A Comparison Between Screw- and Cement-Retained Implant Prostheses. A Literature Review

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Implant-supported restorations can be secured to implants with screws (screw-retained), or they can be cemented to abutments which are attached to implants with screws (cement-retained). This literature review discusses the advantages and disadvantages of each method of retention from different aspects. These aspects include: ease of fabrication and cost, esthetics, access, occlusion, retention, incidence of loss of retention, retrievability, clinical prosthesis fit, restriction of implant position, effect on peri-implant tissue health, provisionalization, immediate loading, impression procedures, porcelain fracture, and clinical performance. Peer-reviewed literature published in the English language between 1955 and 2010 was reviewed using PubMed and hand searches. Since the choice of using either method of retention is still controversial, this review article offers some clinical situations that prefer one method of retention over the other. The review demonstrated that each method of retention has certain advantages and disadvantages; however, there are some clinical situations in which it is better to select one method of retention rather than the other.

Key Words: screw-retained, cement-retained, passivity, retention, review

INTRODUCTION

With the high rate of implant success for edentulous, partially edentulous, and single tooth restorations, the concept of implant therapy is now a highly predictable treatment modality.

Implant dentistry has seen rapid and remarkable progress in recent years. Several questions have been raised concerning materials as well as designs of both implants and implant abutments to achieve maximum clinical success rates.

One of the debates is the choice between screw- and cement-retained implant prostheses, which has long been discussed, but the best type of implant prosthesis remains controversial among practitioners.

There are few publications that comprehensively compare the 2 types of retention. The aim of this review of the literature was to provide an overview of the advantages and disadvantages of the cement- and screw-retained restorations, and also to suggest some clinical situations that advocate for one method of retention over the other.

The factors that are affected by different methods of retention of the prostheses to the implants are: ease of fabrication and cost, esthetics, access, occlusion, retention, incidence of loss of retention, retrievability, passivity of fit, restriction of implant position, effect on

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peri-implant tissue health, provisionalization, immediate loading, impression procedures, porcelain fracture, and clinical performance.

Ease of Fabrication and Cost

The fabrication of cement-retained restorations is easier than that of screw-retained restorations because conventional laboratory and clinical prosthodontic techniques are used for making cemented restorations.[1–3]

The screw-retained restorations are usually more expensive because of the extra components needed, such as plastic sleeves, laboratory fixation screws, and the fixation screws themselves.[4]

Nevertheless, the increased cost of the screw-retained restoration that allows for predictable retrievability must be compared to the potential costs of damaging the cemented restoration if biologic or technical complication occurs.[5]

Esthetics

When the implant is placed in the ideal position, predictable esthetics can be achieved with either screw- or cement-retained restorations.[6] One of the debates regarding using screw-retained restorations is the screw access channel that may be placed in an esthetic area.[1,2,4,7] When there is difficulty in placing the implant in an ideal position for any anatomic limitation, the preangled or custom abutments can be used so that the screw access channel is relocated away from esthetic area.[6]

The use of an opaquer in combination with a resilient composite offered a significant esthetic improvement of implant restoration.[8]

Access

Cement-retained restorations offer easier access to the posterior of the mouth, especially in patients with limited jaw opening.[1,3]

In addition to the difficulty of access, the use of screw-retained restorations in the posterior part of the mouth may carry a risk of swallowing or aspirating the screw or screwdriver.[3,9]

Occlusion

Ideal and stable occlusal contacts can be established with cement-retained restorations because there are no occlusal screw access holes.[1–3,7] These screw access holes will also interfere with protrusive and lateral excursions and, therefore, anterior guidance may be compromised.[1]

The screw-retained restorations where the screw access hole occupies more than 50% of the intercuspal occlusal table require an occlusal restorative material to cover the screw access channel; these restorative materials are susceptible for wearing under functional forces and so the occlusal contacts will be less preserved than when using cement-retained restorations with intact occlusal surface.[1,10–12]

Moreover, the difficulty in achieving stable occlusal contacts when using screw-retained restorations because of the presence of restoration material will affect the direction of occlusal loads which will be distributed as lateral forces to the implant instead of being axially directed.[3]

Retention

The security of retention is considered one of the most important factors affecting implant prostheses longevity.[2]

There are several factors that affect the retention of cement-retained restorations such as taper of abutment, surface area and height, surface roughness, and type of cement.[13–17]

