Evidence-Based Techniques to Assess the Performance of Dental Implants

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The clinical use of evidence-based medicine has been regarded as one of the most significant medical advancements of the last century. As the costs of medical care escalate, clinical decisions have to be made prudently and with a high degree of efficacy. One of the most expensive treatments in dentistry includes the use of dental implants to rehabilitate partial and fully edentulous patients. Due to the high costs of treatments and the ever increasing varieties of dental implants becoming available, the clinician is often faced with a challenging situation to decide the best prostheses for their patients. Furthermore, navigating through the vast database of literature pertaining to dental implants and their related research can be very time consuming and challenging to a dental surgeon before they can make appropriate clinical decisions. Similar to other orthopedic implants, dental implants need to be evaluated for their long-term efficacy in vivo before they are clinically acceptable. In order to help clinician(s) make patient oriented decisions, evidence-based techniques are becoming increasingly popular. This can be a very useful tool in translating research findings into clinical practice, thus narrowing the gap between research and clinical dentistry. This article discusses ways in which evidence-based techniques can help dental surgeons analyze and make informed clinical decisions about dental implant treatments.

Key Words: evidence based dentistry, evidence based medicine, dental implants, dentistry, in vivo, single in vitro, long-term performance

INTRODUCTION

Evidence-based medicine (EBM) is used to analyze clinical data objectively in terms of quality from different studies. It is defined as “the process of systematically finding, appraising and using contemporaneous research findings as the basis for clinical decisions.” Evidence-based medicine is currently recognized as a well-established principle that forms a critical decision-making tool of many clinical specialties. However, compared with traditional medical specialties, EBM is yet to be widely recognized in dentistry and specifically in assessing the performance of dental implants. The application of evidence-based principles in dentistry has led to the term evidence-based dentistry (EBD). However, EBD is not well recognized in comparison with EBM, albeit both follow similar principles. This article attempts to emphasize the need for using EBD in general and in assessing the clinical performance and survival of dental implants, specifically. The terms EBM and EBD will be used interchangeably in this article.

Various authors have proposed definitions for EBD. Some of these include the following. “EBD is the integration and interpretation of the available current research evidence, combined with personal experience” and “the practice of evidence based medicine is the integration of individual clinical expertise with the best available external clinical evidence from systematic research and the integration of patients’ values and expectations.” The American Dental Association has formulated the following definition for EBD based on the concepts of EBM: “an approach to oral health care that requires the judicious integration of systematic assessments of clinically relevant scientific evidence, relating to the patient’s oral and medical condition.
Health care delivery in the future might witness a radical shift owing to the enormous advances of the Internet, which has led to information explosion and the consumer movement. Patients are becoming more empowered with information about their diseases and treatments that many dentists themselves might not be familiar with. Health care information is generally uncontrolled and unevaluated; it is rapidly changing, and dentistry is following these same trends. Dental implants have become popular choices to replace missing teeth. The past several decades have shown significant improvements in the survival of dental implants; for instance, the current 5-year survival rate for dental implant–supported single crowns is close to 95%. However, similar to other orthopedic implants, myriad dental implants, typically comprising various design aspects and surface finishes, apart from clinical factors (eg, immediate vs delayed functional loading), make it a challenge for clinicians to choose the most appropriate prostheses for their patients. Clinicians are faced with difficult situations when deciding the best available option (eg, in terms of clinical survival, clinical performance

