# Theoretical Mechanics And Practical Orthodontics*

SAM WEINSTEIN, D.D.S.,** and
DONALD C. HAACK, M.S.,***
*Lincoln, Nebraska*

## INTRODUCTION

Contemporary education, receiving its nutrients from basic research, continually refutes any policy of isolationism of the separate disciplines. While the boundaries between the basic sciences, at least by definition, may be sharp and definitive, any comprehensive research demands an interplay of bodies of knowledge—a synthesis of disciplines. The complexity of the problems of the physical world, just as those of the social, encourages a breakdown of isolationism. Particularly in the biological sciences is the multidisciplined approach becoming necessarily apparent. The biochemical marriage is a most solid and enduring one. The nuptial vows of biophysics are more recent.

As Rashevsky suggests, "application of mathematics to special biological problems is not new, but a systematic mathematical biology is timely. It is not now possible to 'explain away' phenomena of life in terms of physics, but this approach may be developed in the future. Since biological phenomena are closely related to physical phenomena,—there is a desire to unify all natural sciences."

The attempt at explaining the origin of life from non-living things seems nearer reality. Urey's classical work of the production of amino acids by subjecting certain simple gases to electrical discharge suggests a rapport between the viable and the nonviable—a unification of natural sciences.

To those disciples of practicality and office efficiency, it is acknowledged that purely theoretical hypothesizing may not have immediate practical interest of even urgent direct application to some experimental set-up, let alone positive correlation to this year's income. However, the history of physics reveals that pure theoretical developments led decades later to most astonishing practical results. Today's eminently useful duality of the benison and cataclysm of atomic fission are some years removed from the theoretical dreamings of Bohr and Einstein. More pragmatically, Gottlieb suggests: "The results of today's research is destined to be an integral part of the practitioner's work of tomorrow."

In contemporary orthodontics, a unique situation attains in that the dentist must of necessity combine his knowledge of the problems, sciences, and techniques of general dentistry with sciences usually considered tangential to his field—such disciplines as embryology, growth and development, anthropology, biochemistry, and particularly the science of force action-mechanics.

These additional disciplines are applicable to orthodontics, not in the segregated sense, but as important in-

* Presented at the January, 1959 meeting of the Midwestern Component of the Edward H. Angle Society.

** Associate Professor, Department of Orthodontics, University of Nebraska.

*** Associate Professor of Engineering Mechanics, Lecturer, Graduate Department of Orthodontics, University of Nebraska.

tegrated parts of the whole. It is principally with the science of mechanics and the importance of its application to orthodontics that this paper is concerned.

The physiological reactions which permit the movement of a tooth through its bony environment cannot be fully understood independent of a concomitant understanding of the actions of the initiating forces. Because of the classical work of Oppenheim, Sandstedt, Moyers, Storey, etc., some significant information is now available concerning the biological changes occurring during tooth movement. Though the mechanism of tooth movement is basically biological, it is initiated by force action and, until such time as teeth can be moved by injections or internal medication, the orthodontist will be vitally concerned with mechanics.

Sicher, whose impact on the biology of orthodontics has been significant, feels that in our contemporary attempts to surplant the early "mechanistic" or gadget approach by a more scientific biological one, we have tended to forget the pure physics.

Furthermore, research into the true nature of the biological mechanism of tooth movement is fruitless without a parallel understanding of the force action involved. Within the next decade, biophysical research in the field of orthodontics should answer a number of important questions, some of which might be:

1. What is the quantitative relationship between rate of tooth movement through its bony environment and the reactive pressures on the tooth root?
2. What part is played by the musculature and the geometry of the supporting bony structure in establishing positional stability of the dentition?
3. Can muscle tonus, i.e., the force which it exerts, be changed to accommodate new positions of stability of the teeth?
4. What is the relationship of pressure and the immediate deformation of the periodontal ligament?
5. Can growth of bone tissue be retarded by mechanical means?

