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Screw retained vs. cement retained implant-supported fixed dental prosthesis

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Implant-supported fixed dental prostheses (FDP) represent a well-established treatment option that has evolved to become a standard of care in dental medicine over the past four decades. This success is based on the phenomenon of osseointegration, which has been enhanced through progress in surface technology, refined surgical techniques, the improvement of the stability of interfaces between the implants, abutments and dental prosthesis, as well as the establishment of lifelong prophylactic efforts to prevent biologic complications and failures (1, 4, 8, 35–37, 39, 50). The main focus in prosthetic research is now the development of materials with better biomechanical characteristics and the optimized use of digital pathways for the production of the suprastructures.

In a retrospective study with 303 partially edentulous patients, 511 implants and 367 FDPs were re-examined after 10 years (6, 48). The 10-year survival rate was 98.8% for the implants and 95.5% for the implant-supported prostheses (6, 48). However, when the literature was analyzed using a systematic approach in another study, pooled data from 72 clinical studies revealed 5-year survival rates of 96.03% and 95.55% for cemented and screw retained reconstructions, respectively ($P = 0.686$) (49). For the pooled data, the failure rates at 5 years were comparable to the rates reported in the retrospective clinical study after 10 years, but the results can still be considered good because they reflect the fact that in 72 studies, different patient risk profiles were present. However, the total event rate of technical and biological complications was significantly higher with cemented prostheses (49). This systematic review indicated that the choice of retention type (cemented or screw retained) might not have a crucial influence on the overall survival of the prosthesis, but may be responsible for the development of a certain complication.

Nowadays, clinicians from general dentists to specialists perform restorations using dental implants. An important clinical decision remains the choice of the connection type – cement or screw retained. This connection can have an impact on the prognosis of the overall reconstruction. Which retention system is appropriate for the individual patient depends on diverse factors, including the indication, advantages and disadvantages, ‘retention’ provided, retrievability, esthetics and the clinical performance (failures and complications). In fact, in combination, it is difficult to consider the factors objectively, and therefore criteria are singled out to present the effect of a specific retention type. The aim of this review is to present an overview of factors influencing the overall outcome of screw vs. cement retention for implant-supported FDPs.

Indication, advantages/disadvantages and retention

Both retention types have been applied for single, multiple and cross-arch fixed dental prostheses. Long-span prostheses should preferably be screw retained for easier maintenance – it has been discussed in the literature that long-span restorations have a higher risk of complications (34, 38). This should also apply for cantilevered FDP designs due to the fact that these prostheses require more maintenance and service (3, 38). It might also be easier to achieve sufficient retention for compensation of the leverage of the extension.

However, if the implant is not placed in a prosthetically ideal position – with the future access hole of the planned crown below the planned incisal edge position – cement retention is often the only treatment option. Therefore, proper treatment planning and prosthetically driven implant placement should be mandatory for implant therapy (7, 15, 17, 47). Both retention types have their advantages and limitations. It is therefore the clinician's responsibility to select the most appropriate method of retention for the individual case. A decision tree is illustrated in Fig. 1.

Cement retained implant FDPs are the most often used restorations in implant dentistry (41). The advantage of cement retention lies in the compensation of improperly inclined implants, easier achievement of passive fit due to the cement layer between the implant abutment and reconstruction, lack of a screw access hole, and thus the presence of an intact occlusal table and easier control of occlusion, for example in posterior sites with narrow-diameter crowns (Fig. 1). A major disadvantage of cement retention lies in the difficulty of removing excess cement, which has been associated with the development of peri-implant diseases such as peri-implant mucositis and peri-implantitis (14, 22, 23, 29, 32, 45, 49). Consequently, this adds an additional risk factor to the overall treatment.

Screw retained implant-supported prostheses were initially used when implants were invented, especially supporting full-arch prostheses for edentulous patients with the '*ad modem* Branemark' protocol (1). The invention of the UCLA gold custom abutment in 1988 allowed an easier workflow for screw retention, as it permitted the retention of a prosthesis directly on or inside the implant without the use of a transmucosal abutment (21). However, the reconstruction was cost intensive, and according to Taylor & Agar's (39) classic publication on 'implant prosthodontics' in 2002, screw retained restoration involved nearly four times the component cost of cemented restoration. With the evolution of prosthetic components' designs and digital workflow, the costs have decreased in the meantime. A combined approach with an individualized abutment that is bonded to a