Taper greatly affects the amount of retention in cement-retained restorations[13] machined abutments have mostly 6° of

taper depending on the concept of ideal tapering proposed by Jorgensen for natural teeth.[14]

Regarding surface area and height, the subgingival placement of the implants provides longer implant abutment walls and usually more surface area than prepared natural teeth.[1,15] The minimum abutment height to use cement-retained restorations with predictable retention was documented to be 5 mm.[15] Therefore, when the interocclusal space is as little as 4 mm, screw-retained restorations may be used,[6] since these restorations can be attached directly to implants without intermediate abutment.[18]

Increased surface roughness will offer increased mechanical retention for cements,[17] and so roughening the implant abutments using diamond burs or grit blasting will provide higher retention.[1] However, because of the ideal 6° taper and long surface provided by implant abutments, there will usually be no need for roughening abutment surface to increase retention.[1]

Cement selection is one of the most important factors controlling the amount of retention attained for cement-retained restorations.[17] The cement used with implant restorations can be either permanent or provisional, and it is the clinician's decision to choose a certain type of cement based on the clinical situation.[1,19–21] The concept of using provisional cementation is considered to achieve restoration retrievability without endangering the implant restoration components when loose restoration or abutment screw loosening occurs.[17]

With regard to screw-retained restorations, retention is obtained by a fastening screw. The loss of retention in screw-retained restorations is demonstrating itself as screw loosening.[22] Factors including insufficient clamping force, screw settling, biomechanical overload, off-axis centric forces (forces that are not directed along the long axis of the implant), implant components and prosthesis misfit, differences in screw material and design, and finally hex height and implant diameter will affect the amount of retention of screw-retained restorations.[1,22–33]

To achieve sufficient clamping force the screws should be torqued 50% to 75% of their yield strength, so it is imperative that all screws be tightened to manufacturers' specifications using a torque control wrench in the initial phase of screw tightening.[1,22]

Screw settling or embedment relaxation will occur shortly after screw tightening due to compressing the microscopically rough areas of the screw threads and opposing flanges during screw tightening[23]; therefore, retorquing the screw 5 minutes after initial torquing and again a few weeks later is recommended.[26]

During function and biomechanical overload, both compressive and tensile forces will cause screw loosening. The compressive forces will cause disengagement of mating threads when applied in amount equal to or greater than the preload, the tensile forces may cause plastic deformation of the screw, thereby decreasing the clamping forces that hold the components together.[23,24]

Off-axis centric forces are detrimental to screw-retained restorations. Therefore, excessive implant angles, cantilever prosthesis, and connecting implant to natural teeth using fixed partial dentures should be evaluated and eliminated whenever possible to prevent screw loosening.[22]

Screw loosening is also affected by implant component and prosthesis misfit. Poor fit between implant and components could increase stress in the screw leading to screw loosening.[25–27] The same is applied to nonpassive prosthesis that will apply additional load to the system leading to bending moments constantly loading the implant components and surrounding bone tissue.[28,29]

To prevent screw loosening, various modifications to the screw and implant were reported.[26,30–33] It was found that gold

screws can be tightened more effectively than titanium ones and therefore will provide better retention.[31]

The screw design will affect screw retention, so it has been shown that screw heads with internal hexagon remain tighter than those with slots.[32] Tapered head screws have been abandoned because the head/shaft load ratio was found to be 4:1 as opposed to flat head screws using a 1:1 head/shaft ratio, and this will lead to strained interfaces when using tapered screws that will increase the susceptibility of screw loosening.[27]

In addition, increasing the screw diameter will increase the preload and therefore the retention of screw-retained restorations. Also, enhancing the implant design by increasing hex height and diameter of implant platform can increase stability and resistance to screw loosening.[26,33]

Incidence of Loss of Retention

The screw loosening is a major problem with screw-retained restorations.[34–37] The incidence of screw loosening was 65% for single tooth implant restorations in one study,[34] whereas the incidence of unretained cemented implant restorations was reported to be less than 5% in other studies.[38,39]

However, the improvements in implant systems, including the advent of internal implant-abutment connections, enhancement of torque drivers, and screw materials and design, led to reduction in the incidence of screw loosening.[4,35,36,40,41]

On the other hand, the screw loosening of screw-retained restorations can be considered as an important advantage since the weakest component within the implant-supported restoration will be the prosthetic screw; this will allow for assessing the implant-supported restoration before more serious complications develop, such as implant fracture at screw level especially in implant systems using internal connections.[42,43] Using screw-retained restorations will enable assessing the preload of implant abutment screws over time, since the preload is not constant with ongoing application of forces associated with occlusion.

