Cement-retained versus screw-retained implant restorations: Achieving optimal occlusion and esthetics in implant dentistry

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Statement of problem. Optimal occlusion and esthetics are goals in prosthetic treatment. Implant dentistry is no exception.
Purpose of article. The purpose of this article is to discuss how the choice to use screw-retained or cement-retained implants dramatically influences the occlusion and esthetics. (J Prosthet Dent 1997;77:28-35.)

CLINICAL IMPLICATIONS

Screw retention represents an attachment mechanism that sacrifices occlusion and esthetics for retrievability. Cement retention when appropriately handled is retrievable but does not compromise occlusion and esthetics. An analysis of occlusal table width and screw hole size reveals that screw holes can occupy 50% or more of the width of the occlusal table. Because the screw hole is directly over the implant, vertical loading is difficult and may compromise biomechanics.

Implants placed during the development era had high failure rates and as a consequence, easy and frequent removal of the prostheses was of paramount importance.[1-3] Screw retention in implant-supported prostheses was developed in response to the need for retrievability even though occlusion and esthetics were sacrificed. As knowledge increased and techniques advanced, implant survival rates moved rapidly from the 50% to the 90% range.[1-5] With this dramatic increase in survival rates, the issue of retrievability has not been as clinically significant. However, the use of screw retention, with all of its disadvantages, still remains the retention mechanism of choice for many practitioners as evidenced by the product lines of implant manufacturers.

Many practitioners do not consider cement retention an option in implant-supported restorations because they believe that cemented restorations are not retrievable. Cement, when used appropriately, can retain implant-supported prostheses and provide retrievability.[6] In addition, cement-retained prostheses have superior occlusion, esthetics, passivity, and loading characteristics when compared with screw-retained prostheses.[7] Cement retention has been used in fixed prosthodontics for almost 100 years, and a significant and well-documented history has developed out of its use. This extensive knowledge base should not be discarded without careful consideration of all of the factors.

Forces generated by chewing, swallowing, bruxing, and clenching must be controlled within certain mechanical and physiologic limits if implants and the bone-implant interface are to survive.[8-11] The choice of cement-retained or screw-retained implants has a major impact on the final occlusal design and thereby directly affects the force transmitted to the components and the bone-implant interface. The attachment mechanisms of cement retention and screw retention are dramatically different.

The purpose of this article is to discuss how the choice to use screw-retained or cement-retained implants dramatically influences occlusion and esthetics. It is essential that every practitioner understand these differences when making the choice of the attachment mechanism for implant-supported prostheses.

CEMENT RETENTION

It is well-documented in the dental literature that several factors influence the amount of retention in cement-retained restorations, whether they exist on natural teeth or implant abutments.[12,13] These factors are (1) taper or parallelism, (2) surface area and height, (3) surface finish or roughness, and (4) type of cement.

Taper greatly influences the amount of retention that can be generated in a cement-retained prosthesis.

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Jorgensen[12] established that a 6-degree taper is ideal in crown preparations. He also determined the relative amount of retention for other tapers on prepared teeth and established an inverse relationship between taper and retention. His data show that a 15-degree taper provides approximately one third of the retention of the ideal 6-degree taper, and a 25-degree taper provides approximately 25% or one quarter of the retention generated by the ideal taper (Fig. 1). For conventional fixed prosthodontics, the literature suggests that most practitioners prepare natural teeth with between 15 and 25 degrees of taper. As a result, when cemented to natural teeth, crowns have one third to one fourth the retention when compared with results of the ideal taper of 6 degrees.[14] Most manufacturers machine their abutments to a standard that approximates a 6-degree taper. The conclusion drawn is that machined abutments in implant dentistry (6 degrees of taper) provide ideal retention that is three to four times the retention achieved on natural tooth preparations.

