material	Abbrev.	Component	Manufacturer
Clapearl DC	CLP	Monomer: Bis-GMA, TEGDMA Filler: 70 wt % (mean 3.4 μm), SiO_2, microfiller, glass	Kuraray Medical Inc. Kurashiki, Japan
MDP Primer	MP	Monomer: 10-Methacryloyloxydecyl dihydrogen phosphate (MDP, 0.1, 0.2, 0.5, 1.0, and 5.0 wt% in ethanol)	Kuraray Medical Inc. Kurashiki, Japan
Zirconate Coupler	ZC	Zirconate coupling agent: 2,2-Di(allyloxymethyl)butyl trimethacryloyl zirconate (0.25, 0.5, 1.0, and 2.0 wt% in ethanol)	Kenrich Petrochemicals Inc. Bayonne, NJ, USA
Porcelain Bond Activator	PBA	dimethacrylate monomers, silane coupling agent	Kuraray Medical Inc. Kurashiki, Japan

Table II. Shear bond strength of resin luting cement to pure zirconium at 0 and 10,000 thermocycles

Thermocycles Primer	0	10,000
Cont.	30.1 (2.4)^{a,A}	0 (0)^{a,B}
MP0.1	49.0 (2.0)^{c,A}	31.2 (3.7)^{c,B}
MP0.2	52.7 (2.7)^{c,d,A}	42.0 (4.9)^{d,B}
MP0.5	57.3 (0.9)^{d,A}	41.5 (3.5)^{d,B}
MP1.0	57.0 (4.0)^{d,A}	45.4 (4.2)^{d,e,B}
MP5.0	56.3 (5.2)^{d,A}	42.8 (5.1)^{d,B}
ZC0.25	33.1 (3.4)^{a,A}	14.5 (1.9)^{b,B}
ZC0.5	37.4 (3.8)^{b,A}	13.7 (1.8)^{b,B}
ZC1.0	39.2 (1.2)^{b,A}	13.7 (1.6)^{b,B}
MP1.0+ZC0.5	57.4 (3.4)^{d,A}	46.2 (4.2)^{d,e,B}
MP1.0+ZC1.0	53.7 (4.7)^{c,d,A}	50.1 (2.7)^{e,f,A}
MP1.0+ZC2.0	49.2 (2.6)^{c,A}	42.9 (2.3)^{d,B}
MP2.0+ZC1.0	57.6 (3.2)^{d,A}	54.1 (3.8)^{f,A}

Means with same letters were not significantly different by Student-Newman-Keuls test ($p > 0.05$). Comparisons between primers at each thermal cycling are represented by lower-case letters and comparisons between two thermal cyclings at each primer are represented with upper-case letters.

Table III. Shear bond strength of resin luting cement to zirconia ceramics at 0 and 10,000 thermocycles

Thermocycles Primer	0	10,000
Cont.	17.9 (4.3)^{a,A}	0 (0)^{a,B}
PBA	19.8 (3.4)^{a,A}	0 (0)^{a,B}
MP0.2	49.9 (3.0)^{d,A}	23.6 (3.5)^{c,B}
MP0.5	49.2 (4.0)^{d,A}	38.7 (4.6)^{d,B}
MP1.0	49.6 (3.4)^{d,A}	39.8 (3.0)^{d,B}
ZC0.25	21.2 (1.0)^{a,A}	4.2 (0.9)^{b,B}
ZC0.5	30.7 (3.2)^{b,A}	4.8 (0.7)^{b,B}
ZC1.0	28.6 (1.5)^{b,A}	4.8 (0.7)^{b,B}
MP0.5+ZC0.5	40.1 (1.2)^{c,A}	24.2 (2.7)^{c,B}
MP1.0+ZC0.5	53.4 (0.7)^{d,e,A}	44.8 (2.6)^{e,B}
MP1.0+ZC1.0	57.6 (5.4)^{e,A}	46.0 (1.1)^{e,f,B}
MP1.0+ZC2.0	50.4 (5.4)^{d,A}	40.7 (0.9)^{d,B}
MP2.0+ZC1.0	48.2 (2.2)^{d,A}	48.5 (2.6)^{f,A}

Means with same letters were not significantly different by Student-Newman-Keuls test ($p > 0.05$). Comparisons between primers at each thermal cycling are represented by lower-case letters and comparisons between two thermal cyclings at each primer are represented with upper-case letters.

