REVIEW ARTICLE

Implant Prosthodontics: Current Perspective and Future Directions

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In the 35 years since the concept of osseointegration was first applied to human patients, there have been many advances in the understanding and application of implant dentistry as a method for the replacement of missing teeth. Osseointegration as first defined by Brånemark is a scientific milestone that delineates a certain sense of separation of the old from the new in implant dentistry. Osseointegration was a watershed event that has forever changed the way dentists view their options when confronted with a patient requiring tooth replacement. While dental implant therapy was an option for tooth replacement for many years prior to the publication of Brånemark's work, he gave the field a scientific basis and a sense of respectability it had lacked previously. This was particularly true in academic institutions, where dental implants were largely ignored as a viable choice for tooth replacement. Dental implants are now a major focus of didactic and clinical education in 3 dental specialties and soon will likely become mainstream in undergraduate dental school clinics.

Osseointegration is the single factor that has most dramatically changed the discipline and specialty of prosthodontics since the introduction of fluoridated water. The evolution and change seen in basic science and the surgical understanding of dental implant therapy have perhaps been more far reaching than parallel advances in knowledge of the restorative aspect of dental implants. As the 20th century draws to a close, it is appropriate to review the significant advances and changes in implant prosthodontics that have occurred over the past 2 decades and, more importantly, describe future directions of investigation that are paramount to the advancement of dental implant therapy as a beneficial treatment modality.

OCCLUSAL/RESTORATIVE MATERIAL

When the concept of osseointegration was first introduced on an international scale in 1982, one of the basic tenets of restoring dental implants was that the implant must be protected from the shock of occlusal function or parafunction. This principle was described in detail by Skalak in key publications.[1,2] Avoidance of ceramic or even metallic occlusal surfaces was universally assumed to be of critical importance. The perceived need to protect the implant from occlusal trauma and a desire to simulate the damping effect of the periodontal ligament of natural teeth were the basis of design for one successful dental implant system.[3–10] The perception that maintenance of osseointegration was dependent upon this damping effect led to frequent restorative complications with implant-supported prostheses. During the mid- and late 1980s, as osseointegrated dental implants were increasingly used as a solution for the missing single tooth and in partially edentulous situations, resinous materials that had sufficed in the edentulous mandible opposed by a conventional complete denture rapidly proved to be inadequate in the posterior part of the mouth, particularly when opposed by natural teeth. Frequent repair and replacement needs related to high wear rates convinced many practitioners that the risk of damage to the osseointegrated interface was worth taking if repair and maintenance problems could be reduced. Patient expectations for esthetic implant-supported restorations also created the need to restore implants with more natural and stable materials such as porcelain. The gradual switch from resin to porcelain took a relatively short time. By the late 1980s the transition was nearly complete, and implant manufacturers were bringing

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new components to market that facilitated this transition.[11] Concern for the need to protect dental implants from traumatic shock delivered through ceramic occlusal surfaces has essentially disappeared from the literature. The standard of care for implant-supported restorations today includes the use of ceramic occlusal materials.

Precious metal alloys remain the most frequently utilized materials for the fabrication of implant superstructures. The use of base metal alloys for implant restorations has not been popular; one reason cited for avoidance of base metals in implant restorations is the potential for corrosion between dissimilar metals. While there is potential for pitting or crevice corrosion in any system containing dissimilar metals, it is assumed that corrosion of precious metals against titanium would likely be less than that seen with base metals, and byproducts of the corrosion process would be less likely to be toxic or allergenic than their base metal counterparts. The potential for corrosion between commercially pure titanium or commonly used titanium alloys and dissimilar metals is an area in need of further research.[12–16] Health risks associated with metallic corrosion also need to be explored.