Retrievability

The main advantage of screw-retained restorations is the predictable retrievability that can be achieved without damaging the restoration or fixture.[1,4] Therefore, the prosthodontic components can be adjusted, the screws can be refastened, and the fractured components can be repaired[44] with less time and at lower cost than would be the case with cement-retained restorations.[2,45,46]

Several suggestions and techniques have been introduced to facilitate the removal of cement-retained restorations.

One of the techniques described is the incorporation of screw into the cemented restoration to be used later to lift the restoration off the abutment if activated. Compared with conventional screw retention, this technique improves esthetics and occlusion since the access hole can be placed in the most ideal position without regard to implant position.[47] Another method proposed is to prepare a cylindrical guide hole on the lingual surface of the abutment and an access hole in the lingual side of the restoration. Then, by inserting a removing driver into the guide hole through the access hole and turning it to generate a shear force, the cement will disintegrate and, in turn, the restoration can be easily removed.[48]

Other techniques that have been suggested depend mainly on locating the screw access opening of the abutment screw in cement-retained restoration, in turn, to allow access to the abutment screw with least damage in the future. These techniques are achieved by using abutment screw access guide or placement of a well-defined small

ceramic stain on the occlusal surface of restoration where the screw access opening is located.[49]

Combining both screw- and cement-retained restorations in the same prosthesis was introduced by using at least 1 screw retainer into a series of cement retainers within the same prosthesis.[50,51]

Using abutment inserts is a technique developed so that there will be no need for either screw or cement for connecting the restoration to the abutment. In this technique a standard abutment with perforation on the lingual side is screwed to the implant. An insert is cast to fit tightly into the abutment in a lock and key fashion, and the same insert lodges into the screw of the implant to secure it. This insert has a perforation to match the lingual perforation of the abutment. Then, the restoration is made with a lingual hole to match the abutment and insert through a spring-locked pin. An explorer can be used to push the spring to release the crown for removal.[52]

Provisional cement is frequently used as final cement for cement-retained implant-supported restorations to allow for future retrieval.[6]

In spite of all the proposed techniques to improve the retrievability of cement-retained restorations, screw retention becomes more necessary in extensive cases where prosthesis needs more maintenance, so cantilevered prostheses and full arch implant reconstruction are best restored with screw retention.[10,53]

Clinical Prosthesis Fit

The passive fit of implant prostheses has been stressed because of the ankylotic character of implant abutments and because poor fit is correlated with biologic and mechanical complications.[28,31,43,54,55]

Many authors believe that a cement-retained restoration is more likely to achieve passive fit than a screw-retained one.[1,7,10,39,56,57] This increased passivity of cement-retained restorations rests on the assumption that the cement could act as a shock absorber and reduce stress to bone and implant-abutment structure.[1,56–58] Conversely, screw-retained prosthesis without precise fit between crown and abutment may create substantial stress within the prosthesis, the implant, and surrounding bone.[7]

However, the main factors that affect the prosthesis fit depends on accuracy achieved in the fabrication process, including impression technique, master cast accuracy, component tolerance, casting tolerance, and skill of the technician, while the type of retention does not play a role in transferring or compensating for inaccuracies of prosthesis fabrication.[59]

Screw-retained restorations have been found to produce tighter margins than their cemented counterparts.[60] As a consequence with cement-retained restorations there is always a risk of colonization of the space with microflora which may result in cement dissolution and gingival inflammation.[61,62]

Passive fit of screw-retained restoration can be improved by laser welding of the prosthesis framework.[63,64]

To enhance the fit of single cast framework spark erosion is another proposed technique.

