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COMPARATIVE EVALUATION OF BOND STRENGTH OF EXPERIMENTAL SHOCK-ABSORBING DENTAL CEMENT FOR IMPLANT SUPPORTED RESTORATIONS

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ABSTRACT

Aim. Compare bond strength of experimental shock-absorbing cement with conventional cements used to cement implant-supported restorations. **Materials and Methods.** A total of 42 samples divided into 2 groups; Gp (A): one-piece Titanium implant analogues (n=21) of 0.5mm finish line, 5.5mm height and 6˚ taper were centrally and vertically mounted in transparent acrylic resin blocks. Each analog received Co-Cr coping including a 4mm Ø occlusal loop. Gp(B); Titanium and Co-Cr plates (n=21 each) 8x8x3mm and 6x6x3mm respectively were constructed. Subgroups 1,2,3 according to type of cement used; A1 and B1 glass ionomer, A2 and B2 resin cement, A3 and B3 Medical grade silicone adhesive. Samples were thermocycled 1000 cycles, collected, dried and tested. Tensile and shear bond strength were carried out using universal testing machine, at 0.5mm/min speed. Debonding forces were recorded and statistically analyzed. Failure modes were inspected. **Results:** Mean ± SD recorded in tension were highest for Resin cement SubGp A2 (79.18±18.5 N), then medical grade Silicone SubGp A3 at (71.367±14.896 N), lowest was with SubGp A1 GI cement (41.165±9.73 N). Mean ± SD in Shear were highest for Resin cement SubGp B2 (3.067±0.895 MPa), then medical grade Silicone SubGp B3 (1.844±0.308 MPa), lowest was with SubGp B1 GI (1.073±0.631 MPa). T-student test revealed significant difference between tested groups (P=0.001). **Conclusion:** Experimental medical grade silicone cement showed better mean tensile and shear bond strengths than Glass ionomer cement and lower than that of resin cement, therefore it could present a reliable option for cementing implant supported prosthesis.

KEYWORDS: Shock-Absorbing, cement, silicone, Tensile, Shear

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INTRODUCTION

Dental cements are the link between restorations and prepared teeth, bonding them together through a form of surface attachment (Kipp Wingo,2018). The longevity of fixed dental prosthesis (FDP) depends on many factors one of which is, the type of luting cement used. The clinician‘s understanding of various cements, their strength, weaknesses and their specific indications are of utmost importance to success and longevity of dental prosthesis.

Ideally, dental cements should fulfil specific biological, physio-mechanical, and handling requirements to establish retention and maintain restoration integrity. (Attar N et al., 2013; Pegoraro TA et al., 2007). These requirements include, ease of manipulation, low film thickness, flowability, high compressive and tensile strengths, minimal microleakage, insolubility in oral fluids, colour stability, anticariogenicity, translucency and radiopacity (EE Hill, 2007; Donovan TE and Cho GC, 2015).

Glass ionomer cements (GICs) have certain unique characteristics which make them useful as luting materials. These include adhesion to tooth structures and base metals, anticariogenic properties due to release of fluoride, biocompatibility and low toxicity (Alexandre Cestari, 2018). However, conventional glass-ionomer cements have moderate compressive strength (85 to 126 MPa), and low tensile strength (6 to 7 MPa). It is considered a brittle material therefore unsuitable for use in load-bearing areas (Habib B et al.,2005). Moreover Glass ionomer cement is considered a soluble material and gains its maximum strengths after 24 hours (Tavangar MS et al.,2019) .

On the other hand, resin cements are relatively insoluble and have the highest mechanical, physical, and esthetic properties compared to other currently existing dental cements (Hill EE and Lott J ,2009; Yu H et al.,2009). Resin cements can be divided into 3 subtypes based on bonding mechanism; total-etch, self-etch and self-adhesive (Ladha K and Verma M, 2018). Unfortunately, it forms a tough connection between restoration and tooth, therefore occlusal forces have no way to be vented and it is either transmitted to tooth or to cement itself causing its degradation. In human body no two hard surfaces are joined together without the presence of a cushion in-between.

