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Transformacja w ortodoncji dzięki drukowi 3D

3D Printing transformation in orthodontics

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Wkład autorów: A Plan badań B Zbieranie danych C Analiza statystyczna D Interpretacja danych E Redagowanie pracy F Wyszukiwanie piśmiennictwa

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Streszczenie

Rozwój drukarek 3D zmienił i nadal zmienia wiele aspektów ortodoncji. **Cel.** Celem pracy jest przegląd piśmiennictwa dotyczącego cyfrowej ortodoncji w odniesieniu do praktyki klinicznej i określenia przyszłych trendów w tej dziedzinie. **Materiał i metody.** Niniejsze opracowanie przedstawia w ogólnym zarysie cyfrowy świat ortodoncji. Znajdują się w nim m.in.: ocena rodzajów drukarek 3D, aktualne informacje o drukarkach 3D oraz zestawienie obszarów ich zastosowania w klinikach stomatologicznych. **Wyniki i wniosek.** Niniejsze opracowanie ma na celu przygotowanie ortodontów do wykorzystania szybko rozwijającego się rynku drukarek 3D i produkcji 3D, a także pokazanie, z jaką łatwością można projektować i wytwarzać w technologii 3D, w porównaniu z tradycyjnymi metodami. **(Abay F, Buyuk K,**

Abstract

The 3D printer development has provided and continues to change in many areas in the world of orthodontics. **Aim.** The aim of this paper is to present an up-to-date review of digital orthodontics and to compare it with our clinic experience, to determine where we are in orthodontic practice and where we can go. **Material and methods.** This study provides an overview of the digital world in orthodontics. It includes evaluating types of 3D printers, cerrent information about 3D printers and a compilation of areas of use in dentistry clinics. **Results and conclusion.** This study is to prepare orthodontists to touch on the easy aspects of 3D design and production compared to traditional methods. **(Abay F, Buyuk K, Simsek H. 3D Printing transformation in orthodontics. Orthod Forum 2023; 19 (1-2): 46-52).**

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Introduction

New horizons have been begun in digital orthodontics with the development of three-dimensional (3D) printers. 3D printers provide fast and practical use as well as the opportunity to perform original designs. Moreover, at the same time as removing the problems of working with the technical laboratory, it provides the possibility to save you laboratory-related complications and loss of time. There are three stages of digital orthodontic applications. It is the process of creating digital models scanned with 3D scanners, designing suitable models and appliances with design programs, and producing them with 3D printers.

Aim

The aim of this review is to present an up-to-date review of these three pillars with our clinical experience, to determine where we are in orthodontic practice and where we can go (1-3).

3D Printers and history

3D printing is the process of producing the object that is intended to be produced layer by layer. Stereograph, the Greek word meaning to draw or show an object in three dimensions, was first used by the Japanese scientist Hideo Kodama in the early 1980s (4). After Charles Hull received the first 3D printer patent in 1986, many companies introduced their 3D printers to the market (5). The use of 3D printers is rapidly becoming widespread among dentists with the development and cheapening of 3D printers. The printing resolution and printing speed of 3D printers for dental use are essential parameters (5,6). The 3D printers' resolution, it depends on many factors which include the mild source, the resin type, and the sort of machine. The most important of these is the light source of 3D print. Liquid Crystal Display (LCD) type 3D printers are classified according to their resolutions such as 2K, 4K, 6K and 8K (7, 8).

Vat polymerization type printers

Digital light processing (DLP)

DLP printer, one of the 3D printer sorts observed in 2006, comes from the picture projection technology. It is a device that provides high resolution fast printing, which consists of more than 1 million mirrors that may be controlled and rotated in micron dimensions and can reduce the pixel pitch to a few microns (9).