Potential problems associated with metal-casting technology and materials have led to the introduction of machining and laser-welding of titanium as a substitute for the more traditional lost-wax casting procedures used to construct implant superstructures.[17–20] Prostheses fabricated with this technology fit accurately, are strong, and offer the potential for long-term success. While it is safe to assume that the laser-produced superstructures offer an improvement over cast-metal superstructures, the clinical benefit has not been demonstrated or even examined in a controlled manner. It is likely that laser-welded and computer-machined titanium superstructures will continue to be the state of the art for some time to come. It is anticipated that as this technology becomes more commonly used, the cost of the process can be substantially reduced, and that cost savings would be passed along to the consuming public to bring implant rehabilitation within financial reach of a greater segment of the population. The issues of framework accuracy and misfit of prostheses will be addressed in a later section.

Preliminary activity is underway at several centers examining the feasibility of completely metal-free implant-supported prostheses. The use of ceramic and/or composite abutments and fiber-reinforced composite superstructures presents a potential alternative to more traditional metal-based prostheses.[21] Research in the area of nonmetallic prostheses is currently in its early phase but is likely to progress rapidly as these materials become increasingly popular for traditional tooth-supported prostheses.

OCCLUSAL LOAD/OVERLOAD/ PROGRESSIVE LOAD

Much has been written about the effect of occlusal forces on osseointegrated dental implants. Unfortunately, very little of what has been written is based on scientific evidence, and the need for fundamental research into these issues is important from the long-term perspective as it relates to the survival and function of implant-supported prostheses.

Avoidance of nonaxial loading of dental implants is one example of a clinical concern that is not based on evidence. Many authors have warned of the hazards of nonaxial loading of dental implants, but there is no scientific evidence that the osseointegrated interface between living host and nonliving implant responds differently to compressive forces than it does to tensile or shear forces of similar magnitude. In fact, each of these types of stress transfer is present on the surface of every loaded implant because of the very geometry of the implant and the chemical/micromechanical nature of the bond between implant and tissue. The few animal studies that have attempted to examine this issue have, in fact, shown that nonaxial loading is not detrimental to the integration of the implant, even when nonaxial occlusal forces are greatly exaggerated.[22–24] One exception is a work reported by Isidor that did show evidence of nonaxial load destroying implant integration, but only after the magnitude of load was elevated to catastrophic levels.[25] In that report, forces generated appeared to be far beyond the range of clinical reality and were likely heavy enough to cause substantial deformation of the implant body itself, thereby precipitating bone loss. The fact that, to date, experimental evidence does not substantiate the concern regarding nonaxial loading and implant success makes this an area where much research is needed to permit an understanding of the mechanism of load transfer through the implant to the surrounding bone.

When the issue of nonaxial loading is extended to include the restorative components of dental implants, the concern may well be justified. Screw-retained components of implant systems seem much less able to withstand nonaxial forces than those within the long axis of the implant pillar.[26–29] Tolerances between mechanical components permit relative motion across interfaces, and flexure fatigue becomes an important consideration of long-term prosthesis and implant survival. The potential for nonaxial loading to cause plastic deformation (swaging), wear, or fatigue failure

of implant restorative components is clearly design- and material-dependent, and research is needed to determine the best design(s) for components to resist off-axis loads over extended periods of time. Research to date in this area has largely been done at the industry level and has been driven by issues of interchangeability, ease of manufacture, and patent infringement. Strength and resistance to fatigue failure should be the focus of future implant component research and development.