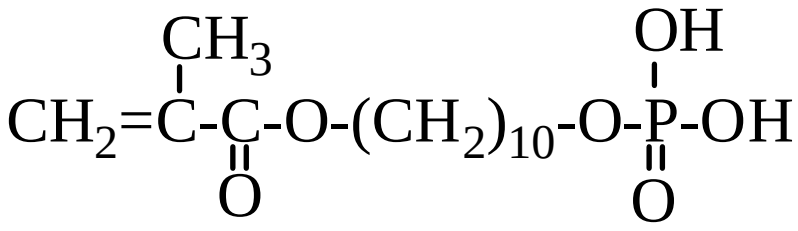
Table IV. Failure mode of zirconium and zirconia ceramic specimens for each primer treatment at 0 and 10,000 thermocycles

Material	Zirconium		Zirconia	
Thermocycles	0	10,000	0	10,000
Primer				
Cont.	AAAAAAA	AAAAAAA	AAAAAAA	AAAAAAA
MP0.1	AABBBBB	AAAAAAA		
MP0.2	ABBBBBB	AAAAAAB	AABBBBB	AAAAAAA
MP0.5	BBBBBBB	AAAAABB	AABBBBB	AAAAAAB
MP1.0	BBBBBBB	AAAABBB	AABBBBB	AAAAABB
MP5.0	BBBBBBB	AAAAABB		
PBA			AAAAAAA	AAAAAAA
ZC0.25	AAAAAAA	AAAAAAA	AAAAAAA	AAAAAAA
ZC0.5	AAAAAAB	AAAAAAA	AAAAAAA	AAAAAAA
ZC1.0	AAAAAAB	AAAAAAA	AAAAAAA	AAAAAAA
MP0.5+ZC0.5			AAAAABB	AAAAAAA
MP1.0+ZC0.5	BBBBBBB	AAAABBB	BBBBBBB	AAAABBB
MP1.0+ZC1.0	BBBBBBB	AABBBBB	BBBBBBB	AAABBBB
MP1.0+ZC2.0	ABBBBBB	AAAAABB	ABBBBBB	AAAAABB
MP2.0+ZC1.0	BBBBBBB	AABBBBB	ABBBBBB	AABBBBB

A: adhesive failure at the zirconium or zirconia ceramic-resin luting cement interface, B: complex adhesive failure and cohesive failure within the resin luting cement.

Figure 1. Structural formulae of MDP monomer and zirconate coupling agent.