Sectioning and soldering the framework has been reported to improve some discrepancies but it may still not create absolute fit.[1,65]

One of the most recent approaches to improve passivity of fit is using the laser scanned computer numeric controlled–milled titanium (computer aided design/computer aided manufacturer).[66]

Restriction of Implant Position

Screw-retained implant-supported restorations require precise placement of the implant to achieve predictable esthetics.[10,47]

However, the use of cement-retained restorations allows for greater freedom in implant placement.[6]

As the manufacturers have not provided angled abutments of less than 17° for screw retention until now, malaligned implants with divergence axis less than 17° have to be restored with cement-retained restorations.[10,67]

In general with good treatment planning and precision surgery using surgical guides, the implant can be placed at its ideal position.[6]

Effect on the Health of Peri-Implant Tissue

Some authors reported gingival inflammation when using cement-retained prosthesis because of difficulty in removing excess cement, especially when the restoration margin is greater than 3 mm subgingivally. This is particularly common in the anterior region when it is recommended to place the implant 3 to 4 mm apical to the cemento-enamel junction or the facial gingival margin of adjacent teeth to develop proper emergence profile.[68]

It has been shown that incomplete removal of cement may result in peri-implant inflammation, soft tissue swelling, soreness, bleeding or exudation on probing, and resorption of peri-implant bone.[10,68–70] The solution for these clinical situations is using either screw-retained restorations or custom abutments for cement restoration with margin following the anterior gingival contours.[68]

One of the techniques proposed for removal of excess cement is using plastic scalers, but even this may result in scratches on the implant surfaces which may encourage plaque accumulation and compromised soft tissue health.[71–73]

Reducing the amount of cement placed in the restoration before cementation can be achieved by placing a luting agent only on the occlusal half of the intaglio of the restoration. In addition, seating the restoration after placing the cement on the fitting surface on the abutment analogue extraorally before the restoration is cemented intraorally can be used to reduce the excess cement.[68]

Creating a lingual vent hole in the implant-supported crowns is another technique to reduce the amount of excess cement being lodged in the sulcus.[74]

The gingival response is found to be better when using screw-retained crowns since no cement is used. However, if prosthetic retaining screws and abutment screws become loose, granulation tissue accumulates between the prosthesis and the abutment and also between implant and abutment leading to fistulae formation, plaque deposition, and screw fracture. Therefore, it is recommended to retighten the screws in full arch fixed prosthesis every 5 years.[32]

Provisionalization

Provisional restorations are frequently used for immediate or early implant loading to achieve better esthetics and to mold soft tissue for proper emergence profile for definitive restorations.[75]

Using screw-retained provisional restoration is preferred over cement-retained restoration because the screw can be used to seat the provisional restoration and to expand peri-implant mucosa.[6,76] Also, screw-retained provisional restoration can be screwed into the master impression to translate additional information to the technician about the contours.[6]

The major disadvantage of cement-retained provisional restoration is the difficulty associated with removing excess cement and managing bleeding at the same time. Moreover, cement residues may cause gingival inflammation.[6]

Immediate Loading

Screw-retained restoration is considered the restoration of choice for immediate loading;

TABLE
Summarization of the situations that prefer screw retention and those that prefer cement retention

Situations That Prefer Screw Retention	Situations That Prefer Cement Retention
Large, full-arch implant reconstructions are preferred to be screw-retained, because complications in these long-span prostheses are more common than those of short-span ones.[10]	Single-unit and short-span implant restorations, assuming that implant table size, implant numbers, and abutment screw torque can be optimized, are preferred to be cement-retained.[10] The only reason for using screw retention in such cases would be if the implant's long axis was too palatal in the anterior region.[10]
Cantilevered prostheses are preferred to be screw-retained, because some maintenance of restorative structures or implants would probably be needed during the lifetime of such prostheses.[10,53]	Cases involving narrow diameter crowns in which the screw access may compromise the crown's integrity are preferred to be cement-retained.[82]
With patients who are at a high risk of developing gingival recession, screw-retained restorations are preferred. This is to allow for their uncomplicated removal and then for the modification of the restorations according to the new situation.[82]	Situations in which the occlusal surface will be compromised with regard to esthetics or occlusal stability due to the presence of a restorative material sealing the screw access are preferred to be cement-retained.[82]
With patients who are expected to lose more teeth in the future, screw-retained restorations are preferred. This is to allow for easy removal of the restorations, thereby modifying the restorations.	In situations of restoring malaligned implants, if the divergence of the implant axis and the retaining screw of the angled abutment which is to receive the restoration is less than 17°, conventional screw retention of the restoration using premachined abutments is not possible.[10,67]
In situations where minimal interocclusal space exists, it may not be possible to achieve adequate retention for cement-retained restorations because these restorations require a vertical component of at least 5 mm to provide retention and resistance form.[15] However, as little as 4 mm of interocclusal space is sufficient to use screw-retained restorations.[6] Additionally, screw-retained restorations can be attached directly to implants without an intermediate abutment, therapy reducing the interocclusal space needed for these restorations.[18]	
In situations in which removal of excess cement is difficult or impossible (eg, if the final restorative margin will be greater than 3 mm subgingivally, the use of screw-retained restoration is indicated).[10,68] An alternative to screw-retained restoration in this situation would be to fabricate a custom abutment for cement retention with a restorative margin following the outline of the gingival contours.[68]	
Cases in which technical or biologic complications are anticipated, screw-retained restorations are preferred to allow for easy removal of the restorations, thereby managing the problems.	

