ORIGINAL RESEARCH

Vertical Marginal Discrepancy of Retrievable Cement/Screw-retained Design and Cement-retained Implant-supported Single Metal Copings

Pedro Luis Tinedo-López[1], Violeta Malpartida-Carrillo[2], Fernando Ortiz-Culca[3], Maria E Guerrero[4], Silvia P Amaya-Pajares[5], Mutlu Özcan[6]

Abstract

Aim: To compare the vertical marginal discrepancy of retrievable cement/screw-retained design (RCSRD) and cement-retained (CR) implant-supported single metal copings cemented on implant abutments.

Materials and methods: Single metal copings were fabricated for 20 4.5 × 10 mm titanium dental implants. Two groups of 10 implants each were randomly allocated. One group received RCSRD metal copings and the other group received CR metal copings. Both types of restorations were fabricated on solid abutments with 5.5 mm of diameter. The copings were cemented with resin cement. After the cementation procedure, cement excess was carefully removed in both groups. Inspections of coping-abutment vertical marginal discrepancy were measured using scanning electronic microscopy (SEM) under 800× magnification. The independent sample Student's *t* test was used to detect differences between groups ($p < 0.05$).

Results: The RCSRD implant-supported metal coping group (57.80 ± 2.34 µm) showed statistically better vertical marginal discrepancy than the CR implant-supported metal coping group (64.40 ± 2.23 µm) ($p = 0.001$).

Conclusion: The RCSRD implant-supported metal copings offer less vertical marginal discrepancy than the CR copings group. This new technique would decrease the marginal discrepancy with less bacterial filtration and biomechanical problems.

Clinical significance: Retrievable cement/screw-retained design is another alternative technique for dental implant rehabilitation that combines the advantages of CR and SR prostheses. The hybrid design offers less vertical marginal discrepancy for better control of bacterial filtration and biomechanical problems.

Keywords: Dental implants, Dental marginal adaptation, Dental prosthesis, Implant-supported.

The Journal of Contemporary Dental Practice (2020): 10.5005/jp-journals-10024-2905

Introduction

Dental implants are an effective treatment option for partially or totally edentulous patients and the success is directly related to the osseointegration process, functional performance, and biologic integration of prosthetic components.[1–3]

Traditionally, implant-supported fixed dental prostheses (FDPs) are retained by either cementing them over an abutment or attaching them to the implant through a screw.[4] Both types of restorations have different advantages and disadvantages.[5,6] Even more, a pertinent literature review stated that when screw-retained (SR) and cement-retained (CR) prostheses were compared, survival rates were similar, soft/hard tissue levels and responses were comparable, and zirconia offered esthetic advantages for both prostheses.[7] However, the residual cement at the implant-abutment interface is the principal disadvantage of the CR prosthesis and produce infiltration, inflammation, and implant failure.[8,9] Moreover, a systematic review stated that comparing the two alternatives, the CR prosthesis has more biological and technical complications.[10]

In dentistry, the concept of vertical marginal discrepancy (VMD) is the measurement of interface between the prosthesis and the abutment once joined through a screw or dental cement. This is one of the most important key factors to attain long-term success of implant-supported FDP because inadequated VMD could cause bacterial leakage, plaque accumulation, and peri-implant

[1]Department of Periodontology, School of Dentistry, Universidad Cientifica del Sur, Lima, Peru

[2]Department of Periodontology, School of Stomatology, Universidad Privada San Juan Bautista, Lima, Peru

[3]Department of Rehabilitation Stomatology, Faculty of Dentistry, Universidad Nacional Mayor de San Marcos, Lima, Peru

[4]Department of Medico Surgical Stomatology, Faculty of Dentistry, Universidad Nacional Mayor de San Marcos, Lima, Peru

[5]Department of Restorative Dentistry, School of Dentistry, Oregon Health and Science University, Portland, Oregon, USA

[6]Center of Dental Medicine, Division of Dental Biomaterials, Clinic for Reconstructive Dentistry, University of Zurich, Zurich, Switzerland

Corresponding Author: Pedro Luis Tinedo-López, Department of Periodontology, School of Dentistry, Universidad Cientifica del Sur, Lima, Peru, Phone: +511 6106400 extn: 324, e-mail: pedro120488@outlook.es

How to cite this article: Tinedo-López PL, Malpartida-Carrillo V, Ortiz-Culca F, *et al.* Vertical Marginal Discrepancy of Retrievable Cement/Screw-retained Design and Cement-retained Implant-supported Single Metal Copings. J Contemp Dent Pract 2020;21(8): 829–834.

Source of support: Nil

Conflict of interest: None

© The Author(s). 2020 Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted use, distribution, and non-commercial reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.

mucositis.[11] In the literature, some authors recommended a VMD of less than 120 µm after copings cementation as originally suggested for fixed prosthesis.[12] In addition, an *in vitro* study reported VMD from 63.6 µm in noncemented cast copings to 116.1 µm after cast copings cementation.[13] However, the SR prosthesis shows always the best marginal discrepancy because no cement is used.[14]

Looking for improvements of implant-supported FDP, both traditional techniques were fused in a new alternative technique called retrievable cement/screw-retained design (RCSRD) implant-supported prosthesis that combines the advantages of CR and SR prostheses.[15–18] This prosthesis has an screw access hole and allows the use of cement (retrievable design). In addition, the RCSRD has two exit areas to remove excess of cement; one is the screw access hole and the other one the marginal interface, offering more control of remnant cement. Another advantages are the possibility to clean the remnant cement excess, to polish the abutment-restoration interface, and could make more comfortable the prosthetic maintenance,[19] which is ideal for periodontal patients. In the literature, some clinical studies reported about RCSRD.[20,21] However, the VMD has not been determined considering the scanning electronic microscope (SEM) that allows exploring the entire perimeter with high accuracy.

Hence, the objective of this *in vitro* study was to use SEM to compare the VMD of RCSRD and CR single copings after have been cemented with resin on implant abutments.

Materials and Methods

This *in vitro* study was performed at Faculty of Health Sciences of the Universidad Cientifica del Sur, Lima, Peru. The specimens consisted of 20 single copings. The sample size was determined by a pilot test of 10 specimens (5 specimens each) using the formula to compare two means with a 95% confidence level, a statistical power of 90%, an accuracy of 5.06 micrometers (µm), and a variance of 7.52 µm. According to this result and a preliminary study,[14] 10 specimens were evaluated per group.

Twenty cylindrical morse taper implants, with a diameter of 4.5 mm and 10 mm in length (Super Line Implant; FX 4510 SW, Dentium, Seoul, South Korea), were connected to 20 titanium hexagonal abutments (AAB 1054550 HL, Dentium, Seoul, South Korea) with 5.5 mm in diameter, 8.5 mm in length, 2 mm in collar height, and 6° of taper. The implants were randomly divided into two groups ($n = 10$): CR and RCSRD.

Cement-retained Copings (Group CR)

The abutments were sandblasted with 110 µm of pure aluminum oxide particles (Duostar Z, Bego, Moscow, Russia) under a pressure of 0.4 MPa to create an opaque surface. The abutments were scanned using an extraoral scanner (Autoscan-DS200 Dental 3D scanner, China) to create a virtual CAD/CAM model pattern. The frameworks of the single prosthesis were designed using a 3-D shape dental software (3shape Dental Designer, 3shape A/S, Copenhagen, Denmark) following the program recommendations as follows: 0.5 mm thickness for all axial walls and 40 µm for cement space in all the intaglio surface, and this information was stored in the template library file for both groups.

The frameworks were sintered with the sintering laser selective machine (Concept Laser Hofmann, Lichtenfels, Germany). The Remanium star CL powered (Co 60.5%, Cr 28%, W 9%, Si 1.5%, other elements <1%: Mn, N, Nb, Fe, Dentaurum, Ispringen, Germany) was slightly melted with a high-temperature laser. Approximately a layer of 20 µm width was formed until the framework was completed. This procedure was performed for all the specimens. All these procedures were done by an expert dental technician.

