Endodontics and Implants, a Catalog of Therapeutic Contrasts

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Dentists may be faced with the choice to retain a tooth by performing endodontic therapy and restoration or to extract the tooth and replace it with an implant and restoration. The purpose of this study was to catalog areas where implant and endodontic therapies differ so as to assist dentists in making treatment decisions and in identifying areas deserving of future research. Differences in diagnostic procedures and prognostic indicators were listed. With respect to treatment outcomes, study designs, success criteria, treatment results, systematic reviews, complications, clinician expertise, and the use of patient-based measures were discussed. The need for clinically applicable consensus statements and treatment protocols was noted. It was concluded that at this time, choices between implant and endodontic therapies cannot be solely based on outcomes measurement evidence; that different modes of outcome measure frustrate direct comparison; that endodontic and implant therapies profoundly differ in many ways; that although rigorous and clearly defined outcome measures have been proposed for use in endodontic and implant outcomes studies, they are very rarely used; that long-term, large, clearly defined studies, with simple and clear outcome measures, for example survival in combination with defined treatment protocols, are needed to measure the clinical performance of endodontic and implant therapies; and it was recognized that broad outcomes data may not be sufficiently specific to directly impact clinical decision making.

INTRODUCTION

The aim of both implant and endodontic therapy is to facilitate rehabilitation of patients' masticatory systems. However, these complementary therapies profoundly differ. Endodontic therapy is intended to retain teeth, whereas implant therapy is intended to replace missing teeth. The need for endodontic therapy is most commonly due to caries, and occasionally due to traumatic injury. In contrast, implant therapy addresses tooth loss most commonly caused by periodontal disease, as well as by caries, and occasionally by trauma. Implant placement requires the absence of disease, whereas endodontic treatment addresses the presence of disease. Endodontic success is often measured by recording the healing or regeneration of previously inflamed, infected, or lost bone tissue, whereas implant success is often measured by recording the absence of inflammation, infection, or of bone loss. Even the consequences of failure differ. Endodontic failure can usually be successfully addressed by retreatment, or by extraction and implant placement, site permitting; whereas, implant failure may vary from minimal consequence should the prosthesis be retained without substantial intervention, to the need for multiple surgeries and/or the provision of a different type of prosthesis. Because the published evidence does not permit a systematic review and scientific comparison of outcomes of endodontic and implant therapy, the purpose of this study is to catalog areas where implant and endodontic therapies

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differ so as to assist dentists in making treatment decisions and in identifying areas deserving of future research.

DIAGNOSIS AND TREATMENT PLANNING

Radiography

For endodontics, periapical radiographs are made, often at different angles, for preoperative, intraoperative or working, and for follow-up purposes. Occasionally, bite-wing or other views are used to augment the periapical films. However, radiographic assessment for implant treatment planning and follow-up is considerably more complex, usually involving panoramic radiographs, full-mouth series, and tomography, as well as bite-wing and periapical radiographs, at multiple treatment steps.

Restorative Planning

Although both implant and root canal treatments are driven by restorative or rehabilitative goals, restorative planning for endodontically treated teeth can be much simpler because the positions of the existing teeth are already established. In contrast, implant treatment planning often must begin with diagnostic wax-ups to establish the occlusion, esthetics, emergence profile, and all functional aspects of the eventual prosthetic tooth or teeth. Only when this is known can implant location be decided and surgical treatment planning initiated; radiographic and surgical stents will usually need to be generated from the diagnostic restorative wax-up.

Medical Implications

Few medical conditions have been linked to endodontic outcomes, but Fouad and Burleson[1] have recently shown that patients with diabetes have a reduced likelihood of endodontic success, especially in cases with preoperative periradicular lesions. With respect to osseointegrated implants, a recent review demonstrated that there is no systemic factor or habit that is an absolute contraindication to their placement in the adult patient, although cessation of smoking can improve outcome.[2] Increasing age, diabetes, head and neck radiation, and postmenopausal estrogen therapy have been correlated with a significantly increased implant failure rate; whereas gender, hypertension, coronary artery disease, pulmonary disease, steroid therapy, chemotherapy, and not being on hormone replacement therapy for postmenopausal women have not been associated with increased implant failure.[3]

However, some medical conditions, such as bleeding disorders or sequelae of radiation therapy, place a premium on tooth preservation and the avoidance of extractions or other surgical procedures. In such instances, endodontics is often performed, even on teeth of no functional value, whereas implant placement may need to be avoided.