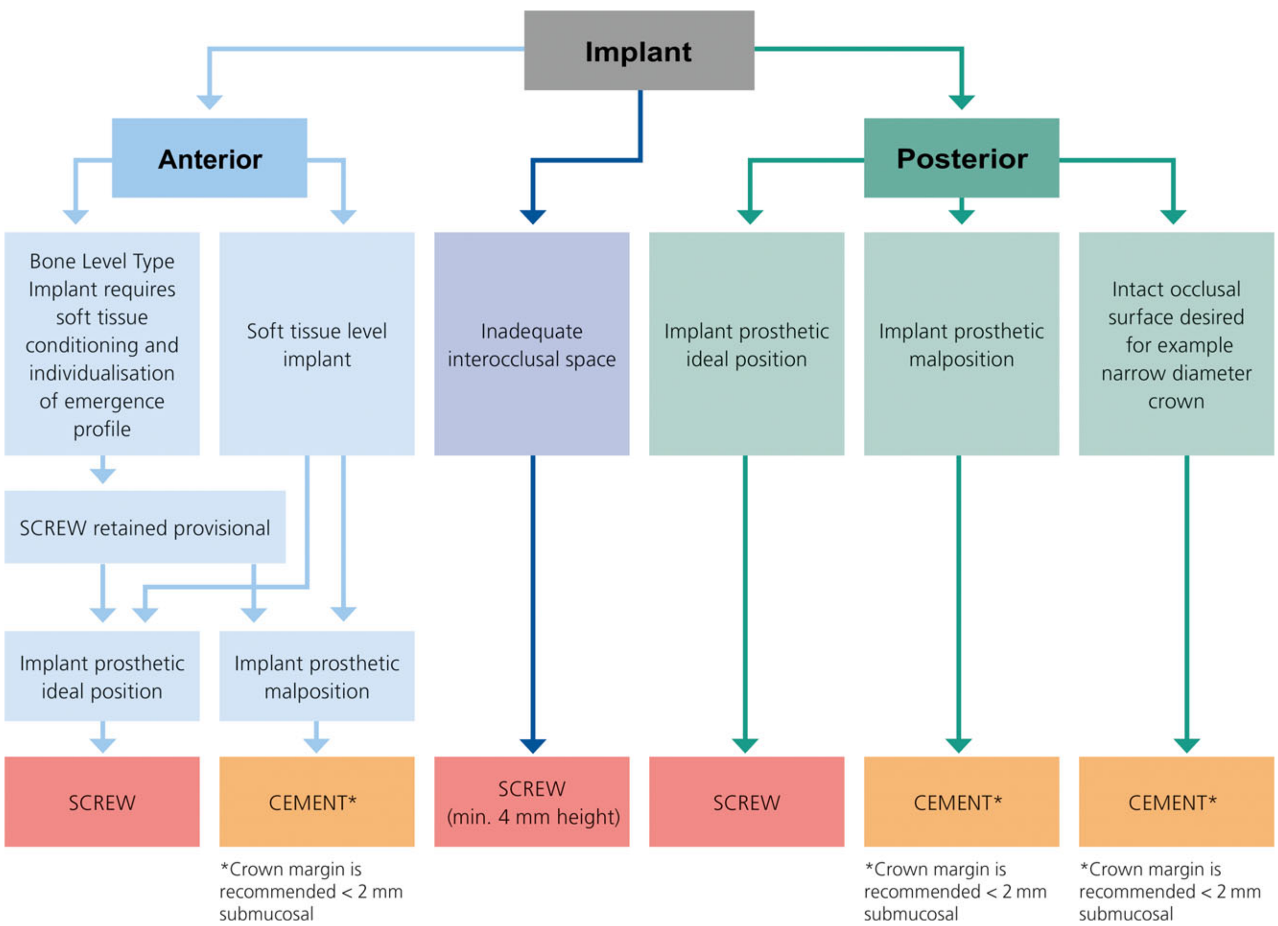

Fig. 1. Decision tree illustrating the pathway of decisions in respect of the indication of screw vs. cementation in fixed prosthodontics supporting implants.

prefabricated titanium or zirconium dioxide base offers a cost-efficient solution; however, this abutment type lacks long-term documentation (51). A case with the use of this abutment is illustrated in Fig. 2A–G.

Cementation can be achieved with provisional or definitive cement. Provisional cementation allows retrievability to a certain extent, while the risk for leakage and loss of retention may be higher compared with definitive cementation. In order to maintain retention during function, basic mechanical parameters are crucial: these factors include height, diameter, conicity, indexing, surface roughness of the abutments, number of abutments related to number of teeth to be replaced, alignment of abutments in the dental arch, straight or angled configuration and the presence of extensions.

For a layer of cement, a certain minimal space must exist. This space can be created by using spacer material in the laboratory or by applying built-in off sets for CAD/CAM production or the built-in tolerance with prefabricated copings. A cement gap may create a critical clinical situation when the crown or FDP has not been seated in the correct position or when the cement material started to set before the final position was found. In this situation, the falsely seated FDP needs to be forced out, with the risk of damage. The entire process of cementation has to be repeated after tedious removal of all the left-over cement and after removal of the FDP which led to this seating error. Even with the use of a 'cemented FDP', in most instances a screw retained abutment exists underneath this FDP onto which the suprastructure is cemented, especially in the case of two-piece

