CLEAR ALIGNER TECHNIQUE

SECOND EDITION

Sandra Khong Tai, BDS, MS

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Preface

The first edition of *Clear Aligner Technique* has become the authoritative text on clear aligner treatment since it was published in English in 2018. The world of clear aligners has changed exponentially since then, with numerous clear aligner systems in the market today. And yet the principles of moving teeth—such as biomechanics, anchorage, and occlusion—based on a proper diagnosis and treatment plan remain timeless. This textbook should be a valuable resource to any clinician, regardless of the aligner system employed in their practice, as the principles of moving teeth and staging tooth movements with aligners described in this text may be applied universally to any aligner system.

This second edition of *Clear Aligner Technique* is a beautifully updated version of the original and definitive text on clear aligner treatment. Chapter 3 on case selection and chapter 4 on digital workflow have been completely rewritten to reflect the integration of digital imaging, 3D CBCT treatment planning, and treatment visualization. In the chapters on Class II and Class III treatment, the concept of combining anteroposterior (AP) protocols with vertical protocols for deep bite and open bite treatment is introduced to assist the clinician in formulating an effective treatment plan for different types of malocclusions. An entire chapter is also devoted to Class II growth modification with clear aligners. Finally, the last section of the textbook is entirely new with a focus on early interceptive treatment including maxillary skeletal expansion. There are a total of 32 case reports to illustrate the principles taught in the text. Each case report has a QR code that leads to an accompanying video that demonstrates the digital treatment plan design, including staging patterns, attachment design, and final occlusal plan. In the years since the first edition, numerous research studies that contribute to our understanding of how clear aligners work have been published. As such, the bibliography has been updated to reflect these latest research publications.

In our rapidly evolving world with artificial intelligence, 3D simulations for both soft tissue and tooth movements with CBCT integration, and improved software algorithms, we are now able to treat almost every type of malocclusion with clear aligners. More complex cases may be treated with a hybrid approach in conjunction with auxiliaries like segmental brackets or temporary anchorage devices. There is limitless potential for the future of orthodontics. Integrating digital technology into our orthodontic practices helps us deliver superior clinical outcomes. I invite you to step into the future of digital orthodontics in clear aligners together with me.

The future is clear!

Acknowledgments

I would like to express my gratitude and appreciation to all who helped in realizing the second edition of *Clear Aligner Technique*. Firstly, Dr Charlene Tai Loh, who is also my partner in the practice, for incorporating the latest research studies on clear aligners in the bibliography. To my team at Astra Orthodontics, who helps us deliver the excellent clinical outcomes you see in this text. A special thank you to Dr Heesoo Oh for her assistance in the cephalometric superimpositions for chapter 12.

I am also deeply grateful to the team at Quintessence Publishing for their expertise in making sure this book meets the highest standards of quality. Their photographic reproduction truly sets the standard for all dental publications. It is through their efforts that the first edition was translated into 13 languages, making this critical resource available to thousands of doctors globally.

Finally, I am truly inspired by all the doctors around the world who came up to me with copies of the first edition of *Clear Aligner Technique* that had been studied, highlighted, and underlined, with written notes in the margins, showing how this valuable resource and knowledge have been instrumental in transforming their lives, their practices, and their patients' smiles. Thank you for pushing the boundaries of innovation together with me.

Dedication

To my daughter, Charlene Tai Loh—you exemplify the next-generation orthodontist. I am inspired by your perseverance, compassion, and dedication in your life's journey. May your passion for creating beautiful smiles transform the lives of many.

To my husband, Merv Chia, my partner in love and life—your unwavering love and support have encouraged me to pursue my dreams. In every challenge, you have been my strength; in every joy, you have been my rock. Thank you for standing with me and believing in me.

01

A BRIEF HISTORY OF THE ORTHODONTIC APPLIANCE

In this chapter:

Fixed Appliances ***1***
Clear Aligners ***3***
Future Directions ***4***

Fixed Appliances

The history of orthodontics dates back more than 2,000 years, making it the oldest specialty in the field of dentistry. Around 300 to 500 BC, Hippocrates and Aristotle reflected on different ways to straighten teeth and address various other dental conditions. Excavations from the Etruscan period revealed human mandibles with wire ligatures and bands splinting teeth together (Fig 1-1). In 1728, Pierre Fauchard, known as the "father of modern dentistry," published a book called *The Surgeon Dentist*. In the chapter on orthodontics, he proposed a horseshoe-shaped piece of precious metal that helped to expand the dental arch, known as *Fauchard's bandeau* (Fig 1-2). It was ligated to the teeth with wire ligatures and expanded the dental arches to move the teeth into alignment.