Liquid crystal display (LCD)-based stereolithography

Many 3D printers are a type of 3D printer that make us of DLP technology-primarily Liquid Crystal Display (LCD), reflecting UV light from the LED screen. UV light is not extended using any lens. In this way, the expansion due to the refraction of the light, referred to as pixel distortion, and its reflection to a wider area than the desired area is not in question. Not using expensive projectors like DLP printers and fast printing from laser stereolithography (SLA) printers enabled LCD type 3D printers to be used in a wider area in the field of dentistry (10, 11).

Laser stereolithography (SLA)

SLA 3D printer is a system that uses a UV laser light source and cures this light source by traveling through the relevant layer. It reflects the laser beam with mirrors called Gallio (12). While the z layer determines the printing time in DLP printers; the x, y and z layers determine the time in laser SLA printers. The printing resolution depends on the size of the laser, which is the light source.

Resins

3D printer resins are liquid products that may form polymers by cross-linking short chains of various monomers and oligomers through a reaction called photopolymerization. Resins normally consist of 3 components: Monomers (10-40%), catalysts, binders (50-80%).

The methyl methacrylate molecule produced from the reaction of acetone with hydrogen cyanide is generally used as the monomer. Although this molecule is a material that dentists have recognized and used for years, it is useful to consider its negative effects on the body (13-15).

Relying at the components, dental resins are resins that contain initiators of 385-405 nanometers and can be produced with 3D printers that produce light at these wavelengths. While dental resins are produced for many purposes, from direct aligner resin to indirect bonding resin, which is thought to take orthodontics to new horizons, there are different dental resins in general dentistry such as cast resin, permanent-temporary crown resins.

3D Printing application areas in orthodontics
Orthodontic model production

Plaster models have been used for diagnostic purposes in orthodontics for years. Orthodontic models can be produced with 3D printers with the current technological development. In the orthodontic version manufacturing procedure, the models transformed to. stl format with intraoral scanners are edited in the proper software. Since 3D printers print layer by layer, the object in .stl format must be sliced. Since 3D printers cannot produce the .stl format directly, slicing should be done with proper programs (Fig. 1).

Clear aligner therapy

The planned tooth movements can be performed in the clear aligner module in software. There are auxiliary units such as determining the limits of tooth movements and automatic attachment placement in software programs. In addition, new free designs can be performed by allowing attachment types designed in .stl format to be added to the system. By determining the amount of movement for the final occlusion, the amount of tooth movement of each clear aligner is determined. After exporting the planned models in .stl format and slicing in the slicer program, models can be produced with a 3D printer (Fig. 2).

The improvement of dental resins has opened new horizons within the manufacturing of clear aligners in orthodontics. Dental resin manufacturers have introduced directly produced clear aligner resins. Clear aligner can be produced directly without the need for model production. It has advantages along with smoothness of the edge surfaces with identical thickness and high compatibility in comparison to the obvious plaques produced by printing the model from the thermoplastic material using the indirect method (16) (Fig. 3).

Aesthetic bracket production

The orthodontic bonding process has constantly persevered with the search for a more aesthetic and purposeful orthodontic bracket. Orthodontic brackets have also changed with the improvement of adhesives to offer a strong adhesion pressure to no longer harm the enamel in the debonding process. This change allowed the brackets to be made of aesthetic materials (17).

The improvement of 3D printers and resins initiates new horizons in orthodontic bracket production. It is possible to produce custom-designed tooth-colored brackets with 3D printers with permanent biocompatible resins (Senertek P-Crown, Izmir, Turkiye). Although it is not as easy as labial orthodontic bracket production, lingual orthodontic bracket manufacturing can also be accomplished with 3D printers. 3D printers reveal the importance of design in orthodontics and increase the possibility of original designs (18) (Fig. 4).

Nasoalveolar molding in individuals with new-born cleft lip and palate

Nasoalveolar molding (NAM) is an adjunctive treatment designed to reorient tissues to the correct position in individuals with cleft lip and palate new-borns. NAM can reduce scar tissue after the surgery. The improvement of 3D printers has additionally caused the development of recent techniques inside the production of NAM. Bauer et al. designed the NAM appliance according to millimetric converged slit lines based on a growth forecast, which they defined as RapidNAM. This method allows it to be used more easily in routine with the development of 3D printers (19-21) (Fig. 5).

