Basic and Clinical Research: Issues of Cost, Manpower Needs, and Infrastructure


The purpose of this initiative is to define the critical research, education, service, and leadership roles of dental schools needed to ensure their ability to improve oral health. Although focused on U.S. dental schools, this is a worldwide agenda that seeks to address the recent Surgeon General’s Report on Oral Health in America. The recognition that dental schools are a national resource necessitates a clear and distinct definition of their role in improving oral health through research and education. This paper will outline the basic tenets and infrastructure that schools must embrace in order to grow, nurture, and sustain their research capacity. Fundamental issues must be addressed for dental schools to compete and flourish in contemporary science and research, given that research must be a part of the fabric of their mission and culture. These issues include manpower needs, training scientist-clinicians, infrastructure, costs, and leadership.

Although this paper will be primarily devoted to the question of research capacity, it is clear that research and education should be inextricably intertwined. Thus, no matter how much research capacity resides in a dental school, the academic culture will ultimately determine whether science is successfully integrated into dental education, including the cultivation of a “new” student body infused with specific research ideals. Thus, we also include here some characteristics of an educational environment that are necessary components for achieving success in scholarship.

Planning for Research

At the outset, dental schools must acknowledge that quality science must be the focus of all research efforts, aimed at generating new knowledge that will enable better diagnosis, treatment, and prevention of oral diseases. Not every dental school will be able to mount a serious basic science or clinical research initiative. Nonetheless, it is imperative that all dental schools contribute in some way and that the contributions be meaningful and of high quality. It is particularly important to recognize that science is a continuum of efforts that includes basic, behavioral, translational, applied, patient-oriented, and educational approaches. Thus, dental schools and their parent institutions must come to grips with their existing strengths and weaknesses and identify opportunities in science where they can make a unique contribution. To define their abilities in this context, dental schools must initiate a comprehensive and thorough planning process. Planning is critical for the dental school to ascertain how best it can contribute to the research enterprise and to identify the tactics, strategies, and resources necessary to ensure a viable research effort. Without a doubt, every dental school needs to be able to say that “ours is an academic institution whose science, in the aggregate, is outstanding!” Without such a commitment, dental schools will not be able to compete within their own institutions for resources necessary for scientific excellence, nor will they be recognized as meaningful contributors to the learned profession.

Currently, dental medicine has pockets of scientific excellence, but, overall, significant science achievement and recognition are limited to a minority of institutions. As such, the perception is that dental science is not sufficiently deep or broad-based to be on equal footing with the medical specialties. Only by making a full commitment to a science-based profession can dental schools be recognized as an equal partner in the field of human health. Dental schools must therefore strive to be centers not only of knowledge transmission, but of knowledge generation.

The NIDCR should actively participate in this effort by providing a new generation of a former NIH
program, the Biomedical Research Development Grants (BRDG), to jump-start research initiatives in dental schools that are less research-intensive. The BRDG should support the planning for new initiatives that have significant scientific promise, as well as provide start-up costs associated with infrastructure and support. To provide expertise and support potential collaboration, partnering with a research-intensive dental school should be strongly encouraged. However, the vast majority of the funding must be used by dental schools that are currently not research-intensive.

This program would create a superb incentive for dental schools that can demonstrate a serious interest in developing research, by providing resources to establish the necessary infrastructure and thus enable some measure of success.

**Manpower Needs and Critical Mass**

A generation ago, breakthrough discoveries could be made by individuals working largely in isolation. However, the rapid accumulation of scientific information and the increasing appreciation of the complexity of human, biologic systems make the “lone ranger” a thing of the past. Today, scientific advances are made most efficiently in large, interactive groups. In addition, because the oral and craniofacial complex is composed of such a wide variety of tissues and organs, dental research by definition is multidisciplinary in nature. Furthermore, for virtually all oral diseases, there is an interplay between the host and behavioral and environmental factors. With a few notable exceptions, dental schools lack the critical mass of high-quality scientists and the commitment to allocate resources that are needed to make rapid progress in a given area of investigation. Communication, collaboration, the sharing of human capital, instrumentation, core facilities, technology, reagents, and expertise are necessary to create the appropriate environment to nurture outstanding science.

No research-intensive dental institutions, and few medical schools, possess the diversity and depth necessary to cover all the bases. Accordingly, specialization and concentration of effort in a few select areas are essential to create a critical mass. To compete in science, the imperative should be for dental schools to do a few things well, rather than many things with mediocrity. Research-intensive schools may be able to develop two to three areas of excellence, whereas schools that are less research-intensive may need to focus on a single area. For the latter, this might be in less technology-dependent (but no less important) areas, such as clinical or patient-oriented research, epidemiology, education, or evidence-based health care. Indeed, the funnel of knowledge relevant to improvements in public health must include an assessment of existing clinical practices, along with a determination of the scientific basis of current diagnostic, preventive, and treatment regimes and approaches. This assessment leads to identification of gaps in knowledge that fuel additional research questions, which, of course, can lead to new fundamental research initiatives.

