Orthodontics and the millennial mechanical ideal

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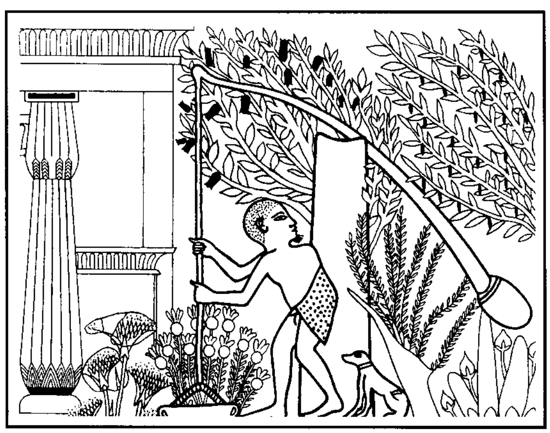
This historical retrospect is appearing in the 20th century's final issue of the *Angle Orthodontist*. This was the century that saw the rise of various specialisms within the field of dentistry, orthodontics prominent among them. This issue of the *Angle Orthodontist* also comes near the end of the second millennium, so it is fitting that we should trace the roots of orthodontics over a period longer than just the previous 100 years. At first sight this would seem a rather unrewarding task; after all, the term *orthodontics* wasn't even coined until the 19th century. A usual account of the field devotes a couple lines to tidbits from previous ages before moving on to chronicle the trial-and-error methods of the orthodontic pioneers of the nineteenth century and the rise of a more uniform specialty in the twentieth.

But such a restricted approach misses a fascinating point in the story of orthodontics, namely, it is the only branch of the healing arts that today, at the end of the second millennium, represents the mechanical ideal so in vogue in medical theory centuries ago. All this can be viewed within the framework of the interplay between technological developments and the way thinkers have viewed the human body.

In the Stone Age, there was little in the way of technology to influence medical thought. Primitive man viewing the entrails of an animal he butchered could hardly begin to speculate on what physiological functions they had served in life. So biological metaphors were drawn from natural forces and occurrences—wind, tides, fire, and the like—rather than from man-made devices.

The advent of artificial irrigation ditches, aqueducts, ovens, lamps, bellows, catapults, etc., in ancient civilizations brought about a different outlook. In the first century A.D., the great inventor Hero of Alexandria considered at least one of five basic devices—wheel (plus axle), wedge, screw, pulley, and lever—essential for any machine, in the same way that at least one vowel is indispensable for any word. In this spirit, some medical theoreticians came to view the human body as a machine of sorts.


Early technology

By far the most influential Greco-Roman physician was Galen (Claudius Galenus), who lived in the second century A.D. The Roman Empire was at the height of its power, and this was reflected by awesome feats of engineering. From the school of Hippocrates, the Father of Medicine some six centuries earlier, Galen adapted and indeed greatly elaborated on the principle of the four humors (blood, yellow bile, black bile, and phlegm) supposedly excreted by four organs (respectively, the heart, liver, spleen, and brain). The proper balance of the humors was theorized to be the basis of health. But apparently inspired by Roman technology, Galen devised an hydraulic theory of nerve transmission by which the cerebral fluid was forced through hollow nerves to stimulate action in the limbs and elsewhere. As for the liver and heart and their various pipes, Galen proposed physiological functions resembling those of a brewery and a smelting furnace. There were, however, no pumps or valves in Roman machines, and Galen did not conceive of a system of blood pumped by the heart, but assumed instead that it merely sloshed back and forth in the veins.

The Dark Ages

The collapse of the Roman Empire in the mid-fifth century marked the beginning of the Dark Ages and a long moratorium on technological innovations and medical theorizing. Roman aqueducts, viaducts, and monuments fell into disrepair, many medical manuscripts were lost forever, and medical thinking became dominated by religion, magic, and outright superstition.