The combination of the two factors of surface area and height are closely linked. It has been demonstrated that an increase in surface area and height increases retention and resistance form.[15] Anatomically, maxillary anterior teeth commonly exhibit short lingual walls on the clinical crown. Thus, crown preparations of maxillary anterior teeth have very short palatal walls. Often these walls are 0.5 to 1 mm in height, which provides a minimal amount of retention and resistance form. Machined abutments placed on implants to replace maxillary incisors or canines provide a dramatically different situation when height and surface area are considered. The margins of machined abutments are routinely 2 or 3 mm subgingival and as a result, walls on the lingual, mesial, and distal surfaces are much longer than the corresponding walls of natural teeth prepared for cemented restorations. To continue this analogy for all teeth, it can be concluded that implant abutments, because of subgingival placement of the implants, offer longer walls and usually more surface area than naturally prepared teeth. The exception to this analogy is molar implants, where the walls may be longer on the implant abutment, but the overall surface area of the natural prepared molar may be greater. The conclusion drawn is that machined implant abutments provide a greater amount of retention than can routinely be created on natural dentition when height and surface area are compared.

The third factor of retention is surface finish. It is recommended to prepare natural teeth with rough axial walls.[16] The rough axial walls provide increased mechanical retention for cements and they do not interfere with seating when a die spacer is used. Implant abutments can be roughened if more retention for a cemented prosthesis is required. This can be done with diamond burs or with grit blasting. However, the dramatically increased

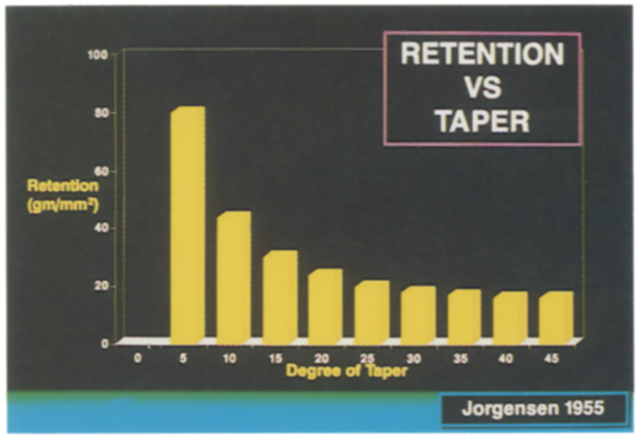

Fig. 1. Jorgensen's data shows inverse relationship between retention and taper.

retention because of the 6-degree ideal taper and the long surfaces usually negates the need for more retention. The conclusion drawn from the comparison of natural dentition and machined posts is that machined posts provide superior retention.

The fourth factor in retention is the type of cement. A wide variety of cements exist with varying degrees of strength. There are two main cements available for use in restorative dentistry, provisional and definitive cements. Provisional cements were developed for short-term use (provisional restorations) and are weak in nature. An example of a provisional cement is Temp-Bond cement (Kerr Mfg. Co., Romulus, Mich.). Definitive cements were developed to provide strong and lasting cementation for restorations.[17] Several examples include zinc phosphate, glass ionomer, resin, and hybrid cements. In conventional prosthodontics strong cements are used for definitive cementation to overcome the lack of retention on preparations and to provide a marginal seal. Cement failure on a natural tooth may result in a crown coming off or a fixed partial denture abutment becoming loose. Cement washout with recurrent decay is a major complication that can lead to tooth loss. Restorations cemented to implant-supported abutments may suffer from similar problems; however, the most significant difference is that metal abutments do not decay and as such are not at risk from this complication, which is prevalent on natural teeth. Definitive cements are not recommended for implant retention because they are too strong for retrievability.[18] The ideal taper of the implant abutment and the longer walls dictate the use of a provisional cement for long-term retention. This allows the operator to control the overall retention of restorations by using a weaker cement to offset the superior retentive features of the implant abutment. Either Temp-Bond cement or a mixture of Temp-Bond cement and petroleum jelly (reduced strength) can be used to cement implant-supported

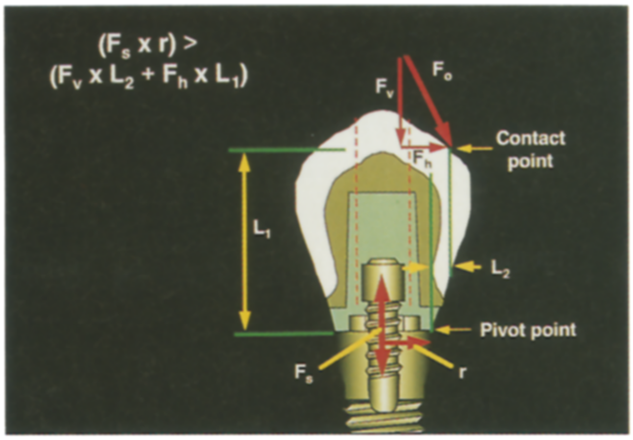

Fig. 2. Mechanics of screw retention shows forces and moment arms.