No matter what research approach a dental school elects to pursue, the issue of critical mass is vital. What constitutes critical mass? A working definition refers to an appropriate mix of scientists with complementary expertise to fulfill a specific research goal(s). At the very least, a critical mass should probably be no fewer than four scientists in any research area, and double or triple that number for a truly dynamic environment. Ideally, a critical mass should have a mix of scientist-clinicians and Ph.D.’s in each area. The role of the scientist-clinician is essential, both as a role model and to provide the clinical perspective that will focus and energize the basic research effort on questions particularly relevant to improvements in oral health.

What kinds of persons should be recruited to these focused research efforts? Broad experience dictates that only truly outstanding scientists—as judged by their prior record of excellence in their mainstream biomedical and/or clinical research discipline—should be recruited to the faculties. It is particularly important to note that the development of a critical mass does not necessarily mean that all individuals are either recruited by or housed by the dental school alone. Rather, it is vital to emphasize that these scientists can and should be recruited in partnership with other units of the university, health science center, or neighboring institutions.

Many types of trained professionals could be recruited to reach this critical mass. In addition to the medical and dental health care professions, many Ph.D.’s meet the criterion of excellence, although they are not for the most part being trained in oral, dental, and craniofacial systems. However, the knowledge base and technological and experimental approaches
in genetics, molecular genetics, cell biology, immunology, microbiology, and, indeed, most disciplines are system-independent and can be readily applied to oral health issues and research questions. Is recruitment of outstanding basic scientists whose track records and prior interests are in a system unrelated to oral and craniofacial complex a good strategy? Can such individuals be induced to bring their expertise to bear on the oral and craniofacial complex? We believe that the answer is unequivocally yes. However, there needs to be strong leadership within the institution to ensure that the science these individuals bring to the table is, at least in part, channeled to oral, dental, and craniofacial research.

Clinician-scientists can play especially important leadership roles by articulating the key clinical questions and, by so doing, setting the research agenda of the critical mass. Within a department or a research unit, a few D.D.S./Ph.D.’s or M.D./Ph.D.’s in leadership roles can organize and provide this vision. It is also noteworthy that Ph.D.’s without clinical degrees can do make terrific research leaders in oral sciences when they appreciate and understand the importance of oral, dental, and craniofacial science and the application of related biomedical sciences to vexing oral problems. When recruiting individual scientists from outside traditional dental venues, dental schools create opportunities to gain increasing recognition in the wider biomedical research community. In turn, new potential lines of funding can become available to support the research program.

The development of critical mass within dental schools’ research groups must next be further augmented by closer alliances between dental schools and other units within the university. These include medical schools, public health, pharmacy, nursing, and other health professions schools, academic health centers, veterinary schools, and schools of basic science, biotechnology, engineering, and health policy. Dental school faculty should be jointly appointed, and even jointly recruited, with relevant basic science departments whenever possible and integrated into the larger university environment. This provides a much larger cadre of colleagues for scientific communication and collaboration, ensures contact with mainstream scientific disciplines, provides access to a broad range of graduate students, including Ph.D. students, and provides access to emerging technologies and core facilities. Joint appointments will likely involve search committees with broad membership and, in the cases of co-recruitment with other units, can result in cost-sharing advantages. Clearly, dental schools that are part of universities or academic health centers have tremendous potential advantages over isolated, free-standing institutions. However, there must be a strong vision and commitment by leadership to turn potential into reality.

The independent tradition and ethos of dentistry and dental schools can work against this integration. However, it must be recognized that the identity of dentistry will only be enhanced, not diminished, if we compete successfully on the larger stage of mainstream biomedical science. Dental medicine has a focus that makes it unique. The challenge is to recruit scientists and to develop programs that command respect in all arenas and that are excellent by the stringent criteria of the broader scientific community.

Training Scientist-Clinicians

Given that teams need to include clinically trained individuals, is there a cadre of dentist-scientists available? The answer is “there are not nearly enough”! A variety of well-known factors have severely diminished the number of such individuals available. Those scientist-dentists that do become available are the targets of intense recruitment competitions. What can be done to increase their numbers?

Currently, there are approximately 4,000 dental graduates each year in the United States. According to the latest Senior Survey conducted by the American Dental Education Association (ADEA), only 1.5 percent demonstrate interest in an academic career path, and many fewer, perhaps 0.2 percent, are interested in basic or clinical research! There are more than 300 full-time unfilled, budgeted, academic positions in U.S. dental schools. To meet the need for renewal of faculty, the number of potential academicians must be tripled or quadrupled, a process that must begin soon.