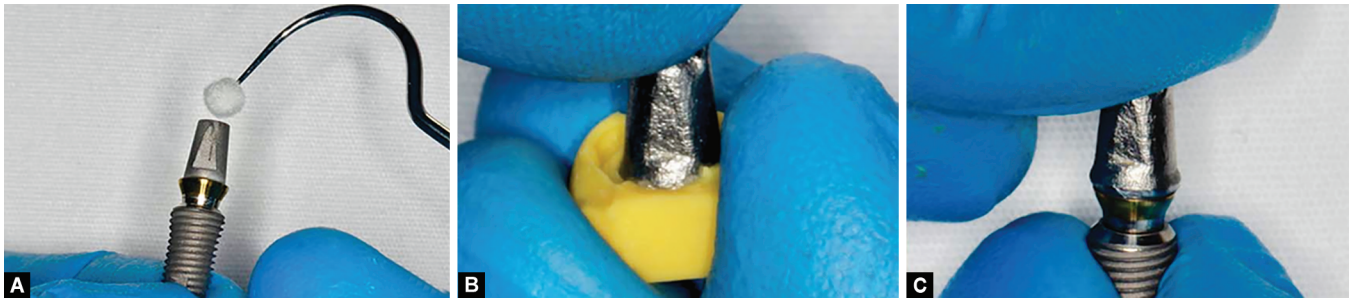
Retrievable Cement/Screw-retained Design Copings (Group RCSRD)

A similar procedure described for group CR was followed. Additionally, a screw access hole was placed at the center of the occlusal surface using a software. The diameter of the screw access hole represented the screw abutment diameter (2 mm).

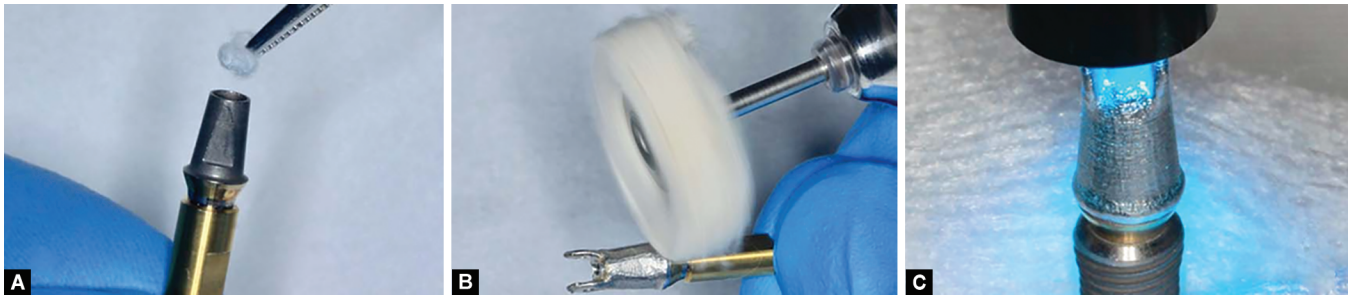
Metal Copings Cementation on Implant Abutments

In group CR, the abutment screws were torqued at 35 N cm using a torque wrench (SCB 10 IT, Dentium, Seoul, South Korea) as recommended by the manufacturer. Later, the abutment screw channels were filled with cotton pellets (Fig. 1A) and an impression of the internal coping surface was made with the polyvinyl siloxane material (Putty, Panasil, Heerfeld, Eschenburg, Germany).[22] After, resin cement (RelyX U200 A_2, 3M ESPE, Minnesota, USA) was applied to the axial walls of the copings and prior to light-curing, the prostheses were seated on the silicone abutment replicas for cement film reduction (Fig. 1B). Then, the copings were placed on the abutments using finger pressure for 10 seconds (Fig. 1C). Finally, light-cure was achieved using a photopolymerization lamp (Litex 682, 3M Dentamerica INC, Pasippany, USA) with 20 seconds per surface at 600 mW/cm.[2]

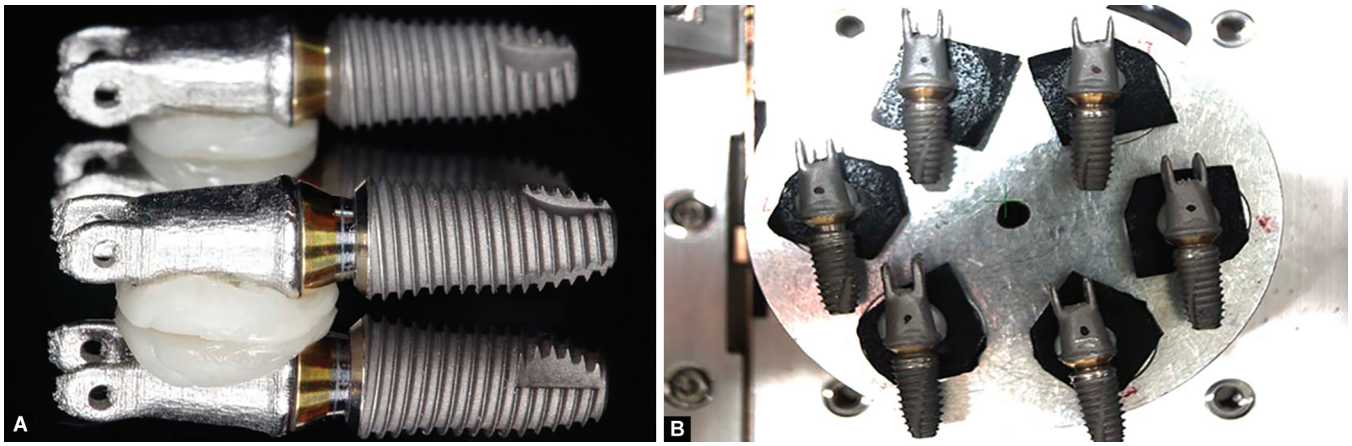
The abutments of the group RCSRD were screwed on their analogs (Dentium, Seoul, South Korea). After, the abutment screw channels were filled with cotton pellets (Fig. 2A) and the copings were extraorally cemented on the abutments using the resin cement. Cement excess was removed with a N° 12 blade and the interface coping-abutment was polished (Universal Polishing Paste, Ivoclar Vivadent, Schaan, Germany) (Fig. 2B). Later, the copings



Figs 1A to C: Representative specimen showing the procedure for CR implant-supported metal coping cementation. (A) Screw abutment channel filled with cotton pellets; (B) Casting set up on the silicone abutment replicas prior to light-curing; (C) Cast placement on the abutment using finger pressure



Figs 2A to C: Representative specimen showing the procedure for RCSRD implant-supported metal coping cementation: (A) Screw abutment channel filled with cotton pellets; (B) Coping-abutment interface polishing; (C) Composite resin light-cured



Figs 3A and B: Representative specimens' stabilization to evaluate the VMD: (A) Representative specimens of RCSRD and CR implant-supported copings; (B) Black points placement at the center vestibular surface of the specimens

cemented on the abutments were placed in the implants, the occlusal screws were torqued, and cotton pellets were placed in the screw access holes before adhesive application with disposable brushes (3M, Minnesota, USA). Finally, the screw access holes were sealed with composite resin (Filtek Z350 XT Universal Restorative, 3M ESPE, Minnesota, USA) and were light-cured with the same photopolymerization lamp (Fig. 2C). All these procedures were done by the investigator.

Vertical Marginal Discrepancy

The specimens were stabilized on the lingual surface using a resin (Fig. 3A). This stabilization allowed a correct visualization of the interface at the vestibular surface, which was confirmed with a digital light microscope under 40× magnification (Model T-1050, Ken-A-Vision, Kansas, USA). Each specimen was marked at the center of the vestibular surface with a black point using a marker (Fig. 3B) in order to identify the first surface evaluated. After, the measurements were made parallel to the coping-abutment interface at three predetermined reference points at the mid-buccal, mid-mesial, and mid-distal side of each abutment. Finally, the averages of these three measurements were considered as the VMD value.

Then, all the specimens were measured using a SEM (Model Inspect S50, FEI, Oregon, USA) without any previous sample preparation. The images were obtained under the following conditions: using a secondary electron detector, 800× magnification, a spot at 5.0, and images scale of 100 µm (Fig. 4). Each specimen was randomly allocated and all measurements were made by an expert microscopy technician who stores the data in a spreadsheet.

Statistical Analysis

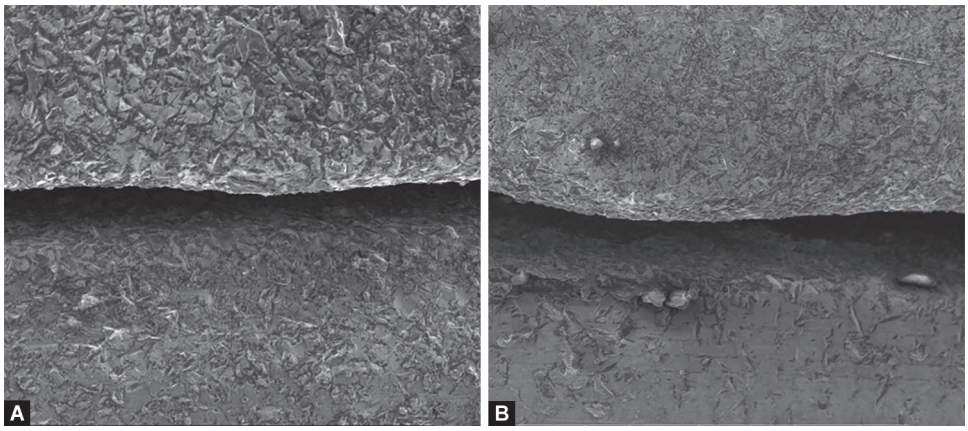
The analysis was performed using the SPSS 24 (SPSS Inc., Armonk, NY, USA) software for windows. The Shapiro–Wilk test corroborated the normal distribution of the data. Then, mean values of VMD for both groups were compared by independent sample Student's *t* test to detect statistically significant differences between groups ($p < 0.05$).

Results

Table 1 displays the descriptive statistics (mean, standard deviation, median, minimum, maximum, and variance) of the VMD values for each implant-supported prosthesis (RCSRD and CR). The highest VMD values were obtained in the CR group (64.40 ± 2.23 µm) whereas the lowest VMD values were obtained in the RCSRD group (57.80 ± 2.34 µm). Table 2 shows the inferential statistics. The independent sample *t* test indicated that VMD values were significantly different ($p = 0.001$) among the two groups. The RCSRD group (57.80 ± 2.34 µm) had significantly the lowest VMD values in comparison to the CR group (64.40 ± 2.23 µm), respectively.

Discussion

Marginal discrepancy is a key factor for the long-term function of implant-supported restorations in the oral environment because it promotes clinical success and prosthesis durability.[23] The objective of this *in vitro* study was to compare the VMD of RCSRD and CR single copings after have been cemented with resin on implant abutments.



Figs 4A and B: Representative SEM images after VMD measurement: (A) RCSRD implant-supported metal coping; (B) CR implant-supported metal coping

Table 1: Vertical marginal discrepancy evaluation of RCSRD and CR implant-supported single metal copings cemented on implant abutments

Implant-retained prosthesis	*N*	*Unit*	*Mean*	*SD*	*Median*	*Minimum*	*Maximum*	*Variance*
RCSRD	10	µm	57.80	2.34	57.13	54.41	61.57	5.49
CR	10	µm	64.40	2.23	64.34	59.78	67.43	5.01

RCSRD, retrievable cement/screw-retained design prosthesis; CR, cement-retained prosthesis

Table 2: Comparison of the VMD between RCSRD and CR implant-supported single metal copings cemented on implant abutments

Implant-retained prosthesis	*N*	*Unit*	*Mean*	*SD*	*95% IC lower superior*		*p value*
RCSRD	10	µm	57.80	2.34	56.13	59.48	0.001*
CR	10	µm	64.40	2.23	62.80	66.00	

RCSRD, retrievable cement/screw-retained design prosthesis; CR, cement-retained prosthesis
*Indicates significant difference (independent samples *t* test, $p = 0.001$)

According with Holmes et al.,[24] VMD is defined as the misfit measured parallel to the path of draw of the casting. However, in the literature we can find studies about absolute marginal discrepancy,[25] marginal and internal fit,[26] and vertical marginal fit,[23] for the marginal accuracy evaluation of compounds cemented or sitted on implants.

