Can biomedical science be made relevant in dental education? A North American perspective

Bruce J. Baum

Gene Therapy and Therapeutics Branch, National Institute of Dental and Craniofacial Research, NIH, Bethesda, MD 20892-110, USA

© Blackwell Munksgaard, 2003
Accepted for publication 5 June 2002

For many years I have argued that biomedical science was a powerful force, under-appreciated by the dental education community, which soon would have a major impact on the nature of dental practice (1–4). This opinion has only become stronger over the last few years, as a result of the truly phenomenal progress being made in the biomedical sciences. My sense of the rate of this progress certainly is a reflection of the field of research in which I am engaged and whose literature I routinely read, i.e. gene therapy. Gene therapy offers a level of biological manipulation that elicits considerable interest, and provides major scientific and clinical challenges. Although the field has significant problems, I have been especially impressed by the first report of a successful human gene therapy trial in France, described in 2000 (5). Two small children (8 and 11 months) with a severe combined immunodeficiency, who were confined essentially to a protective isolation ('bubble') environment in a hospital, were treated by a gene therapy procedure, and thereafter have been able to live with their families and experience a normal life.

While the recent examples of biomedical science progress, directly affecting dentistry may not be as dramatic; they are certainly as meaningful and becoming more numerous. For instance, Kelly et al. (6) reported defining a peptide region of the Streptococcus mutans adhesin protein that is critically involved in tooth colonization and plaque formation. They then synthesized that peptide and, in a clinical trial, showed it specifically could block S. mutans colonization in patients for up to 3 months. Many dental applications have been described for the bone morphogenetic proteins (BMPs; 7). For example, in a pre-clinical model (nude/immunodeficient rats), Alden et al. (8) showed that transfer of the BMP-2 gene into mandibular osseous defects using a recombinant adenoviral vector led to repair of the defect within 3 months. Similarly, in a pre-clinical study, Rutherford (9) used adenoviral-mediated delivery of the BMP-7 gene for ex vivo gene transfer to ferret dermal fibroblasts. When these transduced cells were administered to teeth with a reversible pulpitis, they induced reparative dentinogenesis with apparent regeneration of the dentin–pulp complex (9). Perhaps the most advanced applications of biomedical science involve patients with head and neck squamous cell carcinomas. In controlled trials, use of a specially engineered recombinant adenovirus as adjunctive therapy resulted in tumour-specific cytolysis and enhanced tumour susceptibility to conventional chemotherapy (10).

As these four examples suggest, the biomedical sciences are unequivocally changing the treatment of conditions that are a part of routine general and special dental practice. While these examples are still at different stages of research, it is doubtless that all (or variants of them) will be commonly used clinically within the next 10 years. Unfortunately, from my perspective, these and other highly relevant examples have not led to any substantive change in the way biomedical sciences are being taught in dental schools. Dental educators in most industrialized countries still do not seem to be preparing their students to administer biological therapies in the fairly near future (4, 11).

In North America, the region with which I am most familiar, the average dental student today graduates with little sense of the impending clinical biotechnological revolution and how it could influence his/her plans for practice. They are often unaware of the significant applications to dentistry being made in
gene therapy, tissue engineering, and related fields. Often, initial publication of many such advances are not found in the traditional dental literature, although this is changing. However, there are numerous review journals and other publications, dental in scope, which make accessible current information about relevant biomedical science advances. Additionally, clinicians and dental school faculty members, particularly in industrialized countries, usually have access to the Internet and with that electronic journals and biomedical literature search engines (e.g. PubMed). Thus, they are able to seek out information on scientific advances in fields related to dentistry. Nonetheless, most North American dental students pass through dental school without experiencing any academic pressure to be conversant about biomedical science progress as it relates to their chosen clinical discipline.

