



*Citation for published version:*

Holsgrove, TP, Pentlow, A, Spencer, RF & Miles, AW 2015, 'Cement brand and preparation effects cement-in-cement mantle shear strength', *Hip International*, vol. 25, no. 1, pp. 67-71. <https://doi.org/10.5301/hipint.5000178>

*DOI:*

[10.5301/hipint.5000178](https://doi.org/10.5301/hipint.5000178)

*Publication date:*

2015

*Document Version*

Peer reviewed version

[Link to publication](#)

## University of Bath

### Alternative formats

If you require this document in an alternative format, please contact:  
[openaccess@bath.ac.uk](mailto:openaccess@bath.ac.uk)

#### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

#### Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

1 **Title**

2 Cement Brand and Preparation effects Cement on Cement Mantle Shear Strength

3

4 **Authors**

5

6 Timothy Patrick Holsgrove, Centre for Orthopaedic Biomechanics, University of Bath

7 Alanna Pentlow, Bristol Royal Infirmary

8 Robert F Spencer, Weston General Hospital

9 Anthony W Miles, Centre for Orthopaedic Biomechanics, University of Bath

10

11 **Corresponding Author**

12

13 Timothy Patrick Holsgrove

14 Centre for Orthopaedic Biomechanics

15 Department of Mechanical Engineering

16 University of Bath

17 Bath

18 BA2 7AY

19

20 Email: en1tph@bath.ac.uk

21 **Phone: +441225385961**

22

## 1 **Abstract**

2

3 Creating bi-laminar cement mantles as part of revision hip arthroplasty is well-documented  
4 but there is a lack of data concerning the effect of cement brand on the procedure. The aim  
5 of this study was compare the shear strength of bi-laminar cement mantles using various  
6 combinations of two leading bone cement brands.

7

8 Bi-laminar cement mantles were created using Simplex P with Tobramycin, and Palacos  
9 R+G: Simplex-Simplex (SS); Simplex-Palacos (SP); Palacos-Simplex (PS); and Palacos-  
10 Palacos (PP). Additionally, specimens were produced by rasping (R) the surface of the  
11 original mantle, or leaving it unrasped (U), leading to a total of eight groups (n=10).  
12 Specimens were loaded in shear, at 0.1 mm/min, until failure, and the maximum shear  
13 strength calculated.

14

15 The highest mean shear strength was found in the PSU and PSR groups (23.69 and 23.89  
16 MPa respectively), and the lowest in the PPU group (14.70 MPa), which was significantly  
17 lower than all but two groups. Unrasped groups generally demonstrated greater standard  
18 error than rasped groups.

19

20 In a further comparison to assess the effect of the new cement mantle brand, irrespective of  
21 the brand of the original mantle, Simplex significantly increased the shear strength compared  
22 to Palacos with equivalent preparation.

23

24 It is recommended that the original mantle is rasped prior to injection of new cement, and  
25 that Simplex P with Tobramycin be used in preference to Palacos R+G irrespective of the  
26 existing cement type. Further research is needed to investigate more cement brands, and  
27 understand the underlying mechanisms relating to cement on cement procedures.

## 1 Introduction

2

3 Cementing a new femoral stem within an existing cement mantle during revision hip  
4 arthroplasty is well documented (1, 2). Such a technique aims to minimise the hazards  
5 associated with removing the existing mantle during surgery (3), which include significant  
6 intra-operative bleeding, loss of bone stock, and an 8% risk of intraoperative femoral fracture  
7 (3-5). The cement-on-cement (COC) technique has been shown to be a reliable, with good  
8 to excellent mid-term outcomes providing the existing mantle is not compromised (1, 6-8).

9

10 Several mechanisms of adhesion between the bi-laminar cement mantles have been  
11 suggested. These include mechanical interlocking, polymer chain interdiffusion, chemical  
12 bonding and electrostatic interactions, with different mechanisms contributing to various  
13 degrees (9). Only limited chemical interaction would be possible at the cement-cement  
14 interface, as residual monomer within aged PMMA is characteristically less than 1%, and  
15 terminated PMMA chains within the old mantle have few reactive sites, further limiting  
16 polymerisation (10). It has therefore been hypothesised that the predominant mechanism of  
17 adhesion is by inter diffusion with high levels of monomer in the new cement layer diffusing  
18 into the original layer forming strong polymer chains across the interface (10).

