Fabricating a Face: The Essence of Embryology in the Dental Curriculum

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Abstract: The current explosive growth in developmental biology, fuelled by the almost completed sequencing of the human genome, is bound to have a profound impact upon the practice of medicine and dentistry in the twenty-first century. No other discipline more accurately reflects this impact than embryology, which combines the basic and clinical sciences of genetics, ontogeny, phylogeny, teratology, and syndromology into the essence of modern medical and dental practice. The advent of in vitro fertilization, chorionic villus sampling, amniocentesis, prenatal ultrasonography, intrauterine surgery, and stem cell therapy has vaulted the previously esoteric subject of embryology into clinical consciousness. All these aforementioned procedures require an intimate knowledge of the different stages of development. The alphabet soup of acronyms that now peppers papers proclaiming the genetics and characteristics of various growth factors and cytokines (e.g., FGF, TGFβ) are all based upon an understanding of the developmental mechanisms occurring in the embryo and subsequently in wound healing and oncology. Congenital abnormalities ranging from lethal syndromes to dental malocclusions cannot be diagnosed, treated, cured, or prognosticated upon without a sound conceptualization of embryology. Computer technology has revolutionized the understanding and teaching of embryology by portraying developmental phenomena as three-dimensional model images in sequential depictions of changes proceeding in the fourth dimension of time. Embryology must now form the essential core of the basic sciences in medical and dental curricula. Future dental practice will become rooted in the genetics and morphogenesis of facial fabrication.

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As Isaac Newton said, “What we know is a drop; what we don’t know is an ocean.” Of all the subjects listed in the curriculum survey of 1998 predoctoral dental educational institutions by the American Dental Association, no mention is made of embryology. While it is accepted that this topic might be covered under a variety of titles listed in the survey, including “Gross Anatomy,” “Head and Neck Anatomy,” “General Anatomy-Microscopic,” “Oral Histology,” or even possibly “Genetics,” the omission of embryology as a significant and identified basic science is an indictment of the past century’s undergraduate dental curriculum. More recently, however, the National Board Dental Examination Specifications for 2002 recognized “general embryology” as a minor component of “anatomic sciences” by allocating two out of 100 test questions to the subject. That embryology should be a sine qua non component of the twenty-first century dental curriculum is self-evident in the face of the torrent of information on molecular biology, genetics, and reproductive technology that is influencing our biomedical research environment and also our daily lives. It is somewhat paradoxical that the demise of gross anatomy as the most fundamental of basic sciences necessary for the practice of dentistry, as evidenced by the ever-diminishing time allocated for its teaching, has occurred at the same time as we have seen the emergence of the most vigorous branch of current biology, viz., developmental anatomy, which demands increasing attention and surely dedicated curriculum time. Even the evolutionary aspects of jaws development should be a component of a modern enlightened dental education in the newly developing discipline of “evo-devo.”

The completed sequencing of the human genome is bound to have a profound impact upon the practice of medicine and dentistry in the twenty-first century. The burgeoning new sciences created to explore gene function will also influence the landscape of biomedical science: viz., genomics, proteomics, transcriptomics, metabolomics, and cellomics provide a background environment of diagnosis, prognosis, prevention, and therapeutics that will become part of clinical practice. The current controversies concerning stem cell creation and its therapeutic applications, all of which are rooted in embryological insights, will inevitably have implications for the clinical practitioner. The ethical, legal, religious, and social implications surrounding embryo creation, “designer babies,” preimplantation genetic diagnosis, and stem cell research are among the most significant dilemmas of our times and require insightful knowledge of embryology.
vent of in vitro fertilization, embryo selection and implantation, chorionic villus sampling, amniocentesis, prenatal ultrasonography, and intrauterine surgery has vaulted the previously esoteric subject of embryology into clinical consciousness.\textsuperscript{10} The alphabet soup of acronyms frequently used in papers proclaiming the genetics and characteristics of cytokines, growth factors, and transduction signals are all based upon an understanding of the developmental mechanisms occurring in the embryo and subsequently in wound healing and oncology.\textsuperscript{11}

The study of embryology was until recently a largely descriptive account of the complex cascading choreography of unfolding events of morphogenesis. Its study was largely esoteric and perceived to have little relevance to clinical practice. Embryology seldom found its way into the dental syllabus and, when it did, was given cursory attention, focussed mainly on tooth development as part of oral histology courses.

The increasing sophistication of intrauterine imaging techniques is revealing ever-earlier stages of fetal formation and, significantly, malformation that may allow diagnosis and possible treatment.\textsuperscript{12} The advantage of an intimate knowledge of embryology at different stages of development has immense potential in translating this “basic science” information into clinical decision-making in the treatment of abnormal fetuses and subsequently diseased infants. The basis for understanding the mechanisms underlying normal and abnormal development is inherent in embryological education and thus provides insights into the organization of adult anatomy and its aberrations recognized as syndromes.

The inclusion of embryology in the dental curriculum will enable the clinical scientist of the future to overcome the artificial barrier between the laboratory bench and patient treatment in combining basic science with clinical practice. Embryology is just as significant for the dental student as it is for the medical student.\textsuperscript{13} The fetus in-utero now becomes a potential patient with the diagnostic capabilities of gene sequencing and single nucleotide polymorphism (SNP) identification of disease states.\textsuperscript{14,15} The elucidation of syndromic genes has enormous preventive and possible therapeutic potentials.\textsuperscript{16} Amniocentesis and chorionic villus sampling can now screen the embryo and fetus for potential problems and prognostic determination.