As with nonaxial loading, the literature on the use of cantilevers in implant-supported prostheses is largely anecdotal, and evidence from clinical data is lacking. Nevertheless, many authors have given their recommendations as to when cantilever prostheses are acceptable, what limits of length are permissible, and how many implants are necessary to support a cantilever. The work of Brånemark and colleagues demonstrated the feasibility of fixed, cantilevered prostheses to treat the edentulous mandible, particularly when opposed by a conventional complete denture.[30–38] Other authors have made empirical recommendations for length of cantilever as a function of implant position (A-P spread), arch form and length, cantilever location (maxilla or mandible), and opposing occlusion.[30–38] While these recommendations may have been successful when followed, the evidence to support them is lacking. Similarly, cantilever extensions on prostheses in the posterior part of the mouth are dictated by implant position and convenience, rather than by sound principles of design that have resulted from scientific evidence. Cantilever extensions in the posterior mouth are likely to be at higher risk of mechanical failure because of increased occlusal load, fewer implants, and implant position in a straight line along the arch. As it is difficult to imagine clinical trials gathering sufficient data to make sound recommendations on cantilever length, guidelines based on anecdotal experience and the principle that the shorter cantilevers are kept the better they will serve to minimize the problem of cantilever overload. Some clinicians have advocated placing more implants, in particular, posterior to the mental foramina in edentulous patients and eliminating cantilever extensions on these complete-arch restorations. The concept of a fixed, cantilever prosthesis supported only by implants anterior to the mental foramina, as described by Brånemark and coworkers, was based upon several important factors.[30–38] Placement of implants anterior to the mental foramina allowed the inferior cortex to be engaged by the tip of the implant, increasing primary stability and improving chances that osseointegration would occur. By avoiding more posterior placement, the risk of damage to the mental branch of the inferior alveolar nerve was minimized. Finally, by avoiding the posterior segments as sites for implants, the potential complication of stress shielding related to mandibular flexure could be avoided. The fact that the fixed cantilever concept has been so successful prompts a question: why would clinicians feel it necessary to extend implant placement into the posterior mandible? The increased number of implants necessary and the increased risks associated with the concept make it difficult to justify from the standpoint of increased patient benefit. Prospective clinical trials comparing outcomes from the 2 treatment concepts will be necessary to answer these questions.

The use of tripoded implant placement in the posterior part of the mouth is a concept that makes sense geometrically but has not been demonstrated clinically. The ability to support a prosthesis on a tripod requires that at least 3 implants be present. Sufficient ridge width to allow a bodily offset of 1 implant is frequently not available, and a slight tip in the angulation of 1 implant to give the appearance of an offset or tripod at the level of the occlusal plane is not likely to provide the expected support. To counteract moments generated by occlusal forces in a buccolingual direction, the implants must be bodily offset at the level of the ridge crest, rather than merely being tipped. The advantage of tripoding 3 implants in the posterior part of the mouth, while one assumes that it is likely to improve longevity of a prosthesis and possibly the supporting implants, has not been demonstrated in a prospective manner to be superior to a more conventional design utilizing 2 implants and a 3- or 4-unit fixed partial denture. One implant manufacturer, in fact, recommends that 2 implants and a 3- to 4-unit fixed partial denture are sufficient to withstand occlusal function over time. This recommendation is based on retrospective data demonstrating a low rate of complication with such a design.

Anatomic characteristics of the occlusal scheme that should be placed on restorations supported by dental implants have once again been described many times in an empirical manner but have not been examined scientifically. Cusp height, angulation, type of excursive contact, occlusal table width, and other considerations have all been described extensively but have not been examined scientifically. The variety of recommendations only confuses the clinician, providing little substance for guidance and disagreement as to what scheme or design is appropriate for a given situation in such a complicated and elusive area. This should not be surprising, since these same considerations have never been examined scientifically as they apply to natural teeth either. The generation of

sufficient data for making meaningful conclusions will require studies of such magnitude and expense that they will never likely be done, and human occlusion will remain in the realm of anecdote and empiricism.

Progressive loading has been put forward as a necessary and carefully engineered phase of implant restoration.[39–42] The methods used to gradually increase the functional load on a new implant are well described and justified by their proponents. The principle of Woolf's Law makes progressive loading seem not only advisable but necessary to protect the newly integrated implant. Unfortunately, once again, the scientific literature does not support the clinical practice of progressive loading. No trial has been reported wherein part of the subjects were treated with progressive loading and the other group provided with definitive restorations as the initial and only restoration. Lack of evidence does not by itself condemn the practice, but what little literature is available points to progressive loading as unnecessary. In a classically designed animal experiment by Ogiso et al, monkeys were provided with single implants in the posterior part of the mouth (1 maxillary, 1 mandibular), which were opposed by triple-splinted natural molars.[43] After the period of integration, the implants were exposed and immediately restored with restorations that increased the vertical dimension of occlusion by 4 to 5 mm at the incisors. The animals were observed for periods of either 1 or 3 months and were then sacrificed. Histologic examination revealed that the triple-splinted natural molars showed evidence of rapid, traumatic intrusion, while the implants showed only dense new bone formation. To bring a restoration at the time of its connection to an implant immediately into extreme hyperocclusion opposed by 3 splinted molars and permit its function is anything but progressive loading; this demonstrates how strong the bond of osseointegration can be, even without prior functional loading.

