New concepts in aligner therapy
with the orthocaps system

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Historical background

Overlay appliances have been used in orthodontics for more than 90 years. In the early days, such appliances were shaped like positioners, that is formed as single-unit appliances with tooth cavities to receive both maxillary and mandibular teeth. For minor orthodontic tooth movement, Remensnyder in 1923 described a rubber gingival massaging appliance that he later patented as an “orthodontic appliance”.1

In 1945, Kesling published a landmark article in the American Journal of Orthodontics and Oral Surgery titled “The philosophy of the tooth positioning appliance”.2 In this article, Kesling described the making of a set-up model after teeth had been cast and repositioned in wax on the model base. The “positioner” was thus formed as a negative of the model created by repositioning teeth in wax. Kesling, in a patent that was granted in 1945, stated that, if the extent of tooth movement was beyond the scope of a single appliance, more than one appliance could be used in sequence to move teeth. McNamara et al., Ponitz, Nahoum, Sheridan et al., Rinchuse and Rinchuse, and others also described the use of overlay appliances that took the form of modern-day aligners to achieve orthodontic tooth movement.3–7

As the use of CAD/CAM became common in dentistry in the 1990s, the concept of using digital 3-D scanners and rapid prototyping technology became apparent in the manufacturing of aligners. François Duret, a French innovator and dentist, used CAD/CAM techniques to construct dental prosthetic and restorative units as early as 1983.8 In 1996, researchers like Alcañiz et al. and Hemayed et al. separately described in detail the use of CAD/CAM techniques to create computerised set-ups and rapid prototyping models for diagnostic and therapeutic purposes in orthodontics.9, 10

In 1998, Align Technology commercialised the production of aligners using such CAD/CAM techniques. Although the Invisalign system is the most widely used, some companies, including Ortho Caps, offer alternative aligner techniques, such as the orthocaps system.

Aligner mechanics

The mechano-transduction (transmission of force) of orthodontic forces triggers a tissue response that results in orthodontic tooth movement. Teeth and the surrounding tissue do not differentiate between force generated by aligners or any other type of appliances. The factors that determine the quality and quantity of orthodontic tooth movement depend greatly on the force system that is used, including the amount of force, its duration and dynamics, and the underlying tissue response. It is therefore imperative that the design of the appliances, the material property of the thermoplastics, and the interface between the tooth and the appliance are conducive to creating a force system that ensures controlled, effective and safe tooth movement.

Aligner design

Aligners are removable appliances and are therefore inherently at a disadvantage when compared with fixed appliances. The aligner–tooth interface is mechanically less efficient in transmitting orthodontic force to the surrounding tissue as compared with systems based on brackets and wires. In order to overcome this disadvantage, it is important that the appliance design incorporates features that enable the aligners to have a good grip on teeth and allow the aligners to have maximum surface contact with teeth.

Material properties of thermoplastics

A variety of thermoplastic materials are available that can be used for manufacturing aligners. These materials not only differ in their composition and thickness, but also differ in properties such as elasticity, which is essential for tooth movement. The choice of material essentially depends on the type and amount of tooth movement, the required force levels, and the condition and health of the underlying tissue.

The aligner–tooth interface

As already mentioned, in order to transmit force effectively, it is important to create an interface (contact area)
that allows the transmission of force without loss of magnitude, directional control, or both. This requires an exact aligner fit, as well as an accurate reproduction of the tooth surface and the interdental areas in models that are used to manufacture aligners. Aligners manufactured on such models have the required fit on the teeth to achieve a good grip.

**The orthocaps system**

The orthocaps system is designed to address the core problem that many aligner systems have, namely, the lack of ability to transmit force to teeth without mechanical or directional loss, and the lack of adequate control while delivering forces that move teeth accurately in all six degrees of freedom (x-, y- and z-axis translation and x-, y- and z-axis rotation) in 3-D space.

For this reason, the system emphasises the use of elastic materials in the fabrication of aligners. The orthocaps system (TwinAligner) also uses two different types of aligners for each treatment step throughout the treatment. This technique ensures the use of optimal forces that can be generated by selecting different thicknesses of elastic materials that are used for aligners that are worn at night or during the day (DayCaps/NightCaps).

**Aligner design**

In the orthocaps system, an exact aligner fit is of paramount importance. Modifications to aligner design, like pressure points, dents, divots or certain types of structures, such as power ridges, that are used in some other systems to direct force to certain areas on clinical tooth crowns are thought to be counter-productive. These modifications result in spaces and voids (Fig. 1) that are created between the teeth and aligners and therefore reduce the grip of the aligners on teeth. The main design feature for the orthocaps aligners is thus the ability to encapsulate the teeth completely. This allows the maximum surface of the teeth to be in contact with the soft inner aligner layer, which is more elastic than the outer rigid aligner shell (layer). High-pressure thermoforming techniques also facilitate flow of the aligner material into the interdental areas, thereby increasing the surface contact area with the aligners.

