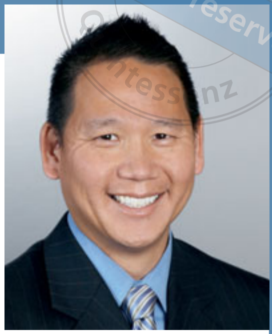
How aligner systems became the world's orthodontic appliance



James Mah

In the beginning

The humble beginnings of aligner therapy began with simple materials; plaster, wax and rubber with the purpose of artistic detailing of patients subsequent to fixed appliance treatment. Kesling[1] (1945) described the process of cutting teeth apart on a plaster cast using a jeweller's saw and repositioning them in improved positions to create a one-piece rubber appliance that he termed a 'positioner'. Kesling had already described the potential to use a series of these appliances for more complex tooth movements. This was also a time when precious and highly refined metals were not readily available and fixed appliances were relatively costly. Given the circumstances, clinicians continued to innovate the method and enjoyed success and popularity. 'Positioner societies' with members and meetings began to appear in the 1950s. Indeed, Bunch[2] (1961) published several case reports of treatment of relatively complex malocclusions with a series of positioners. Around this time, Nahoum[3] (1964) applied thermoforming of clear plastic sheets to plaster casts with repositioned teeth. He worked with a number of plastic sheet materials and thicknesses, and described the appliance as a cosmetic, invisible orthodontic appliance. Nevertheless, positioners became a mainstay in orthodontics and were commercialised by Kesling's family business, known today as TP Orthodontics, as well as other dental laboratories.

Modernisation

Modernisation of this process with the advent of computer use in dentistry led to anticipated utilisation of computers to perform digital diagnostic setups and simulations[4]. At that time, CAD/CAM had just been introduced to dentistry[5]. In an interview published in the Journal of Clinical Orthodontics, Burstone[6] described numerous applications of computers in diagnosis and treatment planning and provided a detailed description of an approach to staging a digital treatment. In the same interview, he presciently stated that orthodontics in the future would be more of a software than a hardware profession. Continued research and development of CAD/CAM in the 1980s provided approaches to digitisation of teeth, computer modelling and digital output to manufacture dental restorations. This pioneering work helped paved the way for computer-generated model surgery for orthognathic surgical planning[7,8] and stereolithographic output[9]. A computer-assisted method to manufacture orthodontic retainers, splints and other removable appliances was described by Sassani et al[10] in 1995. Modernisation also provided novel technologies such as laser scanning. This approach allowed relatively fast and highly accurate digitisation of stone casts[11]. In a technical paper in 1997, Hemayed et al[12] described a comprehensive system to obtain intraoral images, create 3D models of the dentition, segment individual teeth, reposition them and finally create a series of steps to rapid prototype physical models associated with the sequences of tooth movements. Since that time, there has been continual evolution and advancement of these concepts. Intraoral scanning, computer software and hardware, 3D printing and materials have tremendously improved. In essence, every aspect of this process has followed the technology mantra of 'better, faster, cheaper' and continues to do so.

Dedicated clinicians

Despite technological advancements, credit is due to those skilled and dedicated clinicians who collectively made aligner orthodontics into what it is today. In 1964, Nahoum[3] largely limited treatments to anterior teeth. Utilisation of interproximal reduction (IPR) further increased the range of malocclusion corrections. The technique of air rotor stripping added efficiency to this process and was popularised by Sheridan[13] in 1985. Appliance design and delivery were also advanced. In the 1980s, Truax fabricated three aligners (typically 0.015, 0.020 and 0.030 inches) in advance and dispensed them to patients in marked containers. In collaboration with an orthodontist, Dr Rains, this approach was further developed and became STARS (Serial Truax Appliance Rains System). Of particular note, the first thinner aligner was meant to deliver very light gentle forces to initiate the sequence of biological events for physiological tooth movement. Subsequently, the latter appliances were meant to provide more control and continue further tooth movement. A further enhancement to provide more control of tooth movement was the introduction of attachments by Martz[14] in the 1980s, which was an important adjunct to manage dental morphology that lacked features for the aligner to engage the tooth. When digitally designed aligner systems were first introduced, they were similarly limited to treatments of mild crowding and space closure[15]; however, clinicians with an understanding of orthodontic biomechanics applied their skills and demonstrated that aligners could be used to treat complex malocclusions and extraction treatments[16]. Since then, with auxiliaries such as buttons, elastics, hooks and temporary anchorage devices, clinicians have demonstrated treating the entire range of malocclusions using aligner orthodontics. As of this writing, it seems that the capability of aligners is only limited by the skill and expertise of the clinician.

