DIY Orthodontics: Design It Yourself

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DIY Orthodontics

Design It Yourself

Edited by **Nearchos C. Panayi**, DDS, DOrth, MOrth

PhD Candidate
Athens Medical School
National and Kapodistrian University of Athens
Athens, Greece

Private Practice
Limassol, Cyprus

With translation support from
Moshe Davidovitch, DDS, MMSc

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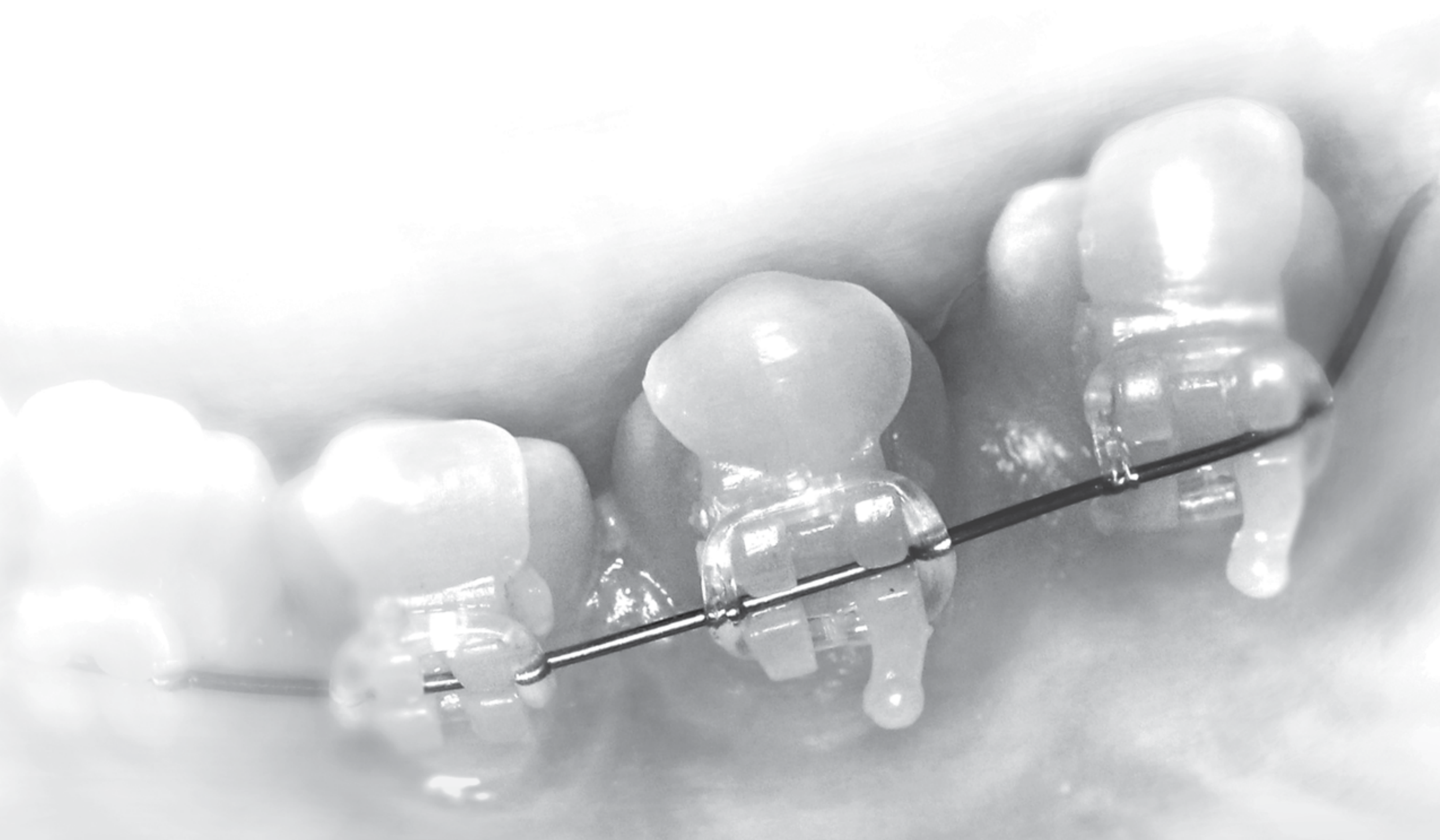

Foreword

with a glimpse into the analog past,
the transforming present,
and the digital future

This book opens the “digital pathway” to 3D success for the orthodontic clinical practice. It is a successful demonstration on how digitization of patient information and digitalization of clinical procedures can lead to a digital orthodontic transformation for the design and manufacturing of patient-specific devices—and in turn to considerable benefits for clinicians and patients.