One critical factor is student recruitment. It is abundantly clear that there are many highly intelligent, motivated students now entering the dental profession. However, these students are selected largely using criteria applicable to clinical dentistry and applied by faculty who are primarily clinicians. Such students tend to be outgoing, people-oriented, committed to careers in clinical care, and motivated by financial as well as humanitarian concerns. If dental
schools are serious about training the next generation of academic dentists, they must diversify their student bodies and select (and even actively recruit) a proportion of students—perhaps as many as 20 percent—who espouse a genuine interest in science. These individuals may not fit the paradigm of the “ideal” dental student. They may be introspective, idea-motivated, and less committed to clinical practice—but highly oriented toward research. And only a minority, perhaps one-quarter of these students, will enter academia. However, these recruits at least stand a chance of committing to an alternative career path. In short, schools must make a concerted commitment to self-renewal by recruiting the “raw material” and training them to populate the next generation of their faculties. It is critical to note, however, that placing this “raw material,” no matter how carefully selected, into an academic environment that does not nurture critical thinking in the scientific method will also lead to failure (see the section below on the educational environment).

Continuing to recruit in the old image can lead to an even greater shortage of scientist-clinicians in the future. The dearth of individuals selecting careers in academic dental medicine is even more problematic in the underrepresented minority community, where the gap between oral health needs and trained professionals is growing. NIDCR and ADEA, in partnership with the nation’s schools, could establish some new and testable student recruitment criteria. In addition to the traditional pipeline models, new models of student selection, with appropriate rewards on the front end, need to be initiated. One possibility is to develop a demonstration project that selects students using criteria sensitive to careers in academic dental medicine and research, tied to a years-in-service payback system similar to that used to recruit students to the armed forces.

Another factor that influences career decisions is financial. The costs of dental education have skyrocketed, particularly at private institutions. Students’ debt burden upon graduation is often so great as to preclude any alternative but a career in clinical practice. Schools, in partnership with NIDCR, ADA, ADEA, AADR, and the private sector, must ally to defray the cost of dental education for students who commit to a career in research. One hundred percent tuition forgiveness must be coupled to a strict time payback provision to ensure that only committed students enter such programs. Of course, there is still the problem of the relatively modest salaries of scientist-clinicians in academics compared to private practice. There is no easy remedy to this conundrum. However, not everyone is motivated solely by money. An academic career has other compensations: the intellectual excitement, with each day bringing unique challenges; the sense of mission; the incredible high that one gets from discovery; the daily interaction with interesting and motivated colleagues; and the flexibility. These advantages can and do offset many of the financial incentives of clinical practice. The rewards system, however, must be reconsidered if the recruitment and retention of high quality faculty are a goal. Among other things, a deterrent to a career in academic dental medicine is the arcane and outdated promotion and tenure system that does not necessarily reward clinician-scientists who spend much of their time in patient-oriented research. There must be a new reward system, coupled with long-term funding streams for research programs, that provides clinician-scientists with attractive and attainable career paths.

In the basic science disciplines, scientist-clinicians will be in competition with Ph.D.’s who have completed a four- to six-year training period, followed by one or more postdoctoral experiences. When applying for their first major grant such as an NIH RO1, Ph.D.’s can have from seven to as many as eleven years’ research experience. To compete successfully in this milieu, scientist-clinicians must be trained in an outstanding Ph.D. program that is continuous and concentrated, and not integrated into clinical training. In some disciplines, postdoctoral fellowship will also be required. A continuing concern is the inordinate time it takes to complete training in postdoctoral and doctoral programs—another potential deterrent to a career path in academic dental medicine. When viewing the manpower issues and opportunities available to recruit the next generation of faculty for careers in academic dental medicine, serious attention must be paid by dental schools, the Commission on Dental Accreditation, the specialty accrediting bodies, ADEA, NIDCR, AADR, and other appropriate agencies to the necessity to rethink the length of time it takes to complete training for specialty and doctoral programs.

As noted above, the cultivation of interest in dental and craniofacial science must begin earlier than dental school. The T35 programs have been an interesting experiment, although they have not proven to be effective in recruiting dental students to academia. College students faced with making ca-
career choices are often most “at sea” and therefore most malleable. A number of summer interns from college have trained in the Forsyth Institute’s laboratories. As a group, they are bright, motivated, and open to considering various career paths, including dentistry and dental academics. Therefore, another program that should be considered is an extension of the T35 mechanism to focus on this very promising group.