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>1. Confidence interval (CI)</td>
<td>Quantifies the uncertainty in measurement</td>
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<td>2. Control event rate (CER)</td>
<td>It is the control (old treatment or nontreatment) event rate</td>
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<tr>
<td>3. Experimental event rate (EER)</td>
<td>It is the experimental (new treatment) event rate</td>
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<td>4. Absolute risk reduction (ARR)</td>
<td>It is the absolute arithmetic difference in bad event rates between the experimental and control groups, calculated as [EER – CER]</td>
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<tr>
<td>5. Relative risk reduction (RRR)</td>
<td>It is the proportional reduction in bad event rates between the experimental and control groups, calculated as [EER 0 CER/CER] and accompanied by 95% CI</td>
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<td>6. Number needed to treat (NNT)</td>
<td>It is the number of patients who need to be treated to prevent 1 additional bad outcome, calculated as 1/ARR, rounded up to the nearest whole number, and accompanied by a 95% CI</td>
</tr>
<tr>
<td>7. Absolute benefit increase (ABI)</td>
<td>It is the absolute arithmetic difference in good event rates between the experimental and control groups, calculated as [EER – CER]</td>
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<tr>
<td>8. Relative benefit increase (RBI)</td>
<td>It is the proportional increase in good event rates between the experimental and control groups, calculated as [EER – CER/CER] and accompanied by a 95% CI</td>
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<tr>
<td>9. Number needed to treat (NNT)</td>
<td>It is the number of patients who need to be treated to achieve 1 additional favorable outcome, calculated as 1/ARR, rounded up to the nearest whole number, and accompanied by a 95% CI</td>
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<tr>
<td>10. Relative benefit increase (RBI)</td>
<td>It is the proportional increase in bad event rates between the experimental and control groups, calculated as [EER – CER/CER] and accompanied by a 95% CI</td>
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<td>11. Number NEEDED TO HARM (NNH)</td>
<td>It is the number of patients who, if they received the experimental treatment, would lead to 1 additional person being harmed compared with the number of patients who received the control treatment, calculated as 1/ARI, rounded up to the nearest whole number, and accompanied by a 95% CI</td>
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<td>12. Cochrane Collaboration</td>
<td>It is an international nonprofit organization that develops evidence-based systematic reviews on health care interventions</td>
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<td>13. Critical appraisal</td>
<td>It is a process followed by the American Dental Association’s evidence-based dentistry experts to evaluate the strength and content of a systematic review. The process of critical appraisal results in a critical summary intended to focus on the clinical utility or application of the systematic review findings</td>
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<tr>
<td>14. Critical summary</td>
<td>It is the process of critical appraisal results in a critical summary, which focuses on the clinical utility or application of the systematic review findings</td>
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<td>15. Crossover study design</td>
<td>It is the administration of 2 or more experimental therapies, one after the other in a specified or random order, to the same group of patients</td>
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<tr>
<td>16. Cross-sectional study</td>
<td>It is the observation of a defined population at a single point in time or in a specified time interval. Exposure and outcome are determined simultaneously</td>
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*Definitions 1 to 3 are used in abstracts describing trials of therapeutic interventions, 4 and 5 are used when experimental treatment reduces the risk for a bad event, 6 is used when the benefit of a new therapy needs to be interpreted, 7 to 9 are used when the experimental treatment increases the probability of a good event, 10 to 12 are used when the experimental treatment increases the probability of a bad event. Definitions 13 to 16 are adopted from the evidence-based dentistry section of the American Dental Association.
in specific age groups, and material considerations) for patients requiring dental implants. An invaluable tool that becomes significant in this scenario is EBD. EBD can be used to scientifically validate and/or assess research data, clinical data, or a combination of research and clinical data to better help dental professionals in their decision-making capabilities. Several other benefits from EBD will be explained in later sections of this article.

Glossary of terms

A comprehensive glossary of terms for EBD is useful to assist researchers and dental professionals who are involved with providing dental health care. A list of terms adopted from the American Dental Association and medicine that are relevant to dentistry are explained further (Table).

Evidence-based medicine typically involves 4 primary steps: (1) formulating a clear question based on a patient problem, (2) identifying relevant literature data, (3) critical evaluation of the validity and usefulness of the identified studies, and (4) applying the findings to clinical practice. Evidence-based medicine influences medical decisions by using the best available scientific evidence. In addition, EBM bridges the gap between research and clinical practice, thus allowing the best available scientific evidence to play an important role in medical decisions. Adopting individual clinical expertise to existing proven clinical research data constitutes EBM. Several factors, including patient preferences, research evidence, and clinical circumstances, are relevant to formulate successful EBM decisions, as shown in Figure 1.

Evidence-based dentistry can benefit patients directly, as the clinical decisions are going to be typically backed by high-quality evidence. In other words, EBD begins and ends with the patient. Furthermore, clinicians can benefit immensely by adopting the principles of EBD in their routine clinical practice. This will also decrease the gap between research and clinical practice (Figure 2). Dental surgeons should be encouraged to interact with patients at regular intervals, ask clinical questions, and ultimately formulate clinical decisions that are most suitable to the patient based on the best available clinical evidence.