The existence of the 400-member Craniofacial Biology Group of the International Association for Dental Research and of the Society of Craniofacial Genetics attests to the significance of the ongoing research in the field of developmental anatomy. The American Cleft Palate-Craniofacial Association has established a core curriculum that explains the syndromes with which its members and the inquiring public are concerned.\textsuperscript{17} An understanding of embryology and the development of craniofacial syndromes are key components of this curriculum. The increasingly sophisticated inquiries by the public about genetics and its implications for reproduction and development are being revealed on websites\textsuperscript{18} that require clinicians to be as informed on these matters as are the lay public. The delineation of syndromes is largely determined by dysmorphogenesis, based upon understanding ontogenesis.\textsuperscript{19,20} The necessity for clinicians to be educated in embryology and its related fields is self-evident.

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Relevance of Embryology to Oral Health Care

In pathology, the phenomenon of inflammation invokes a cascade of growth factors and cytokines that is akin to embryonic developmental mechanisms. These mechanisms provide the concept of “ontogenic inflammation,” by which normal embryonic development acts as a prototype model for inflammation that regulates homeostasis in the adult. Insights into the biology of tissue healing will lead to advances in surgical repair. Intrauterine surgery for repair of orofacial clefts results in scarless healing.\textsuperscript{21}

The components of teratomas and hamartomas contain a range of tissues whose presence is only explicable on the basis of embryological histogenesis phenomena. The intrinsic mechanisms of organogenesis account for the otherwise strange presence of teeth in ovarian teratomata, whose treatment does not invoke dental intervention, but does require a knowledge of the features of odontogenesis. The teeth contained therein are not part of the masticatory apparatus, but are of pathological interest.

The details of odontogenesis have considerable importance for decision-making in clinical dentistry.\textsuperscript{22} The demise of all ameloblasts at the conclusion of their brief task of laying down enamel accounts for the fact that dental enamel has no reparative capabilities. Consequently, damage to enamel, whether by bacterial acid dissolution (dental caries) or trauma,
has led to the raison d’être of the establishment of the profession of dentistry that is devoted to the repair of damaged enamel. Dentists are the replacement soldiers of deficient ameloblasts. The potential for future engendering of amelogenesis for repair of enamel or replacement of missing teeth is based upon a fundamental understanding of odontogenesis.23,24 The manifestations of dentinogenesis imperfecta, the most common autosomal dominant disorder affecting humans, and its clinical treatment, require insights into the genetic origins and the material components of defective dentin to effectively handle the therapeutic approaches to patients suffering this disease.25

The genetic basis of tooth development and dental defects provides insights into the potential for effective diagnosis, prognosis, and the possible prevention of dental diseases.26,27 The rapidly expanding knowledge of the more than 200 genes that regulate odontogenesis occupy a website devoted to this topic.28 The elucidation of the functions of each of these genes will provide insights into their roles in odontogenesis. The capability of controlling these genes by mutation, deletion, or enhancing their expression will provide scientists and clinicians with untold therapeutic potential.

The potential impact of gene therapy on future dental practice has been revealed in bone repair and regeneration and salivary gland dysfunctions resulting from irradiation or Sjögren syndrome and in mucosal lesions and cancer.29 Gene transfer has been effected by viral vectors, DNA vaccination, or introduction of engineered cells. All these therapeutic modalities require acquaintance with embryological techniques that will form the basis for future clinical practice. One can envision a future in which dental diseases will be controlled from their initial genetic pathological misappropriations rather than the treatment of their consequent damage to the system. The whole regimen of dental practice will be predicated upon prevention rather than cure of diseases and disabilities.

Current Embryology Teaching

A survey of dental school curricula was undertaken, inquiring into the amount of time allotted and didactic methods used in teaching embryology to undergraduate and graduate dental students. The teachers of anatomy were surveyed in each dental school. Of the eighteen schools responding to a questionnaire sent to sixty-six schools, indicative in itself of the low level of interest in this topic, a wide disparity of responses was received. The 27 percent response rate was because embryology is rarely taught as a distinct course. A number of schools have no embryology courses, with one school responding that it was an elective subject, after the students requested its inclusion in the curriculum. At the other extreme, some schools reported thirty-two hours spread over the first and second years of the undergraduate program, and thirty-seven hours in the graduate orthodontic program were devoted to teaching embryology. The teaching methods varied from lectures alone to laboratory sessions with microscope slides and CD-ROM computer assignments. The extensive range of prescribed or recommended textbooks appears as Figure 1.

In my opinion, a recommended ideal embryology curriculum for dental students for which fifteen hours of lectures should be allocated would include the following topics:

• Mechanisms of embryology and early embryonic development
• Early orofacial development
• The pharyngeal arches
• The pharyngeal pouches and grooves
• Bone development and growth
• Skull growth
• The calvaria
• The cranial base
• The facial skeleton
• The palate
• The paranasal sinuses
• The mandible
• The temporomandibular joint
• The tongue and tonsils
• The salivary glands
• Muscle development
• The special sense organs: eye, nose, ear
• Odontogenesis

The availability of websites and computer technology to portray the transitions of embryonic development by the morphing of different stages of facial formation should make the teaching of embryology one of the most exciting topics of the basic science dental curriculum. The conversion of two dimensional slide images into three-dimensional models in sequential depictions in the fourth dimen-

372
edifying experiences for teacher and student alike. Should prove to be one of the most stimulating and dynamic subject for teaching. Far from the staid repetition of dead anatomical data in the curricula of medical and dental schools, the exploration and explanation of the rapidly burgeoning cornucopia of information on the phenomena of developmental biology should prove to be one of the most stimulating and edifying experiences for teacher and student alike.

REFERENCES