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Original Research Paper

Orthopaedics

3D PRINTING IN ORTHODONTICS: BEYOND THE HYPE

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ABSTRACT Evolving technology and integration of digital solutions in private practice have transformed diagnosis and treatment planning from a traditional two-dimensional (2D) approach into an advanced three-dimensional (3D) technique. 3D printing is a manufacturing technology, in which an object is created by adding a material layer-by-layer one on top of the other in a specific manner, until whole object is manufactured according to computers design. Elimination of traditional impressions and dental cast production enhance practice efficiency, patient and staff satisfaction for a fully integrated digital and streamlined workflow. A digital workflow reduces the number of appointments needed to deliver an appliance. In the future, as 3D printing technology improves, orthodontists may be able to prescribe, design, and manufacture orthodontic products right in their offices.

KEYWORDS : 3D Printing, Orthodontics, 3D Surface Imaging, 4D Facial Dynamics

INTRODUCTION

The next paradigm shift in orthodontics will be with the development of 3D printers, working in conjunction with intraoral scanners. Major work in the 3D printing orthodontic industry is done by the companies who manufactures Invisalign aligners, the clear plastic aligners that have taken the orthodontic field by storm. Use of an intraoral scanner, software and 3D printing has allowed orthodontists to achieve a more precise control over tooth movement and quicker appliance manufacturing that saved both money and time. 3D printing is further utilized in preparing bite splints and night guards using a transparent biocompatible material.

BRIEF HISTORY OF 3D PRINTING

3D printing is a manufacturing technology, in which an object is created by adding a material layer-by-layer one on top of the other in a specific manner, until whole object is manufactured according to computers design.1 3D printing technology allows the user to create or "print" 3D physical objects, prototypes, and production parts of any shape from a virtual model in a growing range of materials including plastic, cobalt, nickel, steel, aluminium, titanium, etc. 3D printing was developed in 1984 by Charles Hull, when he was using ultraviolet light to cure tabletop coatings later he created the first 3D printer and 3D printing technology, which was named by the founder as stereolithography.2 In 1988, Scott Crump developed fused deposition modelling (FDM), which was commercialized by Stratasys in 1990.3 It is similar to the inkjet technology used in 2D Printers. Objet Geometries, the developer of PolyJet photopolymer (PPP) printing, was founded in 1998.3 Dozens of 3D printers employing variations of SLA, FDM, and PolyJet technologies are now available from many different companies.

ORTHODONTICS PERSPECTIVE

Orthodontics is rapidly embracing with new materials and advanced technologies, making the fully equipped 3D orthodontic office a reality. Recent developments and introduction of intraoral and facial scanners, digital radiology, (CBCT) and additive manufacturing improved the efficiency, accuracy, consistency, and predictability of the treatment outcomes. Computer-aided design and computer-aided manufacturing (CAD/CAM) systems were first used in the dental field in the mid-1980s. CAD/CAM consists of three key components: 1) data acquisition and digitizing; 2) data processing and design; and 3) manufacturing.4 In-office chairside or send to the lab, the digital models give the flexible options for design and manufacture of a large range of orthodontic appliances such as customized indirect brackets, arch wires, expanders, aligners, retainers, etc. Measurements such as overjet, overbite, tooth size, arch length, transverse distances, and Bolton discrepancy can be visualize and calculated.

Dental model and Rapid Palatal Expansion model 3D printed from a STL generated file

3D PRINTING IN ORTHODONTICS

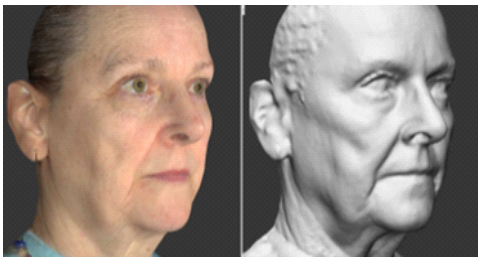
Diagnostic and Working Orthodontic Models

Diagnostic measurements performed on digital models represent high validity, reliability, and reproducibility, and thus may be regarded as an equal alternative to conventional plaster models.5-7 Rapid prototyping technology allows to obtain many identical copies of a digital model without any risk of distortion or deformation, available at any time.8 Printed models have been reported and may be used to manufacture removable orthodontic appliances, expansion appliances, indirect bonding trays, or thermosformable orthodontic aligners.9 The printed dimensional model enabled the clinicians to conduct thorough assessment and visualization of the anatomy and localization of the impacted tooth, also in relations to the roots of adjacent teeth. Model analysis helped the authors to precisely plan the surgical exposure procedure of the impacted tooth.[10]

Facial Scanning

1.3D Surface Imaging

Facial scanners provide 3D topography of the facial surface anatomy, automatic facial landmark recognition, and analysis of the symmetry and proportions of the face. Practical applications further include quantitative and qualitative assessment of growth and development, ethnic variations, gender differences, and isolation of specific diagnostic traits in selected populations of patients with craniofacial anomalies.11 Several techniques such as laser scanning, ultrasound, computed tomography, magnetic resonance imaging, and electromagnetic digitization can analyse facial characteristics in 3D but stereo photogrammetric systems are becoming the instrument of choice in anthropometric research.[12]