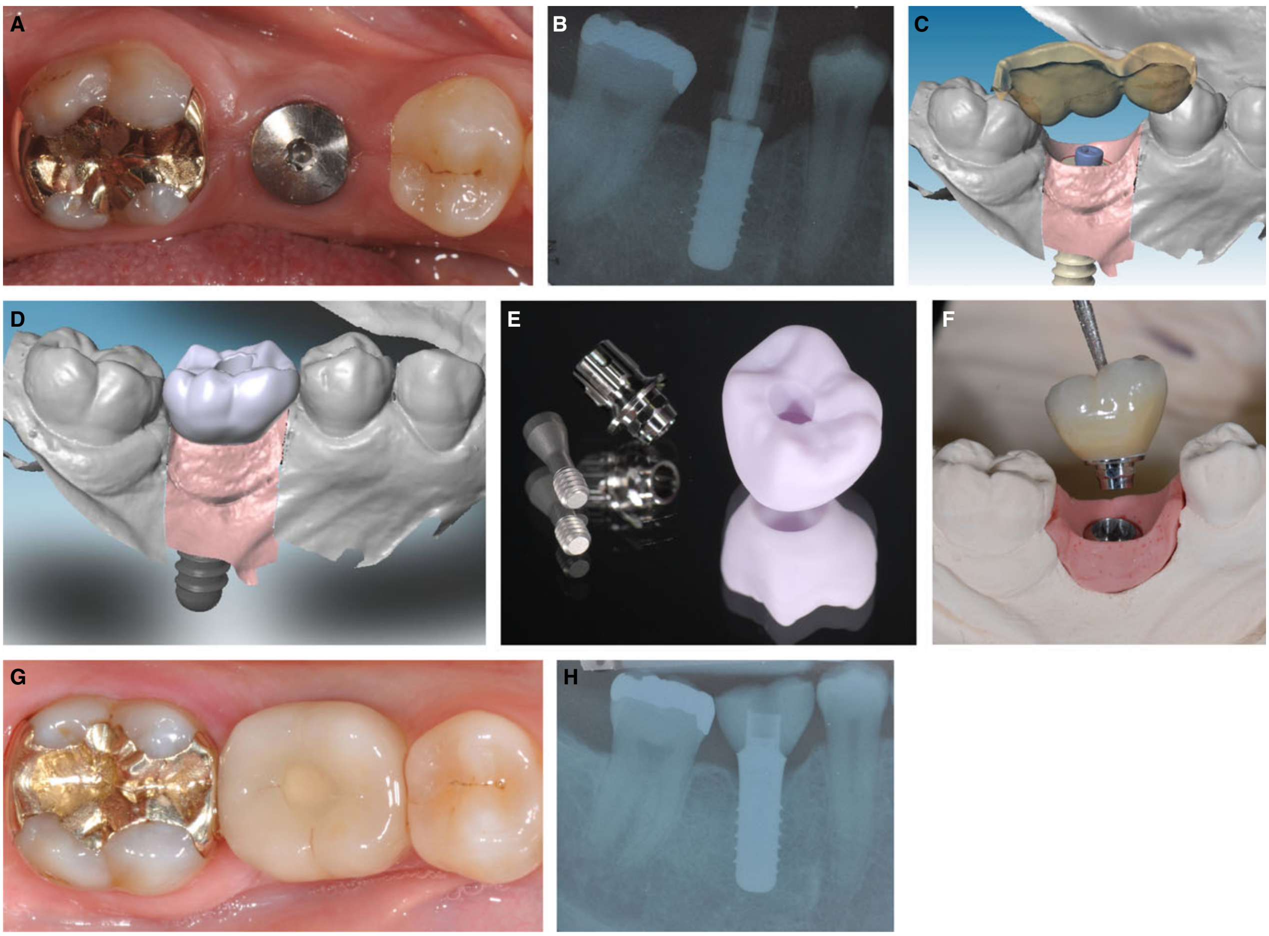

Fig. 2. **(A–H) Patient: a non-smoking, healthy, female, 43 years. Clinical situation: a single edentulous tooth gap region 46 (FDI nomenclature). (A) Soft tissue level regular neck implant was placed in a correct 3-dimensional position. (B) Open-tray impression and bite registration followed 8 weeks later. Peri-apical radiograph for evaluation of the impression coping position. (C, D) Verification of digital image and manual modification, matching occlusion of opposing dentition. (D, E) Lithium disilicate glass-ceramic single crown was delivered to the dental laboratory in a bluish color using a bonded titanium variobase abutment. (F) Definitive screw retained single crown on the cast. (G) Inserted crown torqued with 35 Ncm inside the implant. Occlusion was adjusted and oral hygiene instructions given to the patient. (H) Peri-apical radiograph of final crown.**

implants. In order to fulfill all the requirements for a cemented procedure, the surgical placement of a one-piece implant may turn out to be rather challenging.

Overall, screw retained FDPs have the advantage of more predictable retrievability. They require a minimal amount of interocclusal space (min. 4 mm) (9) and are easier to remove when hygiene maintenance, repairs or surgical interventions are required. Disadvantages are the limited indication, the increased fabrication time and costs for bridge-designed prostheses, and the access hole present in the occlusal table, which might interfere with occlusion in posterior sites. In the anterior zone, access to the screw plays no active role in occlusion, and therefore should be no reason to avoid a screw access (9).

Retrievability

The evolution of high-strength ceramic materials and overall monolithic FDPs has led to new prosthetic options with less risk of chipping; however, they are also more difficult to separate and remove if needed – especially if they have been cemented using definitive cement (47). The removal of cemented crowns on implants made of zirconium dioxide or other strong ceramic monolithic materials is time consuming and not comfortable for the patient.

Several methods for retrieval of implant-supported cemented FDPs have been published. These include access to the underlying abutment screws using separation screws resting on the prosthesis and pushing against abutments (9, 10, 13, 16, 28).

If an abutment screw loosens underneath a cement retained FDP, the chances of decementing the suprastructure, retightening the abutment and recementing are minimal. Most likely the FDP will need to be destroyed by separation.

