Review

Screw-retrievable cement-retained implant restorations: A scoping review of fracture strength and clinical performance

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Abstract

Background. The screw-retrievable cement-retained (SRCR) design combines the benefits of both screw- and cement-retained implant-supported restorations. This concept has sparked interest in implant dentistry. However, there is a lack of research on fracture behaviors and clinical performance of such restorations.

Objectives. The aim of the present article was to review the current literature on the fracture loads and fracture modes of SRCR implant restorations – in vitro studies, and also studies demonstrating the clinical performance of such design.

Material and methods. A literature search was conducted from January 2000 to June 2022, using 6 databases to identify studies on fracture load and clinical performance that fulfilled the eligibility criteria. Thirty-eight studies met the inclusion criteria (22 in vitro and16 in vivo). The in vivo studies comprised case reports/series/letters (9), clinical techniques (2), retrospective/prospective studies (3), and randomized controlled trials (RCTs) (2).

Results. The reviewed articles reported the effects of the SRCR design on the fracture risk if screw access channels were filled or unfilled, with regard to their diameter, and the preparation before or after glazing. The effect of the type of material used in the construction on the fracture modes SRCR restorations was also reported. The long-term clinical data was mainly retrospective and referred to metal–ceramic constructions. Limited long-term clinical data was available for all-ceramic materials and high-performance polymers (HPPs).

Conclusions. Screw-retrievable cement-retained implant restorations appear to have potential in the monolithic design. If the SRCR construction is metal–ceramic or made of a veneered material, special design and abutment selection should be considered. High-performance polymers may be recommended as a substitute for posterior implant restoration.

Keywords: cement-retained, fracture load, screw-retained, screw-retrievable, monolithic screw hole implant

Introduction

The quest for optimal implant restoration with a high success and survival rate has grown by leaps and bounds over the past 5 decades.[1,2] Aside from osseointegration, the form of retention between the crown, the abutment and the implant fixture has the greatest impact on the predictability of the success and survival rate of implant therapy.[3,4] Classically, this type of connection for implant-supported fixed prostheses can be either screw- or cement-retained. The advantages of the cement-retained approach are the passive fit, simple laboratory constructions and favorable esthetics, as the screw access channels traversing the implant crown can be avoided.[5] Despite these benefits, it is well-established that cement-retained restorations are irretrievable and the removal of excess cement can be difficult, possibly resulting in peri-implantitis.[4] Furthermore, in the event of technical issues caused by screw loosening, the abutment in a cement-retained restoration is not accessible and may cause damage to the prosthesis if drilling is needed on the intact crown.[4] Managing complications is less complicated with screw-retained restorations, since they are retrievable for easier maintenance. They also eliminate biological complications caused by the inherently risky cementation process.[6] However, inferior esthetics, more complex laboratory procedures and the lack of passive fit, which may create mechanical strain on the prosthesis, are the main limitations of screw-retained restorations as compared to cemented restorations.[4,7]

To address these limitations and features of implant restoration, the combination of cement- and screw-retained retention has been introduced in the form of screw-retrievable cement-retained (SRCR) restorations. This combination approach eliminates the risk of excess subgingival cement, as the components are cemented extraorally.[8–10] The design also enables the cement layer to act as an interface for the distribution of forces, while the screw access channels facilitate retrieval.[11,12] Furthermore, the cost of fabrication is substantially reduced when the superstructure is connected to prefabricated titanium (Ti) by using luting cement instead of a cast high noble abutment for screw-retained restorations.[13–15] However, the presence of screw access channels itself may interrupt the structural ceramic continuity and interfere with the occlusal morphology, thereby negatively affecting the fracture resistance and longevity of the prostheses.[11,16]

To improve the mechanical and physical properties of SRCR restorations, a few studies have recommended a protocol for their preparation, size, and the filling material of the screw access channels.[17,18] These should be prepared in the blue phase prior to crystallization and glazing to avoid microcracks.[19] In addition, preparation with high-speed burs after zirconia sintering should be avoided to prevent cracks within the restoration.[20] A screw diameter of less than 1 mm and not exceeding half of the occlusal area is also recommended.[17] Filling the screw access with inlay ceramic or bulk-fill composite should be considered to minimize wear and polymerization shrinkage in SRCR implant restoration.[21,22] The location of the screw access channel appears to not affect the fracture risk of SRCR restorations, a finding that warrants further investigation.[23]

Besides optimizing the design of the access channels, the selection of appropriate implant restoration materials and methods may also contribute to the durability of the SRCR design. A variety of computer-aided manufacturing (CAM) materials, including zirconia, lithium disilicate, high-performance polymers (HPPs), and block composite resins, are used to construct SRCR restorations. These may be fabricated as monolithic or veneered constructions, or with predesigned screw access channels (Fig. 1).[8,24,25] Zirconia and lithium disilicate are usually preferred because of their excellent esthetics and high strength.[16,23] However, these materials are often unyielding and prone to excessive occlusal loading, resulting in the chipping and fracture of implant-retained prostheses due to the lack of proprioceptive feedback from periodontal ligaments.[25,26] Furthermore, the wear of the opposing natural dentition caused by ceramics has initiated the manufacturing of implant restorations utilizing HPPs.[25,27] High-performance polymers have a lower elastic modulus than ceramics, more like human bone, and are believed to have a shock-absorbing effect within the implant prosthesis complex.[24,26] Additionally, the low elastic modulus of HPPs has been shown to lessen the pressure on the implant, hence reducing peri-implant bone resorption.[25,28] However, the fracture strength and clinical performance of this material in the SRCR design have been questioned. Poor prognoses have been recorded for the restorations designed as a hybrid or veneered with a lower-strength material.[29,30] Therefore, it is critical to understand and screen relevant literature on the types of designs and materials that have an optimum mechanical strength, which would enhance SRCR performance.[26,30,31]

