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An insight into 3-dimensional printing in orthodontics

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Abstract

The field of orthodontics in its new era is stepping ahead to newer technologic perspective. Additive manufacturing is a relatively new technology with rapidly growing range of applications in many fields of medicine and dentistry. A paradigm shift has constituted the progression from gypsum laboratory to 3-Dimensional printing. 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. The article gives necessary insight into the history, development, available technologies of additive manufacturing and provides updates of application of 3-D printing in orthodontics.

Keywords: 3-D Printing, appliances, rapid prototyping, digitization

Introduction

Rapid development of digital technologies in dentistry began in 1980s with the implementation of software system and computer-aided design and computer-aided manufacturing (CAD/CAM). The concept of CAD/CAM entails three functional elements: (1) digitalization tool for data acquisition (a scanner); (2) software to edit and to process digital data; (3) a manufacturing technology to remodel digital data to a final product. Manufacturing is held either with subtractive or additive methods. Subtractive fabrication is accomplished by removing material from a block by milling or cutting until a desired shape is created^[1]. On the opposite hand, additive manufacturing is stated a process, during which an object is fabricated by adding a raw material layer-by-layer in a specific manner^[1, 2] This process is more correctly described as and is additionally named as additive manufacturing (AM), 3D printing, rapid prototyping, layered manufacturing, solid free form fabrication or desktop fabrication.

3D Printing Over CAD/CAM Technology^[3].

- Subtractive methods like CAD CAM have some limitations in relation with 3D printing.
- Large amount of raw material is wasted because of unused portions of the mono-blocks which are discarded after milling and recycling of the surplus ceramic is also not feasible.
- Milling tools are liable to heavy abrasion and wear due to which their cycling time shortens.
- Due to brittle nature of ceramic, microscopic cracks are often introduced during the process of machining.

History

Dr. Hideo Kodama, a Japanese Lawyer, was the primary person to file a patent for Rapid Prototyping (RP) technology in May 1980. Chuck Hull was the first-one to establish the concept of 3D printing in 1984, when he was using ultraviolet to cure table top coatings. Hull established the 3D Systems company in 1986 to promote the first machine for rapid prototyping, which he called stereolithography (SLA). Scott Crump developed fused deposition modeling (FDM) in 1988, which was later commercialized by Stratasys in 1990. Massachusetts Institute of Technology (MIT) had patented "3-D Printing techniques" in 1993. It is just like the inkjet technology utilized in 2D Printers.

Objet Geometries, the developer of Poly-Jet photopolymer printing (PPP), was founded in 1998.

How Does It Work? ^[4].

3D printing is a manufacturing technology, within which an object is made by adding a material layer-by-layer one on top of the other in an exceedingly specific manner, until whole object is manufactured in line with computers' design. The method must be preceded by creating a project/design in STL (standard tessellation language or stereolithography) file format. STL file is a triangular representation of an object's surface configuration. Each object is made of many triangles

and also the peak of every triangle is represented by the coordinates system. STL is the most ordinarily used file format to edit and formulate the object for 3D printing. The digital project is then sliced into layers and the 3D printer recreates the layers, which are then fused together. Digital design may be created employing a computer and dedicated software (CAD), it may be acquired by scanning the structure we would like to print, or alternatively, it may be converted to CBCT DICOM file. Additive techniques permit to produce complex and sophisticated shapes and geometries with undercuts or holes, which cannot be manufactured by the other available method.