Factors Affecting Prognosis

Relatively few factors are known to affect endodontic prognosis. The primary factor known to affect pretreatment endodontic prognosis is the preoperative diagnosis, ie, the extent of preexisting disease. Chugal et al[4] (p. 342) state: "The major biologic factors influencing the outcome of endodontic treatment appear to be the extent of microbial insult to the pulp and periapical tissue, as reflected by the periapical diagnosis and the magnitude of periapical pathosis." The key to successful endodontic technique appears simply to be the removal of sufficient bacteria to allow normal healing processes to occur. Therefore, the choice of instruments or obturating materials and techniques appear to be unimportant, as long as the biologic objectives are achieved.[5]

In contrast, a multitude of factors have been considered to influence implant prognosis. Patient factors include diabetes, smoking, and oral health. Implant site factors include bone quantity and quality. Implant factors include length, width, geometric form, material, and surface texture. Surgical technique factors include site preparation, the use of different types of grafts, the use of different types of membranes, the use of antibiotics, the choice of immediate or delayed placement into an extraction socket, the choice of one- or two-stage techniques, as well as the use of advanced techniques such as sinus lifting or inferior alveolar nerve repositioning. Restorative factors include time to loading, cantilevering, abutment type, prosthesis type, and the mechanical linkage of implant-supported prostheses to natural teeth. However, little is known about the influence of many of these factors on treatment outcome.

TREATMENT OUTCOMES

Study Motivation

It seems intuitive that outcome studies are motivated by a desire to provide data upon which to make evidence-based clinical decisions. However, few implant or endodontic outcomes studies have sufficient sample sizes, durations, or clearly defined outcome studies to permit comparison. Many implant outcome studies that appear intended to validate a single commercial product, rather than to measure treatment variables, have received commercial funding. Eckert et al,[6] reviewing dental implant systems in 1997, concluded that "on the basis of literature supplied by the manufacturers, only one implant system demonstrated scientifically valid long term success." It is wise for the critical reader to remember that the easiest ways for an investigator to avoid identifying a real difference between therapies is to choose an inadequate sample size, or to choose lax outcome criteria. The authors of this paper do not intend to criticize commercial funding of clinical outcomes studies, merely to identify the weaknesses of some such studies. In contrast, few endodontic outcome studies have been funded from any source, but duration, sample size, and clarity of outcome criteria are at least as problematic.

Endodontic Study Designs

Torabinejad et al[7] recently performed a systematic review of nonsurgical endodontic outcomes studies published between 1966 and 2004. Of the 306 studies, 6 were randomized

controlled trials, 12 were low-quality randomized clinical trials, 14 were cohort studies, 5 were case-control studies, 8 were cross-sectional studies, 4 were low-quality cohort studies, 5 were low-quality case-control studies, 73 were case-series analyses, 42 were descriptive epidemiological studies, 114 were case reports, 18 were expert opinions, 4 were literature reviews, and 1 was a meta-analysis. They concluded that few high-level studies have been published in the past 4 decades related to the success and failure of nonsurgical root canal therapy. Likewise, most studies of endodontic surgical outcomes are of low level.[8]

Implant Study Designs

Eckert et al[9] recently evaluated the quality of current evidence of clinical performance provided by the 6 major American Dental Association–certified dental implant manufacturers in the United States. They found that the evidence supporting dental implant therapy is generally derived from case series studies rather than from higher level cohort or controlled clinical trials. Articles that directly compared different implant systems were not found.