### Learning about science

At a practical level, it is important to recognize that science can function both as a noun (facts to be learned or systems to be understood) and a verb (the process of logical thought and generating knowledge; 4, 12). It is clearly necessary for dental students to learn, to some extent, fundamental biological facts, so that they can understand normal function in tissues that they will be responsible for treating clinically. They also must know certain details relevant to understanding the pathogenesis of, and treatment for, oral and dental diseases. Many North American dental students graduate considering that relevant science is just the set of scientific facts they memorized during their first 2 years. However, arguably, the most critically relevant feature of science for all types of clinical training, including dentistry, is the process of critical thinking (logical thought) that ultimately leads to establishing facts (13). Certainly facts in science can change with time, as we learn more and understand phenomena better. Notably, as McManus suggested in 1991 (14), most of what we teach students by way of facts can be considered as irrelevant or forgotten in a short time. Rather, he and many others argue that it is most critical to teach students how to learn when they recognize a need to know (14).

For a future dental practitioner to use an adhesin-blocking peptide or a recombinant viral vector in treating their patients, society rightfully should expect that the practitioner has some broad general understanding of the biological manipulations involved, i.e. know some facts and processes. However, for clinicians in every age and society, irrespective of the status of scientific knowledge at the time or their society’s state (or lack) of affluence, practising critical thinking and logical thought processes enables them to diagnose and treat their patients better.

Unfortunately, it seems that many within dentistry consider efforts to increase the substance and role of biomedical science in dental education as a challenge to a romanticized technical soul of the profession (e.g. 4, 15–17). Appreciating science, understanding science, and thinking scientifically, however, do not denigrate the traditional technical skills required for current dental practice. Rather, understanding tissue biology and disease, using rigorous logical thought in providing clinical care, and appreciating how biomedical science leads to therapeutic advances, are desirable under any circumstance for any clinical discipline, including all facets of dentistry.

### Why have there been no substantive changes?

The answer to the question posed in my title is of course yes; biomedical science can be made relevant in dental education. However, it has not happened despite highly visible calls to do so (e.g. 17–19). Why is that so? At least in North America, the under-valuation of science and scientific inquiry by most dental school administrators and faculty members as well as by the practising profession, forms the single most critical impediment to making science relevant in dental education. This under-valuation creates a somewhat inhospitable atmosphere that has given rise to many individual manifestations of the overall impediment; each one posing a significant hurdle to overcome (2, 4, 20).

Perhaps the best example of one such manifestation is access to curriculum time (17). For virtually every dental school a holy grail of dental education is clinical training. A reduction in the time students spend in the clinic is essentially a non-starter; it is very unpopular. There is a reasonable pedagogical argument for this circumstance, i.e. the current practice of dentistry is essentially technical. Students must graduate with (and thus be ‘certified’ by a school as having) a reasonable level of competency at providing clinical dental care for society. However, another factor that is likely of major influence is non-pedagogical. Most schools receive a sizeable portion of their operating costs from student-generated clinic income. Therefore, any suggestion to reduce clinic time for students to enhance scientific relevance has a major negative correlate: the school’s financial status will suffer considerably.
A second example resulting from the under-valuation of science comes from the practising profession, independent of, but certainly affecting, dental schools. Following graduation, students must pass standardized examinations in order to be eligible for licensure, i.e. remunerative practice. Licensure examinations in North America put little to no value on critical thinking skills, on complex patient management skills (e.g. caring for ambulatory, medically compromised patients), or on the integration of biomedical sciences with clinical care (17, 21). Students recognize quickly what is needed in order to pass their licensing exams from more senior students as well as from the clinical faculty, and accordingly focus their energies on becoming proficient at technical dentistry. It is not worthwhile for them to spend time on biomedical science or critical thinking skills.