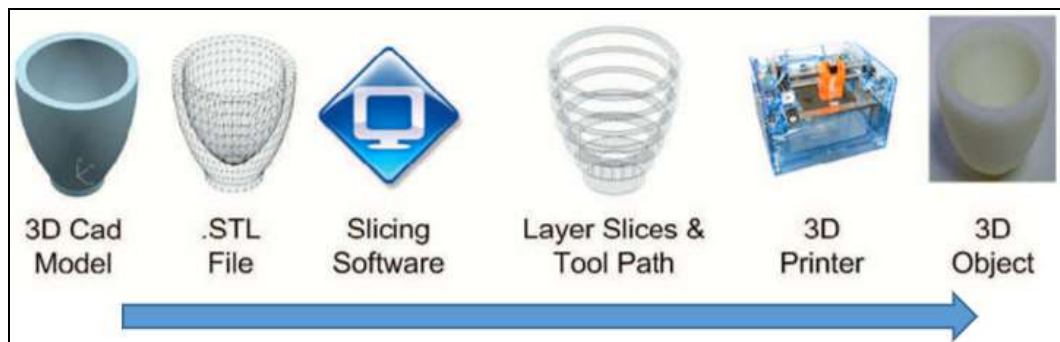


Fig 1: 3D Printing Process

3D Printing Technologies

There are many alternative 3D printing processes, which can be grouped into following categories ^[4, 5]:

1. VAT Photo-polymerization
 - i. Stereolithography (SLA)
 - ii. Digital Light Processing (DLP)
 - iii. Continuous liquid interface production (CLIP)
2. Material Jetting
3. Binder Jetting
4. Material Extrusion
 - i. Fused Deposition Modelling (FDM)
5. Powder Bed Fusion
 - i. Selective Laser Sintering (SLS)
 - ii. Direct Metal Laser Sintering (DMLS)
 - iii. Selective Laser Melting (SLM)
 - iv. Electron Beam Melting (EBM)
6. Sheet Lamination
7. Direct Energy Deposition
 - i. Powder-fed directed-energy deposition
 - ii. Metal wire processes
8. Computed axial Lithography
9. Liquid additive manufacturing
10. 3-D Plotting/ Direct Write Bio-printing
11. Multi Jet Fusion

The first five technologies are those most ordinarily encountered in medicine. Sheet lamination and directed energy deposition are less commonly utilized but still may provide a benefit when used for certain applications.

The main differences between processes are within the way how the layers are deposited to create parts and also within the materials that are used. In a number of the methods the material is melt or soften to produce the layers, as an example, selective laser melting (SLM) or direct metal laser sintering (DMLS), selective laser sintering (SLS), fused deposition modeling (FDM), or fused filament fabrication (FFF), while others cure liquid materials using different technologies, like stereolithography (SLA). With laminated

object manufacturing (LOM), thin layers are divided into different shapes and joined together (e.g., paper, polymer, metal).

Materials Utilized In 3-D Printing

- Thermoplastic polymers like polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polycarbonate (PC), polyether ether ketone (PEEK), composites, metals (rare) etc. utilized in Fused Deposition Modeling (FDM)-Material extrusion
- A variety of resins for photo-polymerization, ceramic filled resins, Epoxy- and acrylic based polymers Infused polymers used in Epoxy- and acrylic-based polymers Infused polymers etc. used in Stereolithography (SLA), Digital light processing (DLP), Continuous digital light processing (CLIP)- Vat photo-polymerization
- Powder such as alumide, polyamide, glass-particle filled polyamide, rubber-like polyurethane, Plastics, synthetic polymers, metal etc. employed in Selective Laser Sintering (SLS), Electron beam melting (EBM), Direct metal laser sintering (DMLS), Selective laser melting (SLM), Multi-Jet Fusion (MJF)- Powder bed fusion
- A sort of acrylic-based photopolymers used in Multi-Jet Printing(MJP) Poly-jet Material Jetting
- Cell-loaded gels and inks based on collagen, photopolymer resins, agarose, alginate, hyaluronic, chitosan, calcium silicate complex, and controlled release polymeric materials with bioactive agents etc. used in Bio-printer.
- Gypsum, sand, metal (rare) used in Binder jetting.