The hierarchy of evidence in dentistry ranges from results of meta-analyses of randomized controlled trials that can be applied to an individual patient, to prior experiences with smaller groups of patients (this can be based on a surgeon’s experience with prior procedures or prostheses) and expert opinions from clinicians. Figure 3 illustrates this concept in the form of an evidence-based pyramid that has been developed by researchers. Such tools can be very useful to incorporate EBM in clinical decision making.
Authors have suggested that meta-analysis and randomized controlled trials (RCTs) generally constitute the highest level of evidence, while uncontrolled studies or expert opinions would be considered the lowest levels of evidence. Yet additional factors including the costs and resources needed to conduct these previously mentioned studies can be limiting factors. Observational studies might provide useful information from both a biological (e.g., infections, peri-implantitis) and technical (i.e., implant loosening, overdenture and prostheses survival) perspective in the case of dental implants.

Factors to Consider in Implant-Related Research

Implant performance and outcomes are prone to bias, which can be due to several factors, including the level of a surgeon’s proficiency with an implant(s) and the familiarity of the operating room staff with equipment. Surgical placement of new implants typically requires a learning curve, thus leading to higher chances for adverse outcomes. Similar to other surgical procedures, clinicians who place implants master their surgical techniques over a certain period of time, thus creating room for inferior initial and/or final outcomes when using new prostheses or techniques. Differences in the surgical approach between surgeons can have confounding results in clinical studies. For instance, simply comparing 2 different implant types or clinical procedures might not be essential for assessing their clinical efficacy. The outcome measures used in the literature to determine the learning curve are mainly intraoperative continuous process variables such as intraoperative time or dichotomous outcome variables such as complication rates. However, complication rates after implant surgery may not be the best tool to assess a surgeon’s level of expertise, as they might be quite rare or expressed after a long follow-up period. Alternatively, a method known as process measurements, which is the time needed to complete the procedure/essential subtasks combined with postoperative measurements such as correct implant positioning, might be useful.

The main purpose of dental implants is to provide in vivo function for the longest possible duration in most cases. However, in some clinical situations, for example, during tooth movement and palatal expansion, orthodontic mini implants might be used for short periods of time. Factors such as surgeon experience, operating room familiarity with new equipment, and other unforeseen incidents during implant placement need to be taken into account before dental implants are evaluated. These previously mentioned factors will most likely play a significant role in EBM outcomes. A close scrutiny of the published literature may be conducted to detect flaws in results reported and to better understand their limitations. Some of the components that might be worth looking at when referring to published clinical studies related to dental implants might include the number of patients recruited, the duration of follow-up, and whether or not outcome measures including absence of pain/infection, esthetics, psychological benefits, and long-term stability/complications were addressed. In addition, long-term survival rates of implants are critical for clinicians to consider before they can make decisions to place them in their patients. Randomized controlled trials constitute the gold standard among clinical studies that provide the most objective results. When a new dental implant is evaluated for its clinical efficacy, there might be conflicting results from the published literature. For instance, 2 different studies might have reported opposite conclusions about the dental implants being good for their patients. However, one of the studies might have placed the implants in a smaller group of patients (e.g., 20 patients) by a single surgeon, while the second study might have carried out a larger randomized clinical trial (e.g., 2000 patients). The conclusions from the second study might carry more validity in terms of being more acceptable to clinicians, while the first study’s conclusions might constitute a mere opinion from a clinician’s experience. When appraising the literature, the dentist needs to consider these previously mentioned factors so that the more valid study results can be used clinically.

An economic analysis is essential to understand fully the relative value of alternative medical devices for improving patients’ outcomes. There are many components to a complete economic analysis, a discussion of which is beyond the scope of this article. The important point to remember is that when a new dental implant is introduced, surgeons need to consider the validity of the evidence (in published literature), for example, in showing superior performance to already existing devices.
before they implement it into their clinical practice. The patient's capacity to afford the prostheses might be an important treatment decision factor.