Many years ago, I had the opportunity to propose the use of computer-aided engineering as a potential clinical tool for preoperative planning, surgical practice, and customization of medical devices. However, the efficient integration of medical imaging with design, simulation, and rapid manufacturing was a long, challenging, and demanding task. It could take weeks or even months to coordinate just the export of images from medical scanners. Specific knowledge and equipment were also necessary to transfer image data to a computer. Extra effort was required to decode and read the “native” formats utilized by those closed systems. Overall, too much effort, too many projects, extensive scientific work, and numerous clinical cases and patient stories have been required in order to prove the value of a digital engineering approach in clinical practice.

By the turn of the millennium, the underlying engineering technologies, as well as the relevant digital 3D workflow, were fully established. Computer-guided implantology was the first concrete example of a successful digital process in dentistry. During the following years, a considerable simplification and automatization of the procedures was achieved, mainly due to considerable software developments but also hardware improvements and increasing computer power. Nevertheless, it took decades to garner widespread recognition for the apparent benefits of engineering approaches in dentistry and medicine, as well as the potential of a generalized digital transformation in health care. Today, everyone wants to “go digital,” even when it is often unclear what that even means.

Strictly, the term *digital* refers to the management of digital information. *Digitization* is the initial step to make all information available in a digital format. And *digitalization* is the next step to develop the appropriate tools to manage the digitized information. The “digital transformation” is the integration of digital data with digital tools into all aspects of any enterprise. The fact that many technologies, such as modern design and manufacturing, utilize digital information and rely on computational procedures leads us to consider ourselves under the “digital umbrella” as well. It is very important though to mention that a successful digital transformation is not just about the technology. It fundamentally changes how an organization operates in order to deliver the potential benefits. It requires a cultural change with new and different ways of thinking. It is a constantly evolving situation that requires experimentation for the implementation of novel processes that are frequently radical and challenge analog routines. In health care, the order always used to be disease, medicine, and then patient. However, a digital health care transformation puts the patient at the center of medical care, affecting how people access or even define health care.

What does a potential “digital health care transformation” really mean? It is estimated by IBM Watson that each person can generate enough health data in their lifetime to fill 300 million books. More medical data has been created in the past 2 years than in the entirety of human history, and this is predicted to double every 73 days. Most data though are unstructured and stored in hundreds of forms such as lab results, images, and medical transcripts. It is called Big Data because it is voluminous and complex. Traditional processing software was inadequate to deal with it, but now there are the technical capabilities to monitor, collect, and process this scale of information. Big Data can be analyzed by intelligent systems that can imitate human learning and reasoning, otherwise called *artificial intelligence* (AI). AI has the capability to sift through billions of pieces of unstructured information and “investigate” millions of patient cases in order to find patient-relevant information, sort its importance, make necessary connections, and summarize conclusions in a predictive way. In addition, such digital processes can employ “cognitive computing” techniques to simulate human thought by learning how to recognize and use the data. The relevant technology platforms can encompass reasoning, speech, and object recognition, language processing, and human-computer interaction. Doctors can interact directly through dialogue, discussing various proposals. Through "machine learning" (ML), digital systems can also be automatically trained and keep learning from any mistakes as well as successes to adapt and become "specialists" in a range of disciplines. As such, a potential digital health care transformation can help clinicians to make informed decisions regarding diagnosis and treatment options. It is also possible to obtain insights on outcomes of various treatment options, to better understand which therapy may be suitable for which patients, and in general to identify information for optimizing therapy approaches and improving clinical guidelines. It is important to note though that such intelligent systems are only assistants that support human experts. Doctors and nurses make decisions that are best for their patients, and they must always have the last word. Computers cannot replace the emotional and social side of people.