Nowadays implant dentistry has become the most efficient method for tailoring restoration and correcting edentulism. Implant treatments exhibit an overall excellent long-term clinical success rate (Ekelund JA et al.,2003; Jemt T and Johansson J ,2006; Snauwaert K et al., 2000). Dental implant systems depend on the biomechanical interaction between bone and implant (Meijer HJA et al.,1996). Masticatory forces induce axial and non-axial stresses, which is transferred to implant-bone interface. High stress concentrations in the surrounding bone can result in pressure necrosis and subsequently in implant failure (Menicucci et al.,1998; Meijer HJA et al., 1996; Esposito M. et al., 2000; Kim W.H., et al., 2019).

It has been well known that the success of dental implant is heavily dependent on initial stability and long-term osseointegration due to optimal stress distribution in the surrounding bone. Stress concentration at the interface between implant-bone system are different compared to the tooth-bone system, where the presence of periodontal ligament serves as hyper-viscoelastic interface (Baggi L et al., 2008; Koca OL et al.,2005; Misch CE and Bidez MW, 2007). For this reason alternatives to reduce the forces transmitted to implants have been studied, some researchers have proposed accessories such as the intra mobile element (Babbush CA et al.,1987), the elastic collar around the neck of the implant(Abu-Hammad OA et al., 2000), or even an artificial ligament(Choi BH , 2000), while other approaches have attempted geometric modifications to optimize implant design according to their biomechanical performance (Bozkaya D et al.,2004 ; Carvalho L et al.,2004; Geramy Aand Morgano

SM, 2004 ; Iranmanesh P et al.2014; Avram Manea, et al., 2019).

On the other hand, results from in-vitro studies indicated possibility to reduce the force transmitted on bone-implant interface by using restoration materials with force absorbing properties such as the hybrid ceramics VITA ENAMIC (Maria Menini, 2016) and Poly-ether ether ketone(PEEK) which showed low stress values in the implant and peripheral bone. (Necati Kaleli et al., 2018).

Cement layer was suggested to act as a shock absorber and enhance distribution of load throughout the prosthesis-implant-bone system, it reduces stress to bone and implant-abutment structure. (Pietrabissa R et al., 2000).

Silicones are elastomeric systems that offer unique combination of flexibility and strength that make them effective in ensuring successful bonding in diverse applications and industries. Silicone adhesives, sealants, coatings, and potting compounds can withstand shock, vibration, impact, and aggressive thermal cycling, while maintaining elasticity, stress resistance, and long-term high-temperature resistance. Along with their thermal stability, silicone adhesives are available in optically clear formulations and a wide range of harnesses while ensuring high bond strength even between dissimilar substrates *(*Venkat Nandivada, 2015*)*.

It is claimed that medical grade silicone adhesive can achieve bond strength equivalent to conventional cements, therefore the null hypothesis of the study is that there will be no difference between experimental medical grade silicone cement and conventional dental cements (glass ionomer and resin cements).

MATERIALS AND METHOD

A total of 42 samples were used in this study. The experimental design comprised 2 groups; in group (A): Twenty-one titanium implant analogues one-piece type (Tixos Nano, LEADER ITALIA s.r.l., Via Aquileja, 49 – 20092 Cinisello Balsamo (MI) ITALY) having a 0.5 mm finish line, 5.5 mm vertical height and 6 degree wall taper were centrally and vertically mounted in transparent acrylic resin blocks (Vertex Self-Curing, 3D systems, Centurionbaan 190, 3769 AV Soesterberg. The Netherlands). For each assembled implant analog a Co-Cr (Remanium Star, DENTAURUM GmbH & Co., KG, Turnstr. 31, 75228 Ispringen, Germany) coping was designed using CAD/CAM software (InLab version 4.0; Sirona) and milled (Roland, MDX 40; Japan) with a 4 mm diameter occlusal loop attached to its occlusal surface (Fig. 1). In group (B); Twenty-one titanium (Gr5 ASTM F 136, Baoji Future Titanium Co., Ltd., China) square plates having dimensions of 8x8x3mm and 21 Co-Cr (Remanium Star, DENTAURUM GmbH & Co., KG, Turnstr. 31, 75228 Ispringen, Germany) square plates of 6x6x3 mm were milled.