In summary, dental schools, in partnership with NIDCR, ADEA, AADR, ADA, and other interested groups, need to initiate new programs and provide financial incentives for the recruitment, training, retention, and reward of scientist clinicians. In this context, Dean Art Dugoni of the University of the Pacific issued a call for a one billion dollar endowment for dental education. In a similar vein, perhaps the establishment of a “superfund” endowment of approximately $250 million dedicated to the training of scientist-clinicians can go a long way towards resolving this problem. This superfund could be generated by a national campaign in partnership with the ADA, ADEA, AADR, specialty organizations, and the private sector. NIDCR could provide supplemental seed money for this initiative. Only by making this powerful commitment to reinforce the development of scientist-clinicians can the learned profession advance and prosper.

A key recommendation of this paper is therefore to convene a special task force of NIDCR, ADEA, ADA, AADR, the dental industry, and selected members of the private sector to seek solutions to (not discussions about) the issues surrounding the recruitment, nurturing, and retention of students, scientists, and clinicians to careers in academic dental medicine. This task force must provide a new mechanism for funding the training of scientist-clinicians.

The Educational Environment

The previous sections addressed the development of a research faculty and the recruitment of a new generation of dental students. This section addresses the dental school context. It is our contention that, for research to thrive in a dental school, the necessary infrastructure must include a serious rethinking of the culture of the educational enterprise.

We stated earlier that, in the best of all possible worlds, research and education are inextricably intertwined. In actuality, this is probably the exception rather than the rule, in part because of the differences inherent in the cultures of research and clinical faculty (Figure 1). Although there are a number of important areas of difference, the most obvious is in the area of “proof” and what is taken to be “true.”

Evidence, Proof, and Truth

Scientists normally test hypotheses of their own formulation, using experimental approaches of their own design. The objective is to generate new knowledge—about basic biological processes, mechanisms of disease, or, in the case of clinical research, about the effectiveness of disease prevention, diagnosis, and treatment. The time frames in which these activities take place are normally measured in years. A typical basic research study will take two or more years from conception to publication. Grant proposals require the generation of a research plan that looks three to five years into the future. What is most important is not the speed with which new data are generated, but rather that the data represent the highest quality evidence and address important questions.

From a scientist’s perspective, rigorous testing of a hypothesis to demonstrate a cause-effect relationship requires an experimental group as well as a positive and a negative control; multiple repetitions of a given experiment; multiple lines of evidence that establish the same conclusion; and finally validation of the experiments by other scientists. If the experiments are validated, the hypothesis is taken to be “true”—that is, until other experiments are carried out that provide more compelling data that invalidates the initial hypothesis. Thus, while much rigorous planning and effort go into generating scientific “proof,” this is understood to be relative: to the experimental conditions, to the available technology, and with a certainty that is almost never absolute (usually 95 percent or greater for statistical validity). Thus, the scientific culture is that truth is based on up-to-date experimental evidence and that all assumptions must be questioned and continually re-evaluated.

In contrast, the clinician faces problems that are human and immediate. When a patient presents in acute pain, the diagnosis, a treatment decision, and treatment must be accomplished in a time frame measured in hours. Similar to scientists, clinicians must continually deal with relative uncertainties and
probabilities and yet, for their patient’s benefit, behave with certainty. The treatment decision can vary from clinician to clinician and may or may not be supported by high-quality evidence in the clinical research literature. Indeed, it is equally likely that the treatment is one that: was taught in dental school; the clinician has good technical expertise with; has shown efficacy in the clinician’s hands in the past; and meets the professional “standard of care.” In educating dental students, clinicians commonly teach their favored treatment approach, which is strongly influenced by personal experience and less consistently influenced by research data.

The relative uncertainty is most clearly evident in the levels of clinical evidence for demonstrating causality (Table 1). The highest quality evidence (level 1), the randomized controlled trial (RCT), is equivalent to the scientist’s rigorous test. Note, however, that there are four levels of clinical evidence lower than the RCT, with increasing uncertainty in demonstrating a cause-effect relationship. For any clinical question, the best evidence available may not be level 1, or in some cases, no evidence may be available at all. Yet the clinician needs to make treatment decisions and provide care to the patient.

Unfortunately, clinical education usually does not explicitly train students to recognize or differentiate between different levels of available clinical evidence, to incorporate uncertainty in their decisions, or to evaluate the outcomes of their care. It is not uncommon for the dental student preparing a crown with more than one prosthodontics instructor to find that the Monday instructor asks for a shoulder and bevel, the Tuesday instructor asks for a chamfer, and the Wednesday instructor asks for a feather-

<table>
<thead>
<tr>
<th>Level</th>
<th>Study Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Randomized controlled trial</td>
</tr>
<tr>
<td>2</td>
<td>Cohort study</td>
</tr>
<tr>
<td>3</td>
<td>Case-control study</td>
</tr>
<tr>
<td>4</td>
<td>Case series (prospective)</td>
</tr>
<tr>
<td>5</td>
<td>Expert opinion (without explicit critical appraisal rules)</td>
</tr>
<tr>
<td>NA</td>
<td>Cross sectional, epidemiology, case series (retrospective), animal studies, laboratory studies</td>
</tr>
</tbody>
</table>
edge. If asked why one preparation is favored over another, instructors are more likely to cite personal experience than to direct the student to the available literature.

