Clear aligners: How has the technology evolved?

By Brendan Day, DTI

Though still a relatively new orthodontic treatment modality, clear aligners have quickly become an increasingly popular alternative to fixed appliances for tooth straightening, since they provide an aesthetically appealing and comfortable choice. However, the recent rapid advancements in aligner technology are yet to be recognised by many dentists, leading to a low adoption rate. This article will provide an introductory overview of aligner treatment and its development.

Traditionally, malalignment has been corrected using fixed orthodontic appliances. However, in 1999, Align Technology made its Invisalign system available for commercial purchase, altering the future path of orthodontics. A clear aligner, Invisalign offered an effective alternative in orthodontic treatment, as its correct use can minimise the plaque build-up, gingival recession and inflammation of soft tissue sometimes associated with fixed appliances. Additionally, its complete lack of metal parts presented an aesthetic advantage, and the ability to remove it at any time (especially relevant during eating) allowed Invisalign patients a level of comfort and hygiene care previously unmatched in orthodontic treatment.

Through its recently introduced Invisalign Go system—a treatment programme aimed at guiding general dental practitioners through the process of identifying, planning and treating suitable cases using the aesthetic tooth straightening solution—Align Technology has become entrenched as the global market leader in clear aligners. Other companies have since recognised the value of this therapy, though, and this increased focus has led to a rapid progression in the sophistication of aligner modelling and manufacturing. Dr Les Joffe, Secretary of the European Aligner Society (EAS), the only International organisation in Europe devoted to the promotion of education and research in aligner therapy, believes that these advancements have not yet been fully recognised by all dental practitioners. In an interview with Dental Tribune, Joffe said that dental professionals often pass judgment on the suitability of aligners based on outdated information and technology. “There is a misunderstanding by many clinicians that aligner treatments are limited,” said Joffe. “Many clinicians base their view on the early stages of aligner development, from around 2001 to 2003. More than 15 years later, the huge strides that have been made in aligner performance are not fully understood and therefore the modality is either not adopted or provided.

These major advancements in clear aligner technology include the integration of much more sophisticated 3-D modelling software, able to customise each aligner to an individual patient’s needs. “Clear aligners have deeply changed orthodontics,” Agnieszka Dziedziul, Clear Aligners Department Manager for NimroDENTAL Orthodontic Solutions, told Dental Tribune. Established in 1999, NimroDENTAL is one of the largest orthodontic laboratories in the UK, using four different aligner systems in its work with dental practices. “When we started making clear aligners 15 years ago, we were limited to creating movements by hand on a plaster model,” said Dziedziul. “Today, though, we use sophisticated software and the latest 3-D printers to create clear aligners that can correct the majority of malocclusions.”

The lack of awareness of clear aligners’ benefits among dental practitioners has sometimes been attributed to a lack of scientific studies on this treatment modality. As aligner therapy has developed and been more widely adopted, however, increasing research into its effectiveness and patient satisfaction rates has been conducted. For example, a 2013 study published in the BMC Oral Health journal compared oral health status and satisfaction levels among patients who had received fixed appliances and those treated with the Invisalign system. It found that Invisalign patients were more satisfied overall and enjoyed greater periodontal health, with slightly lower levels of dental plaque. According to another study, conducted in 2013 and published in The Angle Orthodontist journal, compared with those treated with conventional edgewise brackets, patients who had received aligner therapy had significantly fewer dental visits, shorter treatment duration, fewer emergency visits and less overall chair time.

Aligner therapy is one of the fastest-growing areas in orthodontics, driven significantly by patients who regard it as a more comfortable, convenient and discreet alternative to fixed appliances. Given that market research firm Technavio has projected this market to grow at a compound annual rate of 12.8% per cent globally from 2016 to 2020, the need for organisational bodies to increase education and awareness of aligner therapy is essential. The German Association for Aligner Orthodontics was founded in 2007 and the Japan Academy of Aligner Orthodontics in 2013, with both organisations aiming to foster a space for increasing awareness of the applications and advantages of aligner therapy.

More recently, the EAS was established in 2013, with Dr Graham Gardner serving as its founding and current president. In order to promote education on the latest technologies used by clear aligners, the EAS will be hosting its first AlignerLab workshop on 18 February 2017 in Vienna in Austria. It follows on from the successful first EAS congress in February 2016 and will provide clinicians with an opportunity to engage in a variety of hands-on sessions covering 3-D intra-oral scanning, 3-D printing, virtual treatment planning techniques and tooth movement acceleration techniques.