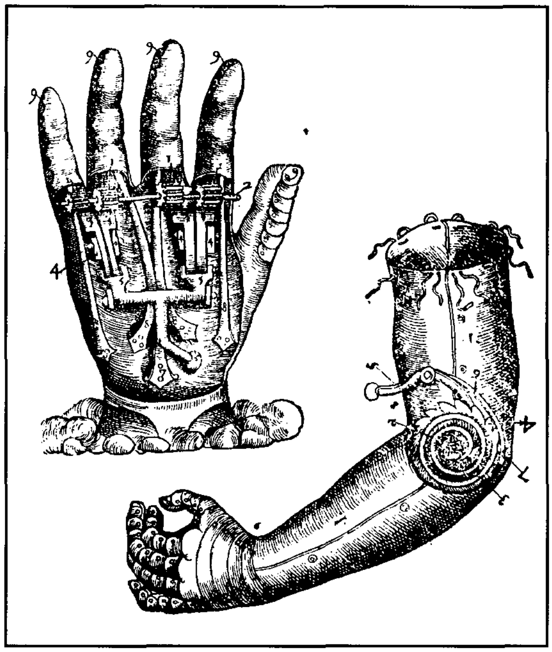
The year 1000 A.D. saw the dawn of the second millennium and roughly marks the end of the Dark Ages and the beginning of the High Middle Ages in Europe. There was a revival of commerce and the movement of ideas, and an awakening of interest in the ancient Greco-Roman philosophical, scientific, and medical manuscripts that had been preserved by Islamic and Jewish scholars and physicians across the Mediterranean or had survived deep in the vaults of the cloisters of Christendom. Christian Europe's first medical school was established in Salerno, south of Naples, around the turn of the new millennium. Universities soon appeared in Bologna, Paris, and Oxford, each with its own medical faculty.

How did dentistry fit into these scientific developments? It was pretty much the odd man out. There was much recourse to folk remedies, such as salves for toothache, and some of these may indeed have had analgesic, astringent, or tooth-loosening effects. There also remained plenty of superstitious practices involving teeth, and in the Christian religious context, toothache suffers could pray to their patron saint Appolonia, whose portrait adorned every medieval church.

When it came to practical procedures, dentistry was at best a craft limited to tooth-drawing. The Latin-speaking university-trained doctors left such manual work to lowly, often illiterate, barber-surgeons, if not to untrained charlatans. Tooth extraction then as now was the most mechanical of medical procedures, involving the application of vectors of physical forces to the hardest and most solid part of the human anatomy, albeit one often weakened by decay.

The Renaissance

Technological innovation in machinery took off during the Renaissance, the great flourishing of arts and sciences that began in the late fifteenth century. The Renaissance man par excellence was Leonardo da Vinci (1452-1519), renowned not just for his Mona Lisa and other artistic masterpieces, but also for his anatomical drawings (with due attention to the teeth and jaws), and his ingenious mechanical inventions.



State-of-the-art artificial hand and arm designed early in the sixteenth century by Ambroise Paré, relying on all the mechanical technology available to him

In the spirit of the age, many of Leonardo's contemporaries were similarly inventive. Francesco di Giorgio, in 1470, designed a turnbuckle bar-spreader/bar-bender. German master engraver Albrecht Dürer (1471-1528), whose etchings and woodcuts contributed to the information explosion from the new printing press, applied geometric theory to his works and developed a technique of three-sided orthographic presentations, standard in engineering and mechanical drawings today. He used this technique for anatomical analyses, not least regarding the proportions of the human head and jaw.

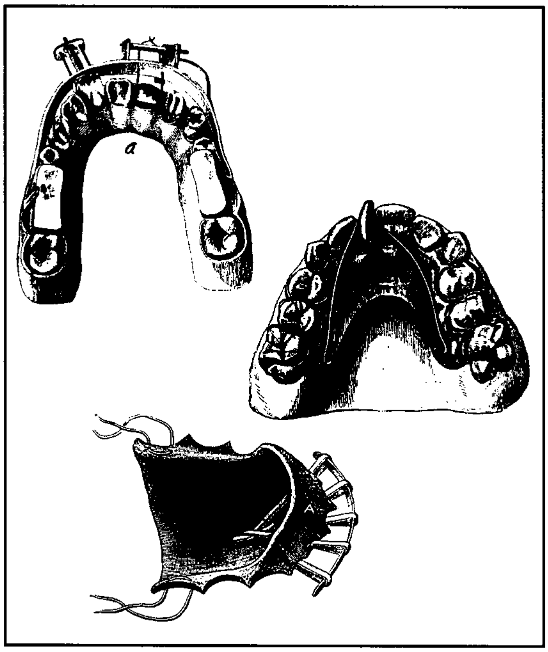
Fascinating were the prosthetic limbs designed (though never executed) early in the sixteenth century by Ambroise Paré (1509-1590), the Father of Modern Surgery. Master Paré devoted a fair part of his writings to dentistry, oral surgery, and prostheses. But most ingenious were the state-of-the-art artificial hand and arm he designed, relying on all the mechanical technology available to him. He incorporated various cogs and ratchet wheels of the kind used in clockmaking, a highly prestigious branch of engineering at the time. Most important for our story are the clock-mechanism springs in Paré's drawing. These were unknown to Hero of Alexandria and the ancients.