Thus, for most dental students and many clinical faculty, there is a disconnect between research and the clinic. Without knowledge of this cause-effect hierarchy, without training on how to access and evaluate continuously emerging evidence, students and clinicians are often unable to discard ineffective therapies and incorporate more effective therapies. Little wonder then that medical doctors can take ten to twenty years to change their practice behavior, and surgeons even longer.6

In thinking about these issues, the research faculty might well ask the following questions related to the role of research in dental education:

• What do we know about the utilization of research findings by clinical faculty?
• How rapidly are ineffective diagnostics and therapeutics eliminated from the curriculum, and how rapidly are efficacious ones incorporated into teaching and practice?
• Does the clinical faculty value and support the research faculty?

Conversely, the clinical faculty might well want to know whether research is truly relevant to the clinical problems they face:

• What research findings are of high quality and of high importance for oral health?
• How could (should) research affect the way my patients are treated and how students are taught?

Dilemmas of Clinical Faculty

Problems for the clinical faculty include: cognitive dissonance, cognitive bias, financial considerations, and assessment of the outcome of treatment.

Cognitive dissonance is the discomfort one encounters when evidence presented is contrary to one’s worldview. Arguably, modern dentistry (post Geiss Report) enjoys almost 100 years of success. The American public is healthier, dentists’ incomes are increasing faster than the consumer price index, and there are more qualified students applying for fewer spaces in dental schools. Why should the clinical faculty change?

Here is just one reason. A wealth of data demonstrates that caries and periodontal disease are specific infections that can be largely prevented. Yet the training provided to dental students, the evaluation of their progress, the awarding of the D.D.S. degree and a dental license, and clinical compensation once they graduate are all predicated on treating those two diseases with surgery.

Cognitive bias is the increasing inability of individuals to make decisions and change behavior as the number of possibilities increase. In an information-rich world where approximately ten high-quality clinical articles in each of the dental disciplines are published each week (and this is increasing by more than 10 percent per year), clinicians are overwhelmed with information. Which studies are valid? What clinical approach does the bulk of the evidence support? The normal reaction when confronted with multiple opportunities is to rely on what one was trained and licensed to do: to provide the “standard of care.”

Schools and dental practices live and die based on their financial solvency. Altering any form of clinical practice can, and will, have significant financial implications. The institutional extrapolation of these unknowns makes alteration even more problematic.

The long-term outcome of clinical planning, implementation, and care is not a common dental school activity. Rather, the key outcomes are determined at the close of a clinical session or the close of a business day. The dogma of care—immediacy of completion—is implicitly and explicitly conveyed to dental students who want to finish the clinical session, the clinical year, and the clinical curriculum.

Dilemmas of Research Faculty

The research faculty have different problems, including: isolation from, and incomplete understanding of, clinical problems; immersion in research that may or may not be directly relevant to clinical practice; and poor communication of research findings so that they are understood by clinicians and students.

Many of the research faculty will not have clinical degrees and therefore will have a more superficial understanding of the nature of the disease processes and of clinical problems. Another problem is that science done in vitro, or even in animal models, may not correctly model human disease and may therefore be quite removed from application to dental practice. Indeed, many apparently promising treatments and drugs fail to survive the hurdle of applicability to humans, despite tremendous promise in preclinical testing. Finally, scientists who have the ability to communicate well with colleagues in their specialized domain of research often have great dif-
difficulty in translating their findings to the potential consumers of scientific knowledge: students, clinicians, and the lay public. Lack of interaction with these groups is probably the greatest impediment to effective information transfer.

**Evidence-Based Healthcare**

All is not hopeless however. Appreciation for and implementation of evidence-based clinical decision making could assist in resolving many of these issues. Essentially, evidence-based healthcare is the application of the scientific method to clinical care. The scientific method as applied to clinical decision making is a five-step process:

1. Asking a focused question (generating a hypothesis)
2. Searching for the best evidence (doing an experiment)
3. Critically appraising the best evidence (analyzing the results of the experiment)
4. Applying the results (evaluating the results)
5. Evaluating the outcome and altering care accordingly (refining the hypothesis)

The research faculty, being conversant with the scientific method, could provide the necessary coaching to teach others how to critically assess new evidence and bridge this gap. The clinical faculty, as experts in the human aspects of disease, could provide the reality check needed to define what is practical and what is impractical in terms of proposed new treatment approaches.