Gardner believes the AlignerLab will highlight how far aligner therapy has come in such a short time. “With the explosion in the 3-D treatment planning and manufacturing processes now available, we at the EAS believe that not only do we need to update our knowledge on the various aligner systems available, we also need to understand the associated hardware—scanners, computers, software, 3-D printing—that is necessary to optimise the aligner system and improve treatment results,” he told Dental Tribune. Gardner envisions the event ideally becoming a regular occurrence to allow dental professionals to trial and compare new systems and developments in aligner technology.
Obesity may influence response
to orthodontic treatment in minors

By DTI

LONDON, UK: In Western countries like the UK, it is estimated that almost every third child is now overweight or obese. At the same time, an increasing number of children are receiving fixed braces to correct malocclusions at an early age. A new study conducted by researchers at King’s College London Dental Institute and published in the Journal of Dental Research has now indicated that the response to this particular type of treatment can significantly vary depending on a child’s body weight.

In the cohort study, the researchers followed a number of adolescent patients, who were classified as normal weight or obese based upon their body mass index, from the start of their treatment to the completion of tooth alignment. During the examinations, it was found that those patients who were obese had a significantly increased rate of initial tooth movement and required less time to achieve tooth alignment compared with normal-weight patients.

The researchers also noticed increased levels of inflammatory biomarkers in the gingival tissue of obese patients prior to orthodontic treatment. The first of its kind to study the relation between obesity and orthodontic tooth movement, it demonstrates that the condition in adolescent patients influences the supporting tissue around the tooth, the researchers said, and this could have important implications for orthodontic treatment outcome in obese patients over both the short and long term.

Levels of obesity have increased significantly throughout all age groups in Western societies in the last two decades, and it has been linked to multiple chronic diseases, including periodontal inflammation. In a 2015/2016 evaluation, Public Health England found that 14 per cent of one million schoolchildren in the UK were classified as overweight and almost 20 per cent as obese.

The King’s study, titled “Impact of obesity on orthodontic tooth movement in adolescents: A prospective clinical cohort study”, was published online on 23 January in the Journal of Dental Research.
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Aligner therapy continues to improve
An interview with the President of the European Aligner Society (EAS) Dr Graham Gardner

Since it was commercially introduced in 1999, aligner therapy has grown and developed substantially as an orthodontic treatment modality. Dr Graham Gardner from Winchester, the President of the European Aligner Society (EAS), an organisation dedicated to increasing education and research in aligner therapy. The inaugural EAS AlignerLab workshop will be held in Vienna in Austria on 18 February and aims to provide a hands-on learning experience for dental professionals interested in upping their knowledge of aligner treatment. Dental Tribune interviewed Gardner about the role of aligners in orthodontics and what the event organisers have in store.

Dental Tribune: What benefits do aligners offer over fixed orthodontic appliances, and how have these benefits developed since aligners were first introduced?

Dr Graham Gardner: In my opinion, the advantages of aligner therapy for the patient are the following:
1) They are more comfortable than fixed appliances.
2) They are more aesthetic, and therefore less noticeable, compared with fixed appliances. This is especially important for someone seeking orthodontic treatment because he or she is already concerned and self-conscious about his or her teeth, as the last thing such a patient would then want is to draw attention to his or her teeth with fixed appliances.
3) Improved maintenance of oral hygiene and no dietary restrictions, as the aligners are removed for eating.

The advantages of aligner therapy for the orthodontist are:
1) Improved treatment planning capabilities owing to the 3D treatment software. Virtual treatment planning allows one to evaluate different treatment options. This can be more clearly discussed with the patient owing to the virtual presentation process. In my opinion, this allows the patient to make a more informed decision on the treatment.
2) Broken brackets and emergencies are things of the past.

Additionally, a benefit shared by both patient and clinician is that adjustment appointments are often quicker and certainly more comfortable for the patient compared with fixed appliances.

What have the main impediments been to the adoption of aligners by dental professionals?

I think that, initially, aligners were basic and our knowledge on how to move teeth with plastic was limited. Hence, in the earlier years, only minor tooth movement could be predictably treated with aligners, and this limited their use and then restricted the number of practitioners prepared to use aligners. Combined with the fact that the practitioner now had to learn new software programmes and how to plan treatment on a computer—a vastly different skill to having the physical study model in one’s hands and brackets on teeth—one can see why the initial take-up was perhaps less than would have been expected.

The first EAS AlignerLab is set to take place in Vienna in February. What prompted the EAS to hold this workshop, and what can participants expect to gain from it?