A key aspect for the success of a digital health care transformation is that humans remain in control. For that purpose, an interdisciplinary approach is necessary. Convergence among various disciplines such as mathematics, physics, chemistry, biology, engineering, and medicine is imperative. An appropriate understanding of the background technologies and training of medics for the ideal application of digital processes in clinical practice is also necessary. Certainly, the application of automated methods does not mean oversimplification of clinical procedures or reduced experience. Systematic clinical training as well continuous collaboration with experienced technology experts is mandatory. The development of relevant technical and clinical standards is a key element in establishing this digital health care transformation. "Certified" procedures and products are mandatory in order to protect public health, preserve quality, and promote safety for all concerned. For that purpose, developing and implementing regulatory strategies and policies for digital health technologies is imperative. The most important consideration in adapting digital procedures should be the optimal results for patient well-being. No one should forget that health care is about caring for people, and ethics should be a key aspect during any digital transformation.

A "digital future" presents possibilities for our life, but it depends on whether we can really embrace and make them happen. Twenty years ago, I was tasked to produce a "virtual human" model for the British MOD and NATO. It took a record time of a few months to generate a whole human anatomy for the first time in an STL format. Today, such a model could act as an input for AI and cognitive computing systems to analyze, study, and predict human anatomy physiologic functions and responses. In the future, such virtual patients or otherwise "digital human twins" will become a common practice for studying every pathology and treatment. From diagnosis to treatment, digital tools are about to change the way every health care professional works. Prior to embracing the forthcoming digital era, however, we should keep in mind that the success of "going digital" relies on the way we think, approach, and use the relevant technologies. As it is demonstrated by the prominent authors of this book, the future orthodontic practice is not that far away.

This book represents the future digital transformation of orthodontics. It is an illustration of future digital orthodontic workflows but also provides the reader the opportunity to adopt and apply this already today. A digital roadmap is provided for orthodontists who wish to provide care for their patients in a personalized 3D way. I would like to express my great appreciation to Dr Nearchos Panayi for his enthusiasm and commitment to adopt digital engineering in his daily orthodontic routine. His passion to share the digital knowledge and experience that he has accumulated during the last few years is admirable. I would also like to extend my gratitude to all the authors of *DIY Orthodontics*. This book is a significant recognition for all those pioneers, engineers, and clinicians who believed, developed, and introduced digital approaches in medicine. It proves that computer-aided engineering techniques are applicable to all clinical fields, as it was once thought and hoped. However, we are still in the beginning of exploring the many possibilities that 3D engineering technology can offer in medicine. We are entering a new universe in clinical practice, and it is a learning process for all involved. Knowledge, experience, as well as guidance and training on best practices are critical. Unrealistic expectations only lead to disappointment, but when we work together—researchers, scientists, engineers, and clinicians—we can get this right! Until then, by reading and applying *DIY Orthodontics: Design It Yourself*, you can already immerse yourself in tomorrow's 3D world.

Panos Diamantopoulos, DPhil, Dr Eng
President, Computer Aided Implantology Academy

Preface

Γηράσκω δ' αεί πολλά διδασκόμενος
I'm getting older while being taught all the time.
—Solon, 630–560 BC, Ancient Athenian legislator & philosopher

In 1957, the Canadian philosopher Marshall McLuhan stated that "As technology advances, it reverses the characteristics of every situation again and again. The age of automation is going to be the age of 'do it yourself.'" This proactive statement has come to be realized in our time.

The progressive nature of technology has given it a presence in modern orthodontics since its recognition as the first specialty of dentistry, as established by Dr Edward H. Angle. Its influence has been continuously evolving and altering the way orthodontics is practiced. The reality is that new materials, techniques, bracket designs and prescriptions, appliances, and software, together with advances in the field of biology, have influenced many aspects of orthodontic treatment. However, most of these advances have been within the confines of traditional clinical practice workflows, with a dependence on an orthodontic laboratory and orthodontic material companies for the necessary appliances and auxiliaries to be used for treatment. The advancement of automation, however, is a departure from that workflow entirely.