**Hindrances to Practicing EBD**

Although EBD is gaining acceptance among clinicians as a theoretical concept, its potential can be fully realized only once it can be applied in a practical way. Some of the factors that might hinder the introduction of EBD might include a lack of education/awareness related to the topic, lack of priority to apply the concept in clinical practice, and inadequate time and resource materials available related to the topic. The fear associated with staff disapproval from applying the concepts of EBD needs to be addressed before it can be successfully applied clinically. To ensure that future generations of dentists adopt EBD, it might be useful to introduce this concept during clinical training, for instance, during dental residency programs.

**Meta-analysis**

Since meta-analysis constitutes one of the highest levels of clinical evidence and provides one of the most objective study results, a discussion related to this topic is essential. Collection of data from multiple studies constitutes a meta-analysis. Meta-analyses are excellent tools to summarize existing scientific literature and produce a single estimate by combining the effect sizes across studies. Furthermore, they generally provide a greater degree of precision when compared with other study types because the estimate from the combined studies is based on a larger sample than any of the individual studies. This will provide narrower 95% confidence intervals than any study conducted on its own.

A search of the term *meta analysis of dental implants* in the PubMed database (in September 2009) between the years 1998 and 2003 revealed a total of 36 results. When the same search was performed between the years 2004 and 2009, it revealed a total of 82 results. It is encouraging to see that there has been a more than 100% increase in the number of meta-analyses in the past 7 years compared with the previous 5 years, probably because of the increased recognition of this study design in assessing the performance of dental implants in clinical dentistry. In a study by Boioli et al., a meta-analytic way of quantitatively assessing osseointegration in submerged and non-submerged endosseous titanium oral implants was investigated. The authors' rationale for conducting this study was based on the lack of normalization of published results in this area. A meta-analysis of specialized literature while adopting an adequate statistical method was employed during their study. The results of the study showed that both categories of implants matched the survival requirements that were current (at that time) but with different behaviors over time. Nonsubmerged implants osseointegrated better initially; however, they were subjected to causes of loss of osseointegration over longer time periods. In a different study, a meta-analysis of 1266 implants was performed to determine if the loading time affected their survival. The authors studied 13 prospective trials and concluded that early implant loading was not associated with worse outcomes compared with conventional loading. However, they mention that adequately powered larger prospective trials need to be carried out to confirm these results.

A drawback associated with meta-analyses includes lack of accepted or consistent methodology in a scientific study(s), which can bias the results. This can lead to inaccurate estimates of the effectiveness of clinical procedures. Important caveats to consider in a meta-analysis include pooling of data and conflicting results of studies, which can influence outcomes. In addition, the consistency in clinical and research methodology that has been used, the sample sizes, number of variables in a study design, and the probability for error or bias in the results of clinical studies need to be considered when performing a meta-analysis. Clinicians can be in a better position to explain the outcomes of certain implants and/or clinical procedures to patients with results from a meta-analysis. However, limitations also need to be considered when analyzing the data.

**Measuring the Efficacy of Dental Implants**

Functional rehabilitation (chewing in the case of dental implants) and esthetic appearance are key factors in assessing the efficacy of dental implants. Other important points to consider in evaluating the success or failure of dental implants include preservation of alveolar bone height/thickness and preventing physiological resorption, thus making
these factors significant in determining clinical efficacy. Some of the short-term (ie, 1–5 years) outcomes to consider in assessing dental implant efficacy may include absence of pain and the duration required by patients to regain complete function. Similarly, long-term (ie, 10 years and longer) outcome measures might include absence of pain, presence or absence of mobility, functional performance (eg, chewing ability), presence or absence of chronic infection, and peri-implant bone loss. Technical complications (eg, veneer and framework fractures in the case of implant-supported overdentures) need to be inclusion factors when determining the clinical efficacy of dental implants. Apart from these previously mentioned factors, an important point to determine clinical success will be to ascertain if patients have psychological benefits (eg, satisfaction) in terms of appearance, function, comfort, and general acceptance of their prostheses. However, this might not be very easy to determine as they can be difficult to measure on a quantitative scale. Observational (ie, prospective) and/or comparative studies might be appropriate in some clinical situations for the follow-up of dental implants when compared with RCTs.