Fig. (1) **(1.1)** The Titanium implant analogue mounted in acrylic resin block. **(1.2)** The Co-Cr Coping is fitted on the implant analogue

Samples grouping (Table 1); the samples of each group were divided into 3 sub- groups (n=7) according to type of cement used. subgroup1: cemented with glass ionomer cement (Ketac-Cem 3M ESPE, USA), Subgroup 2: cemented with resin cement (Relyx U200, 3M ESPE, USA), and subgroup 3: cemented with Medical grade silicone adhesive (Med-1011, NuSil company, USA) (Table 2)

TABLE (1) Samples Grouping

Test Groups	Subgroups Luting cement			Total
	Glass ionomer	Resin Cement	Experimental silicone	
A Tensile bond strength (Copings on Ti Abutments)	n=7	n=7	n=7	21
B ***Co-Cr plates cemented to titanium plates***	n=7	n=7	n=7	21
Total	14	14	14	42

TABLE (2) Composition* of medical grade silicone adhesive

Name	**%**
Silanamine, 1,1,1-trimethyl-N-(trimethylsilyl)-, hydrolysis products with silica	20 - 30
Silanetriol, ethyl-, triacetate	< 10
Glycidoxypropyltrimethoxysilane	< 3

Provided by the manufacturer

Each cement was manipulated according to manufacturer's direction. The plates were centralized during cementation with the aid of cementation jig. The jig consisted of two transparent plexi frames of thickness 3 mm and 12 mm square sides. The plexi frames were evacuated by laser cut at their center. The aperture size created by the laser cut was 8.1x8.1mm for the first one and 6.1x6.1mm for the second one. The plates were seated within the corresponding frames during cementation so that the Co-Cr plates were cemented at the center of titanium plates (Fig. 2). Cementation was done under static load of 5 kg for 10 minutes and excess cement was removed using micro brush.

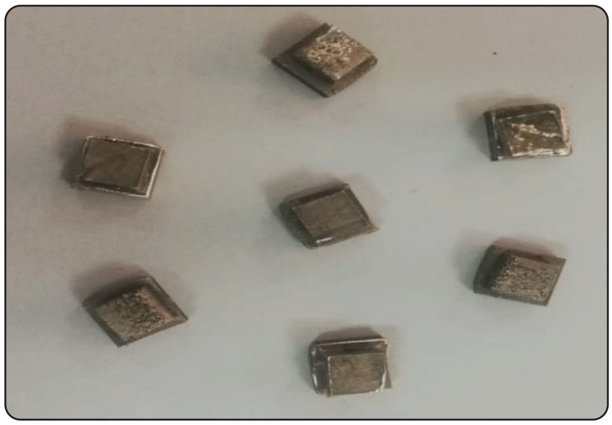


Fig. (2) Cemented CrCo-Titamnium plates for shear bond strength test

Samples were thermocycled for 1000 cycles using thermocycling machine (SD Mechatronik Im Hofpoint 10, 83620 Feldkirchen Westerham, Germany), all samples were dried and collected for testing. Samples of group A were submitted to a tensile test using universal testing machine (The Testometric Company Limited, Lincoln Close, Rochdale, Lancashire, England) at speed of 0.5 mm/min. The failure was confirmed by sudden drop in force measurements in the testing machine and the failure load was recorded in Newton. While samples of group B were sheared by compressive load applied at Titanium-Co-Cr plates interface using a mono-beveled chisel shaped metallic rod attached to the upper movable compartment of the universal testing machine travelling at cross-head speed of 0.5mm/min. The load required to debond the samples was recorded in Mega Pascal. Failure modes were inspected using polarized light microscope (AxioZoom V.16, Zeiss, Oberkochen, Germany)

Data was collected and statistically analyzed using statistical package for social sciences (SPSS, v. 25, IBM, New York, NY). Analysis of variance was used to compare materials. Student t-test was done for compared pairs. Sample size (n=7) was large enough to detect differences. The significance level was set at $P<0.05$.