Automation implies self-regulation or acting independently with limited to no human intervention. This term is rooted in the Greek word *automatos*, which means acting by itself, or by its own will, or spontaneously. Automation, as alluded to by McLuhan, has been incorporated into medicine as a whole, and modern dentistry specifically, but to a lesser degree in orthodontics.

Automation can mean fully automatic or semiautomatic devices or systems where human input has a minor role. A modern CBCT, for instance, is a tomograph that can acquire images in three dimensions only by setting the necessary parameters in a semiautomatic configuration. An intraoral scanner delivers colored accurate surface 3D images by automatically matching different angle scans of points of interest (POIs). Recently, color matching for restorations is also available or even functions for caries detection. Automatic integration of a volume and a surface scan is also available with certain software. 3D printing or milling is another form of automation where 3D images are transferred to dedicated machines and output as real objects following several automation steps. Other such examples are CAD software that performs teeth segmentation and virtual bracket positioning for indirect bonding procedures, which are semiautomation processes. Furthermore, artificial intelligence is being developed to "trace" cephalograms with remarkable accuracy or convert DICOM files into an STL printable format.

Another example of automation in orthodontics is CAD software that performs automatic procedures to help the operator design almost all kinds of appliances, which are then printed or milled in special machines. Aligner 3D printing is in its initial steps but certainly will be the next big step in aligner treatment. Recently, in-house or laboratory wire-bending robots have been developed to manufacture patient-specific archwires. Artificial intelligence is also used by aligner companies to gather data from orthodontists in order to provide assistance for future aligner treatments. Blockchain, although initially developed for use with cryptocurrency (ie, Bitcoin), has also found use in medicine. The ability to automatically share medical data without any central server using only peripheral computers is a promising technology that could also be used between orthodontists for treatment and research purposes.

Customized orthodontic brackets manufactured by companies for individualized orthodontic treatments is an important recent step in the direction of personalized medicine within orthodontics, which has mainly occurred out of necessity in lingual orthodontics. Nevertheless, bracket customization manufacturing is currently available from a small number of companies also in labial orthodontics. Despite this customization evolution, the relatively high cost of such treatment currently deters the mass of patients from availing themselves to such systems. The present book describes a new CAD software called UBrackets, which may place fixed appliance customization within the grasp of the majority of orthodontists and their patients. This tool gives the orthodontist the ability to design the specific patient's tailor-made fixed orthodontic appliances. This has led to the start of a project to create the technology for in-house fixed appliance printing.

Creekmore, in his article "Straight wire: The next generation," lists five reasons why current preadjusted appliances cannot achieve ideal positions: inaccurate bracket placement, variations in tooth structure, variations in the vertical and anteroposterior jaw relationships, tissue rebound, and orthodontic appliance mechanical deficiencies. Moreover, he states that even with the preadjusted appliances, first-, second-, and third-order bends have to be made to move the teeth in the desired positions. Perhaps the use of digital technologies will satisfy these conditions.

It was the Greek philosopher Heraklitos (544–484 BC) who stated that "the only constant is change," or put differently, "nothing endures but change." Within the changes brought on by the digital revolution and the effect of automation processes is the continuous change of human roles. Thus, the whole complex of the contributing factors in practicing orthodontics is continuously changing due to technologic advancements driven by automation. The consequence of automation, as previously stated, is the "do it yourself" concept. It is evident that the concentration of all the digital records of a patient in a computer allows for a global view of the patient, or the *virtual patient*. Moreover, this facilitates in-house designing and printing of the majority of orthodontic appliances, as foretold by McLuhan. Thus, technologic advances directly influence the role of the orthodontist or orthodontic clinic by bestowing on its traditional laboratory tasks without the intermediary steps with their inherent lost time and material requirements. This now includes obtaining the patient-specific fixed appliance brackets as the result of an in-house customized bracket design and printing process.