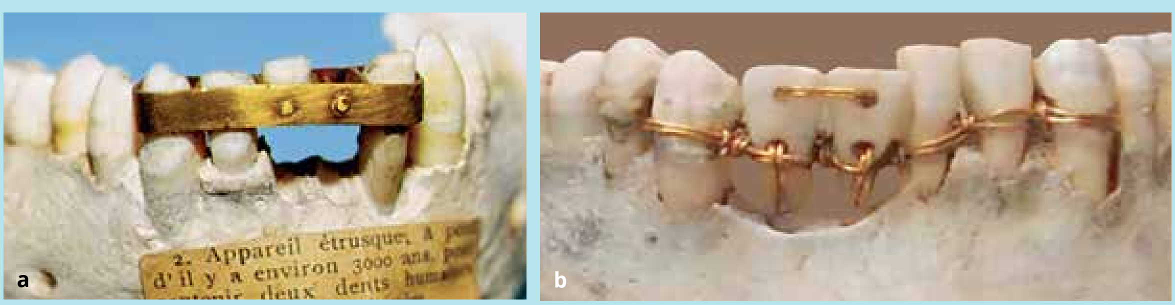

FIG 1-1 *(a and b)* Excavations from the Etruscan period showing metal bands and gold wire ligatures splinting teeth together.

FIG 1-2 Fauchard's bandeau.

FIG 1-3 Pin and tube design of the "ribbon arch" appliance.

FIG 1-4 Full-banded stainless steel appliances.

In 1901, Edward Angle founded the first school of orthodontics in St Louis, Missouri. Angle devised a simple classification for malocclusion that is commonly used today. In the early 1900s, fixed appliances were known as the "ribbon arch" appliance and consisted of gold bands formed around individual teeth with brackets soldered onto the band (Fig 1-3). Wire ligatures and pins were used to secure the archwire to the bracket. Precious metals that were soft and malleable such as gold and silver-nickel alloy were used.

By the 1950s and 1960s, these once relatively expensive bands were being made out of stainless steel (Fig 1-4). Full-arch banded appliances remained the norm until the innovation of direct bonding allowed orthodontists to directly bond a bracket onto enamel. At that time, the fixed edgewise appliance was known as a "zero-degree" appliance. The orthodontist had to make first-order (in-and-out or labiolingual), second-order (tip), and third-order (torque) bends in the archwire to finish the occlusion.

In 1970, Dr Lawrence Andrews proposed building the in-and-out, tip, and torque into the appliance itself, either into the bracket base or the bracket slot. This eliminated the need to make bends in the archwire. This became known as the "straight-wire" appliance and remains the standard of fixed appliances used today (Fig 1-5). There are now many different bracket prescriptions with varying degrees of tip and torque available. Clinicians can choose the bracket prescription based on their preference, their orthodontic philosophy, and the treatment mechanics employed to move teeth.

In 1975, two orthodontists, one American and the other Japanese, independently developed a bracket and wire system that could be placed on the lingual surfaces of teeth. "Lingual braces," as they were known, became an esthetic alternative for patients who did not want the brackets to be visible. Lingual bracket systems have also evolved over time to include digital computer imaging to assist with custom-fabricated bracket bases and archwires (Fig 1-6).

As the quest for a more esthetic orthodontic appliance progressed, sapphire and ceramic brackets became available in the early 1990s. Around the same time, new archwires with elastic and thermal properties such as nitinol, titanium molybdenum alloy (TMA), and heat-activated nickel-titanium

FIG 1-5 Direct bonded straight-wire metal fixed appliance.

FIG 1-6 Lingual bracket system.

FIG 1-7 Custom 3D-printed brackets from LightForce Orthodontics.

eliminated the need to make complex loops and bends in the archwire. Today there are a plethora of variations of the standard twin bracket available; there are self-ligating and non–self-ligating brackets, brackets with different prescriptions, and brackets made of different materials (metal, plastic, ceramic). The latest evolution in bracket variation is 3D-printed custom brackets. Innovations in digital technology and the field of 3D printing now enable the final occlusion of the patient to be set up in a treatment planning software. Based on the final occlusion, brackets can be 3D printed with a customized prescription and custom bracket base, designed specifically for the patient's individual tooth morphology and final occlusion (Fig 1-7).

As we trace the evolution of the orthodontic appliance over the last 100 years, we can see a distinct shift toward an orthodontic appliance that is more esthetic, more hygienic, occupies less surface area on the teeth, is able to accurately move teeth into the final occlusion with compatible biologic forces, and is customized for each unique individual patient.