Dental school faculty, by and large, are not used to thinking in this structured format. Yet, the benefits of this clinical problem-solving approach can be enormous. Evidence-based methods provide a relatively unbiased, rules-based, systematic method for articulating problems and coming to resolution. They can overcome the problems of cognitive dissonance and bias and, combined with economic analyses, facilitate financial decisions. The quantitative methods are outcome-based, facilitating discussion among the faculty. The discussion increases the probability of implementation by providing a forum for the explicit comparison of individual clinician bias versus clinical trial data.

An engaged and interactive clinical and research faculty, using the methods of evidence-based healthcare, will be better equipped to communicate with one another, will come to better appreciate the issues each faces, and will value the complementary skill sets each offers. This collaboration would go a long way toward institutionalizing a scientific mindset among the faculty and their students. It is expected that students would come to value these interactions, see the connections, and apply them throughout their professional careers. Some might even choose to pursue them as a career. Mutual respect for one another’s expertise and a spirit of open-mindedness and collaboration are required to implement such an experiment.

Incipient attempts at this approach have begun at several dental schools that are implementing a “problem-based learning curriculum.” As reported at several ADEA meetings, however, these curricular changes are largely changes in the structure of information delivery rather than in evidence-based clinical decision making. Implementation of training in evidence-based healthcare is a missing integrative piece of the puzzle, which is necessary for linking scientific methodology, critical thinking, and academic and clinical success.

In a typical dental school educational environment, dental students spend the majority of their preclinical training learning the basic sciences. After learning basic clinical skills, students normally transition directly to the intersection of a clinical problem, a patient, and the mentoring clinician. They normally have little, if any, training on how this information transitions through animal and human studies to clinical evidence and finally how it is applied effectively in the clinical environment. Further, they normally receive little training in evaluating the long-term outcomes of the care that they are providing.

**Infrastructure**

Infrastructure comprises the totality of the research environment available to individual scientists. Contemporary laboratory and/or clinical research space, adequate office space and conference areas, animal facilities, biostatistical support, instrumentation, informatics, and technical cores are essential needs to conduct and support viable research programs.

If dental school research efforts are to expand, there are obvious needs for space, instrumentation, and technology within the dental school environment as well as access to other core facilities either within the parent institution or by collaborative arrangement. Renovation and new construction are currently supported by the National Center for Research Resources (NCRR) through matching (CO6) grants. Shared
large instruments are also funded via NCRR. The real need for a core facility within the dental school must be assessed on an institution-by-institution basis. Some highly utilized services—for example, histology and imaging, animal facilities, and statistical support—may be worth the investment. Organization, oversight, and regular review are important in holding down costs. Services such as DNA sequencing, synthesis, gene arrays, transgenic mice, electron microscopy (EM), mass spectroscopy, and sophisticated bioinformatics are probably more cost-effective on a fee-for-service basis, assuming that there is sufficient access. Partnerships must be forged within the university or with appropriate partners in the biotech field to permit ready access to these essential technologies at a reasonable price.

An important area of infrastructure that is sometimes overlooked relates to clinical investigation. Patient flow and related support and regulatory operations are critical elements for the successful conduct of clinical research. In this arena there are mounting regulatory issues, including access to an Institutional Review Board (IRB), Data Safety Monitoring Boards (DSMB), and quality assurance (QA) for the conduct of clinical research. The QA must include auditing of clinical research data, IRB procedures, forms, database management, security, confidentiality, protocol tracking, adverse event reporting, data storage, and the like. These special requirements must be integrated into the infrastructure and thus add to the costs of conducting clinical research. Competing for research funds along with establishing and maintaining a clinical research program is therefore a sophisticated and expensive enterprise. One avenue that dental schools have not adequately utilized is active participation in the General Clinical Research Centers (GCRC), which are funded by the NCRR. The GCRC Program provides long-term support for the establishment and operation of clinical research facilities, support staff, regulatory committees, instrumentation, and core facilities. It can be accessed by collaboration with an existing GCRC, through establishment of a satellite at the dental school, or by direct application.

What can NIDCR do to help? NIDCR has provided leadership recently in several areas, including allocating resources for the establishment of gene array consortia that also serve the dental school. As new and vital technologies emerge such as bioengineering and nanotechnology, targeted monies to encourage the development of core facilities would be of enormous significance to advancing dental science. Another recommendation is for NIDCR, working with ADEA and AADR, to create a working group to evaluate the feasibility of establishing regional core facilities that can be utilized by multiple institutions. In this way, more core facilities can be available to more institutions and investigators, with the net result of reducing the cost burden to the dental schools trying to develop and sustain a major research program. Through this mechanism, it may be possible for some schools to participate in research programs that otherwise would be out of their reach, given cost requirements. This initiative might also help to balance the “rich get richer” scenario that now dominates NIDCR’s funding pattern.

