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Review Article

The Future of Digital Orthodontics: A Prospective Leap from 3D to 4D

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Abstract

The specialty of dentistry is ever changing. We have entered an era of digital dentistry wherein everything falls into our fingertips on click of a mouse. The introduction of digital intraoral scanners, models and aligners has greatly revolutionized the field of orthodontics. The 3D system utilizes CADCAM technology to manufacture and process various orthodontic appliances collectively referred to as 3D printing. But the drawback with 3D technology is that it is static. Orthodontic treatment is more dynamic and hence incorporating a fourth-dimension time into this has led to the advent of 4D technology. This has been widely utilized in many other areas of medicine, and dental specialty especially orthodontics can tremendously benefit from these innovations. This article discusses few aspects of digital dentistry and the future prospects and applications of 4D technology in orthodontics.

Keywords: Digital printing, 4D orthodontics, Digital dentistry

Introduction

Orthodontics is evolving with time. Digital future pertaining to orthodontics means additional diagnostic tools and treatment modalities that augment and expand the scope of orthodontics. Over the last decade, technology in 3D printing has enabled clinicians to enhance their diagnostic and surgical procedures. It allows for better visualization, realistic training and surgical planning. In dentistry, this innovation has revolutionized the practice management system as it could provide maximum accuracy with minimum clinical setup and short operative time.[1]

The use of 3D printing in dentistry is essential in the modern restorative and prosthetic fields, orthodontics, implant dentistry as well as maxillofacial surgery.[2] Specifically, 3D-constructed models have played a principal role in facial reconstruction surgeries (e.g., zygomatic fractures) and temporomandibular disorders that require surgical intervention.[3] 3D printing facilitates better visualization of deep structures and reduced the potential complications during surgery like infection and blood loss due to prolonged operating times.[2] Additionally, 3D printing has aided in the production of removable dentures, prosthetic mock-ups

and trial prostheses, which are all important in aesthetic and restorative clinical daily work.

The challenge with 3D printing is that it is a static process whereas orthodontic treatment is dynamic.[3] 3D printing serves a right away benefit for study models in place of traditional lab fabrication. In order to vary a static method into a dynamic appliance, the longer term for orthodonture is in 4D printing. 4D printing is a digital process that takes 3D printing materials and adds the 4th dimension which is time. This is accomplished by adding movement into the 3D written elements and producing appliances that amendment in form over time. The stimulus for such movement may be a change in temperature, a charge, or kinetic process that alters the shape of the 3D printed object.[4]

4-D Printing

At the 2012 TED conference, Tibbits demonstrated how a static printed object transformed over time. This was the starting point of the 4D printing concept, incorporating the fourth dimension, time. Since then, 4D printing has become a new and exciting branch of 3D printing, increasingly gaining substantial attention from scientists and engineers of different disciplines.[6]

Skylar Tibbits and his co-workers had designed self-folding structures that reshape over time under certain environmental conditions.[7] They converted the stable 3D-printing materials into actively moving objects by the novel 4D-printing approach. The written models remodel into a planned form and performance when fabrication.[2] These are named as self-folding materials. The aim of 4D printing is to produce functional objects rather than static ones.

In the medical field, the term 4D" has been joined to a scanning approach that's used for watching the dynamic characteristics of various organs. It is highly advantageous for the accurate positioning of dynamic tissues during radiotherapy. It also allows orthopedic clinicians to develop printed models of carpal and metacarpal bones to observe thumb movement to assist in arthroplasty procedures. Based on the concept of motion over time, 4D scanning could permit the modelling of complex anatomical structures, thus improving the preoperative planning.[2]

4D printing is the process of self-folding with time under temperature and humidity changes. This concept relies on understanding how the microstructures of 3D-printed models can undergo spontaneous shape transformation under temperature and moisture changes. 4D printing relies on 3D printing of materials followed by selective photo-curing to give the 4D-printed objects a mobile nature. The mechanism of transformation can be assessed by evaluating the strain properties of every component within the printed model and putting them under a controllable pattern.[8]

Steps in 4D printing

4D printing is the latest technology that creates innovation and addresses complex medical problems[9]. 4D printing is to provide benefits to medical practitioners especially in the areas not covered by 3D printing technologies. 4D printing helps to create a 3D physical object by adding smart material layer by layer through computer-operated computer-aided design (CAD) data.[9] It adds a dimension of transformation over time wherever written product are sensitive to parameters like temperature, humidity, time etc. This technology will offer intensive support within the medical field, particularly with higher and good medical implants, tools and devices. Now doctors and researchers will explore with 4D printing technology to supply higher service to the patient.[10]