Endodontic Success Criteria

Unfortunately, endodontic outcome criteria are often inconsistent, ambiguous, and not standardized among studies. Although "success" and "failure" are commonly used outcome descriptors, additional categorical descriptors such as "uncertain," "questionable," or "doubtful" are often used. This is a reflection of the difficulty in using clinical examination findings to indirectly measure the often long and irregular progress along the continuum of the healing process. Orstavik et al[10] developed the Periapical Index (PAI) to address such problems. Key features include defined criteria, a 5-stage periapical health score, comparison to reference images, calibration of examiners, and blinding. Most endodontic studies report data in terms of success, not simply of tooth survival.

Implant Success Criteria

As far back as 1978, the Dental Implants: Benefit and Risk Consensus Development and Technology Conference attendees recommended that follow-up periods of 10 years be used, sampled patients not be preselected, and life table methods be used for analysis.[11] A series of subjective parameters related to function, comfort, esthetics, and patient attitude was defined, as was a series of objective parameters related to bone loss, occlusal considerations, gingival health, mobility, damage to adjacent teeth, sensation, and anatomic integrity of related structures. Albrektsson et al[12] proposed new criteria in 1986 that included absence of mobility and radiolucency, low rates of vertical bone loss, absence of signs and symptoms, and a minimum 10-year success rate of 80%. Few implant studies have used the Albrektsson criteria; survival is more often used and much easier to measure than the Albrektsson criteria. Indeed, it is important to distinguish between reports of implant survival and implant-supported prosthesis survival. Guckes et al[13] recommended that implant outcome measures include prosthesis survival as well as physiologic, psychologic, and economic impacts.

The design of both endodontic and implant outcome criteria is complicated by the needs to unequivocally define meaningful criteria and to identify useful and clinically measurable surrogates for histological processes. Unfortunately, few endodontic and implant studies have used such defined criteria in long-term studies. Critically, many implant studies classify outcomes in a 2-category outcome system (success/failure); whereas many endodontic studies use a 3-three category outcome system (eg, success/uncertain/failure), negating the ability to make direct comparisons of success rates.

Endodontic Outcomes

Friedman[14] comprehensively reviewed endodontic treatment outcomes from the second half of the 20th century in an encyclopedic book chapter. He identified 50 key follow-up studies, 21 key cross-sectional studies, 34 studies distinguishing between endodontic treatment outcomes in vital and necrotic pulps, 8 studies following endodontic retreatment in pulpless teeth without apical periodontitis, 38 studies following endodontic treatment in teeth with apical periodontitis, 6 studies comparing endodontic initial treatment and retreatment in teeth without apical periodontitis, 9 studies following retreatment in teeth presenting with apical periodontitis, 7 studies comparing endodontic initial treatment and retreatment in teeth with apical periodontitis, 31 follow-up studies of apical surgery, 14 studies following apical surgery in conjunction with root canal treatment, 29 studies following apical surgery alone, 27 follow-up studies comparing root canal treatment in teeth with and without apical periodontitis, and 13 studies that followed intentional replantation. Friedman tabulated groups of like studies by preoperative diagnoses and treatments; he also calculated weighted averages in the all too rare areas where relatively uniform success and failure criteria permitted. With respect to initial treatment, he determined that teeth without apical periodontitis were generally more successful than teeth with apical periodontitis. With respect to retreatment, he determined that in teeth without apical periodontitis, retreatment was generally more successful than initial treatment; and that in teeth with apical periodontitis, initial treatment was generally more successful than retreatment. With respect to surgery, he determined that surgery combined with root canal retreatment was generally more successful (weighted average 80%) than surgery alone (weighted average 59%) on teeth with previously failed root canal treatment; and that apical surgery including retrograde filling was generally more successful than apicoectomy alone.