What has often been called the greatest discovery in the history of medicine—the pumping function of the heart and the circulation of the blood—was published in the first half of the 17th century by the Padua-educated English physician William Harvey (1578-1657). This came at a time when mechanical pumps, complete with one-way valves and a system of pipes, had entered general use for draining mines and fighting fires. Interacting with these practical and anatomical developments were monumental advances in theoretical mechanical physics, beginning with Galileo (1564-1642) and culminating with Isaac Newton (1642-1727). The high point in mechanics applied to physiology came from the French philosopher René Descartes (1596-1650). In his work *Traité de l'homme* (Treatise on man) he stated with regard to the human body: "I should like you to consider that these functions follow from the arrangement of the machine's organs every bit as naturally as the movements of a clock or other automaton follow from the arrangement of its counterweights and wheels."

Although Descartes's philosophical ideas about mind-body duality and consciousness remain valid debating issues today, virtually all the specific physical details he offered in the context of 17th-century technology to explain anatomical movement and internal processes were to prove false. The 18th century saw experiments with electricity and the discovery of its role in neural transmission. The latter half of the 19th century was an era of astounding breakthroughs in the basic sciences and medicine, particularly in Germany. Doctors shifted their focus from tangible, visible organs to cellular structures and their pathology, microbiology, the germ theory of transmittable disease, and the body's molecular chemistry.

The mechanical healing art

Dentistry, however, remained mechanical. The modern profession owes its foundation to the Frenchman Pierre Fauchard (1678-1761) and his tome *Le chirugien dentiste, ou Traité des dents* (The dental surgeon, or Treatise on the teeth). Aside from the physics and mechanics of tooth extraction, Fauchard dealt with filing, scaling, drilling and filling, ligations, crowns, and bridges. (An interesting oral mechanical application—a rare departure from teeth, gums, and jaw—was his development of a metal obturator to counter the ravages of syphilis upon the palate.) Although new techniques and tools would evolve, for most of the rest of the millennium dentistry would closely follow Fauchard's vision of precision, knowledge-based, tool-assisted manual operations plus the fitting of metal prostheses on 32 (or fewer) quite solid objects.



Orthodontic devices from the 1800s. Carabelli, 1840, used a screw; Tomes, 1850, a lever; and Kingsley, 1880, a wedge

In this sense, dentistry in the 19th century remained very much in keeping with the general spirit of the age. For despite the advances in chemistry and biology, the overall world-view was still dominated by clock-like mechanics presumed to underlie all the events of the universe. This was reinforced by the outpouring of goods and the transformation of society brought about by the industrial revolution, which was predominantly mechanical in nature. Noteworthy in the latter half of the 19th century was a philosophical current known as mechanical positivism, which was influential in the world of design. Perhaps its best reflection was the minimalist combination of springs, piano wire, and screws in pince-nez eyeglasses.

It's quite fitting and proper that in the midst of this 19th-century world-view we find orthodontics, the most mechanical of all the healing arts, coming into being in France, the Germanic lands, England, and the US. Previous to the 1800s, virtually nothing was done in the way of tooth correction. In the first century A.D., the famed Roman physician Paracelsus recommended strong finger pressure to quickly and forcibly straighten a crooked tooth. This advice was repeated here and there for 18 centuries. As for devices, the Etruscans of pre-Roman Italy tried some metal tooth-straightening attachments, and in the 18th century Etienne Bourdet, a student of the aforementioned Pierre Fauchard, crafted lingual arches of ivory with holes through which string ligatures could pull misaligned teeth.