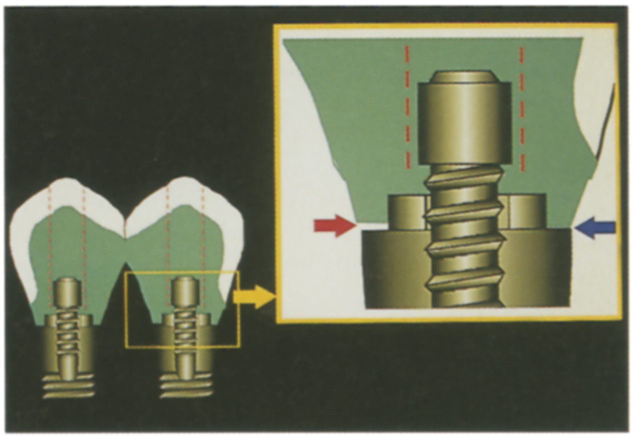

Fig. 3. Screw-retained multiunit casting shows gap at implant-casting interface.

prostheses. Implant-supported prostheses cemented with provisional cements are retrievable and it is the cement chosen that is the controlling factor in the retention attained.[6] This is an important concept. The only argument for screw-retained prostheses is that they are retrievable. The persuasive arguments for cement-retained implant prostheses is that they are retrievable when handled properly and they don't have the significant negative factors associated with screw-retained prostheses. With the proper selection of cements, either individual units or fixed partial dentures can be removed with a tofflemire band, a reverse action bridge remover, or with GC pliers, rubber tips, and carborundum dust. It has been the author's clinical experience that (1) Temp-Bond cement mixed with petroleum jelly provides adequate retention for fixed partial dentures or multiple splinted units supported by implants, and (2) Temp-Bond cement provides adequate retention for single units supported by implants. In instances where the cements fail to provide adequate retention, the principle of progressive cementation can be used, whereby stronger cements are progressively used until adequate retention is achieved. Further research is required to document cement retrievability and develop cements specifically designed for implant-supported prostheses.

SCREW RETENTION

Screw retention of implant-supported prostheses was validated by studies of the Brånemark system.[1,4,5] Screws may be used to attach abutments to implants and prostheses to abutments. It is important that all screws should be torqued to the manufacturer's specifications. Screws designed for different purposes have different mechanical properties because of their size, design, and metallurgic composition. Screws should be tightened to 50% to 75% of their yield strength to provide optimum clamping force.[19] The torque that is applied to the screw is converted into tensile force in the screw (preload), and while under tension the screw holds the two components together (the prosthesis to the abutment or the abutment to the implant).[20] Fulcrums or pivot points are created at the edge where the abutment or casting meets the head of the implant (Fig. 2). In a situation where there is an accurate fit between the head of the implant and the abutment, a continuum of pivot points is created around the circumference (Fig. 2). In this stable situation, vertical occlusal forces that occur over the prosthetic head of the implant will produce vertical loading and will not stress the screw or cause screw loosening. This does not apply when inaccurate castings are screwed into implants and gaps are created (Fig. 3). Vertical loading over the implant head can compress the casting and cause screw loosening. In any situation where a load is applied outside the pivot point (offset loading) that is of sufficient magnitude to overcome the clamping force of the screw, the screw can be stretched, broken, or loosened because of rocking. This upsetting force (F_o), can be resolved into its component vertical and horizontal forces. To maintain equilibrium, the resisting moment of the screw ($F_s \times r$) must be greater than or equal to the sum of the moments created by the offset loading ($F_v \times L_2$) and ($F_h \times L_1$) (Fig. 2).[21] Figure 4 illustrates individual machined abutments that fit properly to provide a stable interface between the head of the implant and abutment. The blue arrows indicate an accurate fit around the prosthetic head of the implant. As a result, pivot points exist ideally all around the circumference. When two or more implants have abutments individually torqued in place with a cemented superstructure, an attachment mechanism exists that provides an accurate fit of the abutment and a passive fit of the superstructure using cement as a grout (Fig 4).[21] In contrast, Figure 3 demonstrates the situation where a casting is screw-retained on two or more abutments. The literature is extensive