We are excited about the first AlignerLab. With the explosion in the 3D treatment planning and manufacturing processes now available, we at the EAS believe that not only do we need to update our knowledge on the various aligner systems available, we also need to understand the associated hardware, such as scanners, computers and 3D printers, and software that is necessary to optimise the aligner system and improve treatment outcomes. It is therefore our objective to bring these two areas together in one event with the AlignerLab.

This will allow attendees to gain an opportunity to listen to world-famous clinicians on different systems, to compare these different aligner systems and to gain hands-on experience with the different equipment associated with these systems. We think it is a unique way to update our knowledge on aligner therapy, with a bonus opportunity to forge links with our colleagues across Europe.

Is the AlignerLab a one-off thing or is it intended to become a regular event?

We hope this will become a regular event because technological developments and advances will continue. Thus, an event at which practitioners can make direct comparisons and trial new systems should become a regular event because technological developments and advances will continue. An event at which clinicians can make direct comparisons and trial new systems should become a popular and regular occurrence.

Thank you for the interview.

Invisalign Go en route to success—2016 in review

By DTI

AMSTERDAM, Netherlands: With launches in Germany, the UK, France and Italy, numerous Invisalign Go introductory seminars and a series of enhancements for the system, Align Technology has just been completed an exciting year with its new product, Invisalign Go. Designed specifically for general dentists, the new aesthetic tooth-straightening product that can treat mild crowding, spacing and orthodontic relapse has experienced a huge demand in record time and promises great potential for the future.

Align Technology’s Invisalign braces are enjoying increasing popularity and have already helped over four million patients beautify their smiles. Until recently, aligner treatment was limited to specialists, however, since the introduction of Invisalign Go this has changed significantly. With the help of case assessment software and a network of experienced orthodontists, general dentists are now able to treat cases of tooth misalignment between the first premolars.

Since its launch, hundreds of interested dentists have already become familiar with the new system through introductory seminars run by orthodontists and long-term and Birmingham this month,” said dentist Dr Andy Toy, an East Midlands-based orthodontist who led the first two courses in London and Birmingham this month,” said dentist Dr Andy Toy, an East Midlands-based orthodontist who led both events. “That tells us that dentists are responding positively, whereas sometimes in other courses, one is lucky to see them after three months and one finds they haven’t really done anything. I think we have made a powerful start here.”

The enthusiasm for the multi-disciplinary system is also reflected in the participants’ positive feedback. “We believe that Invisalign Go will be very relevant to us. We liked the day here, it was a great course with a great instructor who explained everything very well,” Dr Jens Rathje summarised after a training day in Hamburg. The dentist from Lübeck, who specialised in orthodontics and dental hygiene, and his wife, endodontics specialist Dr Isabelle Rathje, were interested in Invisalign Go because they want to expand the scope of their aesthetically-oriented practice.

Equally enthusiastic about the possibilities of the system was Dr Melanie Elger from Hamburg: “What I like about the system is that you have various tools to visualise the treatment for the patient and you have assessment tools to decide which cases can be done with an aligner system and which should rather be treated conventionally.”

Owing to the close cooperation between dentists and orthodontists, Invisalign Go enables a strong bundling of competencies and therefore ensures medically optimal results. In order to expand this approach, Align has published a series of improvements for the product in October that will make the application of the system even more efficient. This includes, for example, the new Invisalign Go Photo Uploader App for iPhone, which allows dentists or assistants to directly capture the intra- and extra-oral photos of their patients and upload them directly to the Invisalign Doctor Site to start the case assessment.

The new ClinCheck Pro 5.0 software also allows for extended application possibilities. In addition to improved visualisation, ClinCheck Pro 5.0 includes a range of new features such as a customisable toolbar, a ClinCheck wizard for better orientation through the treatment plan and a modification warning. Moreover, the case assessment and the tools for assessing the progress of treatment will also be revised. The improvements will make use of the new system and the time spent with patients will be even more effective than before.

Invisalign Go will further expand their training programme due to a growing demand. France, Italy and the UK and new product improvements are to be announced in 2017.
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Accelerated orthodontics and vibration therapy to fast track orthodontic tooth movement (OTM) have been hotly debated topics in the orthodontic industry in recent years. Periodontally Accelerated Osteogenic Orthodontics (PAOO) techniques such as osteotomy, open flap corticotomy, and piezoection have been shown to decrease treatment time. Unfortunately, these techniques are not without limitations, as they have had limited patient acceptance because of their invasiveness and side effects. In the last several years, micro-perforation, which takes advantage of the same biological regional acceleratory phenomenon as classical techniques, has been gaining rapid clinical adoption because of the simplicity of its chairside minimally invasive nature.