To that end, this scoping review is structured in 3 parts to evaluate the concept of SRCR restorations. Firstly, a summary is provided of the various designs of screw access channels and to what extent these may affect the fracture resistance of SRCR restorations. Secondly, the various types of materials from which SRCR restorations are fabricated are described, including metal–ceramics, all-ceramics and HPPs, and how these materials affect the fracture mode and loading of SRCR restorations. Finally, the clinical performance of SRCR restorations is reviewed, and the implications of this retention system for the long-term success of implant prostheses are discussed.

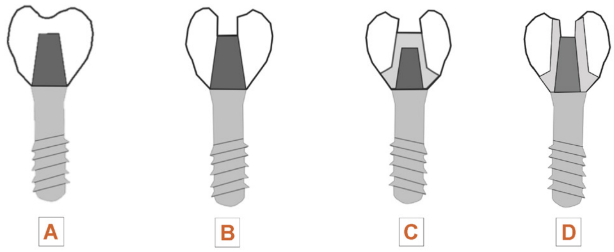

Fig. 1. Conventional cement-retained implant-supported prosthesis (A), monolithic screw-retrievable cement-retained (SRCR) restoration (B), veneered type SRCR restoration (C), and veneered type SRCR restoration with a predesigned zirconia wall (D)

Material and methods

Search strategy

The PICO framework (P = patient problem/population, I = Intervention, C = Comparison, O = Outcome) was used for this review. The research question to be answered was: In cases where implant-supported prostheses are used, do SRCR restorations have a higher mechanical strength and better clinical performance than conventional cement- or screw-retained restorations?

Scopus, Google Scholar, PubMed, SpringerLink, ClinicalKey, and the Web of Science (WOS) were used to search for relevant literature from January 2000 to March 2022. The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement was used in this study.[32]

A manual search of the reference lists for all full-text publications from the following journals was also conducted: "Journal of Prosthetic Dentistry"; "Journal of Oral Implantology"; "European Journal of Oral Implantology"; Journal of Osseointegration"; "International Journal of Oral and Maxillofacial Implants"; "International Journal of Prosthodontics"; "Clinical Implant Dentistry and Related Research"; and "Clinical Oral Implant Research". The following search terms were used: "screw retrievable"; "implant hybrid crown"; "monolithic screw channel implant"; "layered screw channel implant"; "screw cement-retained"; "screw access channel implant crown"; "combination screw cement implant crown"; and "screw retained access channel".

Inclusion and exclusion criteria

Studies were included if the following criteria were met:
- articles in English;
- articles related to the fracture load and mode of the SRCR concept;
- clinical studies using prospective or retrospective designs to evaluate clinical outcomes; and
- clinical case series, technical reports and case reports with at least 12 months of follow-up.

The exclusion criteria were:
- studies related to implant surgery; and
- articles that referred only to cement-retained implant-supported restorations.

Study selection

A total of 457 articles were found in the electronic databases from the initial search: 120 in WOS, 125 in PubMed, 93 in Scopus, 43 in SpringerLink, 37 in Google Scholar, 32 in ClinicalKey, and 7 by hand searching. After initial screening, 263 articles were removed due to duplication or for reasons. Only 71 publications remained after 87 were eliminated based on the title and abstract. Twenty-two in vitro and 16 in vivo full-text publications met the eligibility criteria after a thorough review by two independent reviewers (Fig. 2).

Data extraction and statistical analysis

A meta-analysis was not possible due to the small number of studies included and the heterogeneity of the study designs. Consequently, a descriptive scoping review was used to summarize the influence of the various designs and materials used in SRCR restorations on fracture loads, fracture modes, and also on the clinical performance of SRCR restorations.