**Thermoplastic materials**

Material elasticity is the foremost property that is needed in achieving controlled tooth movements. Elastic deformation of aligner materials generates the force that is required to move teeth. Elastic materials can be deflected or deformed to a greater extent without losing their shape or form. This deformation is generated owing to the difference in the position of teeth between the set-up model on which the aligners are fabricated and the actual position of the patient’s teeth. If the aligner material is elastic, the aligner regains its original shape completely when it is removed from the mouth. This means that the aligner remains active and continues to exert a force until it returns to its original form and thereby moves the teeth effectively. In contrast, inelastic and rigid materials undergo a plastic deformation even at lower deflection levels (strain) and thus lose their form and therefore are unable to move teeth. This is why inelastic materials for aligners are not as effective as elastic materials.

In Figure 2, the material stress is plotted along the y-axis. The amount of stress is the force (F) in newtons...
divided by area (A) in m². The material strain or deformation is measured as a percentage of deflection from the original state of rest. For linear deformation, this is calculated as the increase in length (l) divided by the initial length (L). The elasticity (modulus of elasticity, E) of a material is shown by the gradient of the curve and is calculated by dividing stress by strain as shown in the following equation:

\[ E = \frac{F/A}{\partial l/L} \]

Bending, stretching or deforming a material beyond its elastic limit results in plastic deformation of the material. It is important to remember that elasticity is a material constant and does not depend upon the thickness or geometry of the material. The same degree (%) of deflection or strain would result in permanent deformation of a given material regardless of its thickness or shape.

Orthodontic movement is thus caused by the rebound force that makes the elastic material regain its original state or shape. This force is directly proportional to the area, modulus of elasticity, and the deflection or strain the material is undergoing, provided that the material is not strained beyond its elastic limit as shown in Figure 2:

\[ F = AE(\partial l/L) \]

**Attachments**

Many types of attachments can be used to increase the efficacy of tooth movement with orthocaps. The use of soft and elastic materials also makes it easier to use attachment types that would otherwise be impossible to use with rigid or hard materials. Some of the attachment types are shown in Figure 3.

**Friction pads**

Apart from normal attachments, a new type of attachment, a friction pad, was developed at the Ortho Caps centre in Germany. This friction pad consists of a flat
textured surface that is bonded to the tooth in order to increase the friction between the inner aligner surface and the tooth. The advantage of using friction pads is that these textured surfaces are only a fraction of a millimetre thick, making them almost invisible under normal circumstances and therefore more acceptable to patients. Figure 4 shows the CAD model of the friction pads on two teeth.

The attachments or friction pads are bonded to the teeth by indirect bonding techniques. Preformed attachments or friction pads are sent to the clinician placed in the first aligners ready for indirect bonding. Figure 5 shows the friction pads bonded to several teeth. As can be seen in the photographs, the friction pads are only visible on close inspection. This aesthetic advantage of friction pads over regular attachments makes this type of bonded retention aid much more acceptable to patients seeking an invisible treatment option.

Clinical cases: Before and after records

Case 1
This young adult female patient was treated for maxillary and mandibular crowding and deep bite over 18 months (Fig. 6). The orthocaps Pro system was used without any auxiliaries.

Case 2
This young female teenager was treated for a Class II bite and deep bite over 24 months (Fig. 7). The orthocaps Pro system was used without any auxiliaries. Towards the end of the treatment, a BiteMaintainer was used as an active retainer.

Case 3
This 45-year-old female patient was treated over a total of 28 months with a distalising apparatus based on temporary anchorage devices, followed by orthocaps aligners, to correct the overjet and a midline deviation (Fig. 8).

Case 4
The treatment for this 12-year-old was started in the mixed dentition with orthocaps Kids (Fig. 9). The last phase of the treatment was completed with orthocaps Pro. No auxiliaries were used in the entire treatment, which took 30 months.

Case 5
This 33-year-old female patient was treated for posterior crowding over 28 months (Fig. 10). The maxillary right first molar was extracted and the space closed by moving the second molar into the extraction space with orthocaps aligners. At the end of the treatment, Ortho Caps provided a lingual auxiliary, consisting of four lingual brackets and a pre-ligated nickel-titanium wire within an indirect bonding tray to bond the appliance. Subsequent aligners were designed to immobilise the two premolars, while allowing the second molar to upright. This design created the necessary anchorage in order to upright the second molar effectively.

Conclusion
The mechanical limitations of aligners can be overcome, and satisfactory orthodontic tooth movement, even in complex cases, can be achieved to a certain extent provided the following conditions are met:

1. knowledge of the limitations of aligner mechanics;
2. use of auxiliaries (mini-screws, expansion appliances and partial fixed appliances) in conjunction with aligner treatment;
3. use of elastic thermoplastic materials to avoid plastic deformation of aligners during treatment and to optimise force levels (light forces);
4. accurate reproduction of interdental areas in digital scans to allow maximum aligner–tooth contact;
5. high-pressure thermoforming techniques to achieve better aligner adaptation;
6. sound planning (regulation of the amount of movement per stage) in the treatment staging process;
As the demand and need for aesthetic orthodontic treatment alternatives have grown, aligners have secured a firm place in the orthodontic repertoire. However, the inherent disadvantages associated with the use of removable appliances such as aligners for orthodontic tooth movement pose great challenges in improving their efficacy. The orthocaps system is an effort in that direction.

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

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7. use and placement of suitable attachments and friction pads to increase aligner grip;
8. clinician’s experience and ability to recognise problems during the treatment process;
9. division of treatment into phases and the evaluation of treatment progress (superimpositions and deviation analyses) at regular intervals during treatment; and patient motivation and cooperation.