Twin Block Appliance

One of the maximum common malocclusions in orthodontics is Class II malocclusions. Functional orthopedic treatment is frequently used in adolescents with sagittal growth failure of the mandible. The Twin-Block appliance designed by Clark to strengthen the mandible inside the sagittal direction in patients with Class II mandibular insufficiency has been used by orthodontists for many years since it has a smaller and less visible part compared to other functional appliances (22,23).

It is possible to produce Twin-Block appliance with 3D printers by designing in suitable software program. One of the most important of these is the Invisalign with Mandibular Advancement Feature (IMAF), which Align Technology introduced in 2017. In this design, buccal ‘delicate wings’ are usually placed between the first molar and premolar. Like the Twin-Block, it brings the mandible forward and on the same time allows clear aligner treatment. Through correcting the crowding of the patients' mandible for the duration of progression, the total treatment time can be shortened and the tolerance of the patients to the treatment can be increased (24) (Fig. 6).

Space maintainer appliances

It is easier to prevent the occurrence of malocclusion than to treat it. Many orthodontic problems may be prevented with the aid of preventive orthodontic treatment. Preventive orthodontic treatment includes many applications. Preventive orthodontic applications can reduce the psychological negative effects of malocclusion as well as reduce the treatment costs. Dental impressions and laboratory stages can be eliminated by 3D printers in the manufacturing of area maintainers. It is expected that the compatibility and hygiene of the bands with the teeth will be better (25,26) (Fig. 7).

Indirect bonding tray

Indirect bracket bonding refers to the technique wherein which the bracket position is deliberate by software and is performed by way of creating publications. Bonding no longer simplest improves accuracy but also reduces chair-time. In

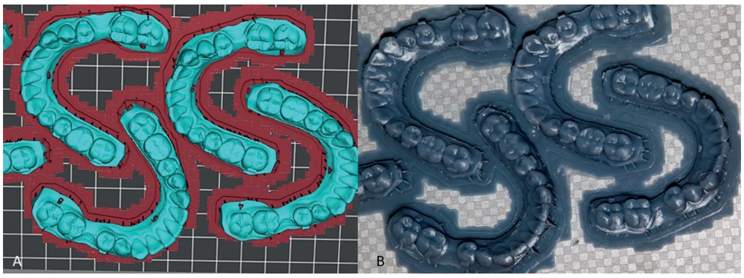

Figure 1. (A) Preparation of models in the software, (B) Image of 3D models.

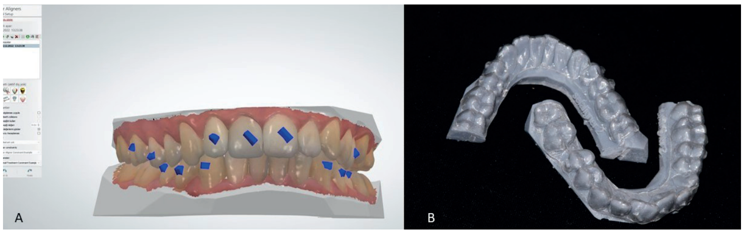

Figure 2. (A) Designing clear aligner in the software, (B) 3D printing models and production of clear aligner by thermoplastic material.

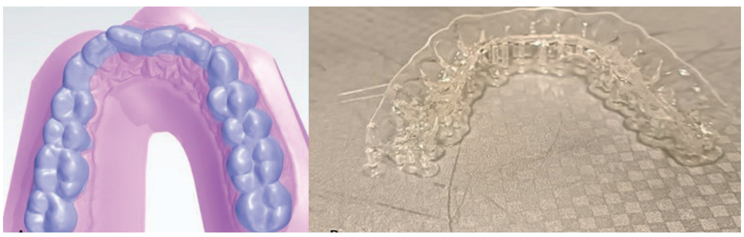

Figure 3. (A) Designing the shell for the models, (B) Directly production of clear aligner.