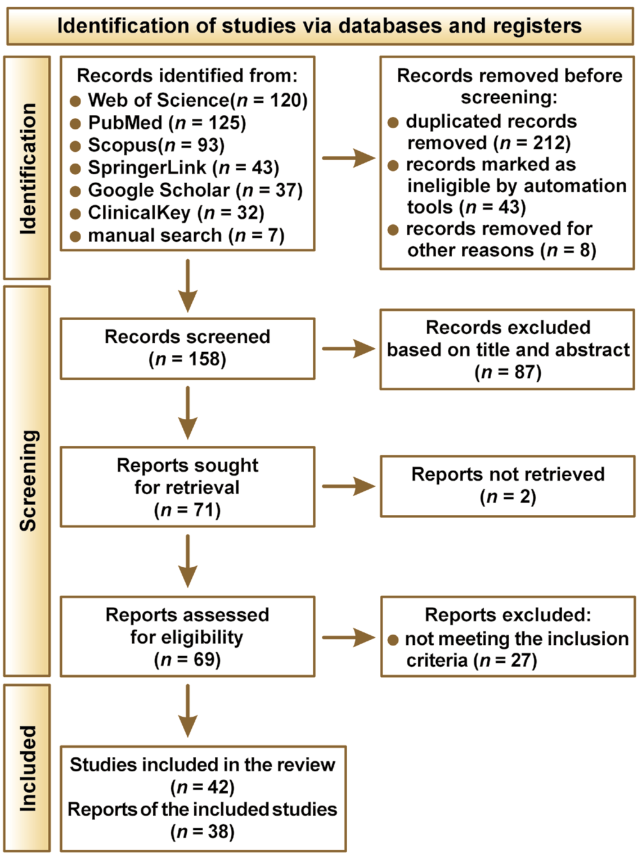

Fig. 2. Flow chart of the study

Results

Influence of various SRCR designs on fracture resistance

The design of the SRCR restorations has been shown in vitro to affect their fracture resistance, and the results are presented in Table 1.[17,19,20,33,34] The most important factor that increases the chipping risk and compromises fracture resistance is the design of the screw access channel.[34] The filled or unfilled screw access channel,[35] its diameter,[17,36] if the preparation was performed before or after sintering,[19,20] and if the screw access channel was specially designed or not[34] were assessed for possible significant effects on the risk of chipping and the fracture resistance values. In an earlier study by Karl et al., more chipping fractures were recorded in cases with the unfilled occlusal screw access channels of screw-retained restorations during dynamic loading.[35] Although in clinical practice, the screw access hole is never left unfilled, this pioneer finding has led to the development of a few protocols for the stability of the occlusal table and the prevention of the chipping of ceramic veneering.[35] Regarding the size of the screw access channel in the SRCR design, a finite element analysis-based study showed that a diameter up to 4 mm received a more vertical bite force before fracture, while a diameter of less than 3 mm received a lower stress force, thus protecting the screw.[17] Al-Omari et al. compared screw-retained, screw-retained offset and cement-retained specimens, and found that the diameter of the screw access channel, which could occupy nearly half of the occlusal table, was the main cause of reduced fracture strength.[33] Interestingly, fracture resistance is unaffected when the screw opening is placed 1 mm offset from the center of the occlusal surface.[33] Though a 1-millimeter diameter has been recommended for the screw access channel, the clinical application is limited, as most screw shanks and heads exceed 1 mm.

Mokhtarpour et al. found that the fracture resistance of the anterior veneered zirconia restoration was reduced when the screw access channel was manually prepared with a handpiece and a diamond bur after sintering.[20] Similarly, the fracture resistance of glass implant-supported restorations in monolithic lithium disilicate and hybrid abutments was reduced by the screw access channel prepared after firing.[19,37] By contrast, with monolithic zirconia, no significant differences in the fracture load values were recorded, no matter if the screw access channel was prepared before or after sintering; however, failure or crack initiation might be due to the heat produced during manual preparation after sintering or re-sintering.[38] On the other hand, specially designed, reinforced metal framework walls of screw access channels have higher fracture resistance than conventionally designed screw access channels for cement-retained metal–ceramic restorations.[18] Similarly, Saboury et al. investigated the influence of reinforcing the framework wall with zirconia before the pre-sintering of the SRCR design.[34] Their reinforcement design had a height of 0.8 mm and a width of 1 mm to avoid interfering with occlusal contacts in the veneered type. As expected, the predesigned zirconia walls supporting screw access channels exhibited higher fracture resistance as compared to screw access channels that were not specially designed, which may be an alternative design for veneered restorations.[34] Nonetheless, since the abutments and the implant analogs were used multiple times, and only vertical compressive load was applied during testing, some of the in vitro results should be interpreted with caution.[34]

Influence of various SRCR materials on fracture resistance

In an earlier test of the fracture load of metal–ceramic restorations, there was a discernible difference between cement-retained and screw-retained restorations (Table 2).[39] Scanning electrographic analysis identified that microcracks were frequently generated in screw-retained restorations, depending on the level of the screw access channel.[39] With metal–ceramic restorations, a significant difference was also recorded in the fracture load values for cement-retained and SRCR restorations using non-adhesive cement.[40] Although the different types of cement used do not affect fracture load in cement-retained restorations, the screw access channel may compromise the fracture load value of SRCR restorations. Since the abovementioned study used non-adhesive cement, future research using adhesive cement when analyzing the performance of SRCR restorations should be conducted. A more recent study compared the effect of using a 15-degree angulated abutment to simulate a tilted implant for cement-retained SRCR with a screw-retained gold cast abutment.[41] In this study, the highest fracture load values were recorded for the cement-retained designs, followed by the SRCR design. Both designs were cemented to prefabricated tilted Ti abutments using self-adhesive cement. The screw-retained design with a castable abutment showed the lowest fracture load value, with the cohesive types of failure occurring within the ceramic veneering.[41] Similarly, Rosa et al. recorded the lowest fracture load values for SRCR restorations on customized computer-aided design (CAD) Ti abutments with self-adhesive cement.[42] In addition, for SRCR restorations fabricated with Ti, chipping fractures were more frequently recorded near the screw access channels than were catastrophic failures, which is similar to a previous study.[35,42] Hence, most studies concluded that cement-retained metal–ceramic restorations frequently have higher fracture load values than implant restorations with screw access channels.[39–42] Screw access channels in SRCR restorations affect the structural continuity of the ceramic by reducing

Table 1. Influence of various designs of screw-retrievable cement-retained (SRCR) restorations on the chipping risk and the fracture resistance values