It is important to note that endodontic outcomes, using contemporary techniques, have been reported for a half century. Strindberg's[15] rigorous landmark 1956 study of up to 10 years reported a 93% success rate for endodontic treatment in teeth having vital pulps or necrotic pulps without apical periodontitis; an 88% success rate in teeth

presenting with apical periodontitis; and an 84% success rate following retreatment in teeth presenting with apical periodontitis. Little may have changed since then; Chugal et al's[16] meticulous 2001 4-year study, using modified Strindberg criteria, reported an 88% success rate in teeth without apical periodontitis; a 63% success rate in teeth with diseased periapices; and a 79% success rate in retreatment cases. The differences in percentage success between the 2 studies might be attributed to slightly differing criteria and treatment by postgraduate students rather than by a specialist, but the same trends were reported, ie, periapical disease reduces long-term success rates, and that retreatment success is approximately intermediate between initial treatment with and without periradicular disease. A recent meta-analysis confirmed this trend with a cumulative success rate of 83% for vital pulps and 79% for nonvital pulps.[17] The long history of endodontics and the widespread use of root canal treatment may have led to a certain current complacency among dentists as to the necessity of performing rigorous outcome studies. According to American Dental Association statistics, approximately 15.8 million root canal procedures were performed by all US dentists in 1999, the latest year reported.[18]

A systematic review estimated that endodontic surgery had a weighted average of 64% success, but that resurgery only had a weighted average of 36% success.[19] These disappointing results underscore the importance of careful initial nonsurgical endodontic treatment; the importance of nonsurgical retreatment as a first line fall-back position; the importance of retreatment being completed before surgery; and the importance of considering extraction instead of endodontic resurgery.[20] Retreatment addresses the bacterial cause of the pathology, and attempts to remove bacteria from the entire canal system rather than just treating and amputating some of the affected apical tissues surgically. Indeed, endodontic surgery has been largely replaced by endodontic retreatment in specialty endodontic practice over the past decade.

Restoration Following Root Canal Treatment

Although restoration is generally viewed as a separate and distinct procedure, it is integral to endodontic success. It is now realized that coronal leakage, or post-treatment ingress of bacteria, is a major source of endodontic failure. The radiographic quality of the subsequent restoration may be as important as the quality of the root canal treatment itself.[21,22] Despite the critical importance of preventing bacterial ingress, timely restoration may often not be provided![23]

Implant Outcomes

Eckert et al's[9] pooled data from the 6 major American Dental Association–certified dental implant manufacturers in the United States on a total of 7398 implants gave an impressive 5-year survival rate of 96%, with a confidence interval from 93% to 98%.

Creugers et al[24] performed a systematic review of single-tooth restorations supported by implants to conclude that single-tooth implants showed an acceptable short-term (4-year) survival of 97%, and an uncomplicated crown maintenance rate of 83%. This type of implant outcome data may provide the most meaningful comparison with root canal treatment outcomes, but direct comparisons cannot be made with the usual 3-category style of endodontic outcome reporting. However, endodontic survival and uncomplicated maintenance rates can easily be measured.[25]

Esposito et al[26] performed a metanalysis of long-term follow-up studies of different scientifically validated implant systems to identify possible differences in failure pattern. The authors stated that the Branemark system was the only system to have prospective long-term follow up studies using well-defined criteria. However, the available data weakly indicated that the Branemark implants had a higher incidence of early failure, which sharply decreased over time; that the IMZ implant with rougher surfaces a lower incidence of early failure, but an increased rate of failure over time; and that the ITI implants, with immediate loading, had a higher prevalence of late failures which was attributed to perimplantitis.

Cochrane Reviews of Implant Interventions

A series of Cochrane reviews by Esposito, Coulthard, Thomsen, Worthington, and Jokstad have systematically examined a variety of factors relating to implant interventions.[25,35]

When comparing preprosthetic surgery to modify the oral anatomy for the retention of conventional dentures to implant-retained dentures, they found weak evidence that patients were generally more satisfied with implant retention than with preprosthetic surgery and soft tissue–supported prostheses.[27]

When comparing different types of dental implants made of different materials, in different shapes, and with different surface properties, they identified limited evidence that implants with relatively smooth surfaces are less prone to lose bone due to chronic infection (perimplantitis) than implants with rougher surfaces.[28] However there was no evidence showing that any particular type of implant had superior long-term success.