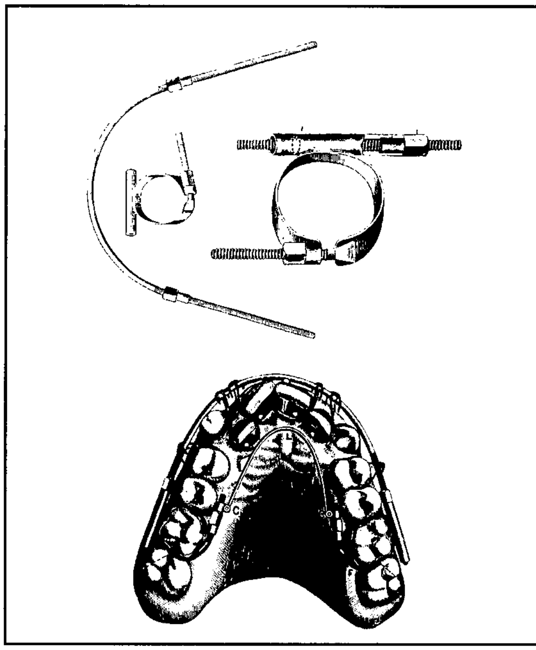
In the 19th century, a dozen dentists—including Parisians J.M. Alexis Schange and William Rogers (an American in Paris), Berliner Christoph Kneisel, Viennese Georg Carabelli, Englishman John Tomes, New Yorker Norman W. Kingsley, and San Franciscan Emerson C. Angell—were inventing orthodontic devices and publishing drawings of their models. Here we see all of Hero's devices in various combinations, often delicately refined in the spirit of the clockmaker's art. Carabelli and Angell used screws (including a variant of Francesco di Giorgio's turnbuckle), Kneisel and Tomes used varieties of levers, Kingsley used wedges, Carabelli used a form of pulley, Rogers used a wheel-and-axle.

But no less important was the spring, which was unknown to the ancients but came into its own with the development of clockmaking in the Renaissance. We find springs in the work of Kneisel, Tomes, and Schange (in the latter case, interestingly, in the form of a rubber band rather than a metal spring). Others made use of lingual arch springs and serpentine springs.

Depending on the device and the dental abnormality to be corrected, the forces, whether by screw, spring, lever, wedge, pulley, or wheel, were applied to the teeth as pushes or pulls from the labial or lingual sides, or from a lateral or vertical direction (in the latter case driven by bite pressure), or circularly as rotation around the tooth's axis. In some instances, namely overcrowding, a force applied to teeth was not intended to move the teeth but to break the palatal suture.

Another sign of the times was that several of the dentists who pioneered orthodontics were American. This was in keeping with a geographic shift across the Atlantic. Although the twentieth century would be the American Century in medicine, in dentistry the United States gained the commanding position much earlier. In the 1840s, the world's first dental school was established in Baltimore, the first dental journal was conceived there, and dentistry's greatest single gift to suffering mankind, general anesthesia, was demonstrated in Boston. In later decades Americans invented vulcanite and other dental materials, pioneered the electric drill, and laid the groundwork for the later dental specializations.

The above-mentioned Norman Kingsley (1829-1913) has sometimes been referred to as the "Father of Orthodontia." It was he who published in 1880 the first American book in this specialization, *Treatise on Oral Deformities as a Branch of Mechanical Surgery.* The title was in keeping with the Renaissance spirit of the mechanical ideal in the healing arts, which orthodontics continued to uphold.



Angle drew upon features of previous appliances—piano wire for labial and lingual elastic arches, screw spindles and bands for fastening to the first molars

The greatest name in the story of orthodontics is, however, Edward H. Angle (1855-1930), a compatriot of Kingsley's and a generation younger. Not long after graduating from the Pennsylvania College of Dental Surgery in his native state, Angle moved to Minneapolis and pursued his interest in orthodontics. This earned him a university professorship in 1886, and he soon gained worldwide attention with a lecture he delivered to the Ninth International Medical Convention entitled "Notes on orthodontia, with a new system of regulation and retention."