RESULTS

1. Tensile test

For group A (copings cemented on implant analogues); The Resin subgroup showed highest mean ± SD values (79.18±18.5N) followed by Silicone subgroup (71.367±14.896 N), while GI subgroup showed the lowest mean ± SD (41.165±9.73 N). The difference between groups was statistically significant as indicated by one-way ANOVA test ($F=12.85$, $P=0.0003 < 0.05$). Tukey's pair-wise post-hoc revealed non-significant difference between (Resin and Silicone) as shown in table (3) and figure (3).

Failure mode: Group A

Chi square test showed significant difference in failure mode distribution between groups ($p=<0.0001< 0.5$). table (4) and figures (4)

2. Shear bond strength test result

Mean values and standard deviation of shear bond strength test for Group B, results measured in mega Pascal (MPa) as function of cement groups for group B (Co-Cr plates cemented to titanium plates); The Resin cement subgroup showed highest mean ± SD values of shear bond strength (3.067±0.895 MPa) followed by silicone cement subgroup (1.844±0.308 MPa), the GI subgroup showed the lowest mean ± SD at (1.073±0.631 MPa). The difference between groups was statistically significant as indicated by one-way ANOVA test ($F=16.41$, $P=<0.0001 < 0.05$). Tukey's pair-wise post-hoc exhibited non-significant difference between (Silicone and GI) as shown in table (5) and figure (5).

Failure Mode Group B

Chi square test showed significant difference in failure mode distribution between SBS subgroups ($p=<0.0001< 0.5$). table (6) and figure (6).

TABLE (3) Tensile test results (Mean values in Newton ±SD) one way Anova

	Variables	Mean	±SD	95% confidence intervals		ANOVA test	
				Low	High	F	P value
A Copings on Ti Abutments	Resin	79.180^{A}	18.500	62.070	96.290	12.85	0.0003*
	Silicone	71.367^{A}	14.896	57.590	85.143		
	GI	41.165^{B}	9.730	32.166	50.164		

Different superscript large letter in the same column indicate statistically significant difference (p < 0.05) *; significant (p < 0.05) ns; non-significant (p>0.05)

TABLE (4) Frequency distribution of failure mode pattern under tensile force (%) for all cement groups

		Failure mode pattern			Statistics
		Adhesive	Cohesive	Mixed	P value
A Copings on Ti Abutments	Resin	10%	0%	90%	<0.0001*
	Silicone	20%	0%	80%	
	GI	70%	0%	30%	