When interarch space conditions are ideal, the abutment for cement retained FDPs offers enough retention with its height and angulation. Machined abutments with six degrees of taper often provide ideal retention that is three to four times the retention achieved on natural tooth preparations (18). Compared with a prepared tooth, the implant abutment has an increased height and longer walls. This combination of taper and height offers enough retention even with provisional cement for definitive use. Provisional cementation has been recommended for implant-supported crowns and FDPs to allow retrievability (9, 25). However, the disadvantage of these cements remains the lack of a marginal seal. Provisional cements can resolve over time and microleakage can develop. In addition, patients may swallow a crown if it loses retention during a meal.

The main advantage of screw retained dental prostheses is the predictable retrievability, which is possible without destroying the FDP. In this instance, the visibility of the access hole helps to find the exact location for the careful removal of the covered FDP. Preferably, the abutment screw has been protected using polytetrafluoroethylene tape (27). Maintenance therefore favors screw retention. With respect to the aging population, patients' desire for FDPs – often with a full-arch or long-span design – is increasing (5). Here hygiene maintenance plays an important role. Even if the implant prosthesis is designed to be cleansable, it can be difficult if the patient is not able to follow oral hygiene instructions. Then the removal of the FDP for maintenance is a possible alternative and helps to preserve the health of the peri-implant mucosa. However, this is only possible with screw retention. This approach is therefore advantageous for elderly or special needs patients.

Treatment protocols for treating mucositis and peri-implantitis require direct access to the working field. Diagnostic and surgical procedures, handling of contaminated implant surfaces and coverage with mobilized flaps should not be hindered by the dental prosthesis. A complete removal of the reconstruction and abutments facilitates these interventions and a submerged healing period.

Provisionalization and esthetics

Treatment of the esthetic zone remains one of the bigger challenges in the field of implant dentistry. The final prosthetic restoration and peri-implant mucosa have to mimic the esthetic details of the previous tooth and match the adjacent dentition. A backward-driven treatment planning process including the determination of prosthetic and surgical risk factors is important for predictable and stable long-term outcomes (11).

The involvement of a provisional phase is essential. It should be supported directly on the implant to facilitate soft tissue conditioning and in order to finalize the peri-implant mucosa but also to convert the mucosal and emergence profile into a profile that is in harmony with the neighboring dentition and offers a pleasing, natural and esthetic appearance (Fig. 3A–C). This is especially recommended if implants are placed at the level of the bone crest.

Fig. 3. **(A) Screw retained provisional restoration. (B) Final peri-implant mucosa of implant site 12I prior to definitive impression after 4 months of soft tissue conditioning with the dynamic compression technique side and (C) frontal view.**

These implants offer more prosthetic advantages as the clinician can individualize the position of the future crown margin, the final mucosal zenith and the emergence profile. Regarding the retention type, screw retention is preferred for the use of a fixed implant-supported provisional prosthesis because it simplifies the technique (9) and can be removed if needed.

Cementation of definitive implant-supported FDPs is a familiar procedure for the dental clinician and more closely follows the procedures routinely performed on natural teeth (39). However, especially with the use of bone-level implant-supported provisionals or FDPs, the cementation procedure is not simple, requires significant attention and should be carried out with great caution (46). Especially in esthetic sites, any peri-implant tissue inflammation can result in severe esthetic problems (41). It is important to place the submucosal crown margin in an accessible position and not too far below the mucosal margin in esthetic sites, and in a paramucosal or even supramucosal position in posterior sites (Fig. 1). Otherwise the complete removal of cement remnants is not predictable.

As early as 1997, Agar et al. (2) concluded in an *in vitro* study that the process of removing excess cement from subgingival margins after cementation of restorations to implant abutments can lead to scratching of the abutments, and cement removal can be incomplete. Another investigation showed that the deeper the margin, the greater the amount of undetected cement, with the greatest amount of cement found in the groups where the margins were placed 2 and 3 mm submucosally (23, 24). A recent investigation found that about 81% of the implants restored with cement retained single crowns with clinical and radiological signs of peri-implantitis had extracoronal residual cement present (45). Therefore, this study concluded that residual cement might act as one of the predisposing factors for peri-implantitis development. Implants with cement remnants in patients with a history of periodontitis may be even more likely to develop peri-implantitis, compared with implants in patients without a history of periodontal disease (22).

In a study reporting on the clinical and radiographic re-examination after 9 years of 588 patients who had all received implant therapy, higher odds ratios for the development of peri-implantitis were identified for implants installed with crown restoration margins positioned ≤ 1.5 mm from the crestal bone at baseline (12).

To avoid the problems associated with residual cement, screw retention is recommended in anterior sites (Fig. 1), since cement removal is very difficult when implants are inserted too deep into the tissue. When an implant is not placed in an ideal prosthetic position, a combination of screw and cement retention might be an option, as presented in a clinical case (Fig. 4A–F). Here the implant was malpositioned and was so deep that cement removal would have been difficult. An all-ceramic screw retained zirconium dioxide abutment was fabricated and the crown margin was placed individually supramucosally and the crown cemented on top.

With an implant placed at the soft tissue level, the shoulder is included in the implant and therefore an emergence profile is given, which does not require a provisionalization phase. Cement removal is easier depending on the position of the implant itself and when the FDP margin is far away from the bone.