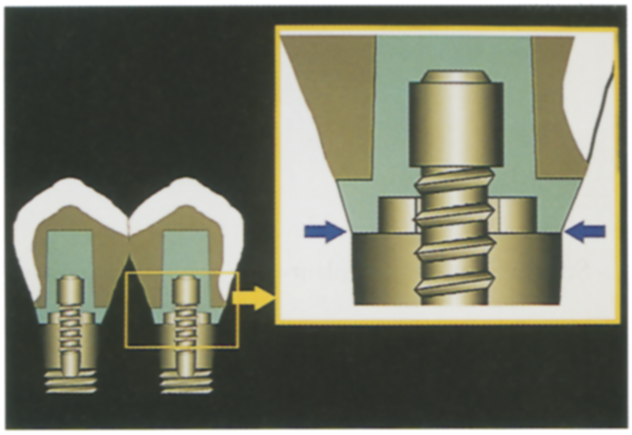

Fig. 4. Cement-retained multiunit casting showing precise fit of individually torqued abutments. Casting fits on abutments passively because of cement grout.

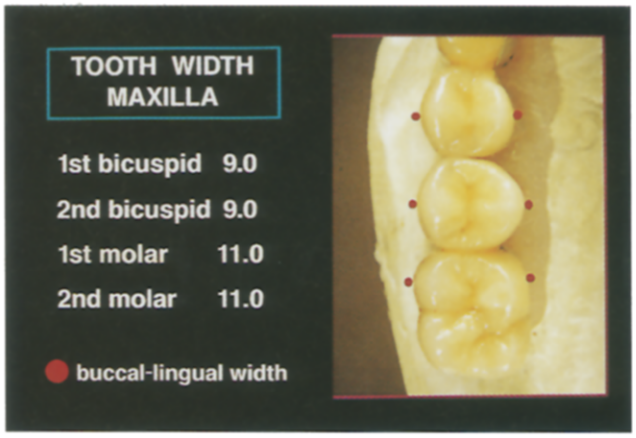

Fig. 5. Maxillary implant-supported prosthesis fabricated for cement indicates average buccolingual widths of teeth (*computer altered*).

in evaluating casting fit to multiple abutments. The evidence is overwhelming and conclusive. With current technology, passive fit of the castings is not an achievable goal that is predictably met in the clinical setting.[22,23] Indeed, truly passive castings remain elusive and nonpassive castings are routinely torqued into position placing inappropriate stress on the bone-implant interface and the prosthetic components. Jemt et al.[23] stated, "It will probably not be possible to connect a multiple implant prosthesis with a completely passive fit in the clinical situation." These misfits leave microgaps and as a result, a precise interface between the casting and the implant is not achieved. Figure 3 shows a two-unit casting screw–retained restoration and the implant casting interface with a misfit. The blue arrow represents the pivot point and the red arrow represents the gap at the interface. Vertical loading over the implant head where these gaps exist allow for compression of the casting and rocking of the framework. This unstable situation is even more significant in offset loading. It is not difficult to conclude that prostheses cemented over accurately fitting machined abutments establish a more stable and passive environment than screw-retained castings with microgaps and unfavorable loading characteristics.[21] There are many clinical studies that indicate screw loosening is a major problem with screw-retained restorations.[7,22,24-27]