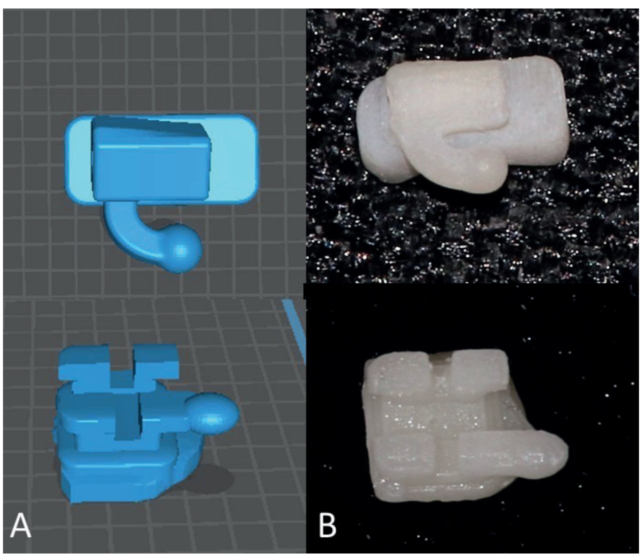

Figure 4. (A) Preparation of aesthetic brackets, (B) Aesthetic bracket production with 3D printer.

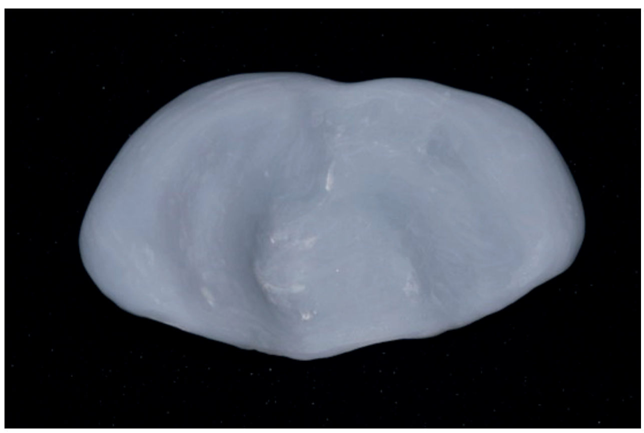

Figure 5. The design of the feeding plate appliance for cleft palate new-borns.

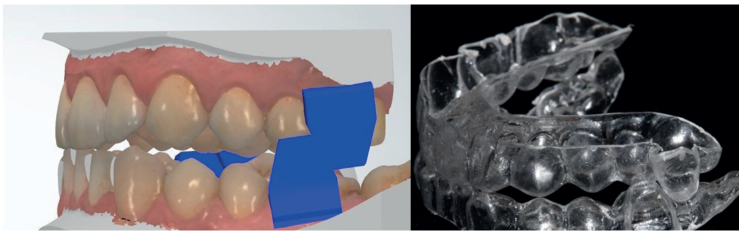

Figure 6. (A) Designing the Twin-Block appliance, (B) Production of Twin block ramps with thermoplastic materials.

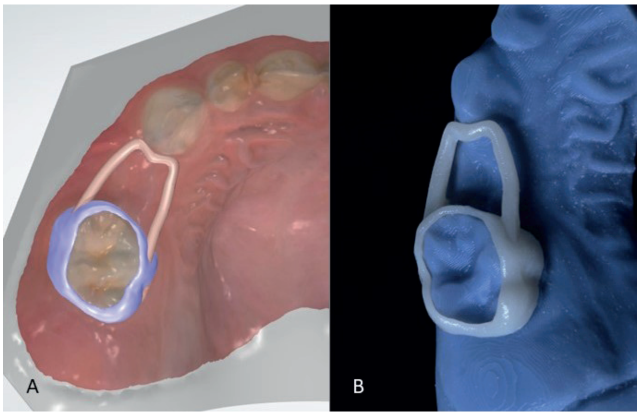

Figure 7. (A) Designing a band and loop space maintainer appliance, (B) Band and loop space maintainer appliance.