Clinical performance (survival, biological and technical complications)

In a recent systematic review by Wittneben et al. (49) evaluating the clinical performance of screw retained vs. cement retained fixed dental prostheses, a Medline (PubMed), EMBASE and COCHRANE electronic database search was performed for papers published between 2000 and September 2012, with 72 articles qualifying for inclusion in the

Fig. 4. (A, B) Initial pictures of a 75 year old female patient with loss of vertical dimension and an old implant restoration 21I (FDI). (C) Implant crown 21I (FDI) with transverse screw retention and pink porcelain which was removed. (D) New reconstruction – screw retained zirconium dioxide abutment in combination with pink porcelain and an all-ceramic reconstruction with a distal cantilever. (E) Final implant 21I and overall restorations and final. (F) Full smile with increase of vertical dimension with fixed prosthodontics. (G) Final peri-apical radiograph.

review. Five-year survival rates of 96.03% and 95.55% were calculated for cement retained and screw retained FDPs, respectively (Table 1). Estimated failure rates calculated for cement and screw retained prostheses were not statistically significant ($P = 0.63$). Comparison of cement and screw retention showed no difference when subgroups with single crowns ($P = 0.103$) or fixed partial dentures ($P = 0.486$) were analyzed. The 5-year survival rate for screw retained full-arch FDPs was 96.71% (95% CI: 93.66–98.31).

The following technical and biological complications revealed a statistically significant difference between screw and cemented prostheses: 'loss of retention' ($P \leq 0.001$), 'abutment loosening' ($P \leq 0.001$), 'porcelain fracture and/or chipping' ($P = 0.020$), 'total technical events' ($P = 0.030$), 'presence of fistula/suppuration' ($P \leq 0.001$) and 'total biological events' ($P = 0.019$). The failure rate of cemented prostheses was not influenced by the choice of a specific cement; however, the cement type did influence loss of retention (49).

Although no statistical difference was found between cement retained and screw retained prostheses for survival or failure rates, screw retained prostheses exhibited fewer technical and biological complications overall (Table 1). The technical complication 'fracture/chipping of ceramic' was encountered significantly more frequently in screw retained compared with cemented prostheses. The complication 'loosening of abutment' was more frequent with cemented reconstructions, and the total rate of technical complications was also significantly higher with cemented reconstructions.

Table 1. Overview of main findings from recent systematic reviews related to outcomes with cement vs. screw retained fixed implant supported reconstruction

Authors, year	Time of included studies	Number of implants/ reconstructions	Number and type of included studies	Minimum follow-up of included studies	Outcome on survival and technical/ biological complications
Sailer et al. 2012 (33)	1990–2011	1692 single implant crowns, 740 partial FDPs, 681 full arch FDPs	59 studies: 9 RCT; 38 prospective; 12 retrospective	Minimum 12 months	• Cemented single crowns: 5-year reconstruction survival was 96.5%. Screw retained single crowns: 5 year: 89.3% ($P = 0.091$) • Cemented partial fixed dental prostheses (FDPs): 5-year survival rate: 96.9%. Screw retained partial FDPs: 5-year survival rate: 98% ($P = 0.47$) • Cemented full-arch FDPs: 5-year survival: 100%; Screw retained FDPs: 5-year survival rate: 95.8% ($P = 0.54$) • Estimated 5-year cumulative incidence of technical complications: cemented single crowns 11.9%; screw retained crowns: 24.4%. Partial and full-arch FDPs cemented 24.5%, screw retained 22.1%; full-arch FDPs, cemented 62.9%, screw retained 54.1% • Biological complications such as marginal bone loss > 2 mm occurred more frequently at cemented crowns (5-year incidence: 2.8%) than at screw retained crowns (5-year incidence: 0%)
Wittneben et al. 2014 (48)	2000– Sept. 2012	5858 fixed implant supported reconstructions	73 studies: 6 RCT; 52 prospective; 13 retrospective	Minimum follow-up time of 3 years	• 5-year survival rates 96.03% for cemented and 95.5% for screw retained reconstructions ($P = 0.69$). No statistically significant differences between the failure rates of the different reconstruction types (I-SC, I-FDP, full arch I-FDPs) • The total event rate of technical and biological complications was statistically significantly higher with cemented reconstructions • The technical complication fracture/chipping of ceramic was statistically higher with screw retained restorations

Table 1. (*Continued*)

Authors, year	Time of included studies	Number of implants/ reconstructions	Number and type of included studies	Minimum follow-up of included studies	Outcome on survival and technical/ biological complications
Millen et al. 2015 (26)	Same data pool as Wittneben et al. (48)	5858 fixed implant supported reconstruction: 979 fixed partial FDPs; 928 full arch FDPs; 61 cantilever FDPs; all fixed prostheses (these were not further defined in the included clinical studies) 2170	73 studies: 6 RCT; 52 prospective; 13 retrospective	Minimum follow-up time of 3 years	**According to simple Poisson regression analysis:** • Screw retained FDPs significantly higher rate of technical complications than cemented FDPs • Screw retained full-arch FDPs demonstrated a high rate of veneer chipping • 'all fixed prostheses': significantly higher rate of biological complications with cement retention than with screw retention **According to simple Poisson regression analysis:** • failures: no significant difference between screw and cement retained prostheses • technical and biological complications: higher incidence rate with cemented prostheses • full-arch FDPs, cantilever FDPs and 'all fixed prostheses' had significant higher complication rates than single crowns
Weber & Sukotjo 2007 (44)	1995–2003	3822 implant supported fixed prostheses: 1036 FDPs ('bridges'); 2612 single crowns; 174 FDPs with combined implant and tooth support	72 clinical studies; 2 RCTs; 51 prospective; 21 retrospective	Minimum 12 months follow-up	• No statistically significance differences were found in implant success or survival rates between screw retained and cemented restorations • Prosthesis success rate at the last reported examination (> 72 months) was 93.2% for cemented and 83.4% for screw retained restorations ($P > 0.05$)

RCT, randomized clinical trial; FDP, fixed dental prosthesis; I-SC, implant supported single crown; I-FDP, implant supported fixed dental prosthesis.

