Digital Orthodontics

Orthodontics, like the other dentistry disciplines, has recently benefited from the influx of digital technological innovations. These innovations have principally involved the means and procedures of diagnosis, with new developments being introduced in the field of photography, tomography, optical and laser scanning. Moreover, several contemporary orthodontic systems implement new "Artificial Intelligence" (AI) technologies to provide the orthodontist with a comprehensive orthodontic treatment package consisting of digital diagnostics, 3-dimensional (3D) digital planning, and computer-designed customized brackets and arch wires. Customized orthodontic treatment systems rely on digital models of the patient's occlusion, which are generated from accurate impressions taken before treatment, scans of the dental arches, scans of the plaster casts, or cone beam computed tomography (CBCT) acquisition. A virtual setup of the desired outcome is then derived, which serves as a 3D interactive treatment planning tool and is used for the production of personalized appliances (archwires, brackets, and indirect bonding transfer devices).

Tools used in digital orthodontic diagnosis and treatment planning

Orthodontics and dentofacial orthopaedics is one of the most complex branches of dentistry that requires a careful interpretation of a large amount of information to attain a correct diagnosis and treatment planning. Similar to a wax setup, the digital setup is a tool that helps with diagnosis and treatment planning and it is up to the creator of the setup to respect the biologic limitations of tooth movement and mimic realistic biomechanics. The creation of a digital setup is much faster than creating a wax setup due to the lab work required when working with plaster. Working with digital setups offers many advantages such as relatively time saving, the ability to superimpose the setup with the original models, determining the precise amount of movement for each tooth, and it can be instantly stored and shared with others easily.

Digital Study Models

Plaster study models were the "gold standard" in orthodontic diagnosis and treatment planning. Later advances brought about more dimensionally stable impression materials than wax and alginate, such as polyvinyl siloxane (PVS). Study models provide a three-dimensional view of a patient's occlusion and are more amenable to routine measurements such as tooth size, arch length, arch width, overjet, overbite, midline discrepancy, curve of Spee, etc. On the other hand, the concept of 3D virtual orthodontic

models seems very favorable in eliminating the problems of conventional plaster models, and simplifying the practice management and communication between different specialties (Figure 1). However, it has disadvantages such as lack of tactile input, scarcity of digital model supplier companies, questions surrounding the accuracy of digital models, additional costs, and time required to learn how to utilize the system; so if it was not achieved accurately, it will need extra time to repeat it.

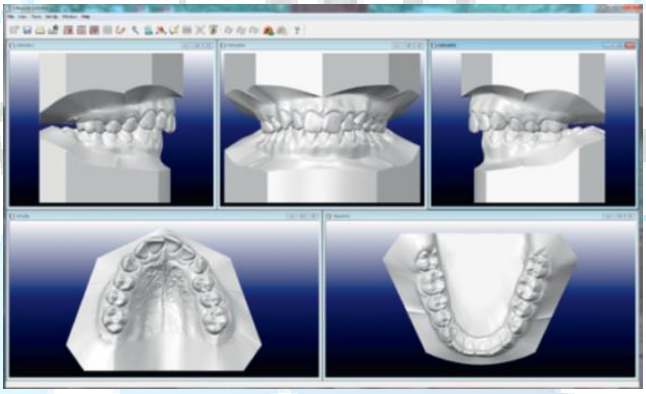


Figure 1: Digital casts, usually produced from intraoral scans, can be displayed with or without symmetric bases. The advantage of the bases is that they help the observer detect asymmetries within the dental arches.

Physical versus Virtual Casts

Whether physical plaster or virtual orthodontic diagnostic casts are to be produced, an impression of the teeth that also gives maximum displacement of the lips and cheeks is desired. Being able to visualize the inclination of the teeth, not just the location of the crown, is important. If the impression is not well extended, important diagnostic information may be missing. If the impressions are to be poured in dental stone without great delay, alginate impressions are satisfactory; if virtual models will be produced, a more accurate and stable impression material (such as PVS) should be used. In specialty practice, virtual models have the great advantage that they eliminate the need for storage space and can be used for computer-assisted fabrication of appliances. There are three ways to generate digital casts: from laser scans of impressions, from scans of casts poured up from impressions, or from direct intraoral scans. Direct intraoral scanning with adequate lip and cheek retraction eliminates impressions that are unpleasant for patients, which becomes more important when multiple scans may be needed to obtain data required for a computer-controlled wire-bending robot to fabricate archwires.

Space Analysis

Space analysis can be accomplished by a computer algorithm. The data for the arch dimensions and tooth widths can be entered by digitizing the already present digital casts, then the computer does the calculations (Figure 2).

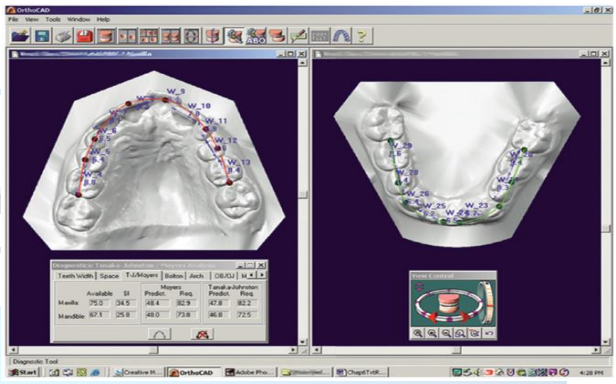


Figure 2: Digital space analysis.

Digital Photographs

Digital photography has replaced films, and digital images have done the same for radiographs. The digital single lens reflex cameras were verified for use in intra- and extra-oral photography and proven to produce perfect images when used with the recommended macro-lens and macro-flash techniques. Digital photography was introduced to evaluate facial harmony. It allows clinicians to establish a more proportional focus on all three structures of the triad to assess patient's deformity (Figure 3).

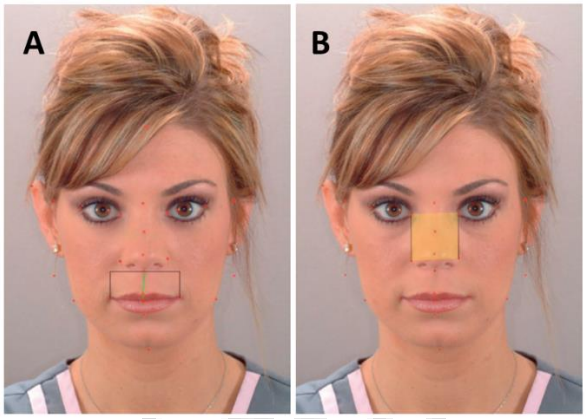


Figure 3: In evaluating facial proportional relationships while looking at digital images on the computer screen, it can be helpful to put a box around the structures to be related, as in A, where the lip commissure height is being related to the central philtrum height, or as in B, where the width of the nose is being related to the interocular width. For this girl, both relationships are normal. Boxes like this can be added to the facial images during the clinical examination and become part of the record.

Examples of Digital Orthodontic Systems

1- Clear Aligner Therapy

The term Clear Aligner Therapy (CAT) embraces a wide range of appliances with differing modes of action, methods of construction, and applicability to various malocclusion treatments. However, there are some limitations such as it depends on patient compliance, which is a crucial factor to achieve the designed tooth movement. Alteration of tooth morphology can result in unfitted aligners, thus re-scanning or PVS impression is required. In addition, posterior open bite is a common side effect of clear aligner therapy.

In 1997, a new company named Align Technology computerized the process of producing a sequence of casts with incremental changes on which aligners could be fabricated. With careful planning, this would result in a sequence of clear aligners (called Invisalign) that could correct a certain range of malocclusions. Diagnostic records for aligner treatment are the same photographs, radiographs, and dental casts as for any other type of orthodontic treatment. For Invisalign sequenced aligners, either an intraoral optical scan (which also records the initial occlusion) or PVS impressions and a bite registration (maximum intercuspation) are obtained. The scan or impressions, photographs, and radiographs are submitted to the company along with the doctor's initial instructions. The production process begins when the intraoral scan or impressions are used to create an accurate 3D digital model of each dental arch. These records are transferred electronically to a digital treatment facility. At the digital treatment facility, technicians virtually segment the individual teeth and clean up obvious artifacts. Then the dental arches are

related to each other, gingiva is added, movement is staged following the doctor's instructions, and this preliminary plan is placed online for the doctor's review as a "ClinCheck" (a software that enables discussing a Digital Model Treatment Plan between the orthodontist and the company). After the orthodontist is satisfied with the planned sequence of aligners, the set of digital models for a patient is transferred to a cast production facility, where a stereolithographic model for each step is fabricated. A clear plastic aligner is formed over each model, using a material that has high-quality physical properties, and the set of aligners is sent directly to the orthodontist.

There is increasing interest in the possibility of doing aligner production in the doctor's own office, using computer software to create the sequence of models, a 3-D printer to make the models for each stage, and a vacuum-forming unit to make the aligners. At this point the available software is much less advanced than Invisalign's, printing the models for each stage is time-consuming, and the improved aligner material is not available; but for simpler cases this already is quite feasible and much less expensive.

Clinician's Role in "ClinCheck": With experience, doctors tend to be more specific in their initial prescription of what they want, or do all the sequencing of steps themselves to set things up for a better result, but the sequence of steps and the amount of movement between steps is specified by algorithms built into a specific software if this is not spelled out in detail in the prescription. In essence, when the ClinCheck is posted for the doctor to examine, the computer technician has sent a draft treatment plan for reviewing. The software used by the computer technicians has default scenarios (run by AI) for different types of malocclusions and default rates of tooth movement. These defaults are satisfactory for simpler cases but not for the more complex ones.

For complex treatment, the doctor must customize the plan in terms of the extent to which "bonded composite attachments" are to be used to increase the aligner's grip on the teeth, the rate of tooth movement with each subsequent aligner (often reducing the amount of movement at critical points), any special components of aligners that need to be added, and the amount and location of interproximal reduction of teeth (if any) that is to be done. These modifications to the original ClinCheck then are used to produce the aligners for that patient.