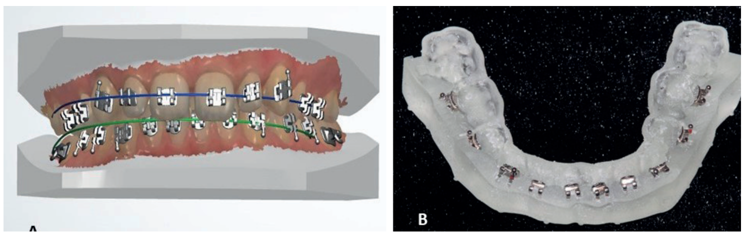

Figure 8. (A) Designing indirect bonding tray, (B) Indirect bonding tray.

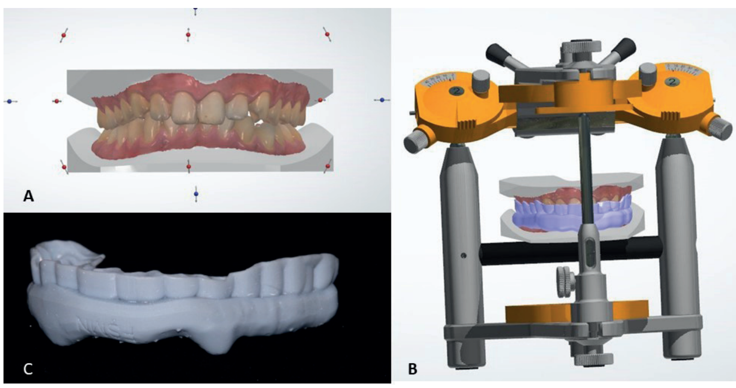

Figure 9. (A) Adjusting the occlusion of virtual models in the software (B) Virtual models in the software, (C) 3D printing of stabilization splint appliance.

addition, computer software can help dentists understand the feasibility of orthodontic plans by simulating the process and effects of orthodontic treatment (27, 28) (Fig. 8).

Stabilization splint for temporomandibular disorders
Stabilizations have features including relaxation of the muscles, placement of the mandibular condyle in the centric position, and protection of the teeth and periodontium. The splint production facilitates with digital design (29). Accurate centric relationship recording, no extra laboratory process required, and adjustment of occlusal recording in centric relationship in virtual articulator reduces chair time (30) (Fig. 9).

Conclusions

The development of 3D printers and dental resins reduces the costs in orthodontic practice and facilitates the production of orthodontic appliances. The development of new designs and the acceleration of worldwide statistics glide will cause extra use of 3D printers in orthodontics. Dental experts ought to be organized for the new digital age.

Piśmiennictwo / References

1. Kihara H, Hatakeyama W, Komine F, Takafuji K, Takahashi T, Yokota J, Oriso K, Kondo H. Accuracy and practicality of intraoral scanner in dentistry: A literature review. J Prosthodont Res 2020; 64: 109-13.
2. Yun D, Choi DS, Jang I, Cha BK. Clinical application of an intraoral scanner for serial evaluation of orthodontic tooth movement: A preliminary study. Korean J Orthod 2018; 48: 262-7.
3. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: a review of the current literature. BMC Oral Health 2017; 17: 149.
4. Kodama H. Automatic method for fabricating a three dimensional plastic model with photo hardening polymer. Rev Sci Instrum 1981; 52: 1770-3.
5. Wohlers T. Stereolithography - A historical perspective. Virtual Phys Prototyp 2012; 7: 179.
6. