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SYSTEMATIC REVIEW

Effects of modifying implant screw access channels on the amount of extruded excess cement and retention of cement-retained implant-supported dental prostheses: A systematic review

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ABSTRACT

Statement of problem. Cement-retained implant-supported prostheses eliminate screw loosening and enhance esthetics. However, retrievability and the possibility of removing extruded excess cement (EEC) have been problematic.

Purpose. The purpose of this systematic review was to analyze the effects of modifying the screw access channel (SAC) on the amount of EEC and the retention of cement-retained implant-supported prostheses.

Material and methods. PubMed, Web of Science, Scopus, and Google Scholar databases were searched with appropriate key words. Related titles and abstracts published up to June 2017 were screened and selected on the basis of defined inclusion criteria. Full texts of all studies were read and subjected to quality assessments. After the initial search, 1521 articles were included in the study. Of these, 11 studies were subjected to critical appraisal, and 10 of them were reliable enough in methodology to be systemically reviewed.

Results. All the studies were in vitro and described a total of 260 specimens. According to the interpreted results, closed SACs caused lower retention with a higher amount of EEC, whereas open SACs caused the reverse. Also, as the abutment height decreased, retention decreased.

Conclusions. Extending the crown's margin into the SAC, leaving the SAC open, and using internal vents in the SAC space are possible methods of modifying the SAC to gain higher retentive values. Also, the use of internal vents in the SAC system and open or partially filled SAC space reduce the amount of EEC. (J Prosthet Dent 2019;121:52-8)

Implant-supported restorations are one of the remarkable achievements in contemporary prosthodontics.[1] Two main retention systems (cement retained and screw retained) are used for implant-supported prostheses (ISPs).[2] Both systems are clinically acceptable; the difference is mainly based on their retrievability and amount of extruded excess cement (EEC).[3] The cement-retained type was introduced to eliminate screw loosening and enhance esthetics.[4] The fabrication of this type of prosthesis is more straightforward and less costly; however, retrieving the prosthesis is much more difficult.[5] Improved retrievability has been proposed by using interim cement,[6-8] by staining the location of the screw access channel (SAC) on the occlusal surface,[9] by using a small lingual screw to secure the crown to the abutment,[10] by preparing a lingual retrieval slot at the abutment/prosthesis interface,[11] and by using vacuum-formed templates for easier identification of the position of the screw.[12] Modifying the SAC of ISPs is another possible solution that may improve retrievability without negatively affecting the biomechanical properties of the ISP.[5]

An optimum cement-retained ISP has to provide sufficient retention for the prosthesis but should be easy to retrieve if necessary.[13] Factors that determine the retention of cement-retained ISPs include cement type, axial wall tapering, surface roughness, and height and width of the abutments.[14-16] Modifying the SAC is another suggested solution that may influence the retention of the ISP.[5,13,17] Koka et al[18] evaluated the role of the SAC filling on the retention of cemented CeraOne gold cylinder to a CeraOne titanium abutment. They

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Clinical Implications

Using a metal insert or preparing vent holes on the abutment body and leaving the screw access channel open or partially filled increases retention and reduces extruded excess cement.

reported that the filled SAC resulted in a significantly higher retention than an unfilled SAC. In contrast, Al-Johany et al[3] concluded that retentive values of zirconia copings were not affected by filling or not filling the SAC.

A major complication of cement-retained ISP is the negative impact of EEC on the surrounding soft tissues, especially with deep subgingival margins,[19,20] inducing peri-implant disease.[21,22] Different methods have been suggested to overcome the problem of the EEC of cement-retained ISPs, including preparing a crown venting hole,[23] reducing the amount of cement,[24] and using a rubber dam or polytetrafluoroethylene tape.[25] Managing the SAC is another possible method[17,26] that may eliminate the cement flow to the head of the abutment screw, preventing future soft tissue complications.[17,27]

As data about the effects of modifying the SAC on retentive strength and EEC seem to be sparse and the authors are unaware of a systematic review on this issue, the purpose of this systematic review was to answer this question "What are the effects of modifying the SAC compared with unmodified abutments on the retention of cement-retained ISP and the amount of EEC?" The null hypothesis was that modifying the SAC does not influence the retention of cement-retained ISPs or the amount of EEC.

MATERIAL AND METHODS

The review was established in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.[28] Firstly, a PICO question was defined to screen the qualified studies based on dental implant abutments (P, population) with any kind of modification, especially on SAC (I, intervention), compared with conventional structure (C, comparison), which improves the retention of cement-retained ISP and limits the amount of EEC (O, outcome).

A data search of articles was performed using PubMed, Web of Science, Scopus, and Google Scholar electronic databases based on MeSH and non-MeSH terms in simple or multiple conjunctions (Table 1). The searching procedure was conducted manually up to June 2017. Software (Endnote v7; Thomson Reuters) was then used for final confirmation, cross-matching, and identifying missing data.

Table 1. Applied MeSH and non-MeSH keywords

PICO	Keywords
Population	(Dental implants [MeSH Term]) OR (Dental Abutment [MeSH Term]) OR (Dental Implant-Abutment Design [MeSH Term]) OR (Dental Prosthesis, Implant-Supported [MeSH Term])
Intervention	(Cementation [MeSH Terms]) OR (Screw Access Channel) OR (Modifying) OR (Modification) OR (Screw Access Hole)
Comparison	(Retention) OR (Prosthesis Retention [MeSH Term]) OR (Dental Prosthesis Retention [MeSH Term]) OR (Tensile Strength [MeSH Term]) OR (Excess Cement) OR (Dental Cement [MeSH Term]) OR (Cement Remnant) OR (Remained Cement)
Outcome	(loss of retention) OR (loosening) OR (gap) OR (cement rest) OR (cement dissolution) OR (survival) OR (risk) OR (success) OR (rate) OR (failure) OR (prosthesis failure [MeSH Terms]) OR (dental leakage[MeSH Terms]) OR (dental restoration failure[MeSH Terms])

Two independent reviewers (A.D., M.R.) evaluated the eligible articles for review. To select the studies, all the English language reports obtained were reviewed, and titles and abstracts were screened for relevance. The review articles and references from different studies were used to identify the relevant articles. In the case of disagreement, the 2 reviewers discussed the article until consensus was reached. The reviewers' agreement was tested by the Cohen κ test using MedCalc software (κ=0.89). The studies were subjected to the Methodological Index for Non-Randomized Studies (MINORS) score calculation for Critical Appraisal and lowering the risk of bias[29,30] (Table 2). Scores for comparative studies can be qualified as follows: 0-6=very low; 7-12=low; 13-18=moderate; and 19-24=high quality. The full texts of relevant abstracts were obtained and selected according to the defined inclusion and exclusion criteria (Table 3).

The initial literature search yielded 1521 articles, and 11 studies[3,5,13,17,18,26,27,31-34] were found sufficiently eligible in methodology and study design (Fig. 1). The full texts of all articles were accessible for the reviewing process. The following data were collected for each study: authors, publication year, study design, sample size, examined tests, and significant outcomes. After gathering information, the possibility of preparing a meta-analysis was judged by an independent statistician and an epidemiologist. Because the collected data were quite heterogeneous (different study designs with different sampling and other factors that might influence the retention or amount of EEC, such as abutment height and preseating), no meta-analysis was carried out.

RESULTS

A total of 1521 articles were found after the initial search (397 on PubMed, 583 on Scopus, 64 on Web of Science, and 477 on Google Scholar). A total of 603 articles remained after removing the duplicates, of which 11[3,5,13,17,18,26,27,31-34] were eligible for screening. Relying on the MINORS scale (Table 2), 3 studies had a score of 18,[3,26,33] 1 had a score of 17,[27] 4 had a score of 16,[5,17,31,32]

Table 2. MINORS score calculation of selected studies

MINORS Criteria	Da Rocha[5]	Wadhwani[33]	Al Amri[27]	Al-Johany[3]	Emms[17]	Biyani[31]	Naik[13]	Wadhwani[34] (2013)	Jimenez[32]	Wadhwani[33] (2011)	Koka[18]
Clearly stated aim	2	2	2	2	2	2	2	2	2	2	2
Inclusion of consecutive patients/samples	1	2	1	2	2	2	1	1	2	2	1
Prospective collection of data	2	2	2	2	2	2	2	2	2	2	2
End points appropriate to aim of study	1	2	2	2	2	2	2	2	2	2	2
Unbiased assessment of study end point	0	0	0	0	0	0	0	0	0	0	0
Follow-up period appropriate to aim of study	0	0	0	0	0	0	0	0	0	1	0
Loss to follow-up <5%	0	0	0	0	0	0	0	0	0	0	0
Prospective calculation of study size	2	2	2	2	0	0	0	0	0	1	0
Adequate control group	2	2	2	2	2	2	2	2	2	2	0
Contemporary groups	2	2	2	2	2	2	2	2	2	2	0
Baseline equivalence of groups	2	2	2	2	2	2	2	2	2	2	2
Adequate statistical analyses	2	2	2	2	2	2	2	2	2	2	1
Results	16	18	17	18	16	16	15	15	16	18	10

Items are scored as follows: 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate). Global ideal score is 16 for noncomparative studies and 24 for comparative studies. MINORS, Methodological Index for Non-Randomized Studies.

and the rest had a score of 15[13,34] from a total of 10 high-quality studies. One study was excluded from the review procedure because of a low MINORS scale score of 10.[18] Although 10 articles were included in this review, no systematic review or a meta-analysis of this subject area was found. The reviewers discussed whether to include the study of da Rocha et al.[5] One of the reviewers asked to exclude it from the study because the authors had modified the copings (not abutments). Because the main goal of that study was improving the retrievability of ISPs by modifying the copings in the direction of the SAC, the reviewer was convinced to keep the article.

All the reviewed articles were in vitro studies describing a total of 260 specimens. Implant abutments were tightened to their analogs at 25 Ncm[3,27,31] or 35 Ncm,[5,26,32,33] or the torque was not mentioned (Table 4). Three studies prepared zirconia frameworks by using computer-aided design and computer-aided manufacturing technology,[3,27,33] and the others used custom-made nonprecious[5,31,32,34] or noble[13,17,26] alloys. All the studies used interim cements except for one,[5] in which resin cement was used (Table 4).

Supplemental Table 1 lists the study designs of the included articles in more detail. Five studies focused only on evaluating the effects of modifying the SAC on the tensile bond strength of specimens,[5,13,17,31,34] 2 studies observed only the effects of modifying SAC on the amounts of EEC and marginal discrepancies,[26,27] and the rest evaluated both these variables.[3,32,33] The crosshead speeds of the universal testing machine for applying dislodgment force were 0.5 mm/min,[3,5,31] 5 mm/min,[13,17,33,34] or 1 mm/min.[32] Most of the reviewed studies evaluated the effect of either closed or open abutment SAC on the dislodgment force.[3,5,17,32-34] Moreover, some of the included studies tried to observe the differences in retention by including other variables such as reducing the height of the abutment,[17,31] modifying the copings/crowns,[5,13,31,32] milling the abutments at different angles,[13] and designing an internal vent in the SAC system.[33,34]

Four studies modified the coping/crown by preparing a SAC on the occlusal site[5,32] or extending the coping/crown into the abutment SAC (1 mm[31] or 2 mm[13]). They indicated that preparing a SAC on the occlusal site not only resulted in no significant differences[5] but also might have caused the least retentive values.[5,32] In contrast, the extension of the coping/crown into the SAC increased retention.[13,31]

Table 3. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
• English-language studies that investigated effect of modifying SAC on amount of EEC or retention of cement-retained ISP. • Research on at least 5 specimens in each group. • Maintaining standard guidelines of calculating amounts of EEC or required force for dislodgments. • Following manufacturer's instruction in all steps of observation such as mounting specimens, preparing crowns/copings, manipulation of cement.	• Case reports. • Studies with missing data. • Repeatedly published studies; last version was included. • Studies in languages other than English. • Studies qualified as "very low" or "low" (MINORS score of <13; for eliminating risk of biases).

EEC, extruded excess cement; ISP, implant-supported prostheses; MINORS, Methodological Index for Non-Randomized Studies; SAC, screw access channel.