The results of the present study showed a statistical significant difference in the VMD between RCSRD (57.80 ± 2.34 µm) and CR (64.40 ± 2.23 µm) cast copings cemented on implant abutments. One study with similar methodology evaluated VMD of CR metal-ceramic crowns on implant abutments using a stereomicroscope.[14] These authors reported a VMD of 54.4 ± 18.1 µm before cementation, 57.4 ± 20.2 µm after crown cementation using glass-ionomer cement, and 67.4 ± 15.9 µm using zinc phosphate. However, the images had low resolution and the limits between the abutment and the cast were unclear, which might interfere with the VMD measurement. In contrast, the present study used SEM to quantify the VMD and this in a recommended method for marginal discrepancy evaluation.[27]

Although no consensus has been reached on the exact level of discrepancy considered acceptable for implant frameworks, several investigations[12,13] have reported that VMD values below 120 µm are clinically acceptable. On the other hand, some literature proposed VMD of 63.6 µm or less in CR implant-supported prosthesis,[28] even though mean values below 30 µm have been difficult to achieve clinically using conventional ceramic crowns.[29]

A combined retrievable technique called the RCSRD prosthesis was described. This prosthesis is cemented on its abutment and has an access hole to be screwed to an implant. This should allow the removal of the prosthesis outside the dental implant without the necessity of the crown destruction. According with the results of the present study, the RCSRD group showed better VMD than the CR group leading to less bacterial leakage and excess cement remaining, which could have less biological problems.

The copings were fabricated through an additive method called selective laser sintering (SLS), which is being increasingly used as a new technology in oral rehabilitation. In addition, Kim et al.[30] compared the marginal discrepancy of metal copings produced with the subtractive method (milling soft metal blocks), the additive method (SLS), and the traditional method (lost wax and casting). These authors concluded that marginal discrepancy with additive (SLS) and subtractive methods was more accurate than the traditional lost wax and casting methods. Moreover, another study[31] compared the marginal discrepancy of metal-ceramic crowns using the SLS method and traditional Co-Cr casting and concluded similar values of better results using SLS.

An important consideration for marginal discrepancy evaluation is the finish line type of the abutment because an abutment with a shoulderless finish line would decrease the marginal discrepancy compared to an abutment with a chamfer finish line.[20] For that, in the present study, chamber finish line abutments were used for easy identification in the microscopy evaluation.

According with the RCSRD fabrication, the abutment has a screw access hole opened on the outside.[15–17,19–21] A disadvantage of this prosthesis is that the screw access hole could affect the resistance of the ceramic. Nevertheless, an *in vitro* study compared

the fracture resistance between CR and RCSRD prostheses and no significant differences were found in the fracture resistance.[31] In addition, da Rocha et al.[32] have reported that the screw access hole has no significant effect on prosthesis retention.

An important limitation of this study was to achieve the correct stabilization of the specimens since the prosthesis-abutment interface had to be viewed from a strict perpendicular plane. However, a digital light microscope was used to verify the perpendicular position of the prosthetic-abutment interface before performing the analysis with the SEM. Another limitation was that the specimens were not subjected to a physiological fatigue load or thermocycling. However, currently there is no consensus on the need for thermocycling in the evaluation of *in vitro* studies.[33]

The findings of the present study suggest that the VMD in RCSRD implant-supported single copings might be more accurate than CR implant-supported single copings cemented on dental implants abutments. Future research with *in vivo* study design and long-term follow-up should assess clinical performance in relation to peri-implant health before promoting recommendation of the RCSRD implant-supported prosthesis.

Conclusion

The RCSRD implant-supported metal copings offer less VMD than the CR copings group. This new technique would decrease the marginal discrepancy with less bacterial filtration and biomechanical problems.

References

1. Chochlidakis K, Einarsdottir E, Tsigarida A, et al. Survival rates and prosthetic complications of implant fixed complete dental prostheses: an up to 5-year retrospective study. J Prosthet Dent 2020;S0022–3913(19):30761–30769. DOI: 10.1016/j.prosdent.2019.11.022.
2. Del Fabbro M, Testori T, Kekovic V, et al. A systematic review of survival rates of osseointegrated implants in fully and partially edentulous patients following immediate loading. J Clin Med 2019;8(12):E2142. DOI: 10.3390/jcm8122142.
3. Pitta J, Zarauz C, Pjetursson B, et al. A systematic review and meta-analysis of the influence of abutment material on peri-implant soft tissue color measured using spectrophotometry. Int J Prosthodont 2020;33(1):39–47. DOI: 10.11607/ijp.6393.
4. Wittneben JG, Joda T, Weber HP, et al. Screw retained vs. cement retained implant-supported fixed dental prosthesis. Periodontol 2000 2017;73(1):141–151. DOI: 10.1111/prd.12168.
5. Sailer I, Muhlemann S, Zwahlen M, et al. Cemented and screw-retained implant reconstructions: a systematic review of the survival and complication rates. Clin Oral Implants Res 2012;23(Suppl 6):163–201. DOI: 10.1111/j.1600-0501.2012.02538.x.
6. Gomez-Polo M, Ortega R, Gomez-Polo C, et al. Factors Affecting the decision to use cemented or screw-retained fixed implant-supported prostheses: a critical review. Int J Prosthodont 2018;31(1):43–54. DOI: 10.11607/ijp.5279.
7. Priest G. A current perspective on screw-retained single-implant restorations: a review of pertinent literature. J Esthet Restor Dent 2017;29(3):161–171. DOI: 10.1111/jerd.12283.
8. Gapski R, Neugeboren N, Pomeranz AZ, et al. Endosseous implant failure influenced by crown cementation:a clinical case report. Int J Oral Maxillofac Implants 2008;23(5):943–946.
9. Pauletto N, Lahiffe BJ, Walton JN. Complications associated with excess cement around crowns on osseointegrated implants: a clinical report. Int J Oral Maxillofac Implants 1999;14(6):865–868.
10. Wittneben JG, Millen C, Bragger U. Clinical performance of screw- vs cement-retained fixed implant-supported reconstructions—a systematic review. Int J Oral Maxillofac Implants 2014;29(Suppl): 84–98. DOI: 10.11607/jomi.2014suppl.g2.1.
11. Nascimento C, Ikeda LN, Pita MS, et al. Marginal fit and microbial leakage along the implant-abutment interface of fixed partial prostheses: an *in vitro* analysis using checkerboard DNA–DNA hybridization. J Prosthet Dent 2015;114(6):831–838. DOI: 10.1016/j.prosdent.2015.05.009.
12. Martinez-Rus F, Ferreiroa A, Ozcan M, et al. Marginal discrepancy of monolithic and veneered all-ceramic crowns on titanium and zirconia implant abutments before and after adhesive cementation: a scanning electron microscopy analysis. Int J Oral Maxillofac Implants 2013;28(2):480–487. DOI: 10.11607/jomi.2759.
13. Koc E, Ongul D, Sermet B. A comparative study of marginal fit of copings prepared with various techniques on different implant abutments. Dent Mater J 2016;35(3):447–453. DOI: 10.4012/dmj.2015-252.
14. Keith SE, Miller BH, Woody RD, et al. Marginal discrepancy of screw-retained and cemented metal-ceramic crowns on implants abutments. Int J Oral Maxillofac Implants 1999;14(3):369–378.
15. AlHelal A, Kattadiyil MT, AlBader B, et al. A Protocol for screw-retrievable, cement-retained, implant-supported fixed partial dentures. Int J Prosthodont 2017;30(6):577–580. DOI: 10.11607/ijp.5321.
16. Proussaefs P, AlHelal A. The combination prosthesis: a digitally designed retrievable cement- and screw-retained implant-supported prosthesis. J Prosthet Dent 2018;119(4):535–539. DOI: 10.1016/j.prosdent.2017.05.019.
17. Rajan M, Gunaseelan R. Fabrication of a cement- and screw-retained implant prosthesis. J Prosthet Dent 2004;92(6):578–580. DOI: 10.1016/j.prosdent.2004.09.009.
18. Malpartida-Carrillo V, Tinedo-Lopez PL, Ortiz-Culca F, et al. Techniques for retrievability and for registering screw access holes in cement-retained implant-supported prostheses: a scoping review of the literature. J Prosthet Dent 2020;123(3):427–433. DOI: 10.1016/j.prosdent.2019.03.011.
19. Singh R, Mahesh L, Shukla S. Extra oral cementation of implant prosthesis: a case report. J Indian Prosthodont Soc 2013;13(4): 627–630. DOI: 10.1007/s13191-013-0319-x.
20. Canullo L, Cocchetto R, Marinotti F, et al. Clinical evaluation of an improved cementation technique for implant-supported restorations: a randomized controlled trial. Clin Oral Implants Res 2016;27(12):1492–1499. DOI: 10.1111/clr.12589.
21. Nissan J, Snir D, Rosner O, et al. Reliability of retrievable cemented implant-supported prostheses. J Prosthet Dent 2016;115(5):587–591. DOI: 10.1016/j.prosdent.2015.10.013.
22. Wadhwani C, Pineyro A. Technique for controlling the cement for an implant crown. J Prosthet Dent 2009;102(1):57–58. DOI: 10.1016/S0022-3913(09)60102-5.
23. Lo Russo L, Caradonna G, Biancardino M, et al. Digital vs conventional workflow for the fabrication of multiunit fixed prostheses: a systematic review and meta-analysis of vertical marginal fit in controlled *in vitro* studies. J Prosthet Dent 2019;122(5):435–440. DOI: 10.1016/j.prosdent.2018.12.001.
24. Holmes JR, Bayne SC, Holland GA, et al. Considerations in measurement of marginal fit. J Prosthet Dent 1989;62(4):405–408. DOI: 10.1016/0022-3913(89)90170-4.
25. Rosas J, Mayta-Tovalino F, Guerrero ME, et al. Marginal discrepancy of cast copings to abutments with three different luting agents. Int J Dent 2019;2019:8657582. DOI: 10.1155/2019/8657582.
26. Uribarri A, Bilbao-Uriarte E, Segurola A, et al. Marginal and internal fit of CAD/CAM frameworks in multiple implant-supported restorations: scanning and milling error analysis. Clin Implant Dent Relat Res 2019;21(5):1062–1072. DOI: 10.1111/cid.12839.
27. Groten M, Girthofer S, Probster L. Marginal fit consistency of copy-milled all-ceramic crowns during fabrication by light and scanning electron microscopic analysis *in vitro*. J Oral Rehabil 1997;24(12): 871–881. DOI: 10.1046/j.1365-2842.1997.00592.x.

28. Siadat H, Alikhasi M, Mirfazaelian A, et al. Scanning electron microscope evaluation of vertical and horizontal discrepancy in cast copings for single-tooth implant-supported prostheses. Implant Dent 2008;17(3):299–308. DOI: 10.1097/ID.0b013e318183621d.
29. Martinez-Rus F, Suarez MJ, Rivera B, et al. Evaluation of the absolute marginal discrepancy of zirconia-based ceramic copings. J Prosthet Dent 2011;105(2):108–114. DOI: 10.1016/S0022-3913(11)60009-7.
30. Kim KB, Kim JH, Kim WC, et al. Three-dimensional evaluation of gaps associated with fixed dental prostheses fabricated with new technologies. J Prosthet Dent 2014;112(6):1432–1436. DOI: 10.1016/j.prosdent.2014.07.002.
31. Derafshi R, Farzin M, Taghva M, et al. The effects of new design of access hole on Porcelain fracture resistance of implant-supported crowns. J Dent (Shiraz) 2015;16(1 Suppl):61–67.
32. da Rocha PV, Freitas MA, de Morais Alves da Cunha T. Influence of screw access on the retention of cement-retained implant prostheses. J Prosthet Dent 2013;109(4):264–268. DOI: 10.1016/S0022-3913(13)60055-4.
33. Gale MS, Darvell BW. Thermal cycling procedures for laboratory testing of dental restorations. J Dent 1999;27(2):89–99. DOI: 10.1016/S0300-5712(98)00037-2.