Orthodontic Applications

3D printing technology is also employed in orthodontics to manufacture models of patients' dentition. Digital dental models contribute to a significant decrease in a need to acquire alginate impressions and casting plaster models, thereby allowing avoiding drawbacks of conventional

orthodontic models. Elimination of traditional impressions and dental-cast production stages have augmented practice efficiency, patient and staff satisfaction for a completely integrated digital and streamlined workflow.

Digital models can be used for orthodontic diagnostic procedures. Diagnostic measurements performed on digital

models represent high validity, reliability, and reproducibility, and thus could also be considered as an equal alternative to conventional plaster models^[6, 7]. Rapid prototyping technology allows to manufacture many identical copies of a digital model without any risk of distortion or deformation, being available at any time⁸. (Fig 2)

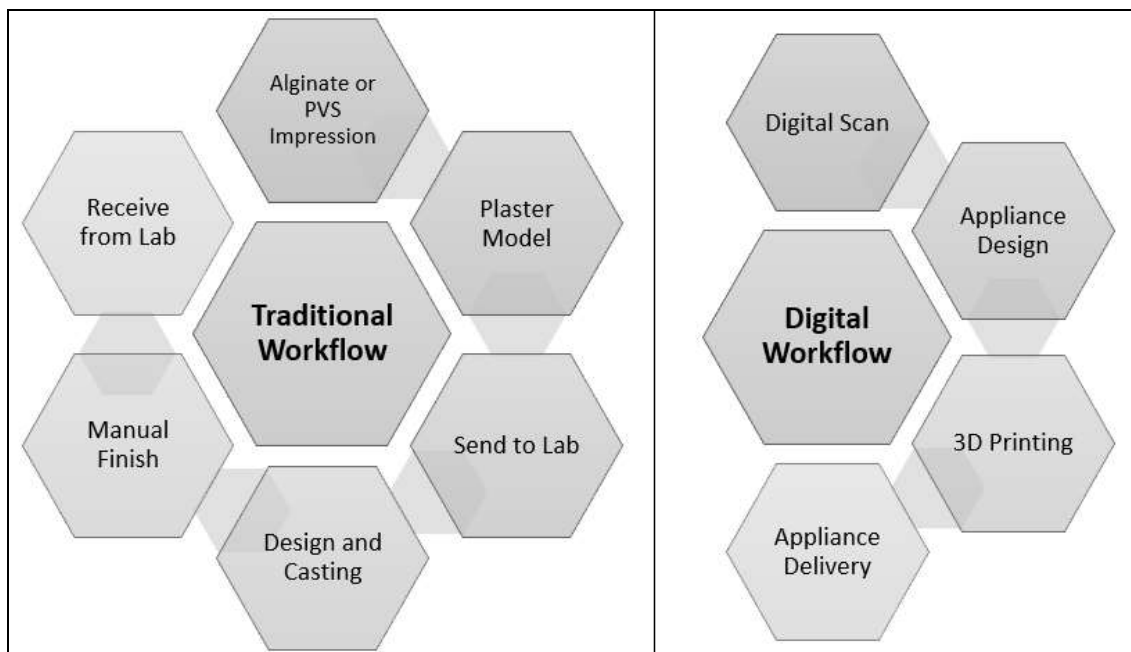


Fig 2: Traditional Versus Digital Workflow

3D printing in combination with computer-aided manufacturing (CAD-CAM) can be used to construct even traditional orthodontic appliances and bring about greater precision in their outcome^[13]. Printed models have been reported and may be used to manufacture various removable appliances (like Hawleys retainer, splints), functional appliances, arch expansion appliances, clear aligners (Fig 3a, b), arch wires, brackets, auxiliaries, trays for indirect bonding, set up models which can make lingual orthodontics and mock surgeries fast and easy^[9, 10]. Metal appliances require bands – merely by scanning the teeth with separators or wedges, the model can be 3D printed in the laboratory and the metal band appliance can be fabricated prior to the patient's appointed

time and delivered at appointment. Digital titanium Herbst^[12], Andresen activator, and sleep apnea appliances are formed with smooth surfaces, no sharp edges, and prime fit on the teeth, palatal and gingival tissues. Additive manufacturing enables features like hinge production, building threads, and wire insertion to be completed in a single build without assembly^[11]. CAD-CAM designed MARPE with increased accuracy would bring about better fit and adaptation^[14]. Thus, Orthodontic digitization and 3D printing have raised the level of standards of care by providing patients with an optimal orthodontic appliance, with elevated levels of accuracy.