Patients must be monitored carefully to verify that tooth movement is tracking with the series of aligners (i.e., that all teeth are seated completely in the aligner after it has been worn for the specified period of time). If the teeth are not tracking, there are several possibilities: not enough wear of the aligners by the patient, insufficient interproximal reduction, insufficient crown height or shape to allow a grip on the tooth or teeth to be moved, wrong type or position of bonded attachments, or movement created in ClinCheck

that is too fast to be biologically possible. A refinement or midcourse correction, with a new intraoral scan or PVS impressions and revision of the treatment plan, often is necessary when tracking deviates significantly from the plan. This is likely to be encountered in the treatment of complex problems even with good patient cooperation.

2- Insignia system (Individually Customized Brackets)

Because of individual variations in the contours of the teeth, no appliance prescription can be optimal for all patients, and compensatory bends in finishing archwires often are necessary. Custom brackets for the facial surface of teeth offer the prospect of eliminating almost all archwire bending (i.e., they could provide the perfect straight-wire appliance). The Insignia system marketed by Ormco company uses custom brackets on each tooth and focuses on eliminating wire bending to make the appliance more time-efficient for the doctor and patient (Figure 4).

The first step in producing the Insignia customized bracket is a 3-D scan of the dentition to produce an STL file (now the most frequent input), or a scan of an impression with high-accuracy impression material, or a scan of dental casts from such an impression. If a CBCT radiograph is available, Ormco processes the crown and root with a proprietary "build up" process, following the contours of the 3-D image to generate a crown and root as a single unit. If a CBCT image is not available, a software calculation of ideal arch form is used to place the roots in the center of the cancellous bone of the jaw. Based on this "anatomically correct" arch form, the software then aligns the virtual teeth and places them in occlusion, with each tooth position determined from the best-fit buccal cusp orientation. The doctor can adjust the tooth positions at this point, and would need to be aware of the software assumptions as this is done.

This digital information then is used to precisely cut each bracket by using computer-aided design/computer-aided manufacturing (CAD/CAM) technology, so that the slot for each bracket has the appropriate thickness, inclination, and torque needed for ideal positioning of that tooth, and archwires with an arch form established for that patient are supplied. The result is "the ultimate straight-wire appliance," with wire bending reduced to a minimum (if not totally avoided). Attempts were made to integrate images of tooth–lip relationships into the database for Insignia, so that tooth display on smile is built into where the brackets are placed on the anterior teeth, and moving the brackets automatically changes the tooth display. It is likely that at the point of approving the set-up for making the brackets, it soon will be possible for the orthodontist to check not only on whether the arch form assumptions are correct, but also to adjust where the bracket is to be placed on the teeth to obtain the best incisor display. It is not possible to get this just by adjusting

the bracket slot angulation and prescription; instead, the bracket must be placed properly on the teeth relative to the lips.

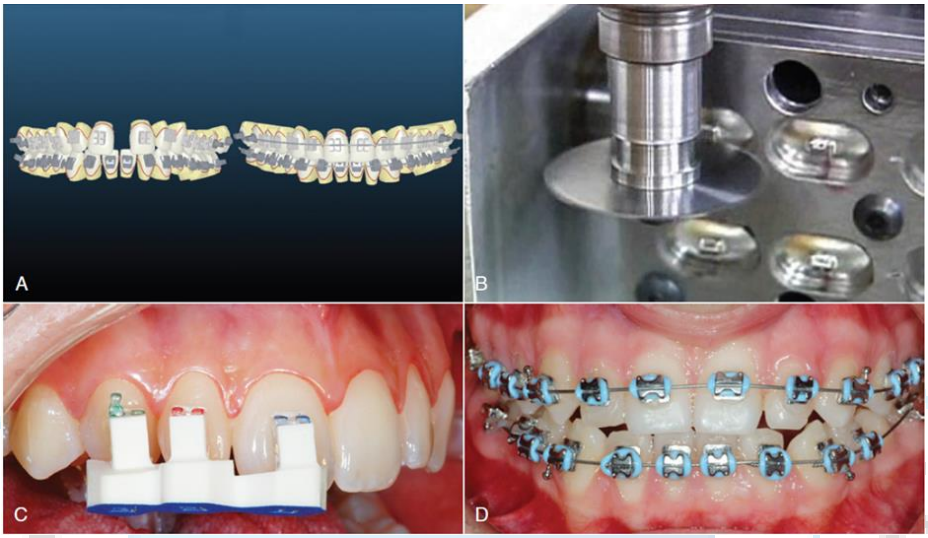


Figure 4: The Insignia system is built around the use of a custom prescription bracket for each individual tooth, coupled with custom archwires with that patient's individual arch form, to produce the "ultimate straight-wire appliance." A polyvinyl siloxane (PVS) impression is used to obtain accurate dental casts, which are scanned into computer memory. (A) This data set is used to place virtual brackets on each tooth and develop a template of the change needed to obtain ideal occlusion. (B) The digital data are used to mill a custom prescription slot for each bracket that incorporates the in-out, tip, and torque needed to position each tooth. (C) Then bonding jigs are fabricated so that each bracket can be placed in the planned location. (D) The appliance in the mouth with an archwire in place.