A final example is a reflection of North American culture; value comes from a level of compensation. The more something costs, the more it is valued in North America. Apparently, according to this value system, most dentists in private practice do not put much value on diagnostic or complex patient management skills, i.e. the intellectual contribution to patient care, because the compensation for these services is quite small. Students learn this lesson quickly by observation (e.g. advertisements promoting low fees for examinations). Additionally, most clinical faculty members, to some degree, engage in private practice and often convey information, including fee structure, about private practice to their students. If practising dentists and clinical faculty valued diagnostic and management services, students would be more inclined to learn desirable diagnostic and management skills (22, 23).

**The process of making science relevant**

There is no magical formula to make science relevant. Most importantly, there must be an overt recognition by faculty and administrators that biomedical and other sciences are important to becoming, as well as remaining, a competent dentist in the early 21st century. Most dental educators realize the essential elements that are required for such change, for these elements are among the same as are needed for conveying value to any portion of a curriculum in a professional school—repetition, reinforcement, and role modelling (22–24). With respect to science, these elements simply are not being instituted because valuing science in general, and biomedical science in particular, involves making a markedly significant cultural and attitudinal shift in dental schools (4, 16, 20). Other concerns are valued more, and thus reinforced, practiced, and displayed by most faculty members.

At a practical level, there are many pedagogical tools that a school can employ to bring about a change in its values, and some that I hope may be useful are described below. To achieve biomedical science relevance in dental education, however, requires faculty members to become educated in modern biomedical science to some degree, to appreciate the principal method of science (logical thought, critical thinking), to engage in discussion, to co-operate and be collegial, and to display openness to grow pedagogically and professionally (25). There also must be a realization that there is no single plan that can be easily applied at every institution. Rather, certain tools may be more useful at one versus another school or in one versus another cultural environment (17). The process of bringing about a significant change in educational values at any school in itself is experimental (i.e. a scholarly pursuit) and, appropriately, should be treated as such by a university community. University and dental school administrators must lend both serious commitment and tangible (financial) support.

**Five directions to consider**

**Faculty development**

The single most important step required to make biomedical science relevant to dentistry is to bring about faculty change through further training and education (4, 17, 26). The faculty members in a dental school, especially the clinical faculty, are critical to the professional development of students. If dental students are to be better versed in science, facts, and process, then it will be the clinical faculty who are best positioned to promote this. Dental school faculty members are dedicated individuals who are under considerable academic and societal pressure to create competent dentists out of entering dental students. Asking more of them creates an added burden, in terms of their workload, knowledge, and possibly their pedagogical expertise. Thus, any administrative effort to increase the relevance of biomedical science in dental education must recognize and address these individuals and their burdens. If, for example, clinical faculty members are required to discuss the medical status of patients and relevant dental/oral pathogenic mechanisms, the administration must provide opportunities for in-service faculty training to ensure their competence at these new activities. Furthermore, faculty who successfully conduct these new, desirable, and demanding functions should receive appropriate rewards from their
universities (either/both academic and remunerative) in recognition of their essential and scholarly contribution to enhancing dental education (27, 28).

Promotion of critical thinking skills
Dentistry is often criticized for being too technique orientated, emphasizing the mechanical versus the biological. However, science is based on techniques as well, and the single most important technique in science is the practice of disciplined, logical thought – critical thinking. Competency in this technique comes from practice. It is a learned skill, promoted in graduate schools and rigorously nurtured in post-doctoral science training.

There are many ways to promote the development of logical thought processes in students. What is essential, however, is that the value for any of these activities is not in arriving at a correct answer, but rather in the way the student comes to an answer. Students and faculty should recognize that an incorrect answer, reached through a process of stepwise, logical reasoning, is not a negative outcome. Early in their professional training, substantive exposure to student-centred learning modes (problem or case-based learning for example) can foster logical thought versus memorization and recall (12, 29–33). The latter are promoted by more traditional, teacher-centred pedagogical methods. Experimental training in science (laboratory experiences) also provides a simple opportunity that directly models the same logical thought processes that are valuable and necessary, clinically. For example, both the laboratory and the clinic can present the student with a puzzling circumstance: a failed experiment and a patient with a complaint, respectively. Similarly, both involve gathering information about the problem before reaching a decision, i.e. obtaining existing data related to the experiment, and determining symptoms and signs in the patient. The knowledge-based thought process leads to an hypothesis in the laboratory, and to a differential diagnosis in the clinic. Finally, this logical progression results in a specific outcome, either a new experiment or a treatment plan. A particularly nice thing about student laboratory experiments is that when mistakes in logic occur, they generally have insignificant consequences, in contrast to when mistakes in logic occur in the clinic with a patient.