Another concern about progressive loading is that there is no evidence that it can even be done in a controlled manner. The argument that provisional restorations made of polymethyl methacrylate or a similar resinous material will transmit less force to an underlying implant than a ceramic occlusal surface would transmit is not consistent with the physics of occlusal function. The load transmitted to an implant is dependent upon the force of contraction of the elevator muscles of the mandible. If a force of 1 kg is generated by the muscles, that force must be transmitted through the restoration, regardless of material, to the implant and its surrounding bone. The damping effect described by Skalak concerning implant occlusion does not affect the total force transmitted and would have an effect only if there were a rapid impact between the teeth, rather than the controlled closure of the mouth with a bolus of food between the teeth.[1,2]

The concept of keeping a provisional restoration slightly out of occlusion or narrowing the occlusal table during the progressive loading phase is also very difficult to control. It has been shown quite dramatically by Richter, in 2 excellent papers studying forces generated on implant restorations, that the forces of occlusion with food between the teeth are substantially higher than forces generated in an empty mouth clench.[44,45] If the highest forces occur with food in the mouth, it is not likely that a slight lack of occlusal contact would be of any protective value during the period of progressive loading. The phrase coined by Dr Leonard Abrams, "Food is a weapon" (personal communication, 1997), appears to be consistent with the Richter studies. While progressive loading may, in fact, be beneficial, the concept is not supported by the scientific literature. There is probably no negative aspect of progressive loading that would contraindicate its use, as long as the period of treatment is not increased unnecessarily and as long as the total cost of treatment is not unduly increased by the practice. The desire to minimize and gradually increase occlusal loading of a dental implant is reasonable; however, well-controlled research of its value is completely lacking, and the little literature available to date actually suggests that there is no benefit to progressive loading. Clearly, this topic warrants further objective exploration.

PASSIVITY OF PROSTHESIS FIT

Many clinicians and authors have addressed the idea of passive fit of implant prostheses as essential to long-term success of treatment.[46–53] Once again, while it makes intuitive sense that a misfitting prosthesis screwed into place between 2 or more ankylosed dental implants might negatively impact the long-term stability of those implants, evidence to support this assumption is lacking.

In 1984 Roberts and coworkers demonstrated that titanium implants placed into the femora of rabbits could withstand the load and even stimulate bone formation following constant orthodontic loading.[54] Earlier attempts to use implants as anchorage for orthodontic therapy met with variable results, although since the introduction of osseointegration the use of implants as orthodontic anchorage has been extremely successful.[55–57] The important point illustrated by these early studies was that ankylosed or osseointegrated implants do not seem to be

damaged by constantly applied loads of high magnitude. In a well-designed study in baboons, Carr et al were unable to distinguish an effect of intentionally applied, measured misfit between implants in the posterior mandible.[58] The lack of occlusal function concurrent with the misfitting prosthesis was postulated as a possible reason that no effect could be seen because of the misfit. Similar studies that examined the use of osseointegrated implants as anchorage for orthodontic movement have shown no deleterious effect from high levels of constant strain placed on implants.[56–59]

Jemt and Book examined the quality of fit of implant-supported fixed prostheses retrospectively and found that, although none of the prostheses examined were passive, there was no evidence of bone loss around any of the supporting implants, even after 5 years of function.[60] They concluded that there must be a range of misfit that is tolerated by implants and still allows for long-term implant stability.