19

20 Concerns remain that the integrity of the bi-laminar cement mantle is weaker than a uniform  
21 mantle and may be more likely to fail. Previous studies have shown the introduction of  
22 antibiotics to the cement, and age of the original mantle, do not significantly alter the shear  
23 strength of bi-laminar cement mantles (10). Large amounts of fluid between the cement  
24 layers has been shown to reduce strength by up to 85% compared to uniform mantles (11).  
25 Rasping of the original cement mantle prior to the addition of the new cement is  
26 recommended in order to increase the bonding of the mantles at a microscopic level (2, 7, 8,  
27 10, 12-14). Greenwald et al. demonstrated the interfacial strength of a COC mantle was 93%  
28 of a uniform cement mantle when the existing mantle was rasped prior to insertion of new

1 cement, and 86% when unrasped (2). However a further study has subsequently  
2 demonstrated that rasping may only make a significant difference when large amounts of  
3 fluid are present between mantles (15).

4

5 The effect of using different cement brands has not been well-studied despite the potential  
6 for a different cement brand to be used in revision surgery compared with the primary  
7 procedure. Different cement brands vary considerably in their compositions and properties,  
8 raising the possibility that they influence the strength of bi-laminar cement mantles. Dang et  
9 al. (16) found no significant differences between different cement combinations when testing  
10 flexural strength, but the effect of cement brand and rasping on the shear strength have not  
11 previously been investigated.

12 The purpose of this study was to investigate the shear strength of bi-laminar cement mantles  
13 comprising different brands of cement. The effect of rasping of the original cement surface  
14 on the shear strength was also assessed.

15

## 16 **Materials and Methods**

17

18 Two brands of commercially available bone cement were used to create bi-laminar cement  
19 mantles, which were tested in shear until failure.

20

21 The two bone cement brands investigated were Simplex P with Tobramycin (Howmedica  
22 International S. de R.L., Limerick, Ireland) and Palacos R+G (Heraeus Kulzer GmbH, Kulzer  
23 Division, Wehrheim, Germany). Bi-laminar cement samples were created in four  
24 combinations, where the first name denotes the original mantle, and the second name  
25 denotes the new cement mantle: Simplex-Simplex (SS); Simplex-Palacos (SP); Palacos-  
26 Simplex (PS); and Palacos-Palacos (PP) (Figure 1). Each of these groups was subdivided  
27 into either rasped (R) or unrasped (U), giving a total of eight test groups (SSU, SPU, PSU,  
28 PPU, SSR, SPR, PSR, and PPR). Ten test specimens were produced for each group.

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28

Simplex cement was mixed using the Summit mixing syringe (Summit Medical Ltd, Bourton-on-the Water, Gloucestershire). The Palacos cement was mixed using a similar Palacos syringe mixing system. All cement was mixed for 1 minute under a vacuum of 67.7 kPa after the introduction of the liquid monomer to the PMMA powder. The plunger of the mixing system was cycled at approximately 1 Hz during the mixing process. The cement was injected into the mould 3 minutes after the introduction of the monomer to the PMMA. All cement was mixed and allowed to fully polymerise at room temperature.

The mould used was based on ISO 5833:2002 (17) for the determination of the bending modulus and bending strength of polymerised cement. The first layer of cement produced ten samples that were 3 mm in depth, 10 mm in width, and 75 mm in length. A second mould was used with identical measurements but with a depth of 4 mm for each sample. This allowed the existing samples to be inserted into the mould, and the new cement layer injected on top to produce bi-laminar samples with an old cement mantle depth of 3 mm and a new cement mantle depth of 1 mm.

After the production of the 3 mm deep samples, the edges were filed to ensure that they would fit into the second mould. The samples were then stored in air, in an incubator at a temperature of 37°C for a period of one week prior to the addition of the 1 mm layer. Samples were stored in the group of ten in which they were produced to ensure that the final samples in a group had been produced from the same cement mix.

On the day of the production of the second cement layers, samples in the rasped group were prepared by hand using 120 grit emery cloth. The method previously described was used to mix and inject the second layer of cement, and when fully polymerised, the samples were stored overnight, in air, at 37°C.