Companies will strive to manufacture new 3D printers with higher capability for accurately printing small objects like brackets at an affordable cost. Moreover, they will turn their interest to creating reinforced resins or other materials that could be used for bracket printing and whose printing result will resemble the material quality and properties of the currently used metallic or ceramic brackets.

goal of this book is to provide the modern orthodontic clinician a description of the current digital technology that is used in orthodontics, including volume and surface scanning, 3D printing, CAD software, and artificial intelligence, and to speculate as to the future developments that can be expected. The former will be summarized within a single chapter in an effort to indicate the directions expected of the latter to describe the future integration of digital technology and its use within the workflow of a completely digital orthodontic office. The second section of the book is a "design it yourself" guide presenting the application of this technology in all aspects of orthodontic treatment. Almost every chapter of this book is a separate subject that should be analyzed, studied, and evolved more by researchers and orthodontic companies in order to create a state-of-the-art orthodontic technology.

The book describes all the necessary technologic ingredients to be used in a self-sufficient digital orthodontic clinic. It focuses on the in-house design and production of tailor-made appliances by digitally diagnosing and evaluating the virtual patient and by creating an individualized treatment plan. Moreover, the book describes the concept of a future network connecting orthodontic offices (globally) to a central artificial intelligence server and to a noncorporate orthodontic blockchain network. This will connect all orthodontists in such a manner so as to create a "super study club" for case sharing and research purposes using cryptography.

Whenever we talk about technology and digital advancements, it is essential to understand that digital technology can make a good orthodontist better, but it will not transform a bad orthodontist into a good one. Furthermore, as it is described in these pages, automation is not to be the substitution of human error with mechanical error. Minimization of such errors is dependent on the changing but ever-present involvement of the human interlocutor. The symbiosis of human experience and knowledge, together with digitized technology, can be honed to better serve our patients and humanity.

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Special thanks to Associate Professor of Orthodontics Apostolos I. Tsolakis, who believed in me, helped me in any possible way, guided me through the field of research, and was my PhD supervisor in Athens Medical School as the eminent expert in animal studies that he is.

I must also thank Professor Panos Diamantopoulos, a world leader in 3D technology and the person who introduced me to 3D technology 6 years ago. Since then, he has become a valuable friend and partner in the amazing world of digital technology.

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My gratitude to all my friends, orthodontists or not, who helped me and encouraged me in compiling the current book.

Last, but certainly not least, I want to thank all the contributors for their efforts and commitment to write timely and practical chapters. This will significantly impact the integration of digital tools within orthodontics toward their inevitable merger culminating in the in-house design and manufacture of any conceptualized appliance. This actualization will not only enable the clinician but will also impact the specialty of orthodontics for the betterment of our patients. The future has arrived. Embrace it.

Dedication

This book is dedicated to my lovely wife, Marina, and to my six children: Christos, Theodora, Andreas, Maria, Nicolais, and Amalia. I want to thank my family, especially my wife, for their understanding and patience, but most of all for reminding me that there are more precious values in life apart from orthodontics.

Contributors

Evangelos Akli, DDS, MS
Group Practice
Austin, Texas

Federico Hernández Alfaro, MD, DDS, PhD
Professor and Head, Department of Oral and Maxillofacial Surgery
International University of Catalonia
Barcelona, Spain

Silvia Allegrini, DMD, MScD
Clinical Director
University of Geneva
Geneva, Switzerland

Private Practice
Pisa, Italy

Christos Angelopoulos, DDS, MS, PhD
Elected Professor, Oral Diagnosis and Radiology Clinic
School of Dentistry
National and Kapodistrian University of Athens
Athens, Greece

Associate Professor of Oral Radiology
Aristotle University of Thessaloniki
Thessaloniki, Greece

Moshe Davidovitch, DDS, MMSc
Associate Professor and Senior Lecturer
Department of Orthodontics
Tel Aviv University
Tel Aviv, Israel

Spyridonas Efstathiou, DDS
Private Practice
Limassol, Cyprus

Alfredo Gilbert, DDS, MS
Private Practice
Mexico City, Mexico

Ioannis Gkiaouris, DDS
Private Practice
Thessaloniki, Greece

Cristina Grippaudo, DMD, MSc, PhD
Professor of Orthodontics
Catholic University of the Sacred Heart
Rome, Italy

