Introduction

The concept of moving teeth as a series of planned stages utilising set-up models and vacuum form clear appliances or positioners have been reported long time ago by Kesling1, Nahoum2, Ponitz3, McNamara et al.4, Sheridan et al.5, Rinchuse and Rinchuse6 and Lindauer and Shoff7. The shortcomings to these previous techniques lie in the relatively limited magnitudes of possible changes due to technical difficulty in constructing precise stages from larger overall movements and necessity of a new model set-up and new set of impressions in almost every clinic visit making this technique unpopular in the profession.8, 9

Computerised Imaging, Virtual Treatment Planning and Orthodontic Treatment of Dental Malocclusions Using the Invisalign Appliance

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The emergence of the revolutionary Invisalign® appliance (Fig 1) in 1998 revitalised the concept and started the new era of an esthetical pleasing orthodontic appliance by means of latest computer assisted technology in imaging, designing and manufacturing (CAI/CAD/CAM), capable of providing new dimensions in addressing the appearance concerns of aesthetically conscious patients who would otherwise have refrained from orthodontic treatment. This technique was officially launched in Hong Kong in late 2001. The new appliance is much more comfortable, hygienic and appealing to patient, however, the application is still limited to some selected cases.

Once the diagnosis and treatment plan has been made, digital images of the clinical photos, panoramic oral radiograph, lateral cephalometric radiograph, a set of polyvinylsiloxane (PVS) impression and occlusal registration bite and the filled prescription form will be sent to the laboratory. By means of sophisticated CT scanning directly on the PVS impressions, detailed digital images are generated, which are converted into dimensionally accurate 3-dimensional electronic study models. The electronic upper and lower study models are virtually fitted together in maximum intercuspation based on information from clinical photos and patient’s bite registration. Computer-modelled gingivae are placed around each tooth and landmarks such as the facial axis of the clinical crown are identified10. This allows precise replication of the original dentition as an on screen 3-D model, which can be manipulated by a team of specially trained graphic technicians using the proprietor’s software Treat® for the correction of malocclusion according to the treatment plan developed by the orthodontist.

It is possible to view the virtual models from pre-treatment malocclusion to final result, step by step and from any angle, anytime and anywhere, through a web-base connection viewing program called ‘ClinCheck®’ (Fig 2).

This on-line treatment plan serves as a powerful communication tool for the orthodontist to enable patients to visualise the final result as well as all the steps in between before the start of the actual treatment11. The orthodontist can review each aligner stage and the related teeth movements together with the patient. Changes made to treatment plan will be reflected in a new virtual set-up for further corrections if necessary, until the orthodontist and patient are satisfied with the plan.

Once the virtual treatment model set-up and staging are approved by the orthodontist, the aligners will be fabricated by means of a computer-aided design/computer-aided manufacture (CAD/CAM) process. Each virtual treatment stage is transformed into a physical laser-cured plastic resin model by a machine called stereo lithography apparatus (SLA). These models serve as templates to produce aligners via a thermo-forming process. The aligners are later laser etched, trimmed, polished, disinfected, packaged and shipped to the orthodontist.

The actual clinical procedure involves wearing of a series of 0.030-inch thick clear removable plastic aligners to move teeth sequentially (Fig 3). Each aligner has to be worn for a minimum of 20 hours over 2-3 weeks before changing to the next one until the end of the treatment12. Depending on case, the number of aligners can go up to 40-50 per arch. Each aligner is designed to move a tooth or a small group...
of teeth in increments of about 0.15 - 0.30 mm. This movement threshold reflects the maximum amount of possible activation with respect to the tooth position and modulus of elasticity of the appliance material.

Case Reports

Case I  Crowding and deep overbite
The following patient presented with the chief complaint of anterior crowding and deep overbite (Fig 4). Correction was successfully accomplished after 12 months of treatment. Relief of crowding and overbite correction were achieved by selective interproximal tooth reduction (IPR), mild incisor proclination and intrusion. Lower midline off was corrected. This case was well monitored and the clinical results were well correlated with the virtual set up throughout treatment.

The corresponding virtual ClinCheck® stages (Fig 5) are as follows:

Case II  Upper anterior spacing
The following female patient complained of drifting of upper incisor and upper median diastema, which had adversely affected her appearance (Fig 6). The total treatment time was only four and a half months. Good oral hygiene had been maintained throughout treatment. The upper midline was well maintained despite of the asymmetrical distribution of the space. The final result is aesthetically pleasing.

The corresponding virtual ClinCheck® stages (Fig 7) are as follows:

Limitations
There are many limitations of the appliance. The appliance cannot be used in growing child especially when there is active dental and skeletal development. The appliance does not allow continue eruption of teeth and growth of the jaws. The whole treatment regime is pre-determined. The orthodontist cannot alter the appliance or treatment plan during the course of treatment otherwise, new impressions is needed to 'reboot' the case, which adds to the overall cost of the treatment. Careful prospective treatment planning is therefore required. Sometimes the virtual movement may not be reproduced clinically which makes the treatment unpredictable. Root paralleling, mesial bodily movement of molars, de-rotation of rounded teeth especially canines and extrusion are less predictable movements. Cost of the treatment is much higher than the conventional fixed orthodontic appliance.

Conclusion
The Invisalign® appliance has gradually developed to become a part of the orthodontists' armamentarium. Given its short and recent history, the appliance is still in its early stage of development. Like any other new technology, it needs time for it to mature. The orthodontist has to go through the learning curve and get acquainted with the development of the technology. Careful case selection, good understanding of its limitations and sound mastering of the technique are absolutely essential to achieve clinical success.

* Invisalign® appliance is an orthodontic appliance developed by Align Tech Inc.

References