1 Shear tests were completed using a ball screw driven testing machine equipped with a 5 kN  
2 load cell (Instron 3365, Instron Ltd., Buckinghamshire, UK). Prior to testing, the samples  
3 were cut down to a length of 10 mm. Pilot testing had demonstrated that longer specimens  
4 remained intact under the maximum load capacity of the testing machine.

5

6 The length and width of each sample was measured using Vernier callipers prior to testing to  
7 ensure that an accurate value of the area could be calculated for each specimen.

8

9 A custom jig was used to mount the specimens (Figure 2), with the 3 mm deep cement layer  
10 fixed to the baseplate, and the 1 mm cement layer floating in line with the crosshead  
11 attachment. The crosshead fixture was designed so as to apply the load through the 1 mm  
12 deep cement layer along the length of the specimen. The specimens were tested  
13 quasistatically, in position control, at a rate of 0.1 mm/min until failure. The load and position  
14 data were acquired for each test at a frequency of 10 Hz.

15

16 The load data was used along with the calculated area over which the load was applied, to  
17 calculate the shear stress. The shear strength of each specimen was defined as the  
18 maximum shear stress of each test, and this value was used for the statistical comparisons  
19 between the test groups. All statistical analyses were completed using SPSS (IBM SPSS  
20 Statistics 19; IBM Corporation, Armonk, NY, USA).

21

22 Each group was tested for normality using the Shapiro-Wilke test. Six out of the eight groups  
23 were normally distributed ( $p > 0.05$ ), and therefore a comparison was made between all eight  
24 groups using a one-way ANOVA with a Bonferroni post-hoc test.

25

26 A further comparison was made in regard to the effect of the brand of the new layer of  
27 cement irrespective of the brand used in the original cement mantle, and on the effect of  
28 rasping prior to the injection of the new cement mantle. This analysis comprised four test

1 groups (SU, SR, PU, PR), with the first letter denoting whether the new cement mantle was  
2 Simplex (S) or Palacos (P), and the second letter denoting whether the old cement mantle  
3 was rasped (R) or unrasped (U).

4

5 Three out of the four test groups in this latter comparison were found to be non-normally  
6 distributed using the Shapiro-Wilke normality test. Therefore, non-parametric tests were  
7 adopted. The groups were first compared using a Kruskal-Wallis test, with Mann-Whitney  
8 tests used for post-hoc analysis. A Bonferroni correction was used to account for multiple  
9 comparisons, with  $p < 0.0083$  required for statistical significance.

10

## 11 **Results**

12

13 The failure of test specimens tended to result in either a fracture directly down the cement-  
14 cement interface, or via a crack that started at the cement-cement interface, which then  
15 propagated into the original cement mantle. There was no observable pattern in the failure  
16 mechanism within or between test groups.

17

18 The shear strength varied considerably between groups, both in terms of the mean, and the  
19 standard error (SE) (Figure 3). The two groups with the highest mean shear strength were  
20 PSU and PSR with magnitudes of 23.69 and 23.89 MPa respectively. The lowest mean  
21 shear strength was 14.70 MPa in the PPU group, which also demonstrated the largest  
22 standard error of 2.2 MPa. The standard error was generally greater in the unrasped groups  
23 (range of SE 0.46-2.2 MPa) compared to the rasped groups (range of SE 0.19-0.55 MPa).

24

25 The statistical analysis of all eight groups demonstrated that there were significant  
26 differences in 7 of the 28 comparisons (Table 1). The shear strength of the PPU group was  
27 significantly lower than all but the SSU and SPU groups. The only other significant



1 differences were that the SSU group had a significantly lower shear strength than the PSU  
2 and PSR groups ( $p=0.014$  and  $0.009$  respectively).

3

4 The comparison of the effect of the second layer cement brand irrespective of the first layer  
5 brand showed that using Palacos on an unrasped surface resulted in a significantly lower  
6 shear strength than using Simplex with either unrasped ( $p=0.007$ ) or rasped ( $p<0.001$ )  
7 surface preparation (Table 2Table ). It was also found that Palacos on a rasped surface had  
8 a significantly lower shear strength than Simplex on a rasped surface ( $p<0.001$ ). There was  
9 no significant difference between the unrasped and rasped groups with a second layer of  
10 Simplex ( $p=0.201$ ) or between the two groups with Palacos as a second layer ( $p=0.108$ ),  
11 though the spread of data was greater in the unrasped groups (Figure 4).

12

### 13 **Discussion**

14

15 The results demonstrate that the altering the combination and preparation of cements used  
16 in bi-laminar samples significantly affects the shear strength. The range of shear strength in  
17 unrasped groups was higher than in rasped groups, though the only group for which rasping  
18 created a significant difference was for Palacos- Palacos.

19

20 The cement mixing systems used in this study were both syringe systems, though they were  
21 not identical for each brand of cement. Whilst this may have introduced an additional  
22 variable, the study aimed to replicate the clinical situation. Therefore, the proprietary Palacos  
23 syringe system was used to mix the Palacos bone cement, and the Simplex bone cement  
24 was mixed with a Summit HiVac Syringe system.

25

26 It has previously been recommended that COC procedures prepare the old cement mantle  
27 with rasping prior to the introduction of new cement into the femoral canal (2, 10). The  
28 results of the present study support these recommendations, and although few significant

1 differences were observed between unrasped and rasped groups of the same cement  
2 combination, the range and SE was lower with a rasped surface in all cases.

3

4 The comparison of all eight test groups suggests that the lowest shear-strength is obtained  
5 by injecting new cement onto an old cement mantle of the same brand without rasping. This  
6 combination of cement brands and preparation also resulted in the largest standard error in  
7 shear strength.

8

9 Comparing the effect of the brand of the new cement mantle and rasping preparation  
10 provides useful data for the clinical environment, as a surgeon undertaking revision total hip  
11 arthroplasty will not have a choice regarding the original cement mantle but instead must  
12 choose the most appropriate technique and cement brand for use in the revision procedure.  
13 This analysis demonstrated that from existing mantles of Simplex P and Palacos R+G, a bi-  
14 laminar mantle with greater consistency and shear strength can be achieved by rasping the  
15 existing mantle prior to the addition of Simplex P for the new mantle.

16

17 It is possible that the results of the present study relate to the curing of the respective  
18 cements. Cement that has low viscosity at the time of injection may be better able to  
19 integrate into the rasped surface of the existing mantle under the post-injection pressure that  
20 is applied during curing. However, it is possible that the presence of the existing cement may  
21 alter curing times, although there is no published evidence to date testing this hypothesis,  
22 and as such manufacturers recommendations do not include any alterations in cementing  
23 technique when cementing onto a pre-existing cement mantle. Further research is required  
24 to fully understand the polymerisation of bone cements in the presence of existing mantles,  
25 in order to further optimise the COC procedure.

26

27 Based on the findings of this study, it is recommended that all cement on cement procedures  
28 use rasping to prepare the existing cement mantle prior to injection of the new cement. It is

- 1 also recommended that Simplex P bone cement be used in preference to Palacos R+G for
- 2 the new cement irrespective of the existing cement type.
- 3