Santiago Isaza, DDS
Private Practice
Bologna, Italy

Rosalia Leonardi, DMD, MSc, PhD
Professor of Orthodontics
Director, Postgraduate School of Orthodontics
University of Catania
Catania, Italy

Manolis Mavrikis, DMS, MScOrth
Private Practice
Samos, Greece

George Michelinakis, DDS, MPhil
Private Practice
Heraklion, Crete, Greece

Ambrosina Michelotti, BDS, DDS
Professor of Orthodontics
Director, Postgraduate School of Orthodontics
University of Naples
Naples, Italy

Stefano Negrini, CDT
Dental Technician
Marconi University
Rome, Italy

Riccardo Nucera, DDS, PhD, MSc
Professor of Orthodontics
Department of Biomedical and Dental Sciences and Morphofunctional Imaging
School of Dentistry
University of Messina
Messina, Italy

Adaia Valls Ontañón, MD, DDS, PhD
Professor
Department of Oral and Maxillofacial Surgery
International University of Catalonia
Barcelona, Spain

Nearchos C. Panayi, DDS, DOrth, MOrth
PhD Candidate
Athens Medical School
National and Kapodistrian University of Athens
Athens, Greece

Private Practice
Limassol, Cyprus

Ch[illegible] Riolo, DDS, MS, PhD
Affiliate Associate Professor
University of Washington School of Dentistry

Private Practice
Seattle, Washington

Rafi Romano, DMD, MSc
Private Practice
Tel Aviv, Israel

Kostas Tsiklakis, DDS, MSc, PhD
Professor and Chairman, Oral Diagnosis and Radiology Clinic
School of Dentistry
National and Kapodistrian University of Athens
Athens, Greece

Apostolos I. Tsolakis, DDS, MSD, PhD
Associate Professor of Orthodontics
School of Dentistry
National and Kapodistrian University of Athens
Athens, Greece

Adjunct Associate Professor of Orthodontics
Case Western Reserve University
Cleveland, Ohio

1 Introduction

Rafi Romano

"Do it yourself" (DIY) orthodontics is becoming requisite in modern orthodontic practice. Nevertheless, this book is titled *Design It Yourself Orthodontics* in order to differentiate it from the "doctorless" direct-to-patient appliances offered online or at shopping mall kiosks.

Technology and 3D software have irrevocably changed the way modern orthodontics is managed and administered. Printed models are eliminating poured plaster casts, appliances can be designed and printed with computer-assisted hardware and software, and tooth movements can be simulated and staged digitally to increase their accuracy and predictability.

Digitization converts real-world information into digital data that can be presented on a computer screen. Volume scanning and surface scanning of the dental arches and the face are transferred to dedicated orthodontic software to build the "virtual patient" for orthodontic diagnosis, tooth movement simulations, and treatment planning.

Artificial intelligence (AI), currently in its initial stages, holds promise in becoming a tool for orthodontic diagnosis and treatment outcome predictions. It also has the potential to assist in defining appropriate treatment options for a specific patient, as well as predicting tendencies of relapse. Furthermore, AI can be a valuable research tool. Blockchain assemblies are described herein that could be a digital tool to connect an infinite number of orthodontic clinicians without a centralized server as a network. This could become a window for participants to view treatment examples, digital appliances, radiographs, etc, without violating patient or doctor privacy.

Dentists and orthodontists can at times be intimidated by mathematics, physics, and technology, which are related to forces and appliance design. Technologic understanding is a time-consuming process with a learning curve that can deter the orthodontist from getting involved. A familiar work pattern and acceptance of a particular appliance serve to create a comfort zone for every clinician. The introduction of a disruptive technology may upset this pattern and disturb the established workflow. Nevertheless, avoidance of these technologies will be to the disadvantage of the practitioner. The longer the delay in integrating these technologies, the greater the learning curve in implementing them. As Darwin stated, it is not the strongest of the species that survives nor the most intelligent—it is the one that is most adaptable to change.