CEMENT VERSUS SCREW-RETAINED IMPLANT PROSTHESES: ADVANTAGES AND DISADVANTAGES

Misch[7] outlined a series of advantages for cement-retained implant prostheses compared with screw-retained implant prostheses. If the issue of retrievability is set aside, it is difficult to justify the use of screws to retain prostheses, with the exception of limited abutment height. In areas of limited interridge space, a screw is more effective than cement, because the abutment lacks the important factors of height and surface area as described earlier. Cemented prostheses have many substantial advantages. They provide a passive stable environment because they are cemented on well-adapted machined abutments with discrepancies in fit of the castings to the abutments being negated by the grouting action of the cement. Nonpassive frameworks are seated and adjusted by use of routine chair-side clinical procedures and indicating materials. Sectioning and soldering is not a routine procedure as it is for screw-retained castings. The lack of screw holes in cemented prostheses provides a design that enhances the physical strength of porcelain and acrylic resin, resulting in less fracture. The occlusal surface is devoid of screw holes and, as such, occlusion can be developed that responds to the need for axial loading. Cement-retained implant prostheses provide easier access to the posterior of the mouth, reduced costs, reduced complexity of components, reduced complexity of laboratory procedures, and reduced chair-side time. In addition, cement-retained prostheses have superior esthetics, which is important from the patient's perspective.

OCCLUSAL CONCEPTS

The selection of screw retention or cement retention as an attachment mechanism impacts significantly on the occlusion. Implants ideally placed under the central fossa or stamp cusps of posterior teeth represent the best opportunity to generate axial loading.[7,8] Clinical experience suggests that this goal is often not attained and thus offset loading occurs. Screws or screw holes in the occlusal surfaces of teeth provide poor esthetics and disrupt the occlusal surfaces. Figure 5 illustrates a porcelain fused to metal prosthesis at the laboratory phase that is supported by implants and designed for cementation. The red dots mark the overall widths

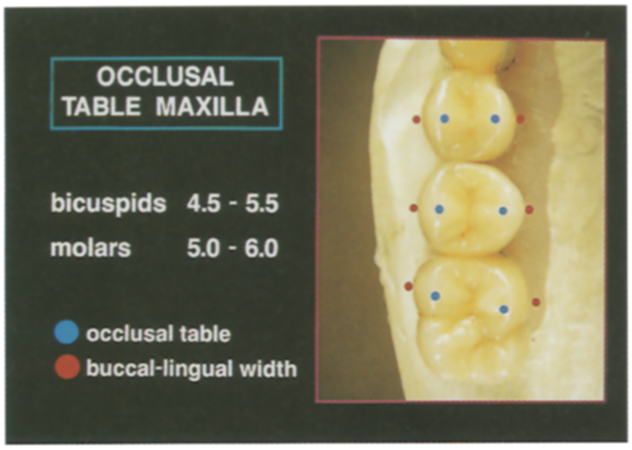

Fig. 6. Maxillary implant-supported prosthesis fabricated for cement indicates average occlusal table widths (*computer altered*).

Fig. 8. Maxillary full arch reconstruction on nine implants designed for cement retention with potential occlusal contacts. Fossa contacts are marked in red dots, stamp cusp contacts marked in blue dots (*computer altered*).

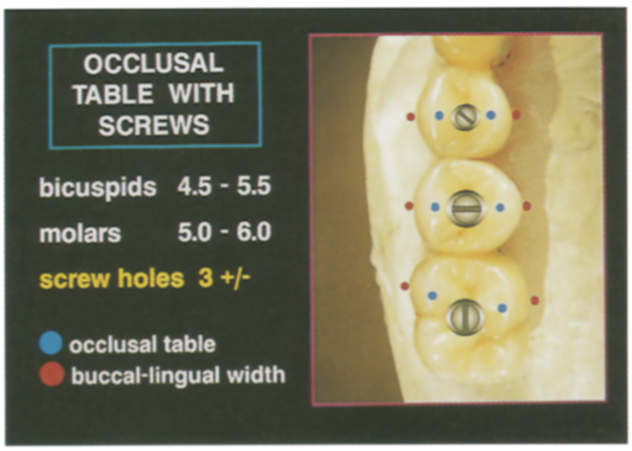

Fig. 7. Computer generated screws placed on Figure 6 demonstrate impact of screws on occlusal table (*computer altered*).