Biological and technical complications were significantly increased with cemented compared with screw retained FDPs. The biologic complication 'presence of fistula/suppuration' was the main event weighting for statistically significant higher event rates with cemented reconstructions (49). These results are consistent with several other reports observing that cement remnants represent a significant risk for peri-implant infection and should be handled with great caution (40, 42, 43, 45).

Millen et al. (26) used the same data but analyzed the reconstruction type itself and concluded that there were no statistically significant differences between the failure rates of the different types of reconstructions (Single Crown, FDPs, full-arch FPDs) (Table 1). Evaluating the pooled data, the authors found that screw retained FDPs had significantly higher rates of technical complications than cemented FDPs, but screw retained full-arch FDPs demonstrated a high rate of veneer chipping. Multivariate Poisson regression analysis showed that there were no significant differences between screw retained and cement retained prostheses in terms of failure; however, a higher incidence of technical and biological complications was seen with cement retained prostheses. Considering the risks associated with cemented FDPs and the limited options for interventions after definitive cementation, Millen et al. (26) recommended a preference towards screw retention of implant-supported FDPs.

A recent and comprehensive systematic review on cementation vs. screw retention was presented at the European Association of Osseointegration Consensus Conference in 2012 (33). This review focused on implant and reconstruction survival, and calculated the estimated 5-year and 10-year technical and biological complication rates obtained from studies with a mean follow-up of at least 1 year. The event rates were grouped for either cement retained or screw retained single crowns, FPDs and full-arch FPDs. No statistically significant differences were reported in the survival of screw retained and cement retained FDPs. Biological complication rates (bone loss > 2 mm) were found to be higher for cemented prostheses, whereas screw retained FDPs exhibited more technical complications (Table 1). The authors concluded that screw retained FDPs should be given preference due to their greater retrievability (33).

In another systematic review, performed by Weber & Sukotjo (44), the success rates of screw retained and cement retained implant-supported FDPs after the last reported examination (> 72 months) were 93.2% for cement and 83.4% for screw. There were more complications with screw retention, but this was statistically not significant (Table 1).

It could be discussed that chipping of ceramic is more likely in screw retained dental prostheses with the presence of an access opening for an occlusal/abutment screw. Hence the integrity of the framework and the veneer layers is interrupted, and tension may be produced during tightening of the assembly. Manipulations with a screwdriver can provoke stress peaks laterally in the region of the access opening (49). Chipping of the resin veneer, which has been seen especially in full-arch FDPs, was found frequently in the review by Wittneben et al. (49). Screw retention is advantageous in the case of an event of a technical complication as it can be repaired more easily then retained in comparison with cement retention. It has been hypothesized that the technical complication 'chipping of ceramic' is probably related to factors other than the retention type. Possible explanations include unsupported ceramic veneering, ceramic or a non-anatomic substructure design, weak porcelain, cooling protocols, handling of ceramics in the dental laboratory and thermal expansion/contraction mismatches might be possible explanations (20, 48). The systematic review of Wittneben et al. (49) showed statistically significantly more biological complications with cemented restorations. The presence of excess cement plays a major role in the development of peri-implant disease, as discussed in the esthetics section of this review (12, 22, 45). In the development of a biological complication, host factors and biological interactions with the materials used play an important role. Unsealed reconstructions – in the case of a misfitting prosthesis or dissolved cement – might cause a micro-gap and a small space between the abutment and superstructure which provides an anaerobic niche for the undisturbed growth of a biofilm (19, 31).

Overall it can be concluded that today there is more awareness of the presence of biological and technical complications in connection with implant-supported FDPs. One systematic review compared the survival and complication rates of implant-supported prostheses in studies published in the year 2000 and earlier, with those published after the year 2000 (30). The data analyzed showed higher survival rates and fewer complications in more recent studies. However, technical complications and the incidence of fractures of the veneering material were significantly increased in the newer studies. A possible explanation is that in the newer publications, minor complications are probably reported in more detail (30).

Conclusions and clinical recommendations for screw retention

These conclusions are based on this review and on the consensus review paper published in 2014 (46). Screw retention may be recommended

- in the presence of minimal interarch space (minimum 4 mm)
- for FDPs with a cantilever design
- for long-span FDPs
- to avoid an additional risk factor with the use of cement and a possible cement remnant
- in the esthetic zone, for provisionalization of implants to enable soft tissue conditioning and finalization of the emergence and mucosal profile
- when retrievability is desired

Implants must be placed in a prosthetically ideal position with the future access hole of the planned crown below the planned incisal edge in order to facilitate screw retention.