Patient-based discussions ‘rounds’
In North America, dental students obtain the vast majority of their clinical experiences interacting with individual clinical faculty members. These discussions may be either enlightening or not, they may be biomedical or procedure orientated, they may be logical or dogmatic. Whatever the nature and quality of the interactions, they are certainly limited. The result is that students can graduate from dental school having, in fact, seen a relatively small number of patients, despite having performed a relatively large number of different procedures with competency. Given the wide variety of ambulatory dental patients who can present to a practising clinician, experiences with more rather than less patients is certainly desirable for pre-doctoral students during training.

A traditional approach to gaining broad clinical experience in medical education is bedside rounds. This activity enables a large number of trainees (pre-and post-doctoral) to share experiences and ideas, to question and to be questioned, and to have fundamentals of biomedical science reinforced in the context of individual patients and their problems. Clinical rounds also demonstrably promote the value of collegial interactions when making significant patient management decisions (34).

While traditional in-patient bedside rounds are irrelevant in the context of pre-doctoral dental education, numerous variations on the theme are reasonable to consider. For example, in our clinical research programme (the NIDCR Sjogren’s Syndrome Clinic), senior clinical staff, post-doctoral trainees, nurses, and students who are on external rotations, meet for weekly ‘chart rounds’ in a conference room to review patients from the past week(s). The discussion includes examination and clinical laboratory results, diagnoses, pathobiological considerations, protocol eligibilities, potential complications, etc. While only one or two individuals may have seen any given patient, all learn from the encounter. In a dental school environment, clinical instructors or post-doctoral speciality trainees easily could use this format regularly to review interesting and educationally valuable cases, reinforce biomedical science, and develop critical thinking skills with small groups of pre-doctoral students (i.e. 5–10). Such an activity can significantly increase the exposure of students to a variety of patient-related issues (e.g. treatment planning strategies, management of medically compromised patients), as well as promote collegial interactions (4, 17).

Reading scientific literature
In North America, during their clinical training years, it is not essential that pre-doctoral (in contrast with post-doctoral speciality) dental students become conversant with any scientific research-based literature, even as it relates to issues in routine clinical practice. Discussions between clinical faculty and pre-doctoral students about patients, their problems, and their treatment,
rarely involve reference to published scientific literature. The recent movement toward evidence-based dentistry in part stems from the recognition that much clinical care in dentistry (as in medicine) is not based on scientifically proven and peer-reviewed fact, and requires evaluation and re-evaluation (35, 36). Indeed, this movement and related activities, such as the Cochrane Collaboration (37), have done much to impart to dental educators the importance of and value to the critical assessment of scientific research upon which recommendations for clinical care are based.

Most pre-doctoral dental students are not routinely required to read current clinically relevant science-based articles. If they are to practise evidence (scientifically)-based dentistry following their graduation, they must learn to utilize relevant clinical research journals while in dental school. Placing value for students on the clinical research literature, such as would occur if clinical instructors commonly would refer to research articles in the context of patient-related discussions with pre-doctoral students, could convey to students that this activity is of critical importance to their professional development (38).