## The Importance of the Concept of Equilibrium

The principle of equilibrium is manifest in many branches of science, physical and biological. All bodies are in equilibrium with their surroundings. Equilibrium controls the behavior of the stars in the heaven and the fish in the seas. The motion of the planets of the solar system and the motion of the electrons of the atom are manifestations of the same principle. The universality of the concept of equilibrium is such that the fact that teeth are in equilibrium with their surrounding environment cannot be questioned. The equilibrium with which orthodontics is primarily concerned is the static equilibrium of forces. In order that the body, in this case a tooth, be in static equilibrium, two conditions must be satisfied: 1. The vector sum of *all* forces acting on the tooth must equal zero, 2. the vector sum of *all* moments of forces acting on the tooth relative to any point must also be zero. Forces which may act on the teeth include those applied directly by the surrounding musculature, forces due to natural functions, such as mastication, forces due to pernicious habits, forces due to the presence of orthodontic appliances, and the *reactive* forces applied to the roots of the teeth by the surrounding bony structure through the periodontal ligament.

From the standpoint of the orthodontist, the idea of equilibrium of the tooth can be further analyzed. In line with the above hypothesis, it is obvious that the tooth must be in equilibrium at any particular instant. However, it may not be so self-evident that the teeth must also be in a mean state of equilibrium extending over a considerable period of time. Over such a period the effects of short term random forces can be expected to nullify each other so that the resultant tooth movement would be zero.

Resultant forces of long duration and repeated application enter into the mean equilibrium picture and under ordinary circumstances cause movement of the teeth. A resultant force in this case may be described as a sort of net force. For instance, a premolar subjected to a .1 oz. force exerted by the buccinator musculature and simultaneously subjected to, say, a .3 oz. force exerted by the tongue could be said to be subjected to a .2 oz. force exerted by the tongue and directed buccally. As long as the crown of a tooth is acted upon by a long term resultant force, the mean equilibrium of the tooth must be accomplished by the development of reactions exerted on the root through the periodontal ligament. Such reactive forces are the initiators of biological actions which culminate in tooth movement.

It must be emphasized that duration of application, as well as the vector properties of force, is important in determination of the mean state of equilibrium. It may be hypothesized that the product of force magnitude and time controls the rate of tooth movement.

## Stability

An additional area of theoretical mechanics which is of great importance to the orthodontist is stability. The orthodontist is concerned with the movement of teeth from positions of malocclusion to positions of good occlusion, but he should be concerned further with the stability of the teeth in their new positions. Putting the teeth into new positions of instantaneous static equilibrium is not enough. These positions must be ones of *stable* static equilibrium so that the teeth will not tend to drift back to their old positions of malocclusion or to new positions of malocclusion with the passage of time.

In general, a stable position is one to which a body will return readily and of its own accord if subjected to minor displacement. That is, the minor displacement referred to will cause the body to be subjected to forces which will dictate a return to its original position. If, however, the minor displacement causes the body to be subjected to forces tending to further increase the displacement, the body is said to be in an unstable equilibrium position.

Stability must consider the origin of some of the forces that act upon the teeth as previously mentioned, i.e., those forces emanating from the musculature, natural functions, or pernicious habits. These are the forces which must dictate whether or not a tooth is in a stable position. It should be noted that these forces do not include those exerted by the appliance, since consideration of these appliance forces could be justified only if the patient were to wear some sort of retentive device indefinitely.

Fischer points out, in connection with hazards of treatment, that "the stability of the denture in malocclusion is the result of the very same forces that will be responsible for the final positioning of the teeth after treatment."