Looking over the hodgepodge of techniques and improvisations in the field—sometimes resulting in Rube Goldberg "monstrosities" (his term)—Angle called for systematization, simplification, and standardization. Seeking a core device that would be continuously worn, stable, streamlined, plateless, and clean, Angle drew upon the most suitable features of previous appliances, especially piano wire for labial and lingual elastic arches, and screw spindles and bands for fastening to the first molars. In the spirit of the Industrial Revolution, the basic parts were interchangeable. Of course, each appliance had to be "customized" to the patient's individual requirements. To this end, Angle developed and patented a standardized system of wire ligatures, with a hook on one end and a pin on the other, that could transmit the mechanical force of the elastic arches to a metal band around the tooth. To objectify the types of malocclusion to be treated, Angle devised a classification system based on the positions of the upper and lower first molars, i.e., the same teeth to which his device was anchored. Angle deemed his methods capable of rectifying all deviations and he strongly opposed extractions for orthodontic purposes.

In the ensuing decades Angle continued to refine his system. Interesting was his approach to the problem of "tipping," by which, in good Newtonian fashion, the tooth to which the force is applied tends to act like a lever. Angle developed the ribbon arch and then the edgewise arch. (This followed his move to Pasadena, California, where orthodontic work for the film industry was plentiful, and his establishing there of the Angle College of Orthodontia). His pride in his precision mechanical work is perhaps best symbolized by the massive Black Forest-style mechanical clock that hung near the desk of his California study.

Great was Edward Angle's influence up to and beyond his death in 1930. But he was not without rivals. Some dentists took issue with his blanket prohibition on extraction for orthodontic purposes. Alternative systems were developed, notably variations on the spring wire arch—first tried decades earlier by the French dentist Lefoulon—anchored at the molars and bent and twisted so as to apply pressure to the teeth where needed. Similar was the spring-beam arch developed by the German orthodontist Paul Simon, which likewise dispensed with ligatures and most clamp bands. Such systems had the advantage of removability, which happened to be favored by European dentists.

Angle's overwhelming emphasis on the relative position of the upper and lower first molars in the classification of malocclusions was also challenged, particularly by Simon. In a way strongly reminiscent of his compatriot Albrecht Dürer's orthographic representations of the human head four centuries earlier, but now making use of a impressively complex mechanical contraption called the "gnathostat" with sliding pointers and markings, proudly reflecting Germanic thoroughness, Simon sought to determine proper and deviant occlusions and proportions on a multitude of indices.

In a way, the gnathostat was the epitome of the mechanical ideal. But there was in orthodontics a contemporary diagnostic medium of a most unmechanical nature. The X-ray was a specific byproduct of a larger focus on electromagnetism and field theory in the decades leading up to the turn of the twentieth century, which brought about the crisis in classical physics and introduced concepts such as relativity and the quantum.

It would be quite a stretch to posit that the overturning of the mechanical ideal in physics was responsible for the trend in orthodontics away from the clear-cut Newtonian vectors of push, pulls, and rotations with metal devices. But it's reasonable to suggest that exposure of the orthodontists through the medium of X-rays to their patients' internal tissues and muscles—which had long been out of sight and hence pretty much out of mind—helped stimulate a fuzzier, body-driven approach. Particularly noteworthy was the rather obscure "monobloc" early in the century and its more popular descendant the activator, both of which were worn primarily at night. These appliances incorporated partial upper and lower plates and theoretically transferred the muscular forces of the jaws, tongue, and cheeks to the teeth needing correction. Entirely nonmechanical were the supplementary jaw-stretching exercises to correct distal bite, introduced and largely abandoned earlier in the century, and recently resurrected by some pediatric orthodontists.

Simon sought to determine proper occlusions and proportions on a multitude of indices using his impressively complex mechanical "gnathostat"

The 21st Century

The opening decades of the 21st century and the third millennium will undoubtedly see continued breakthroughs in the fields of genetic engineering and synthetic biological materials. Researchers will leap ahead in unforeseen directions, and this cautions against making predictions about the future shape of orthodontics.

What we can do, and have done, in these final days of the second millennium is to show the specialty of orthodontics to be the proud upholder of a mechanical ideal in biology and the art and science of healing that enthralled many a great thinker over the past 10 centuries.

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