this is because using this restoration eliminates the need for cement and the associated difficulty in removing excess from the peri-implant area that may interfere with healing and implant integration.[71] In addition it has been shown that the interface of machined components is superior to any cement margin that can be developed.[60]

In addition, screw retention provides the most definitive and rigid splinting when multiple implants are used and therefore enhances implant primary stability.[6]

Impression Procedures

Screw-retained provisional restorations can be screwed in the master impression so as to transfer soft tissue contours to master cast. As a result the definitive restorations will be easily seated without soft tissue impingement.[6]

Porcelain Fracture

Porcelain fracture is a common complication observed in implant-supported restorations.[43] This is most commonly seen in screw-retained restorations because the screw access hole disrupts the structure continuity of porcelain leaving some unsupported porcelain at the screw access hole.[1,3,10,11,77,78]

Clinical Performance

The success rate of cement- and screw-retained implant-supported restorations were evaluated in several studies.[11,79–81] Most of these studies showed that screw-retained restorations have more complications during follow-up periods than their cemented counterparts. However, the percentage of these complications was generally small and most of them were controllable.

Some Situations Prefer One Method of Retention over the Other

It was stated that the selection of an implant system is the first step in determining the feasibility of either a cement or screw retention for the prosthesis.[10] The current implant systems that employ a conical interface between the implant and the abutment or other internally designed connection features have reduced the incidence of screw loosening and other problems associated with traditional hex-top systems. Therefore, it is believed that it is easier and simpler to utilize the traditional cementation methods with these current systems for retaining definitive prostheses. However, there are some situations where it is better or more suitable to use one method of retention rather than another. These situations are summarized in the Table.

Conclusions

The authors do not prefer one type of restoration over the other because both types of restorations, screw-retained and cement-retained, have certain advantages and disadvantages. However, based on reviewing the related literature, it has been demonstrated that one type of restoration is more appropriate than the other in some clinical situations.

References

1. Hebel KS, Gajjar RC. Cement-retained versus screw-retained implant restoration: achieving optimal occlusion and esthetics in implant dentistry. *J Prosthet Dent*. 1997;77:28–35.

2. 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.

3. Misch CE. *Dental Implant Prosthetics*. St Louis, Mo: Mosby; 2005:414–420.

4. Avivi-Arber L, Zarb GA. Clinical effectiveness of implant-supported single-tooth replacement: the Toronto study. *Int J Oral Maxillofac Implants*. 1996;11:311–321.

5. Gervais MJ, Wilson PR. A rationale for retrievability of fixed, implant-supported prostheses: a complication-based analysis. *Int J Prosthodont*. 2007;20:13–24.

6. Chee W, Jivraj S. Screw versus cemented implant-supported restorations. *Br Dent J*. 2006;201:501–507.

7. Taylor TD, Agar JR. Twenty years of progress in implant prosthodontics. *J Prosthet Dent*. 2002;88:89–95.

8. Zarb GA. Toward a new direction for the IJP. *Int J Prosthodont*. 2004;17:129–130.

9. Worthington P. Ingested foreign body associated with oral implant treatment: report of a case. *Int J Oral Maxillofac Implants*. 1996;11:679–681.

10. Chee W, Felton DA, Johnson PF, Sullivan DY. Cemented versus screw-retained implant prostheses: which is better? *Int J Oral Maxillofac Implants*. 1999;14: 137–141.

11. Vigolo P, Givani A, Majzoub Z. Cemented versus screw-retained implant-supported single-tooth crowns: a 4-year prospective clinical study. *Int J Oral Maxillofac Implants*. 2004;19:260–265.