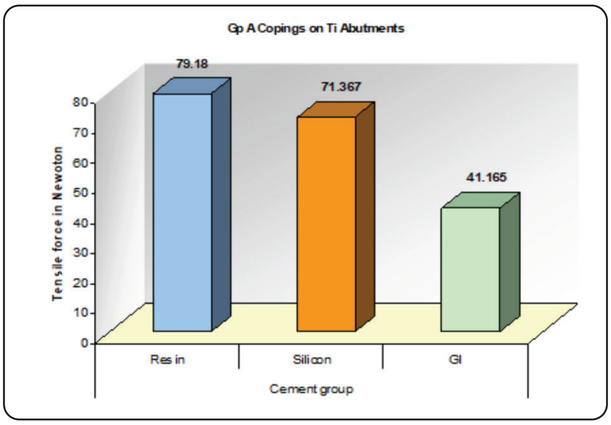


Fig. (3) Tensile test

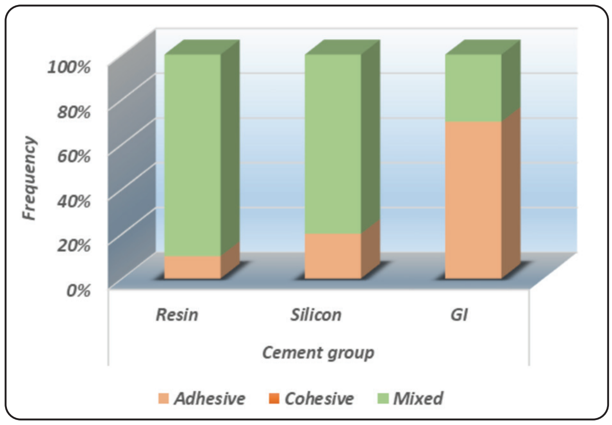


Fig.(4) Frequency distribution of failure modes analysis (%) in tension

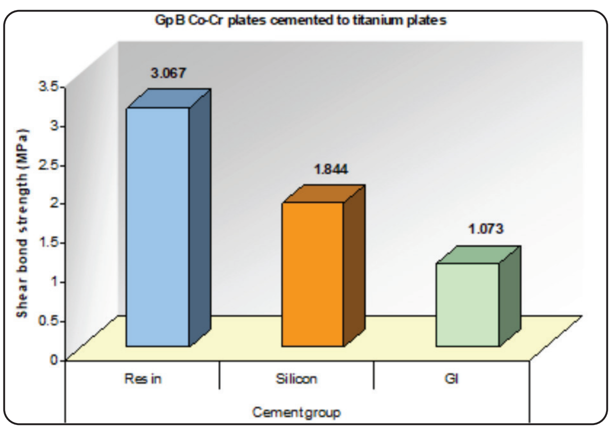
TABLE (5) Shear bond strength test results (Mean±SD) one way Anova

Variables		Mean	±SD	95% confidence intervals		ANOVA test	
				Low	High	F	P value
B *Co-Cr plates cemented to titanium plates*	Resin	3.067^{A}	0.895	2.239	3.895	16.41	<0.0001*
	Silicone	1.844^{B}	0.308	1.559	2.129		
	GI	1.073^{B}	0.631	0.489	1.657		

Different superscript large letter in the same column indicating statistically significant difference ($p < 0.05$) *; significant ($p < 0.05$) ns; non-significant ($p>0.05$)

TABLE (6) Frequency distribution of failure mode pattern under shear force (%)

	Failure mode pattern				Statistics
	Adhesive		Cohesive	Mixed	P value
B *Co-Cr plates cemented to titanium plates*	Resin	10%	0%	90%	<0.0001*
	Silicone	40%	0%	60%	
	GI	70%	0%	30%	



Fig(5) Shear bond strength

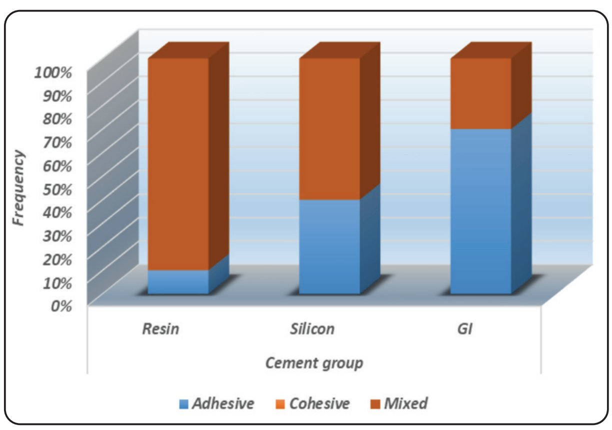


Fig. (6) Frequency distribution of failure mode analysis (%) in shear

DISCUSSION

The purpose of this study was to test the bond strength of a Medical grade silicone that can be used as a cement in an attempt to benefit of using the Medical grade silicone adhesive as a cement is to dissipate masticatory forces directed on the implant and hence to bone, to increase longevity and better function of implant supported prosthesis.