The versatility of digital applications has enabled increased control and greater independence within our clinical settings. This trend has justified the inception of many companies that recognize the need for tools to design and plan individualized appliances according to each clinician's vision for each case, and to enable modifications as needed during the treatment. These tools include multifunctional orthodontic software for virtual patient analysis, treatment simulation, patient education, treatment planning, and smile design. Other software offers the ability to design and create in-house orthodontic aligners, indirect bonding (IDB) trays, customized bands, appliances, and orthognathic surgical splints, etc. 3D printer companies have recognized the application of their technology in dentistry and orthodontics, and new biocompatible printing resins are continuously under development and being introduced in the market for use.

The younger generations of orthodontists and dentists, while certainly less clinically experienced, are naturally better informed as to these technologies because their emergence into the field parallel one another. Older, more experienced clinicians generally are slow to adopt new technologies due to the apprehension created by the disturbance in established principles and the apparent complexity new technology introduces. Young or old, inexperienced or experienced, all clinicians need sources that enable them to accept new technologies and overcome barriers so they can realize their own innovation.

It needs to be understood that technology is not a replacement for the process of coalescing the appropriate diagnostic information into a patient-specific treatment plan. Digital technology can only serve as an assistant, not the master in orthodontic treatments. Ironically, it is the more clinically experienced category of clinicians that can maximize the potential of these tools; however, their aversion to the changes brought by technology has left this potential unrealized. Also, knowledge of new technology should not give the impression in young dentists and orthodontists that it is sufficient for a satisfactory orthodontic treatment result.

This book, as stated in its title, covers the topic of DIY orthodontics from the simple design of expansion and cast/printed appliances using dedicated computer-aided design (CAD) orthodontic software to unique printed appliances designed by general CAD engineering software. As the reader will notice, such tools enable the orthodontist to directly design appliances that cannot be created with any other software. Indirect bonding with digital preparation is thoroughly described with the add-on of a special IDB process that is undertaken upon digital setup. In-house design of customized lingual braces is presented together with an in-house wire-bending robot, for both lingual and labial archwires.

In-house aligner design is presented using uncomplicated software, an aspiration that is currently central in orthodontics. Furthermore, industry efforts to produce a biocompatible material and technique to directly print clear aligners are discussed in these pages and, together with [illegible] applications for AI, are the frontiers in the integration of technology into clinical orthodontics.

One of the most revolutionary chapters of this book describes in-house custom bracket design and printing using a new software called UBrackets. This enables the operator-driven design and building of customized orthodontic bracket bases using composite resin on orthodontic brackets. In addition, as a second software option, the orthodontist can use the software's bracket library to print fully customized brackets. Volume scanning, surface scanning, 3D printing, and AI are covered in separate chapters. A full overview of the digital office workflow is also covered in detail.

To my knowledge, there is currently no similar compilation of these undeniably important aspects of the modern practice of orthodontics. This does not surprise me because the majority of what is described in this book was not in existence even 5 years ago. The importance of a book such as this is highlighted by the frequency at which new companies and products are popping up on the market, offering new ideas and tools to enable simplification of clinical tasks and broaden our professional lives with new and exciting opportunities.

The authors contained in this book are recognized clinicians and researchers whose reputations and contributions are highly regarded. Each presents their respective topic in a well-written, comprehensive, but very readable manner. All the material appearing in this book is not only topical but also extremely up to date with several items receiving initial exposure in these pages. The text and visual presentations complement each other and engender a flowing and enjoyable reading experience of a cutting-edge group of topics.

The biology of tooth movement and the biomechanics applied to do so are constants within orthodontics. Yet with simple DIY tools, the modern clinician can visualize and simulate treatment, and, most importantly, sustain maximum control of the progress of any given treatment. Furthermore, DIY tools facilitate the ability to modify treatment as and when needed without being limited or dependent on outsourced laboratories and/or commercial companies.

The highly innovative nature of this book is sure to make it standard for every orthodontic office. It will go a long way in helping today's clinicians immerse themselves in this fascinating era, which will certainly become the "new normal" in every clinic.

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