12. Ekfeldt A, Øilo G. Occlusal contact wear of prosthodontic materials. An in vivo study. *Acta Odontol Scand*. 1988;46:159–169.

13. Jorgensen KD. The relationship between retention and convergence angle in cemented veneer crowns. *Acta Odontol Scand*. 1955;13:35–40.

14. Gilboe DB, Teteruck WR. Fundamentals of extracoronal tooth preparation. Part 1. Retention and resistance form. *J Prosthet Dent*. 1974;32:651–656.

15. Kaufman EG, Coelho AB, Colin L. Factors influencing the retention of cemented gold castings. *J Prosthet Dent*. 1961;11:487–502.

16. Felton DA, Kanoy E, White J. The effect of surface roughness of crown preparations on retention of cemented castings. *J Prosthet Dent*. 1987;58:292–296.

17. Breeding LC, Dixon DL, Bogacki MT, Tietge JD. Use of luting agents with an implant system. Part 1. *J Prosthet Dent*. 1992;68:737–741.

18. Byrne D, Houston F, Cleary R, Claffey N. The fit of cast and premachined implant abutments. *J Prosthet Dent*. 1998;80:184–192.

19. Mansour A, Ercoli C, Graser G, Tallents R, Moss M. Comparative evaluation of casting retention using the ITI solid abutment with six cements. *Clin Oral Implants Res*. 2002;13:343–348.

20. Simon RL. Single implant-supported molar and premolar crowns: a ten-year retrospective clinical report. *J Prosthet Dent*. 2003;90:517–521.

21. Sadan A, Blatz MB, Salinas TJ, Block MS. Single-implant restorations: a contemporary approach for achieving a predictable outcome. *J Oral Maxillofac Surg*. 2004;62:73–81.

22. McGlumphy EA, Mendel DA, Holloway JA. Implant screw mechanics. *Dent Clin North Am*. 1998;42:71–89.

23. Haack JE, Sakaguchi RL, Sun T, Coffey J. Elongation preload stress in dental implant abutment screws. *Int J Oral Maxillofac Implants*. 1995;10:529–536.

24. McAlarney ME, Stavropoulos DN. Determination of cantilever length-anterior-posterior spread ratio assuming failure criteria to be the compromise of the prosthesis retaining screw-prosthesis joint. *Int J Oral Maxillofac Implants*. 1996;11:331–339.

25. Taylor TD, Agar JR, Vogiatzi T. Implant prosthodontics: current perspective and future directions. *Int J Oral Maxillofac Implants*. 2000;15:66–75.

26. Binon PP. The external hexagonal interface and screw joint stability: a primer on threaded fasteners in implant dentistry. *Quintessence Dent Technol*. 2000;23: 91.

27. Patterson A, Johns RB. Theoretical analysis of the fatigue life of fixture screws on osseointegrated dental implants. *Int J Oral Maxillofac Implants*. 1992;7: 26–33.

28. Duyck J, Naert I. Influence of prosthesis fit and the effect of a luting system on the prosthetic connection preload: an in vitro study. *Int J Prosthodont*. 2002;15:389–396.

29. Smedberg JI, Nilner K, Rangert B, Svensson SA, Glantz SA. On the influence of superstructure connection on implant preload: a methodological and clinical study. *Clin Oral Implants Res*. 1996;7:55–63.

30. Jörnéus L, Jemt T, Carlsson L. Loads and designs of screw joints for single crowns supported by osseointegrated implants. *Int J Oral Maxillofac Implants*. 1992;7:353–359.

31. Andersson B, Per Ödman, Carlsson L, Branemark PI. A new Branemark single tooth abutment: handling and early clinical experiences. *Int J Oral Maxillofac Implants*. 1992;7:105–110.

32. Kallus T, Bessing C. Loose gold screws frequently occur in full-arch prostheses supported by osseointegrated implants after 5 years. *Int J Oral Maxillofac Implants*. 1994;9:169–178.

33. Boggan RS, Strong JT, Misch CE, Bidey MN. Influence of hex geometry and prosthetic table width on static and fatigue strength of dental implants. *J Prosthet Dent*. 1999;82:436–440.

34. Jemt T, Linden B, Lekholm U. Failures and complications in 127 consecutively placed fixed partial prostheses supported by Branemark implants: from prosthetic treatment to first annual check-up. *Int J Oral Maxillofac Implants*. 1992;7:40–44.