Virtual facial model

2. 4D Facial Dynamics

Production sequential 3D surface imaging systems (4D Facial Dynamics) are commercially available to provide a quantifiable understanding of soft tissue mobility, true anatomical motion, and facial expression.13 Human face is capable of making unique micro-expressions which can be of very low intensity and last less than 0.04 seconds. Therefore, the dynamic systems continuously track frame by frame the facial surface movements in order to achieve accuracy in understanding the tracking motions. Assessment of facial animation could be an essential part for orthodontic diagnosis and craniofacial abnormality, virtual surgical planning, and treatment outcomes. Furthermore, various surgical interventions could affect the function of nerves and associated musculature which could influence the magnitude and the speed of the soft tissue motions.[14]

Customized Lingual Orthodontic Brackets

Wiechmann15 et al. introduced 3D printing to create wax patterns of lingual orthodontic brackets, allowing to customize the shape of bracket base. The manufacturing process begins with virtual design of each bracket, which can be customized to fit ideally to the anatomy of lingual/palatal surface of teeth. Digital design allows to customize in – out, angulation and torque values of each bracket; thus, an individual bracket prescription is created for each patient.

Occlusal Splints

Occlusal splints are contemporarily used for treatment of patients presenting with temporomandibular disorders (TMD). Lauren and McIntyre16 were the first authors to describe digital workflow in occlusal splints manufacturing. They suggested digital protocol applied subtractive technology of splint fabrication, which were machined down from acrylic material block. Salmi et al.17 introduced 3D printing for splint manufacturing. The printing process is highly reproducible and faster than conventional technique, thus decreases significantly the dental laboratory workload. The improved 3D printed splint accuracy may reduce time required to trim the splint. On the other hand, there is still a need for further clinical and scientific examination of 3D printed occlusal splints concerning clinical use.

Surgical Templates for Orthodontic Miniscrews and Miniplates Placement Wang et al.18 described a technique of orthodontic miniscrew placement using a 3D printed surgical template. The superimposed CBCT and dentition scan data were imported into CAD software to design virtual surgical template. The template was 3D printed with ABS material (acrylonitrile butadiene styrene) using FDM 3D printing machine. Hourfar et al.19 introduced a method of customized adaptation and placement of orthodontic miniplates using CAD and 3D printing technology. 3D printed model of patient's bone fabricated on the basis of CBCT images were used as a template to position and adopt the miniplate to the bony contour on the model. Stereolithographic 3D printer has were used to manufacture the model. Miniplate final position were established and fixed with screws that served as a guide to fabricate a jig to transfer the plate to the patient's mouth. The main advantage of this technique is precise determination of the final position of an orthodontic miniplate prior to the surgical procedure, which significantly simplifies the process and reduces the time needed for surgery

Orthodontic Retainers

Computer-aided design and 3D printing allows the orthodontics to fabricate customized removable retainers. The procedure has been presented and described by Nasef et al20. The process integrates the application of new technologies, including (CBCT), CAD and 3D printing. A certain disadvantage of the material used may be its white opaque colour. The application of stereolithographic technique would allow to use another printing material, achieving an ideal transparency. Disadvantage of SLS is high costs and low availability.

Removable Orthodontic Appliances

First trials to manufacture removable acrylic orthodontic appliances using computer-aided design and 3D printing were made and presented by Sassani et al.21 The authors reported the application of half automated technique to manufacture acrylic base plates of removable appliances. Al Mortadi et al.22 described a procedure of Adresen activator and sleep apnoea appliance fabrication using computer-aided design and additive manufacturing technology. The next development in the field was fabrication of Hawley retainer with CAD and 3D printing. Al Mortadi et al.23 presented Hawley retainer manufacturing using intraoral scans obtained with TRIOS (3Shape, Copenhagen, Denmark), eliminating the need of conventional impression taking and pouring plaster models.

CONCLUSIONS

The developments of available computer-aided design software and additive manufacturing hardware allowed integrating the technology in orthodontics, and revolutionizing the workflow in orthodontic practices and laboratories around the world. 3D printing is now easily accessible for orthodontists, being a reliable and cost-effective manufacturing method, which may be used in many aspects of orthodontic practice, and its potential is still growing. With the recent advancement in research of diverse technologies and compatible materials, it is possible to obtain single scan digital impressions, virtually design, and 3D print different types of orthodontic appliances. 3D facial imaging provides a detailed analysis in orthodontics, maxillofacial, plastic, and esthetic surgery. In orthodontics the application of (3-D) printing has made the treatment procedures easy, time saving and cost effective apart from the initial investments. With this new technology comes a new workflow for the orthodontic office.

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