Fig 3: (a, b) – 3D Printed Model with Expansion Plate. (c) – 3D Printed Clear Aligner

Conclusion

The fabrication of an orthodontic appliance is a very laborious procedure which necessitates great dexterity for its completion followed by its delivery to the patient to achieve desirable results. In today's era, with the expansion of technological aids and availability of compatible software, it has become feasible to produce single scan digital impressions, to virtually design and to 3D print a variety of appliances used in orthodontics. The 3D printing technology

has served as a valuable boon in orthodontics and is widely employed. Interestingly, the horizons of the scope of its futuristic applications are still broadening.

References

1. Bae EJ, Jeong ID, Kim WC, Kim JH. A comparative study of additive and subtractive manufacturing for dental restorations. *J Prosthet Dent* 2017;118:187-193.
2. Andonovic V, Vrtanoski G. Growing rapid prototyping as

- a technology in dental medicine. *Mech Eng Sci J* 2010;29:31-39.
3. Dawood A, Marti B, Begoña, Sauret-Jackson V, Darwood A. 3D printing in dentistry. *British Dent J* 2015;219(11):521-529
 4. Groth C, Kravitz ND, Jones PE, Graham JW, Redmond WR. Three-Dimensional printing technology. *J Clin Orthod* 2014;47(8):475-485.
 5. Additive manufacturing — General Principles — Overview of process categories and feedstock". ISO/ASTM International Standard. 2015;17296-2(E).
 6. Nalcaci R, Topucuoglu T, Ozturk F. Comparison of Bolton analysis and tooth size measurements obtained using conventional and three – dimensional orthodontic models. *Eur J Dent* 2013;7:66-70.
 7. Fleming PS, Marinho V, Johal A. Orthodontic measurements on digital study models compared with plaster models: a systematic review. *Orthod Craniofac Res* 2011;14:1-16.
 8. Kim SY, Shin YS, Jung HD, *et al.* Precision and trueness of dental models manufactured with different 3-dimensional printing techniques. *Am J Orthod Dentofacial Orthop* 2018;153:144-153.
 9. Ciuffolo F, Epifania E, Durante G, *et al.* Rapid prototyping: a new method of preparing trays for indirect bonding. *Am J Orthod Dentofacial Orthop* 2006;129:75-77.
 10. Martorelli M, Gerbino S, Giudice M, Ausiello P. A comparison between customized clear and removable orthodontic appliances manufactured using RP and CNC techniques. *Dent Mater* 2013;29:e1-10.
 11. Farronato G, Santamaria G, Cressoni P, Falzone D, Colombo M. The digital-titanium Herbst. *J Clin Orthod* 2011;45(5):263-7.
 12. Wiechmann D, Schwestka-Polly R, Hohoff A. Herbst appliance in lingual orthodontics. *Am J Orthod Dentofacial Orthop* 2008;134(3):439-46.
 13. Al Mortadi N, Eggbeer D, Lewis J, Williams RJ. CAD/CAM/AM applications in the manufacture of dental appliances. *Am J Orthod Dentofacial Orthop* 2012;142(5):727-733.
 14. Thakkar D, Ghosh A, Keshwani T. Digital Workflow for CBCT-Guided Customized Miniscrew-Assisted Rapid Palatal Expansion (3D Digital MARPE): A Clinical Innovation. *J Ind Orthod Soc* 2020;54(3):262-266.