## 1   **References**

2

- 3   1.   Duncan WW, Hubble MJ, Howell JR, Whitehouse SL, Timperley AJ, Gie GA. Revision  
4       of the cemented femoral stem using a cement-in-cement technique: A five to fifteen  
5       year review. *J Bone Joint Surg Br.* 2009;91(5):577-82.
- 6   2.   Greenwald AS, Narten NC, Wilde AH. Points in the technique of recementing in the  
7       revision of an implant arthroplasty. *J Bone Joint Surg Br* 1978;60(1):107–10.
- 8   3.   Meek RM, Garbuz DS, Masri BA, Greidanus NV, Duncan CP. Intraoperative fracture of  
9       the femur in revision total hip Arthroplasty with a diaphyseal fitting stem. *J Bone Joint*  
10      *Surg Am.* 2004;86-A(3):480-5.
- 11  4.   Canale ST. *Campbell's operative orthopaedics.* 10<sup>th</sup> ed. St Louis, MO, USA: Mosby,  
12      2003.
- 13  5.   Gardiner R, Hozack WJ, Nelson C, Keating EM. Revision total hip arthroplasty using  
14      ultrasonically driven tools. A clinical evaluation. *J Arthroplasty.* 1993;8(5):517-21.
- 15  6.   Wilson LJ, Bell CG, Weinrauch P, Crawford R. In vitro cyclic testing of the Exeter stem  
16      after cement within cement revision. *J Arth.* 2009;24(5):789-94.
- 17  7.   Lieberman JR, Moeckel BH, Evans BG, Salvati EA, Ranawat CS. Cement-within-  
18      cement revision hip arthroplasty. *J Bone Joint Surg Am.* 2003;75(6):869–71.
- 19  8.   McCallum JD 3rd, Hozack WJ. Recementing a femoral component into a stable  
20      cement mantle using ultrasonic tools. *Clin Orthop Relat Res.* 1995;319:232-7.
- 21  9.   Garbassi F, Morra M, Occheillo E. *Polymer surfaces: From physics to technology.*  
22      Chichester, West Sussex, UK: John Wiley & Sons, 1998.
- 23  10.  Weinrauch PC, Bell C, Wilson L, Goss B, Lutton C, Crawford RW. Shear properties of  
24      bilaminar polymethylmethacrylate cement mantles in revision hip joint arthroplasty. *J*  
25      *Arthroplasty.* 2007;22(3):394–403.
- 26  11.  Li PL, Ingle PJ, Dowell JK. Cement-within-cement revision hip arthroplasty; should it  
27      be done? *J Bone Joint Surg Br.* 1996;78(5):809-11.

- 1 12. Goto K, Kawanabe K, Akiyama H, Morimoto T, Nakamura T. Clinical and radiological  
2 evaluation of revision hip arthroplasty using the cement-in-cement technique. *J Bone*  
3 *Joint Surg Br.* 2008;90(8):1013-8.
- 4 13. Mandziak DG, Howie DW, Neale SD, McGee MA. Cement within-cement stem  
5 exchange using the collarless polished double-taper stem. *J Arthroplasty*  
6 2007;22(7):1000-6
- 7 14. Quinlan JF, O'Shea K, Doyle F, Brady OH. In-cement technique for revision hip  
8 arthroplasty. *J Bone Joint Surg Br.* 2006;88(6);730-3.
- 9 15. Rudol G, Wilcox R, Jin Z, Tsiridis E. The effect of surface finish and interstitial fluid on  
10 the cement-in-cement interface in revision surgery of the hip. *J Bone Joint Surg Br.*  
11 2011;93(2);188-93.
- 12 16. Dang K, Pelletier MH, Walsh WR. Factors affecting flexural strength in cement within  
13 cement revisions. *J Arthroplasty.* 2011;26(8):1540-8.
- 14 17. British Standards Institution. BS ISO 5833:2002 – Implants for surgery – Acrylic resin  
15 cements. London, UK: British Standards Institution, 2002.
- 16