The Cost of Doing Business

In this discussion it is important to keep a few facts in mind. First, biomedical research is expensive. Recruiting the highest echelon of researchers involves commitments of salary, space, technical support, and supplies, often for several years until independent grant support is obtained. Today, a competitive start-up package for a top-level scientist at the assistant professor level approaches $500,000, including his or her salary for the years until grant support is obtained. One can roughly double that figure for a full professor who brings his or her group. An important implication is that one must choose the horses that one bets on extremely carefully and

| Human capital: recruitment of the “critical mass” to include |
| - salaries plus fringe benefits |
| - start-up costs |
| - equipment |
| - supplies |
| - office space |
| - technical support personnel |

| Physical infrastructure support |
| - laboratory space |
| - shared instrumentation |
| - IT |
| - core facilities |
| - access to specialized instrumentation and services |
| - clinical facilities |
| - patient flow |
| - regulatory and compliance issues for patient-oriented and basic research |
| - access to good business practices and grants accounting |
| - patent, licensing, and technology transfer access |
| - grants management support |
with adequate consultation. This is especially true for the recruitment of young scientists who are just emerging from postdoctoral training and have not yet established an independent track record. The institution of the “K” series awards by NIDCR appears to be a potentially excellent mechanism for assisting schools in funding beginning investigators. Its shortcoming is that the amount of support ($125,000 per year for the faculty transition phase), although an improvement over the R29 awards, is still inadequate to establish a fully independent program. It is important that NIDCR consider increasing the level of the faculty transition phase of these “K” series awards.

Second, research is clearly a loss leader! Even in elite research schools and institutes, hard dollars from tuition, clinical care, state funding, endowments, and fundraising are required to subsidize the research effort on an ongoing basis. For example, the Joslin Diabetes Center in Boston subsidizes research by ten to fifteen cents on every dollar; similar subsidies are necessary at MIT’s Whitehead Institute and the Harvard Medical School. Thus, initiating or expanding the research effort will entail not only startup costs, but continuing expenditures to maintain the operation at that level. Why? Given the vagaries of the NIH and NSF funding systems, no scientist and his or her group are always fully supported by grants. Furthermore, the method by which NIH awards overhead virtually ensures that shortfalls carry a double whammy of supporting direct plus indirect costs. It may be timely for NIH to reconsider the methodology by which it determines indirect cost rates so as not to penalize institutes that seek to supplement investigator-initiated grants with industrial contract research, which often carries a lower indirect cost rate. Indeed, it may be timely for NIDCR to work with NIH administration and ADEA, AADR, and ADA to seek some new determinants of indirect cost rates to reduce the subsidy of research funding by the parent institution.

Why then commit to a research agenda if it is fiscally problematic? There are many reasons, some idealistic and others practical. Without question, research provides the only method to ensure that the public good will advance. Progress against oral, dental, and craniofacial diseases and disorders will only be made by the generation of new knowledge, leading to better methods of diagnosis, interception, prevention, and treatment. A health profession, to be worthy of the name, must be actively engaged in this quest, even if it challenges current thinking and the economics of clinical practice.

A second motivation is, quite candidly, the status of institutions of dental medicine and, in the larger context, of the dental profession itself. Dentistry must end its second-class citizenship vis-à-vis medicine. This can only be accomplished by promoting excellence in its intellectual base, by competing successfully in the larger arena of biomedical research, and by generating knowledge that not only benefits oral health but is relevant to systemic diseases. The goal must be to conduct quality science that is published not only in the Journal of Dental Research, but in Cell, Science, Nature, and the Journal of Clinical Investigation. It is imperative to strive to have members of dental school faculties chosen as Howard Hughes Scholars, elected to the National Academy of Sciences, and even nominated for Nobel Prizes. Lofty goals indeed! Perhaps the relevant question here is “why not?!”

Our recent experience in a number of dental institutions, including our own, has confirmed that outstanding basic scientists can be developed, nurtured, rewarded, and gain international recognition doing research on the oral and craniofacial complex, given a research-supportive environment and the appropriate commitment of resources. As stated earlier, it is not necessary to recruit individuals who already have dental medicine backgrounds. Indeed, recruiting scientists from other disciplines broadens the dental science research base and confirms that oral, dental, and craniofacial research is as important as any other.