No.	Study	Type of abutment	Crown materials	Implant manufacturers	Thermocycling (Y/N)	Retention system	Fracture load (Lf) value [N]		Fracture type			Comments
							no SAH	SAH	catastrophic	cohesive		
										within the porcelain	reaching the framework	
1.	Karl et al.[35] 2007	precious metal alloy (Degudent)	MC	ITI solid screw implants; Straumann AG	Y	5-unit FDP	NA	NA	NA	Y	NA	chipping in the unfilled SAH
2.	Al Omari et al.[33] 2010	UCLA cast with Co-Cr alloy	MC	3i LTX external hexagon implants	Y	CR SR SRO	CR: 3,707 ±1,086	SRO:1,885 ±491 SR: 1,721 ±593	load until failure	NA	NA	the diameter occupied half of the occlusal table, reduced Lf
3.	Du et al.[17] 2018	Ti (Bego)	MZ, MC	Semados S Line, Bego	N	SRCR	NA	NA	NA	NA	NA	the diameter reached 4 mm, received more stress
4.	Mokhtarpour et al.[20] 2016	15° esthetic (Nobel Biocare)	VZ	implant analogs tri-channel (Nobel Biocare)	Y	CR SRCR (Hbs) SRCR (Has)	888.3 ±228.9	Hbs: 610.4 ±125 Has: 496.7 ±104.1	load until failure	NA	NA	Lf reduced in manually prepared restorations
5.	Cabrera et al.[19] 2021	Ti (Nobel)	MLD	implant replicas (Nobel Replace)	Y	CR SRCR	1,086 ±144	1,054 ±168 880 ±153*	load until failure	NA	NA	*SAC created after firing reduced Lf
6.	Roberts et al.[37] 2018	Ti bases (hybrid (LD, Z))	MLD	implant (Certain 4.1 mm; Biomet 3i)	Y	CR SRCR	4,714.7 ±594.5	2,892.3 ±451.8*	Y	NA	NA	*SAC created with a tapered diamond bur had the lowest Lf
7.	Zhang et al.[38] 2022	Ti (GuangCi M.D. China)	MZ	Ti implants (ZZT-SP, China)	N	CR SRCR	4,476.46 ±1,023.94	4,467.00 ±415.00 MP: 4,139.00 ±600.59* RS: 4,048.44 ±565.45**	NA	Y	NA	*SAC manually prepared (MP), **SAC resintering (RS) affected Lf (result insignificant)
8	Derafshi et al.[18] 2015	straight prefabricated abutment	MC	implant analog (Dio Corp)	Y	CR CR (stain) SRCR	1,947 1,928 (stain)	2190	load until failure	NA	NA	designed holes with a metal framework wall – higher Lf
9	Saboury et al.[34] 2018	Ti (BioPilar)	VZ	implant analog (Biotechnology Institute, Spain)	Y	CR SRCR (S,W)	5,794.85	2,691.48 (S) 3,878.06 (W)	NA	Y	NA	designed holes with a zirconia wall (W) – higher Lf

Y – yes; N – no; SAH – screw access hole; Co – cobalt; Cr – chromium; Ti – titanium; MC – metal-ceramic; MZ – monolithic zirconia; VZ – veneered zirconia; MLD – monolithic lithium disilicate; FDP – fixed dental prosthesis; CR – cement retained; SR – screw-retained; SRO – screw-retained offset; SAC – screw access channel; Hbs – SAC before sintering; Has – SAC after sintering; SRCR(S) – normal SAC; SRCR(W) – SAC with a designed wall; MP – SAC manually prepared; RS – SAC manually prepared then resintering; NA – data not available.

Table 2. Summary of the influence of metal–ceramic on the fracture resistance of SRCR restorations

No.	Study	Type of abutment	Crown materials	Implant manufacturers	Thermocycling (Y/N)	Retention system	Fracture load (Lf) value [N]		Fracture type			Comments
							no SAH	SAH	catastrophic	cohesive within the porcelain	cohesive reaching the framework	
1.	Zarone et al.[39] 2007	Gold Coping (Argedent 75)	MC	NA	N	CR SR	1,657 ±725	1,281 ±747	NA		Y	microcracks in the SAC of SR
2.	Shadid et al.[40] 2011	UCLA cast with Co-Cr alloy	MC	3i external hexagon (Biomet)	Y	CR (Znp) CR (Zoe) SRCR (Znp)	CR: 3,707 ±1,086 (Znp) CR: 3,169 ±867 (Zoe)	1,700 ± 526	load until failure	NA	NA	the cement type did not affect fracture resistance in CR
3.	Malpartida et al.[41] 2020	UCLA (Ni–Cr alloy, vs a 15°-angled abutment)	MC	Super Line Implant (Dentium)	N	CR SR SRCR	2,718.00 ±266.25	SRCR: 2,508 ±153.59 SR: 2,125.10 ±293.82	NA	Y	N	SRCR (angled abutment) had no effect on fracture load
4.	Rosa et al.[42] 2019	Ti (Conexao)	MC	4 × 11.5 mm; AR morse NP (Conexao)	Y	CR SRCR	2,522 ±40	967 ±560 (Ms) 833 ±195 (Msa)	NA	NA	Y	CR had higher fracture resistance than SRCR
5.	DuVall et al.[43] 2021	UCLA abutment noble metal alloy (Olympia)	MC	Full Osseotite Tapered Certain (Biomet 3i)	Y	CR SRCR	1,155 ±300	3,380 ±530	Y	NA	Y	SRCR layered with pressed ceramic had high fracture load

Ni – nickel; Znp – zinc phosphate; Zoe – zinc oxide eugenol; Ms – metal screw; Msa – metal screw aging.