Purely from the standpoint of mechanics, stable positions of equilibrium are always positions in which the energy stored in the system is a minimum. Since the laws of mechanics are applicable to the teeth individually and to the dentition as a whole, it must be concluded that stable positions of the dentition and its elements are positions in which the energy stored in the system is minimal. Here the system in which energy is stored must be considered to be the teeth, the pertinent bone structure, and particularly, the surrounding musculature. In some instances there may be but one stable location for a tooth or segment of the dentition, but in many circumstances there may be multiple positions in which stability will be achieved. An example of such multiple positions of stability would be molar crossbite. The maloccluded position is stable, since there is no tendency for the tooth to move from this position or to correct itself. This malocclusion represents one of several energy minima. When this crossbite is corrected orthodontically, a new position of minimum energy is achieved and the result is also stable.

Relapse of the treated dentition indicates that the teeth were left in unstable positions at the conclusion of treatment. Stability of the dentition need not imply that the teeth are stationary, since growth may present a changing set of conditions to which the teeth become adapted by appropriate movements. It can, however, be categorically stated that every relapse is the end result of instability.

## Mechanics of Materials

Another subdivision of mechanics with important ramifications in orthodontics is that of the mechanics of materials. Where mechanics as a whole is concerned with the forces of motions, mechanics of materials, in particular, is concerned with stresses, strains, and deformations. Since orthodontic forces are exerted through the medium of fabricated appliances, it is necessarily apparent that a knowledge of the mechanical properties of the materials involved is most essential. Each appliance as constructed by the orthodontist has certain essential mechanical characteristics, such as strength, stiffness, and resilience (energy storage capacity). These properties of the appliance are dependent upon the intrinsic properties of the material, strength, stiffness, hardness, and resilience, as well as the extrinsic properties characteristic of the appliance design, such as shape and size. Important quantitative characteristics of the appliance are dictated by the laws of mechanics of materials, and are of direct concern in that they control the magnitude of the forces exerted by the appliance, the deformation of the appliance, and the rate at which force will be dissipated. Since these properties govern the basic mechanics of the appliance they are of utmost importance for a thorough understanding of this essential tool.

## Summary


1. Scientific orthodontics requires a multidisciplined approach. No single branch of basic science can be sufficient support for its complete understanding.

2. Of particular importance to orthodontics is the science of theoretical mechanics- the science of force action. Unfortunately, most graduate students in orthodontics are not sufficiently prepared in this area by their undergraduate or professional training.

3. The importance of an understanding of force action should be self-evident in view of the fact that force must be relied upon to initiate biological reaction in the movement of teeth.

4. The concept of equilibrium is essential to an understanding of the forces acting upon individual teeth

or upon segments of the dentition. Such forces must include not only those acting upon the crowns but also the reactions upon the roots.

5. Since one of the criteria of successful treatment is the absence of relapse, stability is of primary concern in orthodontic therapy. Theoretical mechanics is the key to understanding and recognizing the characteristics of stable and unstable conditions.

6. The application of orthodontic forces through fabricated appliances makes essential an understanding of the mechanical properties of the materials of which these appliances are made. Mechanics of materials is the discipline embodying such knowledge.

309 Andrews Hall

## References

Rashevsky, N.: *Mathematical Biophysics*, Univ. Chicago press, Chicago 1938.

Wald, George: "The Origin of Life", *Physics and Chemistry of Life—Scientific American*, Simon and Schuster, New York, 1955.

Gottlieb, Bernard.: "Histological Considerations of The Supporting Tissues of the Teeth", *J.A.D.A.* 30: 1859-1883, 1943.

Oppenheim, Albin: "A Possibility For Physiologic Orthodontic Movement", *A. J.O. and O.S.* 30: 277-327, 345-368, June 1944.

Standstedt, C.: "Einige Beitrage Zur Theorie Der Zahnregolierung", *Nordisk Tandlakaretidscrift*, 1904-1905.

Moyers, Robert E.: "Peridontal Membrane in Orthodontics", *J.A.D.A.* 40: 22-27 January 1956.

Storey, Elsdon: "Bone Changes Associated With Tooth Movement, A Radiographic Study", *Australian J. of Dentistry* 57: 57, April 1953.

Fischer, Bercu: *Orthodontics*, W. B. Saunders, Phil., 1952.