Third, an enhanced research agenda and research environment will also have positive effects on student training. Research activity underscores the scientific underpinnings of the curriculum, provides role models for students interested in becoming informed clinicians as well as academicians, and provides an outlet for the introduction of students to research.

Fourth, few U.S. dental institutions have substantial endowments. Noteworthy scientific accomplishments are the raw material for raising public profile through the media, and provide synergies to advance fundraising and development efforts.

Finally, good science attracts corporate support. This can be beneficial in helping to fund infrastructure for clinical research, in providing funding for proof-of-principle studies, and in generating discretionary funds for supporting the basic research mission. The corporate contacts developed can also be valuable as outlets for the commercialization of intellectual property. This type of support clearly has benefits for the institution.
All of these reasons notwithstanding, one of the continuing problems that dental schools have faced over the years is the somewhat fickle nature of NIDCR priorities and funding patterns. Although well intentioned, when program project grant support is threatened, when Centers of Excellence are terminated without adequate notification or replacement, when grant funding is delayed, and when priorities in research shift abruptly, scientists and support staff are displaced, and a carefully built critical mass of scientists can quickly dissolve. Frustration ensues and dental schools wind up with diminished funds, a situation that is not viewed positively by the parent institution.

An important recommendation of this paper is for NIDCR to review and revise its strategic plan to focus on long-term principles, policies, and objectives. Dental schools and other constituencies should actively participate in this process. Such a plan would help dental schools to plan their future programs and to stabilize the critical mass of faculty and funding.

Leadership

Simply stated, leadership matters! Leadership, more specifically leadership with vision, is as essential as infrastructure and financial resources in establishing new scientific paradigms for dentistry. Several elements are critical. These include a true commitment to making an important contribution to knowledge generation. When push comes to shove and competing constituencies are demanding financial resources, adequate support must be identified and allocated to research on an ongoing basis. Does every dean and research director have to be an accomplished scientist to further a research agenda? The answer is no. But leadership must be actively engaged in the intellectual aspects of dentistry on some level. An institution’s leadership must, collectively, have “good scientific taste”—that is, be able to recognize and evaluate superior talent—or have the wisdom to delegate these key decisions to advisors who do. And leaders must be good spokespersons, able to articulate the meaning and value of research to internal and external constituencies. These include faculty, students, clinicians, central administration, alumni, potential donors, politicians, and the communities where dental schools reside. Finally, leadership must provide the persuasive force for research as an integral component of the fabric of dental education, not as an isolated entity that furthers a schism between science and clinical education.

None of this is possible without a strong and vibrant partnership among dental schools, NIDCR, ADEA, AADR, and ADA. As articulated above, this partnership must be extended to include new programs in training, infrastructure, technology acquisition, and support of basic translational and clinical research. Dental schools are a strong and established force within the nation. As a national resource, they not only provide sites for the performance of research that furthers the NIDCR strategic agenda, but they are often able to provide political support that is periodically needed to perpetuate this vital NIH effort. Dental schools and research institutes will also be in the vanguard of the furtherance of dental medicine as a profession. Without research as an integral part of the fabric of dental medicine, the profession will be relegated to teaching the history of its field, and will have no way to invent its future.

Summary of Recommendations

What dental schools can do:

1. Conduct an audit of strengths and weaknesses and generate a strategic plan for research. Identify one or more areas in which to concentrate scientific effort.
2. Identify qualified, visionary leadership for the overall research effort.
3. Recruit, with other units in the university, health center and/or neighboring institutions, outstanding scientists who can compete in the larger arena of biomedical science.
4. Generate a business plan to identify the necessary financial support and infrastructure on an ongoing basis.
5. Establish working relationships with other units in the university and health center and neighboring institutions.
6. Recruit a cadre of dental students primarily interested in science by partnering with NIDCR and ADEA novel recruitment and student selection criteria.
7. Enter into a partnership with NIDCR, ADEA, AADR, and ADA to create a new program and novel incentives for training scientist-dentists.
8. Provide tuition forgiveness and/or development expertise to lead “superfund” contributions.
9. Commit to excellence.
What NIDCR can do:
1. Review and revise the NIDCR Strategic Plan for research to focus on long-term, consistent policies and objectives.
2. Provide seed money of $5 million/year for the “superfund.”
3. Provide new Biomedical Research Development Grants (BRDG) to jump-start research initiatives in dental schools that are less research-intensive.
4. Extend the T35 mechanism to college students; increase the size of K series transitional awards.
5. Assist dental schools in seeking support from NCRR and other NIH agencies for facilities grants and GCRCs.

What ADEA and the ADA can do:
Take the lead to coordinate a superfund campaign of $250 million designed to recruit and retain clinician-scientists, thus renewing the “Dental Academy” and enhancing the scientific basis of dental medicine.

REFERENCES