If it is assumed that misfit is a real problem when dealing with ankylosed dental implants, 2 questions must be asked. First, what level of misfit is clinically important, beyond which damage is likely to occur? The answer to this question is obviously very complex and probably depends upon such factors as bone quality, length and diameter of implants, and implant surface characteristics. Secondly, assuming that misfit is a concern, how does one measure it in a clinical situation? Both questions currently are unanswered and should be the focus of a high-priority research effort for 2 very basic reasons. If misfit is detrimental, the clinician must have the tools to measure it and to avoid it, at least at levels where damage is likely to occur. Equally important, if a moderate level of misfit turns out to actually not be a significant risk factor for long-term implant success, then the technology necessary to provide acceptable implant superstructures need not be extremely precise or expensive. Put another way, enormous effort is currently being expended to improve the accuracy of fit for implant-supported prostheses, but to date, there is no evidence that such precision is necessary for long-term implant-bone health. A realistic understanding of the effects of misfit on the stability of bone adjacent to dental implants is needed.

While experimental evidence demonstrating a detrimental effect of misfit on osseointegration is missing and the issue of misfit as a biologic risk for implant success remains a major question, one can still assume that prosthesis misfit is likely to increase the incidence of mechanical component loosening and/or fracture. The literature describing prosthodontic complications is at best confusing, but some evidence exists that inaccurate prosthesis fit can be the cause of a high rate of component complications.[61–63] From the aspect of mechanical stability, the need for accurately and passively fitting superstructures can be justified. The issue of passively fitting superstructures leads directly into the next topic of discussion.

SCREW-RETAINED VERSUS CEMENTED IMPLANT RESTORATIONS

There are currently 2 differing philosophies of how best to restore dental implants. Prostheses utilizing screw retention have been and remain the standard design in most situations for many clinicians. Others prefer to fabricate more traditional dental restorations for implant use, involving cementation of the restoration. The choice of cementation versus screw retention seems to be primarily one of personal preference of the clinician involved. There is no evidence that one method of retention is superior to the other. Advantages claimed for screw retention are primarily limited to issues of retrievability, which certainly is an advantage for a screw-retained restoration. On the other hand, advocates of cement-retained implant restorations list better esthetics, better occlusion, simplicity of fabrication, and reduced cost of components and construction as distinct advantages for the cemented technique.[64–66] An additional possible advantage of a cemented restoration is that it has the potential for being completely passive when placed in the mouth. The absence of a screw to draw misfitting components together with a clamping force would tend to eliminate strain introduced into the restoration/implant assembly by the tightening force of the screw. If a restoration can be made to seat passively on multiple abutments, the introduction of cement into the space between prosthesis and abutment would not by itself introduce stresses into the system. This potential advantage, coupled with the others mentioned, makes cemented implant restorations increasingly popular.

Advocates of cemented implant restorations frequently state that retrievability of the restoration can be maintained if a provisional cement is used. Unfortunately, there is little evidence that demonstrates predictable retrievability of various provisional luting agents when cementing 2 or more metallic components together. It is likely that a cement that functions well as a provisional cement for restorations cemented to teeth may, in fact, be a permanent luting agent for metal cemented to metal. Similarly, cements used for permanent luting on teeth may be inadequate when cementing metal to metal. Clinically relevant research in this area is needed.

USE OF IMPLANTS AS OVERDENTURE ABUTMENTS

Implants used in conjunction with overdenture prostheses are a popular method to enhance denture retention, stability, and support with reduced cost. Numerous methods of attachment of an overdenture to an implant have been described in the literature, but 2 basic principles of design are currently debated. The question to be answered is whether implants need to be splinted together to better withstand the loads associated with supporting an overdenture, or whether free-standing implants alone can withstand the load. Several studies have examined the effects of overdenture function on implant longevity, with somewhat differing results.[67–73] Asked in a different way, does splinting really reduce the load that an implant receives under function? Maintenance issues also play a role in the discussion. Some would argue that splinting implants together reduces the likelihood of screw loosening and component fracture. Others would submit that the presence of a bar beneath the denture may weaken the denture, leading to fracture problems over the long term. Both arguments can be supported to a degree. Once again, the decision of how to stabilize and retain an implant overdenture is based upon personal preference of the clinician, without meaningful scientific support for the treatment rationale. Additional clinical trials are necessary to determine the best application of implants in overdenture therapy.