Conclusions and clinical for cement retention

These conclusions are based on this review and on the consensus review paper published in 2014 (46). Cement retention may be recommended

- for short-span prostheses with margins at or above the mucosa level
- to compensate for improperly inclined implants
- for cases where an easier control of occlusion without an access hole is desired – for example, with narrow-diameter crowns

The cementation procedure should be carried out with great caution, with the FDP margins placed at or above the tissue level.

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References

1. Adell R, Lekholm U, Rockler B, Branemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg* 1981: **10**: 387–416.
2. Agar JR, Cameron SM, Hughbanks JC, Parker MH. Cement removal from restorations luted to titanium abutments with simulated subgingival margins. *J Prosthet Dent* 1997: **78**: 43–47.
3. Aglietta M, Siciliano VI, Zwahlen M, Bragger U, Pjetursson BE, Lang NP, Salvi GE. A systematic review of the survival and complication rates of implant supported fixed dental prostheses with cantilever extensions after an observation period of at least 5 years. *Clin Oral Implants Res* 2009: **20**: 441–451.
4. Branemark PI, Adell R, Breine U, Hansson BO, Lindstrom J, Ohlsson A. Intra-osseous anchorage of dental prostheses. I. Experimental studies. *Scand J Plast Reconstr Surg* 1969: **3**: 81–100.
5. Brennan M, Houston F, O'Sullivan M, O'Connell B. Patient satisfaction and oral health-related quality of life outcomes of implant overdentures and fixed complete dentures. *Int J Oral Maxillofac Implants* 2010: **25**: 791–800.
6. Buser D, Janner SF, Wittneben JG, Bragger U, Ramseier CA, Salvi GE. 10-year survival and success rates of 511 titanium implants with a sandblasted and acid-etched surface: a retrospective study in 303 partially edentulous patients. *Clin Implant Dent Relat Res* 2012: **14**: 839–851.
7. Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. *Int J Oral Maxillofac Implants* 2004: **19**(Suppl): 43–61.
8. Buser D, Schenk RK, Steinemann S, Fiorellini JP, Fox CH, Stich H. Influence of surface characteristics on bone integration of titanium implants. A histomorphometric study in miniature pigs. *J Biomed Mater Res* 1991: **25**: 889–902.
9. Chee W, Jivraj S. Screw versus cemented implant supported restorations. *Br Dent J* 2006: **201**: 501–507.
10. Chee WW, Torbati A, Albouy JP. Retrievable cemented implant restorations. *J Prosthodont* 1998: **7**: 120–125.
11. Chen ST, Buser D. Clinical and esthetic outcomes of implants placed in postextraction sites. *Int J Oral Maxillofac Implants* 2009: **24**(Suppl): 186–217.
12. Derks J, Schaller D, Hakansson J, Wennstrom JL, Tomasi C, Berglundh T. Effectiveness of implant therapy analyzed in a Swedish population: prevalence of peri-implantitis. *J Dent Res* 2016: **95**: 43–49.
13. Doerr J. Simplified technique for retrieving cemented implant restorations. *J Prosthet Dent* 2002: **88**: 352–353.
14. Gapski R, Neugeboren N, Pomeranz AZ, Reissner MW. Endosseous implant failure influenced by crown cementation: a clinical case report. *Int J Oral Maxillofac Implants* 2008: **23**: 943–946.
15. Garber DA, Belser UC. Restoration-driven implant placement with restoration-generated site development. *Compend Contin Educ Dent* 1995: **16**: 796. 798–802, 804.
16. Gittleman NB. Retrieving cemented telescopic prostheses: technical note. *Implant Dent* 1996: **5**: 91–92.
17. Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. *Int J Periodontics Restorative Dent* 2005: **25**: 113–119.
18. Hebel KS, Gajjar RC. Cement-retained versus screw-retained implant restorations: achieving optimal occlusion and esthetics in implant dentistry. *J Prosthet Dent* 1997: **77**: 28–35.