MDP monomer



zirconate coupling agent

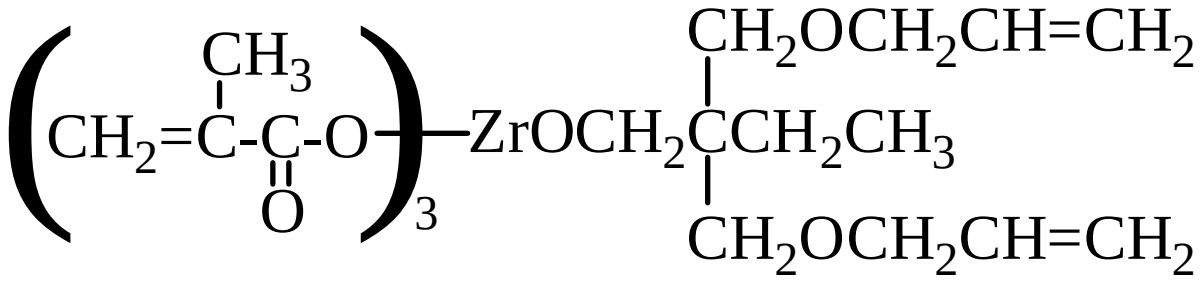
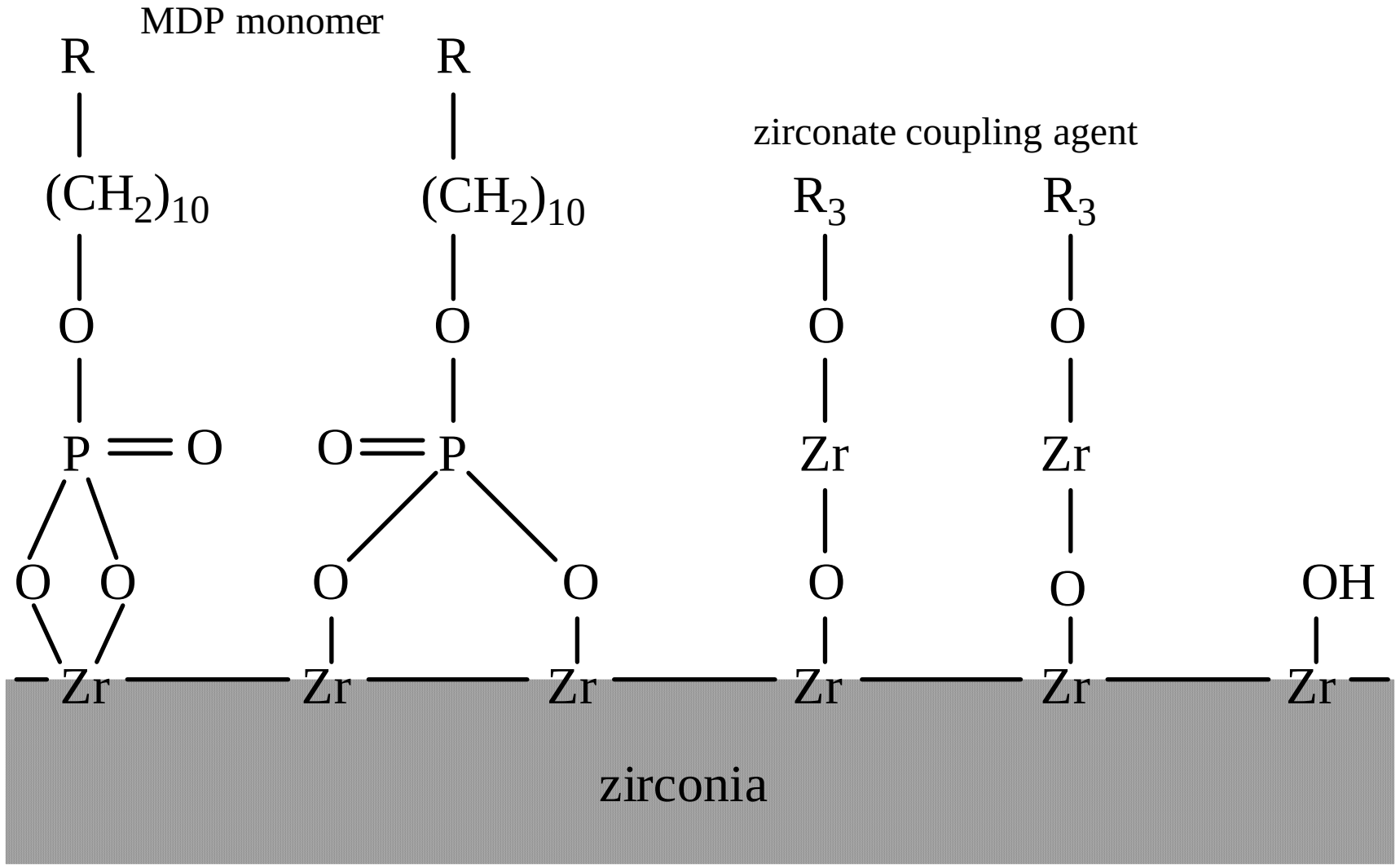


Figure 2. Suggested hydrogen bond model for the MDP monomer or zirconate coupling agent side-chains and adsorbed -OH on the zirconia surface (R: CH_2=CCH_3-COO-).


MDP monomer
zirconate coupling agent
R
R
(CH2)10
(CH2)10
R3
R3
O
O
O
O
P
O
O
P
Zr
Zr
O
O
O
O
O
O
O
OH
Zr
Zr
Zr
Zr
Zr
Zr
zirconia