**DISCUSSION**

The practice of EBM is a lifelong, self-directed, problem-based learning, which leads to the need for clinically important information about diagnosis, prognosis, therapy, and other clinical and health care issues. Authors have mentioned that the “best medical care demands the best evidence, which is the least biased in terms of design, analysis or interpretation.” Dental research has led to significant improvements in the oral health of Americans, for instance, by reducing the incidence of dental caries, development of new restorative materials, better periodontal therapies, and dental implants for replacing missing teeth. The acceptance of a theoretical hypothesis such as EBD by the scientific and nonscientific communities will have credibility if it is supported by evidence. The goal of EBM is to provide credibility to medical science and scientific discoveries, which has further led to its recognition as one of the most significant medical advancements of the 20th century. Furthermore, EBM affords the possibility of rendering treatment to the most number of people with the best proven clinical techniques and/or the most successful prostheses at any given time.

An important contribution that can be envisioned from EBM will be the use of proven treatments in large population groups at affordable costs. As dental treatment costs escalate, it will become essential to incorporate EBD extensively into clinical decision making so that patients can be treated at affordable costs. The direct beneficiaries from EBD will be large population groups in developing and underdeveloped countries. Apart from these societal health benefits (in the developing world), one can also foresee the increasing importance of EBM in the developed world. As the demographics of the United States already reflect a shift toward senior citizens’ becoming the majority, it will be essential that effective yet affordable treatments be developed in the future to sustain them. Evidence-based medicine can directly play an increasingly significant role by providing proven clinical solutions to vast population groups. Clinical research and education to evaluate the best currently available evidence and to identify new information that can help dentists provide health care to patients are necessary.

**FUTURE RESEARCH**

The barriers to the use of EBM include its lack of knowledge and basic skills rather than the concept itself. Dentistry has traditionally been taught based on a mentor-student–based model. This can be beneficial to the doctor undergoing training in that the knowledge is transferred to the trainee by a renowned authority or mentor in the field. This would constitute the clinician imparting his or her expert opinion to a student. However, a drawback with this approach will most probably be that mentored training on an individual basis might have a high probability of not incorporating evidence-based approaches that are based on large clinical trials or techniques. Incorporating evidence-based learning techniques during professional training can benefit both the trainer and trainees such that they are able to critically analyze scientific data. Future studies should emphasize the need for incorporating decision tree analyses to determine...
the best treatment options of benefit to clinicians during various levels of their training.

The field of implant dentistry is practiced by many dental subspecialties (e.g., general dentists, oral surgeons, periodontists, prosthodontists, and orthodontists recently) and is relatively new to the field of dentistry. However, it is not recognized by the American Dental Association as a specialty, unlike other disciplines in dentistry. This has both benefits and drawbacks. For instance, practitioners from different specialties can afford to adopt their own techniques to better the science of implant performance and survival. The drawback with this approach will be the lack of an overseeing body to advance the specialty, unlike other disciplines. This would be an ideal scenario for the introduction of EBD, where it can play a critical filling role in advancing the science based on proven treatment solutions regardless of the specialty that practices implant dentistry. With the vast number of dental implants that are currently available, long-term clinical survival data that reflect reliability in rehabilitating patients with these implants need further investigation. For instance, authors have mentioned that there is comparatively little research to guide practitioners on how the design of abutments influence the outcome of restorations. A common ground on which implant and implant-related research can progress will be possible with the use of evidence-based techniques. This will ensure that poor and inconclusive evidence is eliminated before it can be adopted into future clinical practice. Insurance companies can benefit from EBD studies by being able to provide reimbursements for surgical procedures that are backed by excellent evidence of clinical success. Cost-effectiveness analysis can be obtained from evidence-based research so that maximum benefits are provided to patients at minimal costs. This can also help to recommend future policy changes for both insurance companies and clinicians to provide the most cost-effective treatment solutions. Future directions for federal funding of dental research can be driven by reliable evidence from previous studies. The use of EBD needs to be encouraged such that it is adopted more extensively in dental education as well as private dental practice to advance the discipline of dentistry in general and implant dentistry, in particular.

**ABBREVIATIONS**

EBD: evidence-based dentistry  
EBM: evidence-based medicine  
RCT: randomized controlled trials

**REFERENCES**