4D printing has 2 important steps: processing and programming. The model is first processed into an original shape; then it is intermediately temporized into another shape and eventually programmed to convert to a distinct form once exposed to sure stimuli (e.g., body temperature 37°C or body moisture) during a self-folding pattern. Mixing the microstructures into controlled measures can be challenging, and therefore, the manner in which materials undergo programmed movements is not yet reported.[2]

4D-printed materials can move only in certain directions as programmed before their production. Adjusting the trail of motion of 4D-printed materials can eliminate the employment of dental adhesives (etching and bonding systems) because these materials can rely more on mechanical means of retention rather than the chemical aids. In dentistry, 4D printing would have a good impact on different specialties because the technology can produce dynamic and adaptable materials to be functional within the oral environment under the continuously changing thermal and humidity conditions.[2]

4-D Orthodontics

Currently, the modern use of both removable and fixed appliances relies on data imported from 3D orthodontic software. The pertinency to provide self-straining wires or self-folding removable appliances will build the odontology appliances undergo continuous movement overtime ending up with positioning and aligning teeth within the desirable position and angulation. 4D-printed orthodontic appliances can be manufactured to undergo controlled self-folding movement to move the teeth in certain direction and angulations in pre-determined times.[2]

The research in the 4D printing in dentistry will be increasing as to produce aligners, surgical templates, and odontology braces adjusted as per demand of the individual patient when natural action. The orthodontist can convert innovative ideas into a reality which provides an opportunity to manufacture smart appliances and devices as per the requirement of the patient. Likewise, smart orthodontics implants enhance the function of ligature and wires that help teeth to moves in the desired direction. These implants will change the case with none would like for human management.[11]

4-D Aligners

4D dynamic aligners are produced by using special shape memory polymers that could be formed on the targeted form of teeth let's assume the fourth step within the method of teeth orientating S4, the clear aligner is re-engineered in-lab underneath specific temperatures to form S1, known as "Back from the future" conception. The patient has an activation device to activate the clear aligners (Aligner booster) every 2 weeks and thus recover the form of the clear aligner gradually to go back to S4. The result is, rather than using 4 aligners per arch to align teeth over 2 months, by this method, we use just one aligner.[12]

4D printing is a motivating research topic and might have a positive, practical impact on medical and dental applications. A comprehensive understanding of the folding pattern is important to fabricate functional appliances without harmful effects. This manufacturing technique relies on 3D printing of several materials with enhanced digital shape-memory properties that can change over time under different thermal/physical conditions. 4D printing relies on important the sequence and path of movements, which determine the self-folding pattern.[2]

The coming up with step ought to take into thought the movement of the circumferential structures round the 4D-printed prosthetic appliance. For instance, designing a heart valve should consider the contractile movements of the cardiac muscles along with the motion of cardiac and pulmonary vasculatures in addition to potential aspects of high/low blood pressure. In different words, coming up with 4D-printed appliances ought to be done on kinematic and dynamic bases.[13]

Another important aspect is the shaping time under thermal or physical conditions. In this regard, patients who have newly introduced 4D-printed appliances should be closely monitored as the time of folding can range from minutes to days, and therefore, the success rate of the treatment procedures would depend upon the time of remodeling the fabric into its final form and in final position whereas still being functional. The self-folding time cannot be infinite, that is, the material should not undergo dynamic changes continuously overtime. There ought to exist the questionable automatic property, that is capable of dominant folding sequence.[2]

The other major properties of ideal 4D-printing structures are biocompatibility, modulus of elasticity and coefficient of thermal expansion which should mimic those of body structures to hinder undesired body reactions like swelling, inflammation or ischemic reactions. Additionally, 4D-printing materials should have good strength properties to forestall their fracture overtime, which could necessitate revision surgery.[13]

4D printing helps in the fabrication of shape-shifting materials over time or space with the likelihood to manage their microscopic changes for application in medical specialty engineering. 4D-printed structures should possess smart structures and high resolution in order that they will be thermo-mechanically programmed to change into functional configurations. The shape-shifting behaviour is resultant from the differences in dimensional changes' ratios (coefficient of thermal expansion, modulus of elasticity) of the internal ingredients. Modification of the materials behaviour in microscale can yield their use in stem cells and tissue-engineering research for the production of scaffolds. More collaborative research work must be done on 4D printing in dentistry; and further prospective analyses of the applications of this system have to be discussed.[14]

Conclusion

In the same way Nitinol wires revolutionized bracket systems; 4D printing can revolutionize the future of digital orthodontic treatment. Whether they ar fastened or removable, 4D written appliances would improve the potency of treatment and utilize digital workflows to incorporate many of the imaging and diagnostic tools we have today.

In future, 4D printing can print low-cost, smart, orthodontic appliances using multiple biocompatible materials[14]. Now, 4D printing will solve numerous issues that are the limitation of 3D printing technologies. This technology has the potential to grow as chop-chop as digital odontology.

Conflict of Interest
The author has no conflict of interests to declare.

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