1 **Figures**

2

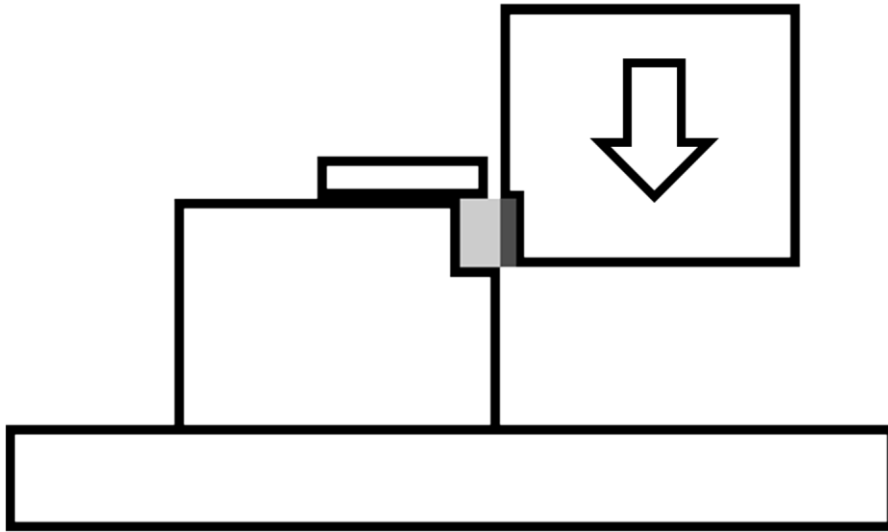


3

4

Figure 1: Bi-laminar cement mantles from left to right: SS; SP; PS; and PP

5



1

2

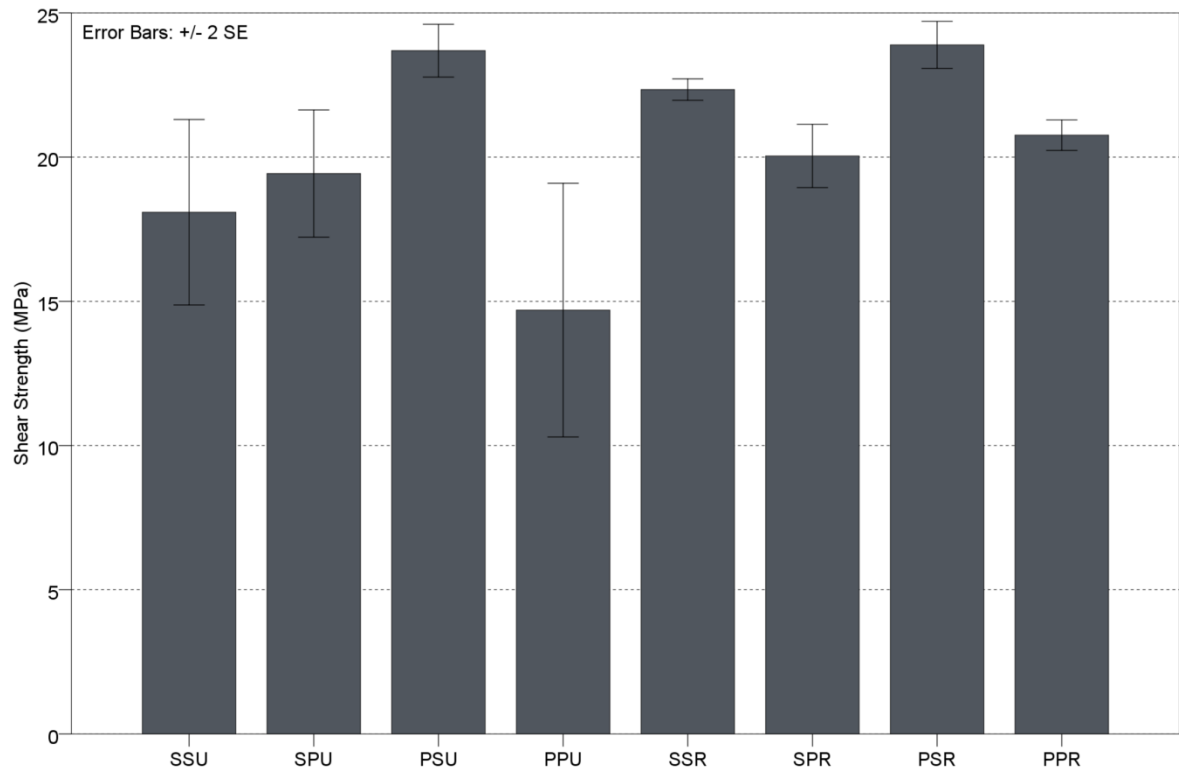
Figure 2: Diagram of the shear testing apparatus. The upper block was fixed to the crosshead of the Instron testing machine. The red area represents the original cement

3

4

mantle, the grey area the second cement layer.