Table 3. Summary of the influence of all-ceramic SRCR restorations on fracture resistance

No.	Study	Type of abutment	Crown materials	Implant manufacturers	Thermocycling (Y/N)	Retention system	Fracture load (Lf) value [N]		Fracture type			Comments
							no SAH	SAH	catastrophic	cohesive within the porcelain	cohesive reaching the framework	
1.	Honda et al.[16] 2017	Ti GingiHue Post	MZ VZ ILZ	Osseotite Implant (Biomet 3i)	N	SRCR	NA	MZ: 7.54 kN VZ, ILZ: 1.45–1.96 kN	Y (MZ)	NA	Y (VZ, ILZ)	the highest Lf for MZ
2.	Hussien et al.[44] 2016	Ti (TiXos; Leader Italia)	MZ, MLD VZ	internal hexagon implants (Tixos; Leader Italia)	Y	CR SRCR	MZ: 2,028.7 ±104.5 MLD: 615.3 ±76.6 VZ: 461.2 ±72.7	MZ: 2,047.8 ±83.2 MLD: 605.4 ±37.9 VZ: 411 ±34.4	load until failure	NA	NA	The highest Lf for MZ (SRCR), a different fracture pattern on the crown with SAC and without SAC
3.	Yazigi et al.[24] 2020	Ti (Bredent)	MZ, MLD	implants (BlueSKY; Bredent)	Y	SRCR	NA	MZ: 2,645 MLD: 1,070	NA	Y	NA	the highest Lf for MZ
4.	DuVall et al.[43] 2021	TiBase abutments (Dentsply Sirona)	VLD MLD VZ PMMA	Full Osseotite Tapered Certain, (Biomet 3i)	Y	CR SRCR	VLD: 2,520 ±400 VZ: 2,330 ±410	PMMA: 3,280 ± 370 MLD: 2,670 ±345	Y	Y	Y	the highest Lf for MLD vs. the veneered type
5.	Mallmann et al.[45] 2018	Ti (Speed; Conexão)	VZ	Implants (Morse AR NP; Conexão)	Y	3-unit FDPt CR SRCR	VZc: 3,803 ±1,038	VZs:2,601 ±830 VZsa: 446 ±575	Y (50% on VZs)	Y (VZc, VZsa)	NA	for SRCR VZ, lower Lf than for cemented, aging reduced Lf
6.	Rosa et al.[42] 2019	Ti (Conexão Sistemas)	VZ	Morse taper (Conexão Sistemas)	Y	CR SRCR	MC: 2,522 ±406	VZ: 932 ±309 VZa: 817 ±282	Y	NA	NA	VZa showed lower Lf

PMMA – polymethylmetaacrylate; VZc – veneered zirconia cement-retained; VZs – veneered zirconia screw-retained; VZsa – screw-retained aging; VZa – veneered zirconia aging; ILZ – indirect composite-layered zirconia.

the metal–ceramic bond strength. This decreases the fracture load value and increases the risk of chipping in a way not observed in cemented restorations.[33,35,39,42] Interestingly, when metal–ceramic layered with pressed ceramic was used, higher fracture resistance was recorded for SRCR restorations as compared to cemented restorations.[43] This finding could be due to the steps involved in the protocol for surface treatment, the application of self-adhesive cement and pressed ceramic material.

Given the ongoing interest in selecting the optimal material for an implant prosthesis, a few studies have reported an intriguing finding regarding the SRCR concept on all-ceramic materials utilizing Ti-base abutments (Table 3).[16,19,44,45] After load testing, the monolithic zirconia of SRCR restorations frequently survived and was found to withstand the highest fracture loads.[16,24,44] Other materials, such as monolithic lithium disilicate, also showed high fracture loads, with the fatigue fracture resistance being unaffected by screw access channels.[24,43] Scanning electrographic analysis showed that the fracture patterns were different from those in metal–ceramics in that they started in the cervical area and continued occlusally; this seems to be due to the greater stress transmitted at the abutment–implant junction, caused by the high fracture load value.[16,24,38,44] Meanwhile, veneered SRCR restorations showed a significant reduction in the fracture load values as compared to monolithic and veneered cemented restorations.[16,42,44,45] Cracks in veneered materials vary with regard to cracks from the internal surface of the framework and chipping within the ceramic on the feldspathic veneer.[42,43,45] Additionally, increased porcelain chipping and a decrease in fracture loads were observed following thermal cycling, implying a slow crack propagation in aged porcelain.[42,45] Therefore, special designs with special screw access channels, using finite element analysis, fractographic analysis and video recordings should be further investigated.

Aside from ceramics, several studies have studied the fracture resistance of implant crowns made of CAD/CAM composites and HPPs, such as resin nano-ceramic, polyetheretherketone (PEEK) and polymer-reinforced ceramics (Table 4).[24,25,30,46] Joda et al. investigated the monolithic designs of resin nano-ceramic (Lava™ Ultimate) bonded to Ti, and found no detectable fractures after quasi-static loading, regardless of the abutment type.[25] Tribst et al. confirmed that the use of the SRCR design did not affect the survival of a monolithic perforated crown made from VITA Enamic, a polymer-reinforced ceramic bonded to TiBase®.[47] Yazigi et al. found that fracture load was the highest for PEEK (BioHPP) fabricated as a monolithic implant SRCR, followed by CAD/CAM composites blocks, Grandio blocs and polymer-reinforced ceramics (VITA Enamic).[24] Nonetheless, the monolithic polymer-reinforced ceramic, the weakest of the 3 materials, has a lower fracture load than normal physiological loading of the posterior molars and should be used with caution.[24] In contrast to the monolithic design, the SRCR design had a negative impact on