19. Keller W, Bragger U, Mombelli A. Peri-implant microflora of implants with cemented and screw retained suprastructures. *Clin Oral Implants Res* 1998: **9**: 209–217.
20. Kelly JR, Benetti P. Ceramic materials in dentistry: historical evolution and current practice. *Aust Dent J* 2011: **56**(Suppl 1): 84–96.
21. Lewis S, Beumer J 3rd, Hornburg W, Moy P. The 'UCLA' abutment. *Int J Oral Maxillofac Implants* 1988: **3**: 183–189.
22. Linkevicius T, Puisys A, Vindasiute E, Linkeviciene L, Apse P. Does residual cement around implant-supported restorations cause peri-implant disease? A retrospective case analysis. *Clin Oral Implants Res* 2013: **24**: 1179–1184.
23. Linkevicius T, Vindasiute E, Puisys A, Linkeviciene L, Maslova N, Puriene A. The influence of the cementation margin position on the amount of undetected cement. A prospective clinical study. *Clin Oral Implants Res* 2013: **24**: 71–76.
24. Linkevicius T, Vindasiute E, Puisys A, Peciuliene V. The influence of margin location on the amount of undetected cement excess after delivery of cement-retained implant restorations. *Clin Oral Implants Res* 2011: **22**: 1379–1384.
25. Michalakis KX, Hirayama H, Garefis PD. Cement-retained versus screw-retained implant restorations: a critical review. *Int J Oral Maxillofac Implants* 2003: **18**: 719–728.
26. Millen C, Bragger U, Wittneben JG. Influence of prosthesis type and retention mechanism on complications with fixed implant-supported prostheses: a systematic review applying multivariate analyses. *Int J Oral Maxillofac Implants* 2015: **30**: 110–124.
27. Moraguez OD, Belser UC. The use of polytetrafluoroethylene tape for the management of screw access channels in implant-supported prostheses. *J Prosthet Dent* 2010: **103**: 189–191.
28. Okamoto M, Minagi S. Technique for removing a cemented superstructure from an implant abutment. *J Prosthet Dent* 2002: **87**: 241–242.
29. 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**: 865–868.
30. Pjetursson BE, Asgeirsson AG, Zwahlen M, Sailer I. Improvements in implant dentistry over the last decade: comparison of survival and complication rates in older and newer publications. *Int J Oral Maxillofac Implants* 2014: **29** (Suppl): 308–324.
31. Quirynen M, van Steenberghe D. Bacterial colonization of the internal part of two-stage implants. An *in vivo* study. *Clin Oral Implants Res* 1993: **4**: 158–161.
32. Ramer N, Wadhwani C, Kim A, Hershman D. Histologic findings within peri-implant soft tissue in failed implants secondary to excess cement: report of two cases and review of literature. *N Y State Dent J* 2014: **80**: 43–46.
33. Sailer I, Muhlemann S, Zwahlen M, Hammerle CH, Schneider D. 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.
34. Salvi GE, Brägger U. Mechanical and technical risks in implant therapy. *Int J Oral Maxillofac Implants* 2009: **24** (Suppl): 69–85.
35. Schnitman PA, Shulman LB. Recommendations of the consensus development conference on dental implants. *J Am Dent Assoc* 1979: **98**: 373–377.
36. Schroeder A, Pohler O. Sutter F [tissue reaction to an implant of a titanium hollow cylinder with a titanium surface spray layer]. *SSO Schweiz Monatsschr Zahnheilkd* 1976: **86**: 713–727.
37. Schroeder A, van der Zypen E, Stich H, Sutter F. The reactions of bone, connective tissue, and epithelium to endosteal implants with titanium-sprayed surfaces. *J Maxillofac Surg* 1981: **9**: 15–25.
38. Shadid R, Sadaqa N. A comparison between screw- and cement-retained implant prostheses. A literature review. *J Oral Implantol* 2012: **38**: 298–307.
39. Taylor TD, Agar JR. Twenty years of progress in implant prosthodontics. *J Prosthet Dent* 2002: **88**: 89–95.
40. Vigolo P, Givani A, Majzoub Z, Cordioli G. A 4-year prospective study to assess peri-implant hard and soft tissues adjacent to titanium versus gold-alloy abutments in cemented single implant crowns. *J Prosthodont* 2006: **15**: 250–256.
41. Vindasiute E, Puisys A, Maslova N, Linkeviciene L, Peciuliene V, Linkevicius T. Clinical factors influencing removal of the cement excess in implant-supported restorations. *Clin Implant Dent Relat Res* 2015: **17**: 771–778.
42. Wahlstrom M, Sagulin GB, Jansson LE. Clinical follow-up of unilateral, fixed dental prosthesis on maxillary implants. *Clin Oral Implants Res* 2010: **21**: 1294–1300.
43. Wannfors K, Smedberg JI. A prospective clinical evaluation of different single-tooth restoration designs on osseointegrated implants. A 3-year follow-up of branemark implants. *Clin Oral Implants Res* 1999: **10**: 453–458.
44. Weber HP, Sukotjo C. Does the type of implant prosthesis affect outcomes in the partially edentulous patient? *Int J Oral Maxillofac Implants* 2007: **22**(Suppl): 140–172.
45. Wilson TG Jr. The positive relationship between excess cement and peri-implant disease: a prospective clinical endoscopic study. *J Periodontol* 2009: **80**: 1388–1392.
46. Wismeijer D, Bragger U, Evans C, Kapos T, Kelly JR, Millen C, Wittneben JG, Zembic A, Taylor TD. Consensus statements and recommended clinical procedures regarding restorative materials and techniques for implant dentistry. *Int J Oral Maxillofac Implants* 2014: **29**(Suppl): 137–140.
47. Wittneben J-G, Weber HP. *ITI Treatment Guide: Extended Edentulous Spaces in the Esthetic Zone*. Berlin: Quintessenz Verlags-GmbH, 2012.
48. Wittneben JG, Buser D, Salvi GE, Burgin W, Hicklin S, Bragger U. Complication and failure rates with implant-supported fixed dental prostheses and single crowns: a 10-year retrospective study. *Clin Implant Dent Relat Res* 2014a: **16**: 356–364.
49. Wittneben JG, Millen C, Bragger U. Clinical performance of screw- versus cement-retained fixed implant-supported reconstructions – a systematic review. *Int J Oral Maxillofac Implants* 2014b: **29**(Suppl): 84–98.
50. Zarb GA, Schmitt A. Osseointegration and the edentulous predicament. The 10-year-old Toronto study. *Br Dent J* 1991: **170**: 439–444.
51. Zembic A, Kim S, Zwahlen M, Kelly JR. Systematic review of the survival rate and incidence of biologic, technical, and esthetic complications of single implant abutments supporting fixed prostheses. *Int J Oral Maxillofac Implants* 2014: **29**(Suppl): 99–116.