5



1

2

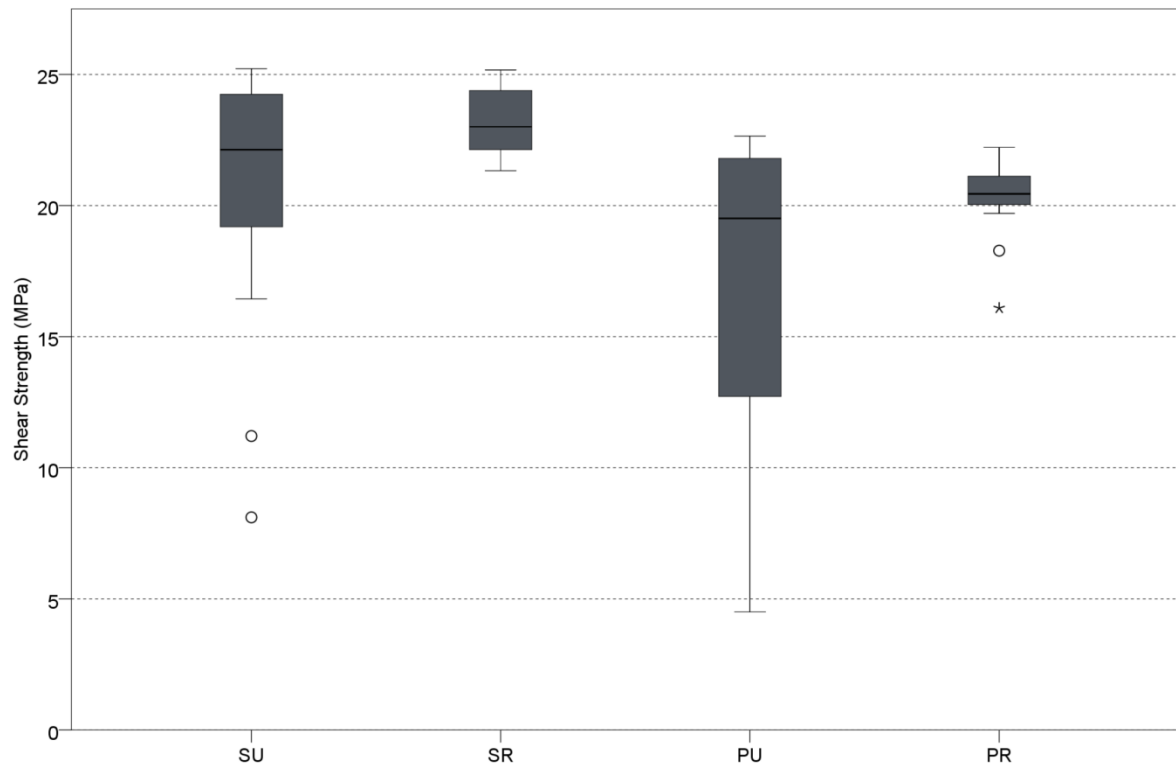
Figure 3: Mean shear strength of each cement-cement group (n=10). Error bars denote the confidence intervals

3

4

5





1

2 Figure 4: Boxplot of the shear strength for each cement-cement group based on the brand of

3

the new cement mantle and preparation (n=20)

1 **Tables**

2

3 Table 1: Comparison of shear strength between bi-laminar cement test groups. Significance

4 denoted with bold font ( $p < 0.05$ )

BRANDS	SSU	SPU	PSU	PPU	SSR	SPR	PSR	PPR
SSU		>0.999	<b>0.014</b>	0.845	0.199	>0.999	<b>0.009</b>	>0.999
SPU	>0.999		0.196	0.081	>0.999	>0.999	0.136	>0.999
PSU	<b>0.014</b>	0.196		<b>&lt;0.001</b>	>0.999	0.561	>0.999	>0.999
PPU	0.845	0.081	<b>&lt;0.001</b>		<b>&lt;0.001</b>	<b>0.024</b>	<b>&lt;0.001</b>	<b>0.005</b>
SSR	0.199	>0.999	>0.999	<b>&lt;0.001</b>		>0.999	>0.999	>0.999
SPR	>0.999	>0.999	0.561	<b>0.024</b>	>0.999		0.402	>0.999
PSR	<b>0.009</b>	0.136	>0.999	<b>&lt;0.001</b>	>0.999	0.402		>0.999
PPR	>0.999	>0.999	>0.999	<b>0.005</b>	>0.999	>0.999	>0.999	

5

- 1 Table 2: Comparison of shear strength between bi-laminar cement test groups based on the  
 2 new cement mantle and preparation. Significance denoted with bold font ( $p < 0.0083$ )

BRANDS	SU	SR	PU	PR
SU		0.201	<b>0.007</b>	0.028
SR	0.201		<b>&lt;0.001</b>	<b>&lt;0.001</b>
PU	<b>0.007</b>	<b>&lt;0.001</b>		0.108
PR	0.028	<b>&lt;0.001</b>	0.108	

3