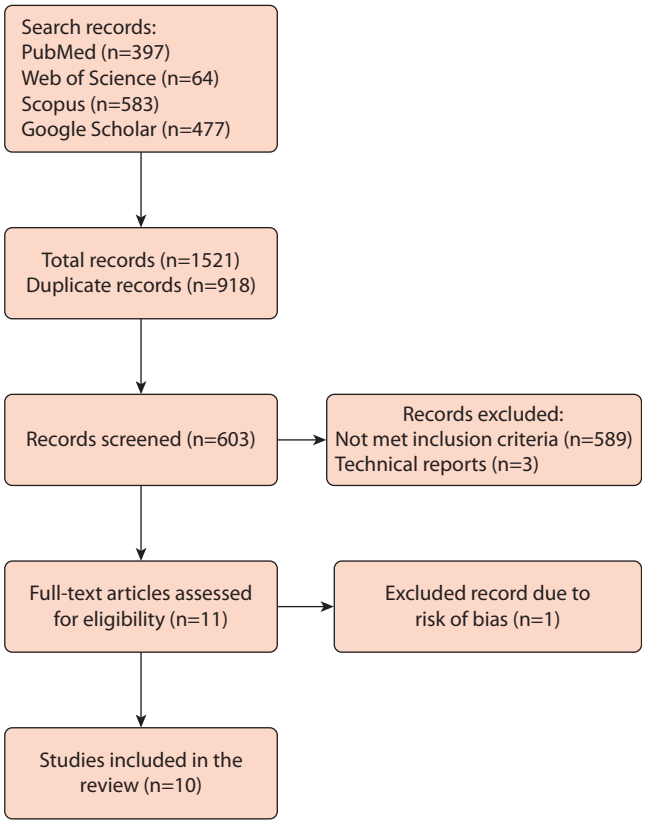

Figure 1. Search strategy based on PRISMA guidelines. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analyses.

Two studies reported a reduction in the abutment height in their study groups as 0, 3, 6, and 9 mm[17] and as 0, 1, 2, and 3 mm.[31] They reported that as the abutment heights decreased, the retention values also decreased.[17,31] Also, groups with a closed SAC showed lower retention values than groups with a 1 mm filled SAC at different reduced heights.[17] The effect of abutment milling at different angles (15, 22, and 30 degrees) was investigated,[13] and those with an abutment buccal wall of 15 degrees showed higher retention.[13] Designing an internal vent in the SAC was performed in 2 studies, and both reported the highest retention.[33,34]

All the included studies indicated that the group with a closed SAC showed the highest amount of EEC.[3,26,27,32,33] They claimed that modifying the SAC caused the lowest amount of EEC if they were completely filled to 2 mm from the occlusal surface,[3,27] if they were open, if the crowns were preseated,[32] or if there was an internal vent in the SAC.[26,33] Two of the mentioned studies also stated that modifying the SAC did not significantly affect marginal discrepancies after cementation.[26,27]

DISCUSSION

Retrievability is one of the critical issues regarding cement-retained ISPs. If the clinician is not aware of the SAC location, removal of cemented ISPs may cause irreversible damage to the crown or abutment.[5,35,36] The first part of the null hypothesis concerning the influence of modifying the SAC on retentive values was rejected according to the reviewed studies.

Wadhwani et al[34] designed a 2-radius vent in the SAC in 1 of their study groups. The SACs of other groups were either unfilled or completely filled with resin. The final results showed that retention was significantly higher in both vent and unfilled groups.[34] They reported that the cement flow pattern was clearly better in the vent group because the vents acted as an internal reservoir.[34] The idea of using an internal vent was also reported by Wadhwani and Chung.[33] However, the design of the internal vent was completely different from that of the previous study. They believed using holes increased the possibility of abutment structural failure, especially in zirconia abutments. Therefore, they used a 20-gauge metal insert with a 4 mm length, obtained by sectioning a metal syringe cannula.[33] Both abutments and copings were prepared from zirconia blocks, and the results showed the vent group presented significantly higher retentive values than the other 2 groups (filled/unfilled SAC). They claimed the metal insert caused a higher amount of cement to remain within the SAC, which might lead to resistance to dislodgement.[33] In the group with a closed SAC, cement failure appeared at the abutment site due to adhesive loss. The failure was similar to that of the internal vent group; however, the intaglio of the restoration was void of cement at the screw access site, suggesting a different mode of failure.[33] If cement remains on or in the abutment, higher forces may be needed to dislodge the restoration. Wadhwani and Chung[33] recommended using an insert instead of physically changing the abutment of a poorly retained restoration.

Naik et al[13] observed the role of a 2 mm crown extension alongside milling the buccal wall of abutments at different angles (15, 22, and 30 degrees). Their comparative analysis showed crown extensions produced higher retention; as the taper increased, the retention decreased accordingly. They believed engagement of the casting in the SAC could compensate for the loss of ISP retention up to 22 degrees of the taper.

Biyani et al[31] surveyed the role of 1 mm crown extension and also abutment height reduction (1, 2, and 3 mm) on the retention of ISPs. They recommended that clinicians consider using additional retentive features like extending the crown into the SAC, which provides about 50 N resistance to dislodgment in situations with reduced interarch space. They believed crown extension had a greater impact on the shortest abutment (3 mm) than on other heights. The shorter crown with a short extension provided for an easier cementation procedure as the amount of trapped air and reduced hydraulic

Table 4. General information of reviewed articles

Study	Year	Objectives	Sample Size	Abutment Detail	Torque	Framework Material	Method of Framework Fabrication	Cement
Da Rocha[5]	2013	Influence of screw access channel on retention of cement-retained implant prostheses	16	2 mm collar height (Tiprep; Bionnovatio)	35 Ncm	Cr-Co	Custom	Self-adhesive resin cement (RelyX U100)
Wadhwani[33]	2014	Effect of an insert placed within screw access channel of implant abutment on amount of cement retained and on dislodging force	36	Procera abutments; Nobel Biocare	35 Ncm	Zr (Procera)	CAD-CAM	TempBond NE
Al Amri[27]	2017	Effect of size of unfilled space of abutment screw access channel on amount of extruded excess cement and marginal accuracy	12	4.5 mm wide and 7 mm long (Astra Tech Implant System; Dentsply Sirona)	25 Ncm	Zr (Cercon Base; Degudent GmbH)	CAD-CAM	TempBond
Al-Johany[3]	2017	Effect of size of unfilled space of abutment screw access hole on amount of extruded excess cement and retention of zirconia copings	36	4.5 mm wide and 9 mm long (Tidesign, Astra Tech Implant System; Dentsply Sirona)	25 Ncm	Zr (Cercon Base; Dentsply Sirona)	CAD-CAM	TempBond NE
Emms[17]	2007	Effect of implant abutment wall height, platform size, and screw access channel filling method on retention of castings	12	15-degree preangled abutments with 9 mm height (Brånemark System, Nobel Biocare)	Not mentioned	Type III gold castings	Custom	TempBond
Biyani[31]	2015	Effect of engaging metal extension to screw access channel on loss of retention of crowns cemented on shorter abutments.	8	TiDesign 4.5/5.0 abutments (Astra Tech Implant System)	25 Ncm	Nonprecious metal alloy	Custom	TempBond NE
Naik[13]	2009	Effect of extending a casting into screw access channel of an implant abutment on retention	8	Straight Abutments (Brånemark System, Nobel Biocare)	Not mentioned	Type III gold castings	Custom	TempBond
Wadhwani[34]	2013	Effect of implant abutment and screw access channel modification on retention of metal copings cemented onto implant abutments.	27	Anatomic abutments (CrossFit regular, Straumann)	Not mentioned	Nonprecious metal alloy	Custom	TempBond NE
Jimenez[32]	2016	Methods for reducing excess cement of implant- retained restorations (restoration preseating, open abutment screw access, and open crown vents) and their correlations to retention	80	Straight implant abutments (GingiHue Biomet 3i)	35 Ncm	Nonprecious metal alloy	Custom	Freegenol
Wadhwani[26]	2011	Effect of implant abutment modification on amount of cement extruded at crown-abutment margin and vertical discrepancy	27	Straight RC Anatomic Abutments for bone-level implants (Straumann)	35 Ncm	High noble porcelain bonding alloy	Custom	TempBond NE

CAD-CAM, computer-aided design and computer-aided manufacturing.

pressure might be relatively lower in taller abutments. The role of reducing abutment height alongside modifying the SAC was also observed by Emms et al.[17] The SAC was modified by being completely or partially (up to 1 mm from occlusal) filled at different reduced abutment heights (3, 6, and 9 mm). They noted that with a decrease in surface area and height, the retention would also decrease. They believed if the restoration was well fitted, it would be better to completely fill the SAC to make further retrievability easier. In contrast, if the retention of the ISP is compromised, it is more appropriate to partially fill the SAC to enhance the final retention of the ISP.

One of the reviewed articles compared only the retention of the ISP with complete and partially (up to 1 or 2 mm from occlusal surface) filled SACs without any height reduction.[3] In contrast with previous studies, the study did not find significant differences in retentive values among the study groups. The authors claimed the reason might be the long abutment (9 mm) used in their studies. Therefore, the effect of SAC space would be more trackable in shorter abutments.[3]

One of the valuable studies on this topic was done by Jimenez and Vargas-Koudriavtsev.[32] They observed the role of several factors, such as modifying the SAC by either filling or not filling, preseating, and crown venting

in the retention of the ISP and the amount of EEC.[10] Although the mean retentive values in groups with an open SAC were higher than those with a closed SAC, the difference was not significant.[32] They found the preseating protocol not only compromised the effect of modifying the SAC but also caused a significantly lower tensile strength.[32] The negative impact of preseating on the evaluated retention might be due to the adhesive tendency of abutment analogs and interim cement, where most of the cement remained on the analog instead of the coping.[32] They also revealed that crown venting did not affect the retention of the ISP,[32] which was similar to the results of those of da Rocha et al.[5] The idea of preparing a vent on the crown was developed by da Rocha et al by preparing an access channel on the prosthesis to make it more retrievable. Da Rocha et al followed a technique first introduced by Rajan and Gunaseelan,[36] who suggested preparing an access channel on the prosthesis and who believed this technique would not reduce the bond strength or would impair the retention of crown. Therefore, da Rocha et al[5] prepared 2 groups, one with and the other without an access channel on the prosthesis, and reported the same results as Jimenez and Vargas-Koudriavtsev.[32] However, the prepared copings were without veneering porcelain to prevent porcelain fracture because of the access channel in the prosthesis.

On the basis of the reviewed studies, the second part of the null hypothesis regarding the influence of modifying the SAC on EEC was also rejected. According to the reviewed articles, the restoration margin in ISPs may be deeper than in the natural tooth. Also, the junction between implant and restoration is flat and lacks the curved anatomy of the cementoenamel junction of a natural tooth. EEC to a depth greater than 3 mm is difficult to track or remove.[37] Al Amri et al[27] evaluated the effect of different space sizes of SAC (completely or partially filled up to 1 and 2 mm from occlusal surface) on the amount of EEC and the marginal accuracy of implants with zirconia restorations. They found a significant reduction in the amount of EEC when the SAC space became larger in size; however, marginal discrepancy was not significantly different among the study groups regarding the different space sizes of the SAC. The space size of the SAC may act as an internal reservoir for the cement to flow into; otherwise, it may be extruded through the margins.[34] Zinc oxide, with or without eugenol, was used in most of the screened studies because of its higher retrievability and cleanability.[27] A similar study design was followed by Al-Johany et al,[3] and their final result regarding the amount of EEC was also similar.

The effect of designing an internal vent on the amount of EEC was observed by Wadhwani et al[26] and Wadhwani and Chung.[33] In seating a crown, there may be a limited space for cement to flow into, which may lead to compromised marginal adaptation.[26] Designing an internal or external vent may improve the final marginal fit.[23,26] There is a possibility that the vents allow trapped air to escape easily or act as a cement reservoir.[26] Wadhwani et al[26] prepared two 0.75 mm radius holes placed 3 mm apical to the occlusal edge of the abutment and 180 degrees apart from each other in one of their study groups. They reported that the group with the internal vent caused a 36% reduction in EEC, whereas this amount was 90% in the group with a closed SAC. In another study, Wadhwani and Chung[33] tracked the amount of EEC, as their secondary goal, when a metal insert was used in the SAC as an internal vent. They found that both groups with an open SAC and internal vent retained more cement inside the SAC than the group with the closed SAC, with significant differences between them.[3]

Jimenez and Vargas-Koudriavtsev[32] evaluated the effect of modifying the SAC, preseating, and crown venting on the amount of EEC in addition to observing retentive values. They found the control group (with closed SAC, without crown vent, and without preseating) showed the highest amount of EEC compared with other groups, with significant differences between them. Also, they found no correlation between the amount of EEC and retentive values,[32] which contrasts with the results of Wadhwani and Chung.[33] That study showed increasing the quantity of cement within the abutment and restoration increased retention. Jimenez and Vargas-Koudriavtsev[32] believed that resistance to tensile strength depends on the technique not the amount of EEC. They administered the crown preseating protocol, a successful approach suggested by some studies,[38,39] to eliminate the amount of EEC before cementation. Although preseating the crown reduced the amount of EEC, it compromised the retention of the samples.[32]

The present review tried to clarify the effect of modifying the SAC on the amount of EEC and the retentive strength of ISPs. However, some limitations were encountered during the study: various study designs with various variables could affect the retentive strength of specimens directly or indirectly, as could the unequal volume of cement used for luting both restoration and abutments in various studies.

CONCLUSIONS

Based on the findings of this systematic review, the following conclusions were drawn:

1. When increased retentive strength is required, it is better to modify the SAC if the abutment height is short or if the fit of the definitive prosthesis is in doubt.
2. Engaging the crown margin into the SAC, an open SAC, and using a metal insert or radius vent holes in

the SAC space are efficient methods of modifying the SAC when higher retentive strength is required. Other techniques like crown venting, reducing abutment height, and preseating are not effective for obtaining higher retention.

3. Using a metal insert or radius vents in the SAC system and leaving the SAC space open or partially filled are possible methods of reducing the amount of EEC.

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