Upon examination of various surgical techniques, it was found that although the reported data allowed comparison of 2 versus 4 implants to support a mandibular overdenture, and for crestal versus vestibular incision for implant placement, there was no strong evidence supporting superior success for either of these 2 aspects of surgical technique.[29]

Review of bone augmentation techniques for dental implant placement determined that no one technique could be deemed superior to others. However, there was weak evidence that a nonresorbable membrane was better than no membrane for permitting bone growth around dental implants, and that a resorbable membrane over a bone graft may allow healing with fewer infections than a nonresorbable membrane.[30]

With the intent to minimize the risk of implant failure, osseointegrated implants had generally been kept load free during a healing period, but more recently immediate and early loading have become widely used in mandibles with good bone quality in order to minimize the use of provisional prostheses. Weak evidence from trials in people with healthy lower jaws found that immediate or early loading had similar outcomes to delays of several months. However, these specific data should not be extrapolated to general case.[31]

For dental implants in zygomatic bone for the rehabilitation of the severely deficient edentulous maxilla, they found that there is no strong evidence to compare the effectiveness of dental implants into the cheekbone as an alternative to bone grafting or similar procedures. However, it seemed that zygomatic implants yield high survival rates in poorly reported short-term case-series investigations.[32]

Although hyperbaric oxygen therapy has been advocated to improve the success of implant treatment in patients who have undergone radiotherapy, systematic review failed to demonstrate that hyperbaric oxygen can improve healing in such patients.[33]

A review of measures used to maintain health in the tissues around dental implants indicated that antibacterial mouth rinses may help to reduce plaque and bleeding around dental implants, at least in the short term, and that there is no evidence that electronic toothbrushes are better than ordinary toothbrushes.[34]

Review of data on the treatment of perimplantitis revealed the complete absence of long-term or even medium-term randomized clinical trials designed to compare perimplantitis treatments. However, this does not necessarily mean that all currently used treatments are ineffective.[35]

Maxillary Sinus Floor Augmentation Procedures for Implants

Systematic reviews and a meta-analysis have addressed questions related to the efficacy of various maxillary sinus augmentation and related surgical procedures.[36-38] In the short term, 1 to 4 years, it appears that implants placed in augmented sinuses have survival rates from 62% to 100%, with figures of approximately 90% being commonly quoted.

Complications

Goodacre et al[39] reviewed the literature concerning complications with implants and with implant prostheses between 1981 and 2001. They stated that even though it was not possible to calculate an overall complications incidence for implants and their associated prostheses, there appears to be a greater number of clinical complications associated with implant prostheses than other types of prostheses. Conventional fixed partial dentures and resin-bonded prostheses were associated with the next greatest number of complications. Especially relevant to this current article, post and core prostheses had a substantially lower rate of complications than either fixed partial dentures or implant prostheses; however, their review was not designed to compare endodontically treated teeth to implant prostheses.

Pjetursson and colleagues[40,41] have systematically reviewed the survival and complication rates of implant-supported fixed partial dentures and of combined tooth-implant–supported fixed partial dentures. They concluded that biological and technical complications were frequent, and that survival rates of combined tooth-implant–supported prostheses were lower than those of implant-supported fixed partial dentures. A 10-year prospective cohort study by the same team concluded that implant-supported single crowns had lower complication rates than implant-supported fixed partial dentures, which in turn had lower complication rates than combined tooth--implant–supported fixed partial dentures, and that complications increased the risk of failure.[42]

Endodontic disease and the endodontic complications relating to its treatment are usually measured within endodontic outcomes studies and treated as failure, rather than as being separated into a complications category. Other common disease processes, namely caries and periodontitis, may later affect or cause the loss of root canal–treated teeth, but these diseases are generally treated as being different from endodontic therapy. It is now generally recognized that periodontal disease and endodontic disease are separate entities that do not interact unless in their terminal and untreated stages. Caries does not affect titanium implants, and peri-implantitis is widely considered to be a different disease entity than periodontitis. Thus, it is important that caries risk and periodontitis risk are included in overall prognostic determinations of natural teeth. Fracture occurs in both implants and in endodontically treated teeth; however, the risk factors associated with fracture probably greatly differ between these 2 disparate therapies.