Table 4. Summary of the influence of high-performance polymers (HPPs) of SRCR on its fracture resistance

No.	Study	Type of abutment	Crown materials	Implant manufacturers	Thermocycling (Y/N)	Retention system	Fracture load (Lf) value [N]		Fracture type		Comments
							no SAH	SAH	catastrophic	cohesive	
1.	Joda and Brägger[58] 2014	Ti (synOcta, CADCAM CARES, Variobase (VB))	RNC (Lava)	implant (Straumann)	N	SRCR	NA	1,100–1,500 (S) 1,300–1,500 (C) 1,100–1,200 (VB)	NA	Y	monolithic implant crowns made of RNC are stable prosthetic reconstructions under laboratory testing
2.	Tribst et al.[47] 2020	Ti (Conexão Sistemas)	PIC (VITA Enamic)	Morse taper implants (Conexão Sistemas)	Y	CR SRCR	NA	NA	Y	Y	fracture was commonly observed on the emergence profile
3.	Yazigi et al.[24] 2020	Ti (CEREC; Bredent)	PEEK (P) composites (C/Grandio blocs) PIC (E/VITA Enamic)	implants (Bremen, Germany)	Y	SRCR	NA	2,030 (P) 915 (C) 670 (E)	NA	Y	fracture load was the highest on PEEK
4.	Preis et al.[30] 2017	Ti	PEEK (BioHPP) RNC (Lava) CADCAM composites	implant analogs (Straumann)	Y	CR SRCR	PMV: 921.3 PPV: 1,329.8 CO: 1,667.6	PMV: 964.3 PPV: 978.0 CO: 1,526.8	NA	Y	layered resin-based were weakened with SAH

RNC – resin nano-ceramic; PIC – polymer-reinforced ceramic; PMV – polyetheretherketone + milled composite veneer; PPV – polyetheretherketone + composite paste veneer; CO – composites.

fracture loads when implant crowns made of the PEEK (BioHPP) substructure and a layered with CAD/CAM milled composite were used.[30] The SRCR design also resulted in the failure of PEEK (BioHPP) layered with conventional composite paste.[30] In terms of the biomechanical behavior of HPPs, a high prevalence of fracture was observed at the emergence profile and in the cervical area in the monolithic design, as well as in the screw access channel in the veneered design.[47] With an increasing fracture load, a higher concentration of stress was transmitted to the implant–abutment junction, resulting in cracks near the emergence profile.[16,24,38,44]

Clinical performance of SRCR restorations fabricated from various materials

Few authors have applied the SRCR design to implant restorations in clinical settings (Table 5). Rajan and Gunaseelan described a protocol for fabricating the SRCR concept for metal–ceramic restorations.[48] The ceramic superstructure was cemented on metal cast abutments and excess cement was removed extraorally.[48] Three other studies documented how SRCRs were used to restore fully edentulous maxillae and mandibles.[49–51] In addition to casting gold abutments, SRCRs were milled from Ti as a cost-effective solution for the multi-unit fixed partial denture.[49] In a retrospective analysis of edentulous patients restored with SRCRs, porcelain chipping occurred in only 10.9% of cases, indicating a low rate of complications.[50] AlHelal et al. developed a protocol for a cementation technique that avoided the use of die spacers at the cervical finish line, thereby preventing the excess cement complications.[9] Based on this clinical report and technique, SRCRs using metal–ceramics have improved implant restoration survival rates by preventing damage to the porcelain when the screw loosens, as well as reduced the cost of maintenance.[52]

Regarding all-ceramic SRCR restorations, Proussaefs et al. recommended a digital workflow for monolithic zirconia bonded to a custom Ti abutment, using the SRCR technique.[10] The prostheses were cemented while positioned intraorally. After extrication from the mouth, the cement was removed extraorally after polymerization.[10] With a similar technique, Wasiluk et al. assessed the incidence of undetected cement by using custom Ti cement abutments fabricated for SRCR restorations.[53] Excess cement was recorded on the distal (17.9%), mesial (15.0%), palatal (8.8%), and buccal surfaces (3.4%).[53] Therefore, with these procedures, the risk of undetected cement residue was reduced when polishing and cleaning were possible for SRCR restorations. The SRCR design with monolithic zirconia and an angulated screw channel (ASC) revealed no difference in crestal bone loss.[54] Joda and Ferrari evaluated an SRCR implant crown made of monolithic lithium disilicate bonded to a Ti base, and reported no complications after 1 year.[55] In a randomized split-mouth trial, a monolithic lithium disilicate implant crown fabricated as an SRCR was reported to have a 100% survival rate.[23] Cicero et al. reported no complications following a 3-year follow-up using a hybrid approach (a zirconia coping layered with pressed lithium disilicate luted to a Ti base).[56] Using a similar veneered approach, fractographic analysis revealed premature failures and cracks near the screw access channel.[57] However, with the exception of 2 studies, there were limitations, i.e., the majority of them were clinical techniques and case reports.[10,23,54–57]

Screw-retrievable cement-retained implant restorations using HPPs have been reported in a few studies. When bonded to a prefabricated abutment, monolithic resin nano-ceramic (Lava Ultimate) fabricated using a digital method demonstrated a more favorable esthetic outcome (Variobase®).[58] Monolithic SRCRs with polymer-reinforced ceramics (VITA Enamic) have been shown to have an excellent outcome, with no prosthetic or biological complications.[59] However, when zirconia abutments were used, 80% of bonding failures occurred within the 1st year of service in the monolithic type fabricated from resin nano-ceramic.[29] As a result, researchers have emphasized the contraindication for resin nano-ceramic bonded to a zirconia abutment as an implant restoration material. Nonetheless, limited information is available on the application and clinical studies of PEEK and block CAD/CAM composites as an alternative for implant restoration.