The use of magnets for overdenture retention has been popular from time to time. New innovations in magnet technology have occasionally sparked renewed interest in their use, but results have frequently not lived up to expectations. While reports of new designs and types of magnets have been relatively common in the literature, follow-up reports of problems associated with their use have not been readily available. The concern over chronic exposure of living tissues to strong magnetic fields has also been the subject of publications in the dental literature.[74–80]

NUMBER OF IMPLANTS NEEDED TO SUPPORT A RESTORATION

One of the most difficult decisions to make in planning the treatment of a patient with dental implants is, how many implants are necessary to support the planned restoration? The concern over the predictability of single implants used to replace single posterior teeth is included in this question. To date, there are no prospective data available addressing this issue. The literature can be cited frequently for anecdotal recommendations for the number of implants necessary to restore the edentulous arch with a fixed, implant-supported prosthesis. Unfortunately, these recommendations range from one extreme, where 4 implants are deemed adequate to support a complete-arch fixed prosthesis, to the other extreme, which recommends that each individual missing tooth be replaced by an individual implant.[81–84] Once again, anecdotes drive clinical decision-making because there is no scientific evidence to provide answers. The fact is that restorations designed according to both extremes of implant numbers necessary can be shown to work in a given clinical situation. The value of fewer implants as a cost-saving approach has merit for many patients, where the financing of implant restoration is a major factor in patient acceptance. On the other hand, if the number of implants available is more than adequate to support the planned prosthesis, loss of 1 or more of the implants may not be critical to the success of the final restoration and may avoid the need for additional surgery to place additional implants, as well as the added time necessary for osseointegration to occur.

Research in the form of prospective clinical trials is the only way in which answers to the above questions can be answered objectively. These answers are particularly important if dental implant therapy is to ever become a viable treatment alternative for the average dental patient. In all likelihood, prospective research intended to answer these questions is unlikely to ever be funded at a level that will allow the answers to be found. The ultimate solution may simply be based upon accumulated retrospective reports of small numbers of patients, with the potential for bias to enter into the results. It is unfortunate that most retrospective reports deal with positive results, rather than with complication and failure. The publication of retrospective reports of treatment that did not meet expectations is of much more value to the clinician than the more common type of report, which advocates a particular treatment protocol or methodology based upon minimal evidence gained from retrospective reports on small numbers of patients.

CONNECTING IMPLANTS TO NATURAL TEETH

Much has been written about the problems associated with connecting implants to teeth in the same restoration. Most of the concerns expressed focus on the phenomenon of natural tooth intrusion.[85–87] While many theories have been advanced as to the

etiology of the intrusion phenomenon, no experimental evidence is available that prompts an answer.

There is well-founded concern that a prosthesis that incorporates a tooth as one terminal abutment and an implant as the other is a mechanically complex assembly resulting from the differential support for the 2 ends of the prosthesis. The presence of a periodontal ligament as attachment and support for the root of the natural tooth and the ankylotic nature of the osseointegrated interface give, at least theoretically, concern that the tooth must intrude to the point of loading the suspensory fibers of the periodontal ligament while the implant is absorbing load immediately without intrusion. Kirsch and coworkers attempted to address this problem by designing the IMZ implant.[3,88] Rangert et al suggested that the design of the Brånemark implant allows for enough flexure within the implant pillar assembly to accommodate for the periodontal ligaments of natural teeth.[89,90] The concern over the differential in support of a tooth versus an implant may, in fact, have less of an impact on the mechanical function of an implant restoration than one would expect. Bone itself is a flexible, resilient tissue.[91] Loading of bone through a periodontal ligament probably causes bone deformation similar to the deformation caused by the loading of an implant. This deformation could be expected to accommodate, at least in part, the differential between tooth support and implant support. The use of a single implant and a single tooth as abutments for a 3- to 4-unit fixed partial denture made in a straightforward manner as a 1-piece restoration and cemented with a permanent luting agent has been widely used, with few long-term problems reported. It seems that the complications with attaching teeth to implants are primarily limited to tooth intrusion problems, and if the tooth is prevented from intruding, either with a permanent cement or with a mechanical locking device such as a horizontal screw attachment, the concern might diminish. Determination of the etiology of tooth intrusion is an ongoing area of research focus.

