Orthodontics in the Digital Age

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Introduction

The utilisation of cone-beam computer tomography (CBCT), 3D scanning, Computer-Aided Design & Computer-Aided Manufacturing (CAD CAM), digital planning, computer designed brackets and robotic wire bending in orthodontics has significantly reshaped the orthodontic scene in the past 10 years.

3D scanning and digital models

3D scanning and digital models were introduced to orthodontics, commercially, in 1999 by OrthoCad (Cadent, Carlstadt, NJ)[1]. At that time, the digital model was created by scanning plaster casts.

The 3D digital model is essential in CAD/CAM. It is produced from 3D scanning data in an STL (surface tessellation language, three-dimensional non-coloured data) file format. The scan can be generated either directly or indirectly. The direct scan will involve an intraoral scan while the indirect method is to scan an impression (negative scan) or plaster cast (positive scan).

3D digital models require no physical storage space – no model box! As a result of the recent large leap in internet speed 3D digital models can now be shared in a matter of seconds, as of course can digital radiographs and photographs. It has made digital interdisciplinary treatment planning, and soon the fabrication of appliances, almost routine.

Fig 1 Digital model constructed from an intraoral scan

Customised bracket CAD/CAM technology

CAD/CAM technology has been used in dentistry since 1985. The Cerec system from Sirona (Siemens, Bensheim, Germany) was initially used in restorative dentistry for the manufacture of single crowns and later multiunit bridges. In orthodontics, it was first applied to the fabrication of customised lingual brackets (eg, Incognito, 3M-Unitek; Insignia, Ormco) and later robotic wire bending (eg, SureSmile, Orametrix).

Most of today's stock brackets have torque, tip and rotation prescriptions based on average tooth anatomy for the average arch and facial shape. However, there is considerable individual variation in tooth structure, shape and size, as well as arch and facial shape and form, which means that some teeth are not positioned ideally using stock brackets[2]. Claims are made that customised orthodontic appliances overcome these individual variations and can also minimise clinician error in bracket positioning. Robotic wire bending, it is claimed,

can further enhance this customisation with some reports suggesting that it may lead to reduced treatment duration[3].

Customised brackets are made using a digital model of the patient's teeth. The scan is submitted to the relevant company so that virtual brackets and can be placed in an ideal position to achieve the 'virtual set up'. Each company has their own technique for this customisation (Table 1).

Product	Manufacturer	Type of appliance	Customisation
Insignia (Greco A 2011)	Ormco, Orange, CA, USA	Labial	Customized slot
Suresmile (Larson B 2013)	Orametrix, Inc., Richardson, TX, USA	Labial	Customized arch wires with conventional brackets
Incognito (Wiechmann 2002, 2003)	3M-Unitek, Monrovia, CA, USA	Lingual	Individualization of bracket bases, slots, and arch wires
Alias	Ormco, Orange, CA, USA	Lingual	Customized composite base

Table 1 Early providers of customisation. These systems are regularly upgraded and still available today

Insignia

Insignia (Ormco, Orange, CA, USA) utilise a customised slot on a standard base. Once the desired outcome is confirmed by the clinician in the virtual setup, the slots are cut into the brackets for eventual full size straight wire insertion.

According to a randomised clinical trial by Penning et. al.[4], comparing a non-customised (DamonQ) group to a customised (Insignia) group, the customised group had more loose brackets, a longer planning time, and more complaints. The customised orthodontic system was not associated with significantly reduced treatment duration, and treatment quality was comparable between the two systems. On the other hand, the orthodontist's years of experience did have a significant effect on treatment duration, quality of treatment outcome, and number of visits.

Suresmile

Suresmile (Orametrix, Inc., Richardson, TX, USA) use customised wire and conventional brackets, with clinicians choosing their preferred bracket. CBCT data can be merged with the virtual model when planning the tooth movement to visualise the bone housing. Suresmile is more commonly used as a finishing wire after levelling and aligning, however, it is not just used for finishing but can also be used in levelling and aligning as well as space closure. Bends will be incorporated in the main arch wire to maintain torque in space closure, similar to combination arch wires.

According to a retrospective study[5], two groups of patients, one group treated with Suresmile and one group treated conventionally, were compared by using the American Board of Orthodontics Objective Grading system (ABO OGS). It concluded that Suresmile resulted in a lower mean ABO OGS score and a reduced treatment time when compared to conventional approaches, demonstrating the potential to both decrease treatment time and improve quality. However, one of the negative issues with Suresmile is bracket debonding during the finishing phase which can make this stage of treatment more frustrating.

Lingual appliances

In the Incognito Lingual system (3M-Unitek, Monrovia, CA, USA) both the bracket bases and archwires are individualised. The digital models are used as a template to design virtual brackets and wires. Virtual brackets are printed in wax and cast in a gold alloy while archwires are formed by a wire-bending robot. Dental casts, brackets for indirect bonding, and wires are delivered to the clinician to commence treatment.

According to a retrospective study[6], the accuracy of this lingual orthodontic technique was examined by comparing the digital set up and the final result. The study showed this customised lingual technique was accurate in achieving the tooth movement planned in the setup. However, there were some positional discrepancies of up to 1 mm and some rotational discrepancies of up to 4°.