The null hypothesis was accepted and the experimental silicone cement provided bond strength with the metal substrates within the range of conventional cements (glass ionomer and resin cements).

Medical grade silicone adhesive was selected because the material is designed and manufactured with Proven biocompatibility the adhesive was tested for biocompatibility, and it is already used in areas under skin to cement tubes of pace makers to the device. So, using it intraorally will not cause any biologic reaction. The tested silicone had lots of advantages was convenient for application as it is supplied in as a gun dispenser and is translucent in color with low viscosity and low film thickness. It has appropriate working time of around 5 minutes, and it cures with non-exothermic reaction.

Comparison of the experimental silicone cement was made with two of commonly used adhesive cements; self-adhesive resin cement and glass ionomer cement. Both have well known clinical success.

A lot of procedural steps were taken in current study. One-piece implant analogue were selected for the study. It was made from grade V titanium alloy simulating implant abutment, being one piece prevents micromotion between implant and abutment which may cause reading inaccuracies during tensile testing. The analogues were positioned centrally and vertically inside block to ensure that the force direction is identical in all specimens.

A loop was included in the design of Co-Cr coping for easy attachment to the moving arm of universal testing machine. Two plexi- plate sheets were laser cut for accurately centralize placement of titanium and Co-Cr plates on top of each other during cementation of samples for shear bond strength.

Thermocycling was carried out for 1000 cycles to simulate cyclic thermal fluctuations in the oral environment, equal to 15 months (Gale M S et al. 1999).

Results of this study showed superior tensile bond strength of medical grade silicone that exceeds that of glass ionomer cement. This result is in disagreement with Rayyan MM. whom in 2014 tested an industrial grade silicone for tensile and shear bond strength, his data displayed that results for silicone based cement came inferior to resin cement and GIC. This may be attributed to the type of silicone used in his study which was not formulated for adhesive purposes while the medical grade silicone adhesive (Med-1011, NuSil company, USA) used in this study was manufactured to adhere to substrates such as ceramics, glass, metals, urethanes, and other silicones. The high bond strength of the medical grade silicone may be attributed to the action of the special primer used which is specially formulated silanes. In general, silanes form a large chemical group of hybrid inorganic-organic compounds containing direct ≡Si-C≡ bonds. It has been recommended that a silica-coating is needed before silica-rich surface is needed for silanization in order to form strong ≡Si-O-Si≡C linking which is induced by silica-coating of metals. The high tensile and shear bond achieved by silicone cement in this study comes in accordance with Matinlinna J, et al 2004 who found that titanium can bond with different forms of silanes without silica-coating.

Although, titanium without silica-coating has shown some adhesive bonding with different forms of silanes (Matinlinna J, et al 2004).

On observing the failure mode; in both groups A and B the mixed mode of failure predominates in sub groups 2 and 3 which is indicative that the adhesive bond strength for both resin and silicone cements was near to the cohesive strength while for glass ionomer the adhesive strength was weaker. For silicone cement; the higher percentage of mixed failure in group A may indicate that the cohesive strength was weaker under tension.

The results of current study are promising and may open the gate to a new cement to be used not only with implant prosthetics, but also with teeth. Silicone adhesives proved themselves in many household and industrial purposes and lately in medical field. It may be the time to be redirected to dental use.

CONCLUSION

Within the limitation of the present in-vitro study, it could be concluded:

Experimental medical grade silicone adhesive performed better than glass ionomer cement to resist tensile dislodging force of metal copings and had non-significant difference in shear bond strength compared to Glass ionomer cement. Although Siliconee cement displayed lower TBS and SBS compared to resin cement, it could present a reliable option for cementing implant supported prosthesis. Further clinical researches are still needed to conform that claim in the oral environment.

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