Clear Aligners

The history of clear aligners can be traced back to 1945, when Dr H. D. Kesling first proposed a clear, vacuum-formed tooth-positioning appliance for minor tooth movement. It was a labor-intensive process that required manually repositioning teeth reset in wax, and a clear vacuum-formed retainer was made for every tooth movement in a series of stages until the teeth were aligned. This technique was capable of minor tooth alignment. However, the amount of labor required for the task precluded its use on a wide scale, particularly for correction of more complex malocclusions.

Another half-century went by until two graduate students at Stanford University in 1997 applied 3D computer imaging graphics to the field of orthodontics and created the world's first mass-produced, customized clear aligner system. This new technology revolutionized the world of dentistry and orthodontics, launching it into the 21st century and the digital age.

There is a distinct difference between evolutionary change and revolutionary change. Evolutionary change comprises incremental changes that take place gradually over time. The evolution of fixed appliances represents variations and incremental improvements to a bracket and wire system that has taken place over the last 100 years. Revolutionary change, in contrast, is transformational change. It is profound, dramatic, and disruptive. Revolutionary change challenges conventional thinking and requires a radical paradigm shift in our mindset. Clear aligner technology represents a revolutionary, transformational change in orthodontics that challenges the conventional thinking of how orthodontists move teeth. However, the advent of clear aligner technology does not mean that 150 years of orthodontic principles are no longer valid. The time-tested principles and concepts of bone biology, biomechanics, anchorage, and occlusion still apply. However, in this 21st century of digital technology, the clinician must now learn to apply those principles of orthodontics to the field of clear aligner technique.

Clear aligners have already evolved since they were released to the market in 1999. In the early days of clear aligners, most clinicians understood them to be an orthodontic appliance that was suitable for the treatment of Class I cases with minor crowding, resolved primarily with interproximal reduction. Today, clear aligners from Align Technology are made of a new tripolymer plastic and make use of optimized attachments with force activations built into the design of the aligner itself (Fig 1-8). The teeth are moved according to sophisticated computer algorithms developed in the software program. Currently most aligners on the market are thermoformed, but the future will be in 3D printing the actual aligner itself. There are many clear aligner systems being developed all over the world, and it is evident that this will be the future of orthodontics.

FIG 1-8 Clear aligners.

It is important to understand that **clear aligner treatment is a technique, not a product**. There is a common misconception that clear aligners are a "compromise" orthodontic appliance that is only capable of minor tooth movement. However, the clear aligner system of today is a *comprehensive* orthodontic appliance capable of treating a wide range of malocclusions. The remaining chapters of this text discuss the principles of clear aligner technique and lead the clinician through a process of learning how to apply the principles of orthodontics to clear aligner technique.

Future Directions

As we look toward the future evolution of orthodontics, the ideal orthodontic appliance could be conceived as a custom-made orthodontic appliance made to adapt to individual tooth morphology and anatomy. It would be customized to move each individual tooth with the exact amount of force required to move it based on the tooth morphology and root surface area. It would have customized biomechanics and would be able to adjust the rate of tooth movement according to the individual's bone physiology. The final occlusal outcome would be customized according to the individual's dental arch form, smile esthetics, and soft tissue lip support. The tip, torque, in-and-outs, and occlusal contacts would be designed uniquely for each individual. This ideal appliance would be esthetic, hygienic, and comfortable and would accomplish correction of the malocclusion in the shortest time frame possible.

In reality, the future evolution of orthodontics has already arrived in the present, as clear aligners utilize digital technology together with CBCT integration for diagnosis, treatment planning, and designing the final occlusal outcome. To a certain degree, it is possible to customize the biomechanics and manage anchorage by staging tooth movements in a specific sequence in the software program. The rate of tooth movement may also be adjusted according to the individual's bone physiology by altering the scheduled number of days for aligner changes, depending on the individual's response to tooth movement. The final occlusion setup in the software may be customized according to the individual's dental arch form and preferences for smile esthetics. Soft tissue facial scanners allow for integration of the patient's soft tissue data with software programs that move teeth, allowing us to design an esthetic, harmonious smile that is customized for an individual's face.

If the future is already here, where do we go now? As orthodontists, it takes courage to step outside our comfort zone of the familiarity of brackets and wires to embrace a new orthodontic technique. It takes vision to challenge the status quo of conventional orthodontic thinking. It takes innovation to think of new ways of moving teeth. Finally, it takes diligence and time to produce well-designed scientific research in the field of clear aligners so that we can continue to practice clinically sound, evidence-based orthodontics. The future lies in continuing to innovate with passion to transform the future of our profession.

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