35. Jemt T, Laney WR, Harris D, et al. Osseointegrated implants for single tooth replacement: a 1-year report from a multicenter prospective study. *Int J Oral Maxillofac Implants*. 1991;6:29–36.

36. Laney WR, Jemt T, Harris D, et al. Osseointegrated implants for single tooth replacement: progress report from a multicenter prospective study after 3 years. *Int J Oral Maxillofac Implants*. 1994;9:49–54.

37. Carlson B, Carlsson GE. Prosthodontic complications in osseointegrated dental implant treatment. *Int J Oral Maxillofac Implants*. 1994;9:90–94.

38. Singer A, Serfaty V. Cement-retained implant-supported fixed partial dentures: a 6-month to 3-year follow-up. *Int J Oral Maxillofac Implants*. 1996;11:645–649.

39. Mish CE. Screw-retained versus cement-retained implant supported prostheses. *Pract Periodontics Aesthet Dent*. 1995;7:15–18.

40. Ekfeldt A, Carlsson GE, Borjesson G. Clinical evaluation of single-tooth restorations supported by osseointegrated implants: a retrospective study. *Int J Oral Maxillofac Implants*. 1994;9:179–183.

41. Goodacre CJ, Kan JYK, Rungcharassaeng K. Clinical complications of osseointegrated implants. *J Prosthet Dent*. 1999;81:537–552.

42. Taylor TD. Prosthodontic complications associated with implant therapy. *Oral Maxillofac Surg Clin North Am*. 1991;4:979–991.

43. Zarb GA, Smith A. The longitudinal clinical effectiveness of osseointegrated dental implants: the Toronto study. Part III: problems and complications encountered. *J Prosthet Dent*. 1990;64:185–194.

44. Chiche GJ, Pinault A. Considerations for fabrication of implant-supported posterior restorations. *Int J Prosthodont*. 1991;4:37–44.

45. Uludag B, Celik G. Fabrication of a cement- and screw-retained multiunit implant restoration. *J Oral Implantol*. 2006;32:248–250.

46. Guichet DL, Caputo AA, Choi H, Sorensen JA. Passivity of fit and marginal opening in screw- or cement-retained implant fixed partial denture designs. *Int J Oral Maxillofac Implants*. 2000;15:239–246.

47. Chee W, Jivraj S. Designing abutments for cement-retained implant-supported restorations. *Br Dent J*. 2006;201:559–563.

48. Okamoto M, Minagi S. Technique for removing a cemented superstructure from an implant abutment. *J Prosthet Dent*. 2002;87:241–242.

49. Schwedhelm ER, Raigrodski AJ. A technique for locating implant abutment screws of posterior cement-retained metal-ceramic restorations with ceramic occlusal surfaces. *J Prosthet Dent*. 2006;95:165–167.

50. Preiskel HW, Tsolka P. Cement- and screw-retained implant-supported prostheses: up to 10 years of follow-up of a new design. *Int J Oral Maxillofac Implants*. 2004;19:87–91.

51. Rajan M, Gunaseelan R. Fabrication of cement- and screw-retained implant prosthesis. *J Prosthet Dent*. 2004;92:578–580.

52. Ghalili KM. A new approach to restoring single-tooth implants: report of a case. *Int J Oral Maxillofac Implants*. 1994;9:85–89

53. Taylor TD, Belser U, Meriscske-Stern R. Prosthodontic considerations. *Clin Oral Implants Res*. 2000;11:101–107.

54. Carr AB. Comparison of impression techniques for a five-implant mandibular model. *Int J Oral Maxillofac Implants*. 1991;6:448–455.

55. Jemt T. In vivo measurements of precision of fit involving implant-supported prostheses in the edentulous jaw. *Int J Oral Maxillofac Implants*. 1996;11:151–158.

56. Guichet DL. Load transfer in screw- and cement-retained implant fixed partial denture designs [abstract]. *J Prosthet Dent*. 1994;72:361.

57. Kim WD, Jacobson Z, Nathanson D. In vitro stress analysis of dental implants supporting screw-retained and cement retained prostheses. *Implant Dent*. 1999;8:141–151.

58. Pietrabissa R, Gionso L, Quaglini V, Di Martino E, Simion M. An in vitro study on compensation of mismatch of screw versus cement-retained implant supported fixed prostheses. *Clin Oral Implants Res*. 2000;11:448–457.