Discussion

In restoring dental implants with monolithic or veneered ceramic crowns, SRCR incorporates the advantages of both the traditional screw and cement techniques.[12] The different fracture load values, and crack initiation and propagation mechanisms were all influenced by different SRCR implant restoration designs and materials. The size and design of the screw access channel, and whether its preparation is performed before or after sintering are all relevant elements that influence the ultimate performance of the SRCR design. Oversized diameters of screw access channels not only contribute to the fracture risk, but also influence stress concentration at the margin of the channel, which makes the restorations vulnerable to failure, particularly in patients with excessive bite force.[17] Furthermore, grinding an intact lithium disilicate restoration after crystallization and glazing should be avoided, as more cracks occur than when grinding the crown while still in its pre-glazing or blue phase. After crystallization and glazing, the strength of the crown increases from 130–150 MPa to 350–450 MPa.[23] Regarding zirconia, diamond bur grinding rather than tungsten carbide is recommended before sintering to avoid phase transformation in the zirconia microstructure.[59] To improve the fracture resistance of SRCRs, screw access channels with surrounding zirconia walls should be used for the reinforcement of the restoration.[34]

Table 5. Summary of the clinical performance of SRCR fabricated with various types of materials

	No.	Study	Study period	Study design	Type of implant	Number/site	Retention system	Superstructure material	Abutment	Implant survival	Prosthesis complications	Comments
Metal–ceramic restoration	1.	Rajan et al.[48] 2004	NA	clinical report	NA	1/molar	SRCR	MC	–	Y	NA	the use of provisional cements is not indicated in SRCR
	2.	Uludag et al.[49] 2006	NA	case report	Swissplus, Zimmer Dental, San Diego, California	9 units	SRCR (FPD)	MC	–	Y	NA	milled abutment as alternative to cast abutment for SRCR
	3.	Al Amri[51] 2016	NA	clinical report	Standard plus ITI: SLA	maxilla	SRCR	MC	–	Y	survived after 5 years	peri-implant crestal bone levels were stable in SRCR multi-unit restoration
	4.	Lixin et al.[50] 2010	22–62 months	retrospective	Camlog RootLine, Camlog	234/maxilla 119/mandible	SRCR	MC	–	99.15%	10.91% ceramic chip-off	–
	5.	Nissan et al.[52] 2016	12 years	retrospective	Nobel, Zimmer, 3i, MIS	148/maxilla 245/mandible	CR SRCR (SAH created after firing)	MC	NA	Y	ceramic fracture, screw loosening	adding SAC on the metal framework decreased the need for refabrication
	6.	AlHelal et al.[9] 2017	NA	clinical technique	NA	premolar, molar	SRCR	MC	custom Ti	NA	none	–
All-ceramic restorations	1.	Proussaefs and AlHelal[10] 2018	NA	clinical technique	NA	premolar, molar	SRCR	MZ	custom Ti	NA	none	–
	2.	Wasiluk et al.[53] 2017	NA	prospective case series clinical trial	Osseospeed TX (Denstply)	premolar, molar	SRCR	MZ	custom abutment	Y	none	the majority of cement residue was on the distal(17.9%) and mesial (15%) site
	3.	Di Fiore et al.[54] 2023	36 months	prospective clinical study	Nobel Parallel (CC)	molar	SRCR	MZ	ASC TiBase	96%	96%	–
	4.	Joda and Ferrari[55] 2018	NA	case report	NA	molar	SRCR	MLD	TiBase	Y	none	–
	5.	Khamis and Zakaria[23] 2022	12 months	randomized controlled split-mouth trial	SuperLine (Dentium)	molar	CR SRCR	MLD	Tibase (preparable)	None	none	no significant differences between both groups
	6.	Cicero et al.[56] 2021	3 years	case report	NA	premolar, molar	SRCR	hybrid, MZ	TiBase	Y	none	–
	7.	Juica et al.[57] 2022	NA	case report	Tapered Internal (BioHorizons)	premolar	SRCR	hybrid	TiBase	Y	Y	catastropic failure due to overloading, poorly designed material
Resin nano-ceramic restorations	1.	Joda and Brägger[58] 2014	NA	case series	tissue level (Straumann)	premolar, molar	SRCR	RNC	TiBase (prefabricated vs. custom)	Y	none	favourable esthetic outcome for the prefabricated bonding bases
	2.	Schepke et al.[29] 2016	1 year	randomized controlled trial	ASTRA TECH implant system	premolars	SRCR	RNC	stock vs. custom zirconia	Y	Y	poor prognosis of RNC luted to zirconia abutment
	3.	Lambert and Mainjot[59] 2017	1 year	case letter	tissue level (Straumann)	premolar, molar	SRCR	PIC	TiBase	Y	none	–

ASC – angulated screw channel.