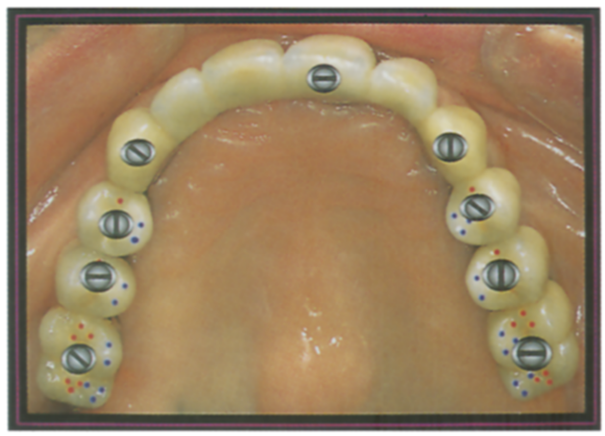

Fig. 9. Computer generated screws placed on Figure 8 indicate that presence of screws disrupts ability to generate optimum occlusal contacts (*computer altered*).

of the teeth, with the average widths of maxillary posterior teeth for the first and second bicuspids 9.0 mm and for the first and second molars 11.0 mm.[28,29] The occlusal surface provides for both the occlusal table and the sluiceways; however most of the occlusal contacts occur within the confines of the occlusal table. The width of the occlusal table varies from tooth to tooth, usually occurring in the range of 4.5 to 5.5 mm for premolars and 5.0 to 6.0 mm for molars (Fig. 6). Screws are 3 mm in diameter and thus screw holes are ±3 mm, dependent on the components used and the skill of the laboratory technician. This represents at least 50% of the occlusal table for molars and more than 50% of the occlusal table for premolars (Fig. 7). The area where the screw hole exists may be a critical area when one attempts to generate an optimum occlusion. A full arch reconstruction provides a more complete example of the impact of screw holes on occlusion. Figures 8 and 9 represent a maxillary full arch restoration supported by nine implants with contact points and screws generated by computer for demonstration purposes. Figure 8 is a restoration that is cement-retained with potential central fossa contacts marked with red dots and stamp cusp contacts marked with blue dots. Figure 9 is the same restoration, similarly marked for occlusion, with screws added in the location of the implants. This allows a comparison of the potential for occlusal contacts and axial loading, and it can be seen that screw holes have used up a large percentage of the occlusal table as well as interfering with the contacts that axially load the implants. In addition, the presence of screw holes is highly unesthetic. It can be concluded that the cement-retained implant restoration is superior in both esthetics and occlusion. This effect carries over to protrusive and lateral protrusive movements in terms of ability to generate occlusion as illustrated in Figures

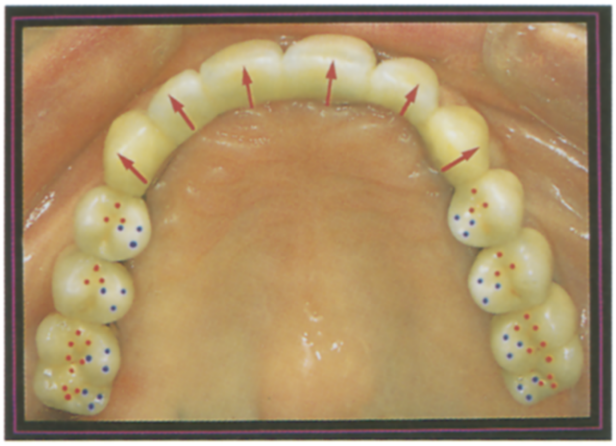

Fig. 10. As in Figure 8, occlusal contacts marked in ideal locations on full arch reconstruction designed for cementation. Protrusive and lateral protrusive guidance are indicated with red arrows (*computer altered*).