The degree of loss of tooth structure is widely considered to be a predictive factor for long-term clinical restorative success. Much in vitro data highlights the critical importance of loss of tooth structure in endodontically treated teeth, and subsequent modes of restoration, but the authors of this current paper are unaware of high-level clinical evidence that quantifies this key issue.

Clinician Expertise, Experience, and Technical Quality

Currently, most endodontic care is provided by general dentists. Initially, most endoseous implants were placed by specialists, but it is expected that over time most implants will be placed and restored by general dentists. The outcomes literature reflects this history; much data on endodontic outcomes has been derived from dental school general teaching clinics or general practices, whereas much data on implant outcomes has been derived from multi--specialty clinics.

Limited evidence suggests that operator experience or training and technical quality as measured by radiographs, has an influence on endodontic outcomes.[21,22,43-47] Researchers have expressed their disappointment at the poor technical

execution of many endodontic cases.[43,44] Interestingly, a large retrospective study of over 44,000 endodontic cases showed that overall 94% of nonsurgical root canal–treated teeth remained functional over an average follow-up time of 3.5 years, and that specialist practice provided similar rates of clinical success, even when treating significantly more complex cases.[25]

Some evidence suggests that general dentists can achieve results similar to those of specialists in single tooth replacement cases.[48,49]

Patient-Based Measures

Patient-based measures, or life quality measures have very rarely been reported in the endodontic literature.[50,51] Possibly, the obvious and overwhelming relief of pain,[50] or prevention of potential pain, by endodontic procedures has overshadowed the need to measure patient perceptions. It is important to remember that extraction also effectively removes pulpal and periradicular pain, but extraction may be traumatic in of itself and results in tooth loss. Interestingly, satisfaction has been significantly better when endodontic treatment was provided by endodontists.[50]

The application of patient-based measures to implant outcomes is much more advanced than for endodontic outcomes, but is still at an early stage. A systematic review by Strassberger et al[52] determined that most studies showed a low level of evidence; most studies were conducted in patients who were edentulous or restored with complete dentures or overdentures; that most studies used nonstandardized questionnaires; that clinical criteria were more commonly used than psychosocial criteria; and that the most commonly asked questions involved chewing function, esthetics, speech, and general satisfaction.

A comprehensive book chapter by Feine and Heydecke[53] "Implant overdentures versus conventional dentures" concludes that implant overdentures provide patients with better outcomes than do conventional dentures. These positive outcomes include psychosocial outcomes such as satisfaction and oral health–related quality of life, as well as functional outcomes such as chewing ability. This improved function with implant overdentures could increase the range of foods consumed by edentulous patients, which, in turn, also may improve their nutritional status and general health.

Esthetics

Esthetic function and perception by patients or dentists have rarely been measured. Certainly, numerous case reports demonstrate that beautiful gingival form, emergence profile, tooth form, and appearance can be created using implants; however, the technical challenges may be considerably greater than for retention of a natural tooth. Conversely, natural teeth may be misaligned or ravaged by disease processes.

Life Curves

Implant outcomes are often characterized by relatively high initial failure rates that decrease after the first few years. Branemark[54] even suggested that a steady state of implant survival could be achieved following a period of initial losses. Endodontic survival curves may show a like tendency, but relatively few have been published. However, it is believed that late endodontic failures may be substantially more common than late implant failures due to the ingress of new microbes through new caries and through restorations that become defective over time.

"CONVENIENCE"

On occasion, extraction of teeth has been advocated as a matter of "convenience" when implant-supported restorations are being provided. Rationales have included the removal of potential future sources of periodontal or periradicular disease or simplification of restoration design. Examples include the fabrication of a single large implant-supported restoration instead of 2 smaller restorations separated by natural teeth, or to more easily achieve a uniform occlusal plane. However, it is important to remember that to date there are no data demonstrating that implants are broadly superior to natural teeth. Patient welfare, oral health, and function must trump dentist convenience.