59. Heckmann SM, Karl M, Wichmann MG. Winter W, Graef F, Taylor TD. Cement fixation and screw retention: parameters of passive fit. An in vitro study of three-unit implant-supported fixed partial dentures. *Clin Oral Implants Res*. 2004;15:466–473.

60. Keith SE, Miller BH, Woody RD, Higginbottom FL. Marginal discrepancy of screw-retained and cemented metal-ceramic crowns on implant abutments. *Int J Oral Maxillofac Implants.* 1999;14:369–378.

61. Coleman AJ. Macromolecular leakage beneath full cast crowns. Part I: the diffusion of lipopolysaccharide and dextran. *J Prosthet Dent*. 1995;74:187–197.

62. Rosenstiel SF, Land MF, Crispin BJ. Dental luting agents: a review of the current literature. *J Prosthet Dent*. 1998;80:280–301.

63. Iglesia MA, Moreno J. A method aimed at achieving passive fit in implant prostheses: case report. *Int J Prosthodont*. 2001;14:570–574.

64. Helldén L, Ericsson G, Elliot A, et al. A prospective 5-year multicenter study of the Cresco implantology concept. *Int J Prosthodont*. 2003;16:554–562.

65. Eisenmann E, Mokabberi A, Walter MH, Freesmeyer WB. Improving the fit of implant-supported superstructures using the spark erosion technique. *Int J Oral Maxillofac Implants*. 2004;19:810–818.

66. Jemt T, Back T, Petersson A. Precision of CNC-milled titanium frameworks for implant treatment in edentulous jaw. *Int J Prosthodont*. 1999;12:209–215.

67. Chee WW, Torbati A, Albouy JP. Retrievable cemented implant restorations. *J Prosthodont*. 1998;7: 120–125.

68. Dumbrigue HB, Abanomi AA, Cheng LL. Techniques to minimize excess luting agent in cement-retained implant restorations. *J Prosthet Dent*. 2002;87: 112–114.

69. 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.

70. Parel SM, Sullivan DY. *Esthetics and Osseointegration*. Dallas, Tex: OSI Publishers; 1989:19–23.

71. 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.

72. Quirynen M, van der Mei HC, Bollen CM, et al. An in vivo study on the influence of the surface roughness of implants on the microbiology of supra and subgingival plaque. *J Dent Res*. 1993;72:1304–1309.

73. Dmytryk JJ, Fox SC, Moriarty JD. The effects of scaling titanium implant surfaces with metal and plastic instruments on cell attachment. *J Periodontol*. 1990;61: 491–496.

74. Schwedhelm ER, Lepe X, Aw TC. A crown venting technique for the cementation of implant-supported crowns. *J Prosthet Dent*. 2003;89:89–90.

75. Schneider RL. Fabricating custom provisional restorations for the ITI solid abutment system. *J Prosthet Dent*. 2002;88:105–107.

76. Albrektsson T, Jansson T, Lekholm U. Osseointegrated dental implants. *Dent Clin North Am*. 1986;30: 151–174.

77. Torrado E, Ercoli C, Al Mardini M, Graser GN, Tallents RH, Cordaro L. A comparison of the porcelain fracture resistance of screw-retained and cement-retained implant-supported metal–ceramic crowns. *J Prosthet Dent*. 2004;91:532–537.

78. Zarone F, Sorrentino R, Traini T, Di Iorio D, Caputi S. Fracture resistance of implant-supported screw- versus cement-retained porcelain fused to metal single crowns: SEM fractographic analysis. *Dent Mater*. 2007;23:296–301.

79. Parein AM, Eckert SE, Wollan PC, Keller EE. Implant reconstruction in the posterior mandible: a long-term retrospective study. *J Prosthet Dent*. 1997;78: 34–42.

80. Levine RA, Clem D, Beagle J, et al. Multicenter retrospective analysis of the solid-screw ITI implant for posterior single-tooth replacements. *Int J Oral Maxillofac Implants*. 2002;17:550–556.

81. De Boever AL, Keersmaekers K, Vanmaele G, Kerschbaum T, Theuniers G, De Boever JA. Prosthetic complications in fixed endosseous implant-borne reconstructions after an observation period of at least 40 months. *J Oral Rehabil*. 2006;33:833–839.

82. Stanford CM. Application of oral implants to the general dental practice. *J Am Dent Assoc*. 2005;136: 1092–1100.