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CAD/CAM in Orthodontics – A Magnanimous Journey

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Abstract

Orthodontics is one branch of dentistry which deals with dynamic manipulation and function of the stomatognathic system. Likewise, it has to witness the dynamic changes in its diagnosis method and treatment planning. The field of orthodontics has witnessed many revolutionary techniques and evolved enormously in terms of benefiting the patient. CAD/CAM is one promising methodology that has shown a significant impact in modern dentistry and surpassed some of the challenges an orthodontist has been facing all these years. It has changed the view through which we see the patient's condition. The application of 3D technology allows the practitioner and patient to utilize virtual treatment planning software to better identify case objectives and visualize treatment outcomes.

CAD/CAM has many applications in orthodontics, which include aids for diagnosis and treatment planning, clear aligner treatment, customized lingual appliances, customized brackets with patient-specific torque, machine-milled indirect bonding jigs, robotically bent archwires, indirect bonding systems, customization of orthodontic appliances like distalization appliance etc., Acceleration of orthodontic treatment (OT) has received growing attention in recent years, especially in adult patients.

Digital workflow is the current trend in orthodontic practice and has speckled every aspect of orthodontics in terms of documentation, study casts, analysis of dental malocclusion, smile designing, treatment planning and fabrication of orthodontic appliances. The current article aimed to establish a narrative description of the digital workflow and applications of the CAD/CAM process in Orthodontics.

Keywords: Orthodontics, CAD/CAM, 3D Printing, Orthodontic appliances.

1. Introduction

Over the past two decades, technology has swung to its peak and gone leaps and bounds in the field of dentistry. Dentistry has witnessed many new path-breaking innovations, which have changed the face of diagnosis and treatment planning all the while to date. The world is going digital vis-a-vis dentistry [1]. The technological swag being carried out over the years is truly revolutionizing the way dentistry is practiced and how dental laboratories are fabricating the appliances [2].

The field of orthodontics has been witnessing enormous reforms in terms of diagnosis and treatment modalities through the years, under which the concept of digitalization or digital workflow can be well subsumed. Digital workflow is the current trend in orthodontic practice and has speckled every aspect of orthodontics in terms of documentation, study casts, analysis of dental malocclusion, smile designing, treatment planning and fabrication of orthodontic appliances [3].

In the parlance, intra-oral scanning has become a sophisticated technique progressively replacing dental impressions. This system has witnessed good precision with excellent patient feedback. The digital impressions of the patient can be stored according to convenience and easily transported to the lab for the fabrication of customized appliances. Though digital dental models aid in the diagnosis, treatment planning and simulation of the results at the end of the therapy, they cannot directly reproduce physical models and appliances. To further process, this 3D workflow needs a computer-aided design and manufacturing (CAD/CAM) process that comprises elaboration of the digital data, previously acquired with the intra-oral scanner and the production of a precise 3D physical model [4].

2. Background and Digital Workflow

Materials CAD-CAM procedure involves a group of linked processes used to create three-dimensional physical models [5]. Subsequently, it enables the layer-by-layer construction of a model that replicates nearly every form of the external and internal anatomical structure in accordance with the 3D input. To construct the end object, subtractive and additive manufacturing are used [6,7]. Additive manufacturing is a relatively new technology consisting of a computer-aided design and computer-aided manufacturing (CAD/CAM) workflow, which allows the substitution of many materials with digital data. This process requires three fundamental steps represented by the digitalization of an item through a scanner, the editing of the data acquired using software, and the manufacturing technology to transform the digital data into a final product, respectively [5]. The fundamental steps involved in CAD/CAM Process are given in figure 1. The current article aimed to establish a narrative description of the digital workflow and applications of the CAD/CAM process in the field of Orthodontics.

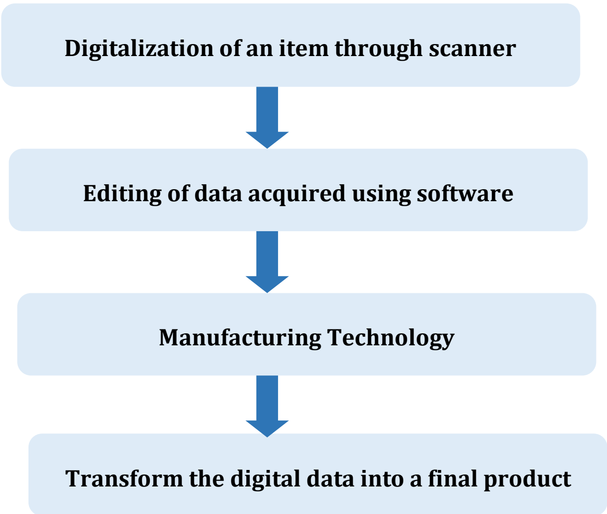

Figure 1. The fundamental steps involved in CAD/CAM Process

3. CAD/CAM Applications in Orthodontics

The whole scenario in dentistry, particularly in orthodontics, the CAD/CAM procedure involves five different printing technologies [8-11] as described in table 1.

3.1 CAD/CAM in customized Orthodontic appliances

Many manufacturers of customized Orthodontic appliances guarantee that these appliances surpass the hindrances of regular appliance set-up and progress towards improved treatment efficiency, total treatment time reduction and satisfied overall treatment results.

3.1.1 Ormco insignia

This is one of the most commercially available comprehensive CAD/CAM orthodontic appliances which is available in standard and self-ligating applications with the optional use of esthetic ceramic brackets. After an intraoral scan of the patient's dentition, digital models are obtained, and a virtual buccal-lingual boundary is constructed from the soft tissue outline [12, 13]. Subsequently, a virtual setup is created, and the brackets without slots are placed in the virtual setup. The actual brackets will be made, and slots will be cut based on the desired tooth position. The position of the bracket is recorded and transferred to the model. An indirect bonding tray comprising the bracket transfer jigs is made to transfer the virtual bracket position to the patient's mouth. Finally, the position of the slot determines the tooth movement and not the bracket. The Insignia software allows the clinician to set up and refine the 3-dimensional position of individual teeth, adjust the arch form, alter the smile arc when needed, and detail the dental contacts in final centric occlusion [12]. The main advantage of the Insignia system is the customization of bracket slots, and the disadvantage is the error in bracket positioning.

3.1.2 OraMetrix- SureSmile process

OraMetrix's SureSmile begins with a 3D scan of the patient's dentition using the OraScanner (OraMetrix). The scanner is moved over the entire dentition for visualization of all surfaces, including undercut areas of the tooth. At this juncture, the clinician will be able to diagnose and plan treatment with respect to tooth and arch dimensions. In this system, the wire-bending robot forms archwires as per the desired outcome, and the custom wire will be fabricated. The customization occurs in the final stages of the treatment. The advantage of this system is that the preferred bracket system could be used, and precision can be increased during the finishing stage [3,12]. SureSmile's concept of focusing on the wire instead of the bracket to achieve ideal results seemed novel. The advantage of this system is that the preferred bracket system could be used, and precision can be increased during the finishing stage.

3.1.3 Incognito

The Incognito contemplates a customized lingual orthodontic appliance and is designed as per the anatomy of the tooth and its position as well slots based on desired ideal tooth movement. A series of wires will be formed based on the position of the bracket slot in the virtual setup. Subsequently, with the help of an indirect bonding tray, the virtual position of the bracket will be obtained precisely. The advantages of this process are optimal aesthetics, the accuracy of outcome, reduced incidence of white spot lesions, decrease in discomfort and precise direct rebonding of debonded brackets due to the good adaptation of the custom base of the bracket [14].

3.2 Custom Removable Appliances

3.2.1 Invisalign

Invisalign was developed by Align Technology Inc. (Santa Clara, CA, U.S.A.). The process enables a sequence of aligners composed of transparent plastic engaging buccal, lingual, palatal, and occlusal surfaces to move the teeth in a determined direction. The duration of the wear is two weeks, and it is changed and advanced accordingly. The movement of teeth is about 0.25 - 0.35 mm, and the total duration of treatment is about 9 - 15 months [15].

The conceptualized virtual software cuts the virtual models and separates the teeth for them to be moved individually. With the help of the software, a virtual gingiva is placed along the gingival line of the clinical part of the crown, which would serve in future as a margin of limitation for the aligners. The bracket prescriptions are followed to position the teeth and align them properly. The processed data would be sent to the orthodontist to view the virtual corrections at each stage, and this is referred to as ClinCheck. Once the orthodontist confirms the treatment plan, a series of aligners will be manufactured using CAD / CAM technology [16].

Table 1. Different printing technologies involved in CAD/CAM procedure

Technology	Application
Stereolithography (SLA) & Digital Light Processing (DLP)	Layer-by-Layer model printing with the use of a photo curable liquid resin
Fused Deposition Modelling/Fused Filament Fabrication (FDM/FFF)	Formation of solid objects using a thermoplastic material. Material is released layer-by-layer and these strata are fused together when the entire structure solidifies
Selective Laser Sintering (SLS)/Melting (SLM) and Electron Beam Melting (EBM)	Selective laser sintering/melting (SLS/SLM) aims to print 3D objects using powder materials (e.g., polyamides, polycaprolactone, hydroxyapatite, stainless steel, titanium, and Co/Cr). This powder is heated above the glass transition or melting temperature using a high energy CO_2 beam, thus sintering/melting the particles together in a specific pattern. Electron beam melting (EBM) technology is based on the use of metal powder (stainless steel, titanium, etc.) as a printing material. In this case, the powder is submitted to sintering by a computer-controlled electron beam in a vacuum.
Binder Jetting (BJ)	Binder Jetting (BJ) is a technique aimed at realizing objects by adding a pattern of binding liquid on a powder substrate
Material Jetting (MJ)	An evolution of SLA technology is represented by Material Jetting (MJ), which employs a liquid photopolymer as a printing material. This latter is extruded by a series of small nozzles on a building platform and then cured with UV light.

