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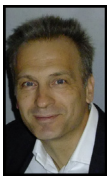
Orthodontic material applications over the past century: Evolution of research methods to address clinical queries



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The advances in the field of materials as they relate to orthodontics can be divided into the actual evolution of materials applied to daily practice and the changes in research methods to study the performance and the biologic properties of the materials. Although it is evident that new materials have saturated the market during the past century, the basic concepts of attaching one appliance to the enamel to use as a grip and inserting wires into that to control the spatial orientation of a tooth are identical to the original concepts. In contrast to that, the numbers of treatises about those subjects and the complexity of instrumentation and analytic tools used in published research have advanced tremendously and at a frenetic pace. This highly specialized pattern of research may effectively raise boundaries across research areas, since the complexity of the issues allows researchers to comprehend the content of journal articles in a narrow spectrum of disciplines. The purposes of this article were to review the advances in the research methods for investigating the various properties of orthodontic materials and to assist the reader in navigating this topic. A synopsis of the materials is also provided, listing future applications that already exist at the experimental stage or are yet unavailable but with the relevant technology already presented in broader scientific disciplines. (Am J Orthod Dentofacial Orthop 2015;147:S224-31)

The application of dental materials science in orthodontics coincides with the use of gold wire alloys by Edward Angle; the father of the specialty might not have imagined the impact that materials would have in current orthodontic practice. As the field progressed and grew to the dimensions of a specialty, the principles and mechanics of materials, which are typically taught in the first year of an undergraduate engineering curriculum, were incorporated in postgraduate orthodontic curricula along with accompanying elements of materials.

In the United States particularly, the disciplines of orthodontic mechanics and materials science received further emphasis, possibly because dental graduates entering orthodontic programs often had a bachelor's degree in natural or engineering sciences, thus allowing for the cultivation and growth of materials research and bringing a new perspective to traditional and empirically taught concepts of the topic.[1]

The advances in the field of materials as they relate to orthodontics can be divided into (1) the actual evolution of materials applied to daily practice and (2) the changes in research methods to study the performance and the biologic properties of the materials.

With respect to the first topic, although it is profoundly evident that new materials have saturated the market during the time period examined, the basic concepts of attaching one appliance to the enamel to use as a grip and inserting wires into that to control the spatial orientation of a tooth are identical to the original concepts. Of course, there have been different modes of attaching this "handle" to the tooth structure, along with many bracket materials and designs (lingual, self-ligating), and more alloy selection options are available, but the foregoing changes are within the path of the original concept.

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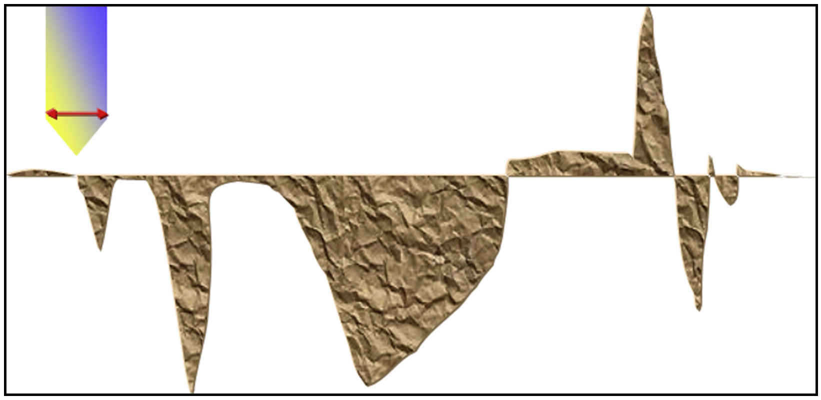

Fig 1. Various methodologies are used to assess roughness. This is a graph of the profilometry with a stylus method demonstrating the problems in assessing the actual variations of peaks and valleys on a surface, establishing the limiting factor of stylus size.

Although aligners have revolutionized the conventional appliance configuration and constitute a new means of tooth movement, they can also be seen as representing a new version of the removable appliance tooth movement pattern that was popular in the middle of the previous century. Collectively, orthodontists practicing in the Angle era could easily have adapted, with only a few hours in a briefing seminar, to the conditions of the specialty 100 years later.

Nevertheless, the number of treatises about these subjects and the complexity of the instrumentation and analytic tools used in the published research have advanced tremendously and at a frenetic pace. For example, the engineering approaches in materials science and mechanics, the methods used to study the biologic mechanisms of tooth movement, and the data-analysis attributes of clinical trials require a strong background in the respective sciences involved; this makes it almost unattainable even for contemporary orthodontists to follow the developments across the various fields. This highly specialized pattern of research may effectively raise boundaries across research areas, in the sense that the complexity of issues allows researchers to comprehend the content of journal articles in a narrow spectrum of disciplines. This has been highlighted by studies investigating the characteristics of orthodontic publications, which showed a significantly higher frequency of multiauthor teams with affiliations from different scientific disciplines within a decade.[2,3]

The purposes of this article are to review the advances in the research methods for investigating various properties of orthodontic applications of materials and to assist the reader in navigating this topic. A synopsis of the materials is also provided, listing future applications that already exist at the experimental stage or are yet unavailable but for which the relevant technology is already presented in broader scientific disciplines.

EVOLUTION OF ORTHODONTIC MATERIALS RESEARCH APPROACHES: A LIST OF PARADIGMS

The next paragraphs describe briefly the shift that has occurred in the past decades in the approaches to resolving several issues related to orthodontic materials and their applications. The subheadings lead the reader from the first steps of intervention beginning with bonding and covering appliances and their properties. This section is complemented with an overview of in-vivo aging studies or retrieval analyses, which constitute the greatest breakthrough in the area of simulation of the clinical environment.

Bonding

Roughness of enamel. The alterations in the composition, topography, and roughness of enamel have been topics of research because of concern about potential irreversible changes caused by orthodontic bonding. The traditional approach to assessing roughness has been to use images of enamel (initially microscopic images and later scanning electron images) to quasi-quantify the effect of bonding on enamel appearance; this method is hampered by an apparent lack of sensitivity because the roughness variations of the surfaces can only be approximated. Later, a stylus-type of profilometric analysis of the surface of the substrate before and after bonding was used to investigate the increase in various roughness parameters, which are used to describe the variations of the surface (peaks, valleys, and so on). As shown in Figure 1, the conventional approach with profilometry