There is also growing evidence that the application of mechanical energy-based therapies such as vibration can stimulate and accelerate bone formation and possibly bone remodelling. Orthodontic tooth movement, caused by the application of light continuous forces that induce bone formation and remodelling, could logically be accelerated by the application of vibrational force, with the benefit of reducing the overall treatment time. Since 2009, AcceleDent (OrthoAccel Technologies) has offered a piezoelectric vibration device, offering the promise of accelerated orthodontic treatment based on delivering mechanical stimulation to the dentition. At this point, research on the efficacy of this device in accelerating OTM has been mixed, and clinicians debate its value.

The debate on vibration therapy as it applies to accelerated orthodontics in general, and the efficacy of a specific device specifically, should consider other factors in evaluating efficacy. First, there is a distinct possibility that frequency optimisation of the devices concerning bone formation/remodelling has not been established. AcceleDent operates in a low frequency range, however, research points towards the benefit of high frequency bone formation in bone modulation. Secondly, current research indicates that high frequency low magnitude (HFLM) vibration therapy as applied to orthodontic treatment may have multiple potential benefits, including, but not limited to, accelerated OTM.

Current vibration devices used in orthodontic therapy

As mentioned previously, the most common, commercially available, vibration device for orthodontic treatment is AcceleDent manufactured by OrthoAccel Technologies. This device delivers a vibrational frequency of 30 Hz and requires 20 minutes per day user wear time.

Several early studies on the AcceleDent device seemed to demonstrate higher rates of OTM than the established norms. However, there are other more recent studies that have failed to establish the advantages of the same therapy. A study by Woodhouse et al. (2015) analysed the AcceleDent device to demonstrate its effect on OTM in extraction cases. They found that the supplemental vibrational force did not significantly increase rates of orthodontic alignment with a fixed appliance. Another comprehensive report on vibration therapy by investigators Yadaia et al. (2017) concluded that low frequency mechanical vibration using AcceleDent had no significant effect in accelerating tooth movement. The recent studies regarding the apparent ineffectiveness of AcceleDent may be explained by the relatively low vibrational frequency of the device. For purposes of this discussion low and high frequency are defined as:

- Low frequency—less than or equal to 43 Hz.
- High frequency—greater than or equal to 90 Hz.

In a 2010 study by Jened and Rubin, ovirctomised rats were subjected to either low or high frequency vibration. Bone formation rates for subjects treated with high frequency were 199 per cent greater when compared to controls, whereas bone formation for low frequency rat subjects were not significantly different than controls. Trabecular bone volume and thickness were also significantly higher for subjects treated with high frequency. Similarly Akhandi et al. found a statistically higher rate of alveolar bone formation (+90 per cent) at higher frequencies, with a five minutes per day application. In short, the most pronounced osteogenic effects of vibration seem to occur well above the AcceleDent's low vibrational frequency.

Practically speaking, five minutes of daily wear time may be beneficial, as it will reduce the dependency on significant patient compliance. In order to realise the maximum benefits of vibration therapy, shorter wear times would likely result in bone formation, and improve results. Given all other factors being equal, the studies suggest that a higher frequency device would deliver equivalent amounts of HFA Energy to the dentition in a significantly reduced timeframe.

The future of vibration therapy: Expanded application, multiple benefits

The apparent limitations of current commercially available vibration devices should not diminish the potential importance of vibration therapy. Setting aside applications such as implant dentistry and prosthodontics suggested by the osteogenic properties associated with vibration therapy, there are at least four important clinically beneficial orthodontic applications that can be anticipated. These potential applications are: 1) as a nightly clear aligner seating device; 2) analgesia, relief from normal discomfort associated with orthodontic treatment; 3) accelerated orthodontic tooth movement; and 4) enhancement of orthodontic retention. Setting aside overuse of vibration restores normal circulation to the PDL, which is otherwise restricted by compressive forces. Increased blood flow intercepts the ischaemic response and limits inflammation.

Improved aligner seating

The importance of properly seated aligners, to efficient tooth movement in aligner therapy is clearly understood. Improperly seated aligners can slow treatment, forcing patients to backtrack to previous trays, and create unintended collateral tooth movements, with a consequence being time consuming and costly refinements. Seating recommendations range from using ‘chewies’ to biting on hard objects. Some clinicians advise seating only when trays are new (immediately post change), while others recommend daily seating. With the current seating modalities, it is unlikely that patients consistently seat aligners fully. A seating protocol, that takes only five minutes nightly, delivering a range of other patient benefits, would insulate that aligners are fully seated throughout treatment. Consistent proper aligner seating, would likely result in more efficient, faster aligner treatment, even absent biomechanical effects caused by vibration itself.