COMPLICATIONS OF PROSTHODONTIC TREATMENT OF DENTAL IMPLANTS

The implant/prosthodontic literature is extremely difficult to examine and come to any conclusion with respect to the complications one may encounter associated with prosthodontic treatment of dental implants. It is even more difficult to determine the frequency of those complications once they have been defined. Many reports of prospective implant trials define complications only as they relate to surgical complication and implant loss. Others mention treatment needs, such as recurring screw loosening or fractured restorative veneers on implant-supported prostheses, but do not quantify the occurrence of this type of event.[29,92–98] The simple fact is, any occurrence that is unexpected and requires intervention by the practitioner to correct must be recognized as a complication of treatment, and it must be described as such in reports of clinical trials, regardless of whether they are prospective or retrospective. Reports on the survival of implants that do not comment on the frequency of every type of complication that occurred during the study are of little value to the restoring clinician and the patients who experience those complications. While dental implant therapy is rapidly becoming the treatment of choice for partial and complete edentulism, the frequency with which the patient and restoring clinician can anticipate complications of any type must be known to allow informed decision-making regarding how teeth are to be replaced. This problem can only be addressed by more detailed reporting of the results of clinical trials and leads directly to the final topic of this paper.

TREATMENT OUTCOMES

One of the most powerful tools of clinical dental research is the prospective clinical trial designed to examine specific treatment outcomes when compared to a standard or control. The assumptions that drive decision-making in treatment planning must be based upon head-to-head comparison of outcomes, preferably long-term. There are several as-yet unpublished papers that attempt to make direct comparisons of 2 or more treatment modalities, and more of this type of research is critical to an understanding of the long-term effects of treatment. As an example, is there evidence that suggests that a single implant–supported restoration is better treatment than a 3-unit fixed partial denture supported by 2 vital natural teeth? Every clinician has his or her own opinion as to the answer to such questions, but opinion-based treatment carries the risk that the opinion on which the treatment is based may be wrong. Diagnosis and treatment planning decisions in prosthetic dentistry have traditionally been based upon empiricism and arguments as to the most appropriate treatment for a given patient in a given situation. These arguments have more frequently been decided based on the forcefulness of the personalities advocating one technique over another, rather than on any assessment of treatment outcome.

The determination of what treatment option is best for the patient currently seated in the dental chair will always be based to some extent on individual patient needs and the preferences of the practitioner proposing treatment. It would be gratifying if clinicians had something more to look to for guidance.

Evidence-based treatment in the prosthodontic aspects of implant therapy may be best determined not by small, prospective clinical trials, but rather by larger, retrospective evaluation of treatment outcomes of homogeneous patient populations. This is not to say that the well-controlled, randomized, double-blinded, prospective clinical trial is not the best tool to answer research questions. What it means is that answers to the complex questions involved with the restorative phase of implant treatment are realistically not likely to ever be answered by such well-controlled trials, because of funding limitations and the enormous costs involved with running such trials. Stated another way, sufficient resources to conduct the trials are not available, and if evidence is to be obtained on which treatment decisions can be based, retrospective data on a large scale may be the only alternative.

CONCLUSION

Vital questions concerning implant prosthodontics are so complex and difficult to measure that the only hope for realizing significant answers may be to accumulate multiple, small, retrospective reports of both success and failure, and then to occasionally evaluate these reports in larger groups. If prospective, controlled clinical trials must be mandated to answer these questions, they may never be answered. Basing clinical decisions on nothing more than clinical anecdote and the occasional retrospective report, while less than ideal scientifically, may be the only practical option available for answering many of the questions posed in this discussion. While much of the evolution of implant prosthesis design, technology, and application has been the result of competitive trial and error, the one basic tenet that has pervaded recent success is recognition of the fact that biologic processes must be understood, accommodated, and enhanced if further success is to be realized.

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