The future

A constant in the history and development of aligner systems is the undeniable appeal to patients. Worldwide consumer awareness and demand continues to grow and expand to treatments of children and teens. Clinicians embrace aligner systems as this is most often the chosen modality for general dental practitioners to provide orthodontic treatments to their patients; look no further than the instruments and inventory required to provide fixed orthodontic treatment compared to aligner treatments. All the while, numerous companies that provide aligners have emerged. Although there may be claims and appliance protocols introduced into the marketplace as a differentiator from conventional norms, an unavoidable and inevitable reality is the biology of tooth movement and patient diversity. For example, reduced wear schedules[17] are largely unsupported by robust controlled studies. While the orthodontic literature is rich with articles on the biomechanics of fixed appliance orthodontics, comparatively very little exists on aligners. The biomechanics of fixed appliance bracket and wire systems are essentially beam mechanics with many concepts of orthodontic treatment developed around them. Some clinicians apply fixed appliance concepts to aligner orthodontics without understanding that the fundamentals are different and those concepts do not apply. An example is bite ramps in aligners. Teeth are limited to the amount of movement allowable in each aligner and will not intrude any more than the adjacent teeth. Fixed appliances allow for more individual tooth movements as there is slop in the arch slot and flexibility in the archwire. Another misunderstanding relates to resolving rotations with buccal and lingual attachments, akin to buttons on these surfaces in fixed appliance treatments. Momtaz and Mah[18] showed that additional attachments may be detrimental to resolving rotations. These are but two examples and there are numerous other areas that warrant investigation and better understanding. Herein is where the future of aligner orthodontics lies – a better understanding of aligner biomechanics coupled with an understanding of the biology of tooth movement. As the profession learns and educates itself, there is a learning curve. Reports of efficacy of tooth movement range from an overall 41%[19] to 57%[20] and more recently 74%[21]. Systematic reviews of the efficacy and efficiency of aligners also seem to indicate work in progress. Robertson et al[22] found an overall low to moderate level of certainty for most orthodontic tooth movements (rotations, intrusion, bodily movement) while Rossini et al[23] found limited mesiodistal movements and space closure most predictable, followed by mild arch expansion and molar distalisation movements. However, it is important to note that these studies largely are for an initial series of aligners and do not include revisions during treatment. Additionally, there have been improvements in materials, use of auxiliaries such as attachments, and changes in staging protocols. Aligner systems today are not the same as those even 5 years ago.

As I write this editorial, I am under a 'COVID-19 shelter in place/stay home' order with the exception of managing dental emergencies. It is notable that no emergencies related to aligner orthodontics have appeared while loose brackets, poking wires, and broken appliances are common. Needless to mention, at this time prior to the anticipated peak of the virus pandemic, trips taken for orthodontic emergencies add to the existing societal risk to patients, staff and dental practitioners. This leads to further discussion of situations where aligners may be superior to fixed appliances. The literature supports the safety of clear aligners, particularly from a periodontal and caries/decalcification perspective. Additionally, there may be certain craniofacial morphologies such as hyperdivergent patients that may be better treated with aligners as there are no associated deleterious changes in the vertical skeletal dimensions relative to fixed appliances[24].

One of the enduring lessons of this virus pandemic is the choice of biomechanics that are self-limiting in the event that a patient cannot be seen for long periods of time. Complications associated with active appliances such as closing chains that are not secured in the terminal end with a steel ligature have caused undesirable and almost unbelievable amounts of rotation. Similarly, nickel-titanium coil springs and torqueing springs that are unsupervised are also concerns. An advantage of aligners is the ability to start and stop treatments according to the situation at the time. Additionally, appliances can be delivered to the patient to resume the next steps of movement. Remote dental monitoring of treatments has emerged as an invaluable resource to accommodate social distancing guidelines, clinical supervision and peace of mind surveillance of treatment progress.

In summary, the rich history and experience of clear aligner orthodontics in combination with tremendous patient appeal and demand as well as the safety and continued improvements in efficacy of aligners will continue to maintain it as the world's most desirable orthodontic appliance.

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