Students need to learn what for them is an important clinically relevant scientific article, and how to read it. As with acquiring skills in critical thinking, the ability to read and understand clinical research publications is a learned skill. This is a skill that requires guidance from the faculty and requires practice by the student. Teaching students the importance of and how to read the clinical scientific literature can be accomplished within the context of existing courses at a dental school, or can be the subject of a separate, multiyear course. Like other traits of value for a health professional, reading scientific literature must be associated with faculty repetition, reinforcement, and role modelling. If pre-doctoral students are in the habit of reading peer-reviewed literature relevant to patient care while they are receiving their professional training, it is likely that they will continue the practice after graduation (39, 40).

Practical training of students in internal medicine

I have long been an advocate of dental students receiving clinical training in internal medicine as part of their pre-doctoral education (4, 41, 42). I have numerous reasons for this viewpoint, many of which are tangential to the present concern. However, there is one reason that is quite relevant. Dental students around the world take formal classes in many fundamental biomedical science disciplines, e.g. biochemistry, physiology, pharmacology, etc. These subjects also occupy a large segment of the early training time of students. Following completion of these courses, particularly during the clinical training years, students (and faculty) seem to ignore these disciplines (4, 11, 17). At least in North America, surprisingly little effort is expended to convey value for, or utilize in any way, this portion of dental education. I often refer to dental school training in the biomedical sciences as merely a rite of passage, with no practical outlet.

The principal reason for pre-doctoral dental students to receive training in internal medicine is that they can immediately recognize a reason for learning about such subjects as cardiac muscle contraction, kidney electrolyte transport, and oxygen exchange in the lung. Time on in-patient wards can provide a myriad of scientifically based experiences, providing them with a general appreciation for disturbances in normal function, allowing them to appreciate the use of many pharmaceuticals upon which they have been lectured, and (unfortunately) to see examples of, and responses to, adverse affects. These are patient-based experiences that likely will be indelibly impressed upon them as clinicians (43). Certainly as dentists they will not be called upon to treat patients for emphysema or congestive heart failure or renal insufficiency, but they will, in great likelihood, be treating the dental problems of patients with such conditions in their offices and clinics (3, 17). Training in internal medicine will provide relevance for much of a pre-doctoral dental student’s biomedical science education, and it will also help them to care for people and not merely perform procedures (3, 4, 44).

Conclusions

There is overwhelming evidence that biomedical science is relevant to, and capable of dramatically influencing, the practice of dentistry. Dental educators, organized dentistry, and practising dentists have a choice: do they wish to engage or avoid this influence? The benefit of avoiding biomedical science is maintenance of a comfortable status quo. This has been the choice to date in North America, and superficially it is understandable. However, like many choices, this selection has a downside. The benefit of comfort comes with potentially severe risks: to become irrelevant or secondary as a health profession, and to be training students who, in all likelihood, will become obsolete during their practice lifetimes.

The benefits of engaging biomedical science are more idealistic – professional growth and, likely better, more universal, dental care for society (45). This too has considerable risk for it will lead to financial burdens.
on schools, the need to develop training and development programmes for existing faculty, increased training time for students, re-structuring licensure procedures, and ultimately a different style of dental practice from that which exists now. However, such risks are consistent with dentistry’s growth as a profession. In my view of reality, there is no choice; if dentistry is to remain a significant health profession it (schools, organizations, practitioners) must embrace biomedical science and scientific thinking, and make it relevant at many levels. As the ancient sage Hillel said 2000 years ago, ‘if not now, when’? (46). We may not have the opportunity for choice much longer.

Acknowledgements
I wish to thank Drs J. Atkinson, E. Gagari, D. Nash, S. Pillemer, V. Sankar, J. Ship, M. Snead, and S. Tran for their timely and constructive comments on an earlier draft of this essay.

References

Address:
Dr Bruce J. Baum
GTTB, NIDCR, NIH
Building 10, Room 1N113, MSC-1190
Bethesda, MD 20892, USA
Tel: +1 301 496 1363
Fax: +1 301 402 1228
e-mail: bbaum@dir.nidcr.nih.gov