ECONOMICS, COST BENEFIT, AND RESOURCES

Although several authors have discussed the economics of single tooth implants, and the comparison of single tooth implants to fixed partial dentures, direct comparison with retention of a tooth by root canal treatment and restoration has not yet been made.[55,56] To date, a rigorous cost/benefit comparison of implant single tooth replacement and tooth retention by endodontics has not been made; however, Moiseiwitsch[57] suggests that although the endodontic, restorative, and periodontic cost of retention was generally less than the cost of replacement by an implant-supported prosthesis, the costs could be close, and that the treatment plan should be based upon the prognosis of each tooth being considered. Certainly, more resources and time are needed for implant therapy than for endodontics and routine restorative procedures.

CONSENSUS STATEMENTS AND STANDARDIZED TREATMENT PROTOCOLS

At this time, we lack the clinical outcomes evidence,[58] or truth of performance, upon which to make clinical decisions regarding implant and endodontic prognosis. Even the establishment of consensus can be a formidable task. Established, broadly accepted, treatment protocols based on consensus are largely lacking. To date, few implant consensus statements have included the detail needed to guide dentists' decisions on a case-by-case basis,[59] but detailed clinical recommendations are now beginning to be expressed.[60]

The authors of this paper are unaware of any consensus conferences on endodontic therapy. Possibly, endodontic

practice decisions have changed little over the past few decades, except in the increased use of retreatment and the decreased use of surgery. Despite persuasive data on the value of endodontic retreatment, as of 2000, no consensus occurred among or within 10 different European dental schools regarding clinical case management.[61]

In August 2006 The Academy of Osseointegration's (*www.osseo.org*) State of the Science on Implant Dentistry Committee will hold a consensus workshop. Two of the 8 carefully crafted questions posed are highly relevant to the broad purpose of this current paper: "In patients requiring single tooth replacement, what are the outcomes of implants as compared to tooth-supported restorations?" and "For teeth requiring endodontic treatment, what are the differences in outcomes of restored endodontically treated teeth compared to implant supported restorations?" The American Dental Association Foundation (*www.ada.org*) has issued a request for proposals for systematic review to support evidence-based dentistry and dental research. Two clinical questions posed are "What are the clinical, biological, psychosocial and/or economic outcomes of treating a pulpally involved (periodontally sound) single tooth through endodontic care, extraction and implant placement, fixed partial denture and/or extraction without implant placement?" and "What are the longitudinal beneficial and harmful effects of endodontic services compared to extraction and implant placement?" Likewise, the American Association of Endodontists Foundation has identified "Long-term cost effectiveness of endodontic treatment compared to treatment alternatives" as being a research priority for its grant program. However, purely evidence-based answers to these questions will be elusive at this time.

The authors of this paper suggest that knowledge of minor or even moderate differences in overall treatment outcomes or in treatment costs might not substantially impact clinical decisions. However, the identification and quantification of specific factors that affect rehabilitative prognosis in individual patients would be extremely useful in formulating standardized treatment protocols and individual treatment plans. Such factors might include bone quantity, bone quality, caries risk, periodontal disease risk, as well as the critically important factor of the amount of remaining tooth structure.[62]

CONCLUSIONS

1. At this time, choices between implant and endodontic therapies cannot be solely based on outcomes measurement evidence. The existing evidence is inadequate and not amenable to direct comparison. Few useful consensus statements and standardized protocols exist. We suggest that the dentist be guided by Hippocrates: "As to diseases, make a habit of two things: to help, or at least, to do no harm."
2. Although outcome data is inconclusive and not suited to direct comparison, endodontic and implant therapies profoundly differ in other ways, including biological processes, diagnostic modalities, outcome measures, failure patterns, failure modes, consequences, resources needed, and in some specific health care implications.
3. Although rigorous and clearly defined outcome measures have been proposed for use in endodontic and implant outcomes studies, they are very rarely used. The use of simple survival measures and life table analyses in combination with defined treatment protocols might allow a clinically relevant data bank to be efficiently realized.
4. Long-term, large, clearly defined studies, with simple and clear outcome measures are needed to measure the clinical performance of endodontic and implant therapies.
5. Outcomes information alone is insufficient to derive treatment matrices and clinical treatment decisions. Risk factors need to be identified and quantified.

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