4. Miscellaneous applications

4.1 Piezocision: Assisted orthodontic treatment using CAD/CAM customized orthodontic appliances.

Piezocision procedure involves localized piezoelectric alveolar decortications combining buccal incisions and corticotomies with a piezotome. Corticotomies have been regarded as accelerating Orthodontic treatment. In this aspect, the combination of peizocision with customized appliances holds significant clinical relevance. The CAD/CAM allows the manufacturing of custom-made orthodontic appliances, which decreases treatment duration [17].

4.2 CAD/CAM fabricated Mini-Implant guides

In cases of Angle class II malocclusion, distalization of maxillary first permanent molar is considered the prime choice of treatments, and this can be achieved by using Intraoral or Extra oral appliances. Mini implants as intra-oral appliances remain the main stray in this kind of treatment. It has its advantages over other appliances such as avoiding molar extrusion, cost-effectiveness, integration with concomitant biomechanical initiatives and minimal degrees of surgical invasiveness. The CAD/CAM insertion guide system facilitates the safe and precise insertion of mini-implants in the desired sites. This process is efficient for clinicians to establish mini-implant– borne anchorage as a novel procedure and can be performed in a single appointment [18].

4.3 CAD/CAM in rapid maxillary expansion

Hyrax appliance requires cumbersome laboratory techniques for their fabrication. CAD/CAM technology can be used to achieve a complete digital workflow to produce Hyrax appliances. In addition to this, it has the advantage of avoiding molar separators for band placement as the clasps are modelled surrounding the molar extending to canines without involving the interdental spaces. This process has the advantage of designing the appliance as per the requirement by changing the thickness or the design of the arms of Hyrax to have a differential force and individualising the way the forces are transferred from the expansion screw to the dentition [19].

4.4 CAD/CAM based indirect bonding system

With the introduction of the Indirect bonding system by Silverman et al, bracket positioning has become easy and efficient with increased accuracy, reduced chair side time and increased patient comfort. It allows for easy over-correction and control of in-out movements of teeth. It was developed as a manual laboratory process. It has been reported that a silicon-based tray has better precision compared to a thermoformed tray. So recently, indirect bonding uses CAD/CAM that designs a virtual model to produce a bracket transfer jig. This jig facilitates the bonding of the bracket to the target tooth [20].

4.5 CAD/CAM based retainers

Retention is necessary at the end of orthodontic treatment to avoid relapse of the teeth. Multiple forms of retention exist and present different advantages and disadvantages. Xiaolei et al. indicated that the digital method was more effective in lingual retainer construction than the standard process [21]. Traditionally, it has been indicated that the indicators of bacterial plaque accumulation and gingival inflammation are higher with the use of stainless-steel retainers. The smoothness and polish of CAD/CAM retainers allow less plaque accumulation and therefore less inflammation [22]. Shim H et al. reported that CAD/CAM fixed retainers showed less relapse and fewer failures than lab-based and traditional chairside retainers [23].

5. Advantages of CAD CAM Process [4]

- CAD/CAM printed models are more accurate, unlike the traditional models where they undergo technical errors and distortions while handling the materials.
- 3D intra-oral scanning is more comfortable than the traditional Impression technique.
- There is a reduction of time since the clinicians can directly send the STL files to the technicians resulting in a digital workflow.

- The process involves relatively high scanning accuracy with good precision.

6. Conclusion

Time and again it has been proven that technology waves things ahead in terms of efficiency, ease of doing the process and quality of the work. The dental manufacturing industries have witnessed monumental changes since the evolution of CAD/CAM tools in product design and fabrication. There are many significant advances in orthodontic technology in the recent decade mainly due to the incorporation of CAD/CAM technology for the fabrication of orthodontic appliances. This procedure allows for the production of newer high-strength materials with excellent biocompatibility, excellent precision fit and long shelf life.

In the current review, common CAD/CAM systems and their applications in Orthodontics were discussed. The advantages of this technology outweigh the disadvantages in terms of better fit and enhanced aesthetics for the patient. The sole purpose is to develop an aid system for the development of orthodontic appliances or devices in terms of swiftness and reliability to meet the results. Nevertheless, to increase the accuracy and durability of these devices many more additional and advanced research and materials are still required owing to the benefit of patients.

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