Fig 2 Maxillary lingual appliance

CAD/CAM designed retainer

A CAD/CAM fabricated nickel-titanium (NiTi) lingual retainer, Memotain, invented by Dr Pascal Schumacher in 2012[8] is made of 0.014" x 0.014" rectangular nickel titanium cut from a nickel-titanium sheet. The difference between a robotic bent wire retainer and Memotain is there is no wire bending, reducing the risk of wire fracture. It has less than 0.5mm error according to Wolf[9]. Kartal[10] showed periodontal outcomes and survival rates of Memotain, versus five-stranded mandibular lingual bonded retainers, were similar. At the moment, there is no well-designed study showing that CAD/CAM fabricated nickel-titanium lingual retainers, in the long term, are superior to other types of retention.

Fig 3 CAD/CAM designed maxillary NiTi retainer

3D printing

The possibility of fabricating metallic orthodontic appliance with 3D printing by laser sintering has become viable in the last few years[1]. This has meant metal orthodontic appliances such as RMEs, lingual arches, transpalatal bars, MARAs etc will become more commonly digitally produced in the laboratory, or even the clinician's office, rather than made manually in a dental laboratory. After scanning the dental arch, the digital model is submitted to the technician to design and manufacture the appliance, again utilising commercially available software (eg: e 3Shape Appliance Designer). After design confirmation, the appliance is printed by a laser sintering machine using Remanium Star CL (Dentaurum, Ispringen, Germany), a metal alloy powder composed of Cobalt, Chromium, Tungsten and Selenium. The first layer of metal powder is melted by the laser beam in one spot, soldering the powder together. The process is repeated layer by layer. After polishing, if active elements like an expansion-screw are required, they are laser soldered in place. This technique eliminates the discomfort of impressions and increases the design flexibility and precision of the appliance.

Currently 3D printed appliances are not readily available from many dental laboratories in Australia. Clinicians wishing to utilise this method of constructing orthodontic appliances may need to consider the extra time and financial cost of sending the job to an overseas laboratory.

Fig 4 3D printed RME

Remote monitoring

'Dental Monitoring' (Dental Monitoring SAS Paris, France) is software which helps the clinician to monitor treatment progress. It consists of a mobile phone app, a patented movement tracking algorithm and an online doctor dashboard.

The 3D scan is uploaded by the clinician to a server as an initial reference. During treatment, patients will follow the app instructions and, using their smart phone, upload photos of their teeth for processing by the DMTM algorithm. This is then assessed by the DMTM doctors and can be accessed on the web based Doctor Dashboard. The clinician is notified when new results are available and whether alerts have been detected for example for poor oral hygiene, non-tracking aligners, and broken appliances.

The early recognition of broken appliances, non-tracking and poor oral hygiene allows the clinician to take early remedial action which improves treatment efficiency. Patients benefit from the reduced financial and time costs in clinical attendance, especially those living in remote areas. During the COVID lock down, tele-orthodontics has helped clinicians to monitor treatment progress.
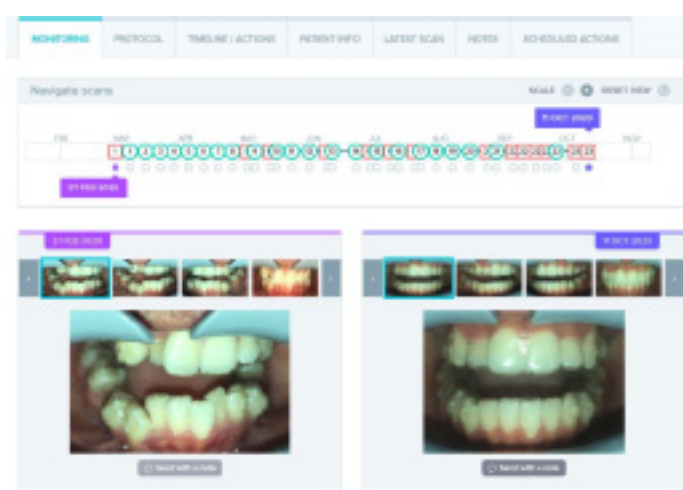
According to a retrospective study of remote monitoring of sequential aligner treatment by Hansa et. al.[11], there was a statistically significant reduced number of appointments, 7.56 compared with 9.8 for the control group who were traditionally monitored. However, this may not be clinically significant as there is no significant differences between the two groups in terms of treatment duration, number of refinements, number of refinement aligners, or time to 1st refinement. The study also does not mention any differences in treatment outcomes.

Conclusion

From banded to bonded, from metal to ceramic and from physical to digital, orthodontics keeps evolving. Technology may make orthodontics more 'user friendly' and minimise the barrier to undertaking treatment, however, it does not change the biomechanics and biological limitations of treatment.

Many products are introduced into the market and claim superiority without any peer reviewed research. As dental professionals, we still must provide evidence-based and patient-centric orthodontic treatment with proper diagnosis and treatment planning.

References available upon request

Fig 5 DM Dashboard showing the initial and latest 'photo exam' of the monitored patients over the treatment timelines

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