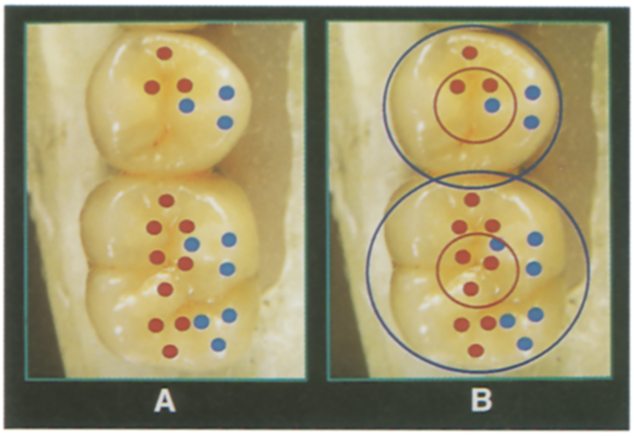

Fig. 12. A, Maxillary prosthesis designed for cementation. **B,** Target is occlusal surface indicated by blue circle. Bull's-eye is area over head of implant indicated by red circle (*computer altered*).

Fig. 11. Computer generated screws placed on Figure 10 indicate that presence of screws disrupts protrusive and lateral protrusive contacts and interferes with ability to generate anterior guidance (*computer altered*).

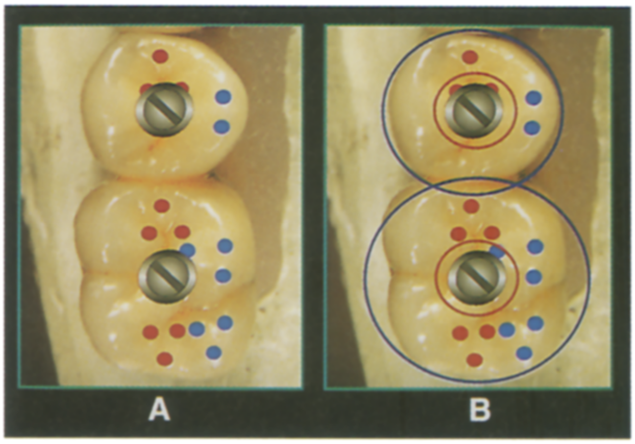

Fig. 13. A and **B,** Computer generated screws placed on Figure 12 to demonstrate concept of doughnut; 1.1 mm of occlusal table remains in bull's-eye after screw hole is placed (*computer altered*).

10 and 11. With the cement-retained implant restoration, all of the anatomic surfaces of all of the teeth are present to develop protrusive and lateral protrusive relationships. Screw-retained implant prostheses may lack the proper anatomy on the cuspids and central incisors for the smooth transition into protrusive and lateral protrusive movements; thus, anterior guidance may be compromised. Generating optimum occlusion is important to all clinicians regardless of their individual philosophy, and when the choice is made to use screw-retained prostheses, occlusion is compromised.

AXIAL LOADING

The ability of the bone-implant interface to survive under loading is a result of many factors. Biomechanics, biomaterials, interfacial loading, and physiologic response are all relevant issues for implant and bone health. In 1988, Brunski[30] clearly defined the enormity of the problem. Many factors interact in a complex manner to produce a load at the bone-implant interface. Offset loading is one factor that can be controlled with prosthesis design. Although the literature is inconclusive in determining the negative consequences of offset loading on the bone-implant interface, biomechanical principles show that increasing offset loading increases the stress at the bony interface.[30-35] The limit at which the load transfer goes beyond the body's ability to positively respond has not been determined and that limit is unique to the individual environment of the individual implant in an individual patient. The bone-implant interface appears able to survive with some degree of offset loading; however, there appears to be an increase in the incidence of prosthetic complications such as screw loosening and breakage.[22,36] As such, prudent control of offset loading is suggested through prosthetic design. The ability to generate vertical or axial loading may be compromised when the choice is made to use screw-retained implant restorations. Axial loading is preferred for implants and the bone-implant interface, and offset loading may be harmful.[7,8,30,32] It is desirable to generate vertical loading over the prosthetic head of the implant. Herein lies the concept of the target, the bull's-eye, and the doughnut. A maxillary molar and a premolar are shown in Figure 12. Figure 12, *A* shows all of the possible contacts for a cement-retained prosthesis and *B* shows the concept of the target and the bull's-eye. The entire occlusal surface of the tooth represents the target (outlined by the blue circles in Figure 12) and this area will be loaded during mastication, swallowing, clenching, and bruxing. The red circles in Figure 12, *B* are the bull's-eyes and they represent the area over the prosthetic head of the implants where vertical loading occurs. The bull's-eye produces ideal loading, and any contacts or forces outside this area represent offset loading. Cement-retained implant prostheses provide access to the bull's-eye and thus have the ability to vertically load the prosthetic head of the implant. Figure 13, *A* and *B* demonstrate a screw-retained prosthesis with potential contacts and the target areas outlined with the blue circles and the bull's-eyes outlined with the red circles. The use of screws for retention reduces the area in the bull's-eye for vertical loading. The prosthetic head of a standard 3.8 mm implant is 4.1 mm. The size of a standard screw hole is 3 mm. This leaves a ring or doughnut of 1.1 mm around the screw hole for axial loading.