Non-pharmacological analgesia

Discomfort or pain is a common side effect of orthodontic treatment. The forces applied to the dentoalveolar complex which are required to move teeth, compress the periodontal ligament (PDL) causing inflammation. Pain is most notable when seating a new aligner, or immediately after wire changes and adjustments, when pressure on the PDL is at its greatest, and diminishes as the aligner material expands, and/or the dentition com- plem. In a study accepted in September 2005 by the Angle Orthodontist for future publication, Lobre et al found in a randomised clinical trial that vibration therapy resulted in significantly lower perceived pain and less OTC medication use. One theory that vibration restores normal circulation to the PDL, which is otherwise restricted by compressive forces. Increased blood flow intercepts the ischaemic response and limits inflammation.

Accelerated OTM

It is well established that bone undergoes formation and resorption in response to external loading such as gravitational forces, as well as to internal loading such as muscular activity. Recent research with both animal and human models have demonstrated anabolic responses such as bone growth and changes in bone mineral density in response to vibration. Since OTM is fundamentally based on bone remodelling (formation and resorption) there is little doubt that HFLM vibration has the potential to favourably impact OTM.

In a recent split-mouth randomised trial involving bilateral maxillary canine distraction after first premolar extraction on 15 human subjects, Leethanakul et al. (2015) investigated the impact of vibration on accelerated tooth move-
ment, as well as on cytokine activity related to osteoblast and osteoclast differentiation (specifically IL-1b levels in GCF). The patients applied vibration to the experimental canine using a commercially available electric toothbrush operating at high frequency (125 Hz). This study found significantly increased tooth movement (+36 percent) accompanied by a threefold increase in average IL-1b levels.²⁵

It can be hypothesised that vibration, amplitudes the familiar osteoblast–osteoclast cellular response causing bone formation and resorption, when the teeth are under force (i.e., from fixed appliances and aligners). In the absence of force, vibration causes new bone apposition only, which has potential implications for the retention phase (see below). Note that the frequency of the device creating the accelerated tooth movement in the Leethanakul study was in that high frequency range shown to have superior effects on alveolar bone formation by Iken and Rubin, and Alikhani et al.¹³⁻¹⁴

Enhanced retention
Vibration therapy warrants the attention of the scientific community to further explore its effect during the orthodontic retention phase. Scientific literature documents that the primary reason for orthodontic relapse is the inability of collagen fibres (Transseptal fibres and PDL) to reorganise quickly after the completion of orthodontic treatment and the delay in new bone apposition.⁶ Studies suggest that vibration can have potentially favourable impacts on both bone formation and reorganisation of the PDL fibres.

A study from Rubin et al. (referred above) states that vibration therapy by itself has always been anabolic, which means it led to bone apposition and a decrease in bone resorption. Reports have documented an increase in bone density, bone formation, Type-1 collagen and non-collagenous matrix expression in response to the therapy.⁶

Recent studies by Yadav et al. (2013) and Alikhani et al. (2013) (both referred above) have demonstrated that vibration therapy improved not only bone density, but also restored the integrity and thickness of the collagen fibres. With evidence suggesting that vibration therapy positively impacts both bone morphology and the PDL fibres, vibration during the retention phase may play a significant role in preventing orthodontic relapse.

Conclusions
The current debate over vibration therapy and its impact on accelerated orthodontic tooth movement, should consider other potential benefits of this therapy including applications for aligner seating, relief of normal orthodontic pain, enhanced retention and applications to implant dentistry and prosthodontics.

It can be hypothesised that a vibration device operating in the high frequency range would likely be most effective in creating OTM as well as offering shorter wear times impacting compliance. The most commonly available commercial device operates at a frequency that is below thresholds having statistical significance in creating orthodontic tooth movement as documented in several recent studies, and requires a relatively long, 20–30 minutes daily wear time.

The strong supporting data concerning the positive effects of vibration therapy on bone formation, bone density and collagen fibre reorganisation leads us to believe that this modality of treatment may revolutionise the concept of orthodontic retention.

The effects of high frequency vibration therapy may be useful in modifying the bone density to the clinician's advantage in implant placement or to maintain the thickness of bone trabeculae in edentulous patients undergoing prosthodontic treatment.

Editorial note: A complete list of references is available from the publisher.

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