These modifications have only been evaluated using in vitro testing with standardized parameters, and therefore, clinical studies are timely and highly needed to validate these in vitro findings.

In terms of the influence of materials, the majority of studies concluded that screw access channels in metal–ceramic restorations weakened the porcelain and reduced fracture load in SRCR.[33,39,40,42] Screw-retrievable cement-retained restorations may harm the geometrical variations of the framework, resulting in porcelain cracking.[33,41] Such cracks were found to be distributed in areas of higher mechanical resistance near the screw access channels, whereas jagged lines were discovered in areas of low-stress concentration.[35,39] Furthermore, cracks formed during thermocycling led to failure after aging.[33] There were conflicting reports on the fracture loads of cement-retained and SRCR restorations.[18,41] These could be attributed to the use of different implant systems, cement types, screw access channel diameters, filling materials, number of loadings, fatigue cycles used, and thermocycling effects.[11,18,43] As a result, additional standardization methods are required to prevent bias in future clinical studies.

Differences in screw access channels, on the other hand, do not affect the fracture load value of SRCRs constructed entirely from monolithic ceramics. Screw-retrievable cement-retained restorations fabricated with monolithic zirconia and monolithic lithium disilicate had a high fracture load, which exceeded masticatory forces of 900 N in the posterior region during load testing, indicating the suitability of these materials for posterior molar restorations.[16,19,24,60] Catastrophic fractures occurred only when the load was increased to 2400–4500 N.[16,19,45] High fracture loads in monolithic ceramics have raised clinical concerns about stress concentration in the cervical peri-implant bone area.[60,61] To alleviate this concern, zirconia crowns have been veneered with lithium disilicate or composite resins. This veneering also improves shade matching and occlusal wear on the opposing teeth, as monolithic zirconia is relatively opaque and hard.[56] However, the presence of screw access channels in veneered restorations has increased tension near the channels while decreasing fracture loads.[16,34] The fracture mode ranged from catastrophic to chipping within the porcelain, but the veneered type is able to withstand physiological masticatory forces in the molar region.[16,45,62] The diameter of the screw access channel, occlusal contact, and the quality of bonding between the layering materials must be investigated further to avoid premature failure.[57]

High-performance polymers have been recommended to compensate for the absence of periodontal ligaments through absorbing forces and withstand a greater load to avoid stress being transmitted to the surrounding bone.[30] High-performance polymers have a high modulus of elasticity, allowing them to deform before cracking.[24,46] They also exhibit distinct mechanical behavior depending on the underlying abutment or the monolithic/veneered design of the structure.[24] The load capacity causes their failure mode to originate from the cervical part to the top of the restoration. The presence of screw access channels for SRCRs in these materials also causes no stress and performs similarly to the cemented type. High-performance polymers can withstand forces greater than those occurring on a natural posterior molar, except for SRCRs fabricated with polymer-reinforced ceramics, which failed catastrophically at a load of 600 N. These materials create a grey zone that compromises esthetics when monolithic designs are used. To address this esthetic issue, a hybrid abutment or veneered abutment has been proposed,[46] but this deteriorates physical properties and fracture load performance.[30] Consequently, when selecting materials for HPPs, especially for the veneered type and hybrid abutments, caution should be exercised. In general, to avoid failure at the emergence profile and cervical area, there should be a minimum thickness for this material. For posterior implant restorations, materials with a low modulus of elasticity that absorb energy and have comparable fracture resistance, are preferable.

Few authors have used SRCRs in clinical studies regarding implant-supported restorations. Only clinical techniques and retrospective clinical studies have been reported, although the use of metal–ceramic SRCRs is considered to be simple and as effective as cemented restorations.[9,48,50] For all-ceramic restorations and monolithic HPPs, no damage and mechanical complications were observed at the interface of the Ti base abutment, suggesting that this was a suitable clinical method for implant-supported prostheses.[19,44,54,55] Further clinical trials and studies with a longer follow-up are required before recommending routine application of this method, especially of the veneered type.[8,54] Selecting suitable abutments and material types is fundamental to ensure the satisfactory clinical performance of SRCRs.

Conclusions

Metal–ceramic SRCRs have a generally lower fracture load value than cemented implant-supported restorations, although the differences may vary considerably. Cracks start mostly at the screw access channels. There is no significant difference in the fracture load values between SRCRs fabricated as monolithic ceramics and cement-retained restorations. The adhesive bonding between Ti abutments and monolithic ceramic frameworks showed no damage at the interface and did not affect the fracture risk. For the veneered type, the presence of screw access channels in zirconia and lithium disilicate significantly reduces fracture load as compared to cemented restorations, but is sufficient to withstand molar masticatory forces. Among HPPs, monolithic forms of ceramic-reinforced PEEK and resin nano-ceramic demonstrated higher fracture resistance than those occurring clinically.

However, monolithic polymer-reinforced ceramic networks and veneered restorations had lower fracture resistance and should be used with caution.

Regarding the clinical performance of SRCRs fabricated with metal–ceramics, the clinical data is mainly retrospective and contains case reports. However, no controlled randomized clinical trials RCTs) have been conducted. Monolithic SRCRs fabricated with all-ceramic restorations have shown good short-term clinical performance within 1–3 years post-loading. For veneered SRCR restorations, clinical data demonstrating the predictability of this approach is lacking. High-performance polymers may be recommended as a substitute for posterior implant restorations, but clinical data is scarce; hence, further investigations are needed.

Ethics approval and consent to participate

Not applicable.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

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