CONCLUSION

Occlusion and esthetics should not be arbitrarily discarded through the use of screws to achieve retrievability. With dramatically increased survival rates for dental implants, the once centrally important issue of retrievability takes on less significance. The proper handling of cement-retained implant prostheses provides for retrievability without compromising the occlusion, esthetics, and stress distribution to the prosthetic components and bone-implant interface. The impact of offset loading on the bone–implant interface is not well understood and further research is required in this area. Cements providing different levels of retention, designed specifically for implant dentistry, are another area for research and development.

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Noteworthy Abstracts of the Current Literature

Effect of surface finish on the flexural strength of feldspathic and aluminous dental ceramics.
Giordano R, Cima M, Pober R. *Int J Prosthodont 1995;8:311-9.*

Purpose. The purpose of this study was to examine the effects of grinding and polishing on three types of dental ceramics.
Material and Methods. A conventional feldspathic ceramic material (VM6) (Vita VMK 68, Vita Zahnfabrik, Bad Säckingen, Germany), an aluminous ceramic material (VN3, Vitadur N 338, Vita Zahnfabrik), and a ceramic material (VBM, Vitabloc MKI, Vita Zahnfabrik), used in the CEREC system, were obtained. A total of 105 bars, 3 mm × 3 mm × 30 mm, were made from VM6 ceramic material. These blocks were randomly divided into seven groups ($n = 15$): group A, as fired; group B, self-glazed; group C, overglazed; group D, ground; group E, polished; group F, ground-annealed; and group G, polished-annealed. Forty-five bars of the same dimensions were made from VN3, and these specimens were randomly divided into three groups ($n = 15$): group A, as fired; group B, ground; and group C, polished. Forty-five bars of the same dimensions were also cut from blocks of unfired VBM; these bars were then fired under vacuum and randomly assigned to three groups ($n = 15$) with the same treatments as the VN3 specimen groups. Grinding the specimens referred to subjecting the bar to a diamond wheel for 15 seconds under 15 pounds of force at 350 revolutions/min. Polishing the specimens referred to using a series of wheels coated with various diamond pastes for 20 seconds under 15 pounds of force at 350 revolutions/min. The specimens were then subjected to 4-point bend testing at a cross-head speed of 0.25 cm/min. The greatest tensile force was applied to the treated surface of each specimen. Next, flexural strengths of the specimens were calculated, and analysis of variance and Tukey's HSD tests (a 0.05) were used for data analysis.
Results. Analysis of variance revealed a significant difference among all the material groups. The flexural strength values progressively increased from the as-fired to the polished groups within each material. The self-glazed VM6 group (group B) did not exhibit significant strengthening; however, the overglazed group (group C) demonstrated a significant increase in flexural strength. The annealed groups were not found to be significantly different from each other; however, these groups were significantly stronger than the as-fired, polished, and ground groups. The strength of the annealed groups was similar to that of the overglazed group. The flexural strength values of each of the VN3 groups were significantly different. Finally, the strength of the polished VBM group was significantly higher than that of the as-fired and ground groups.
Conclusions. Polishing the tested materials significantly increased their flexural strengths. Application of an overglaze to the feldspathic porcelain increased the flexural strength; however, this increased strength was significantly less than that generated after polishing. Polishing the Vitabloc MKI ceramic also resulted in a significantly increased flexural strength. *16 Figures.—DL Dixon*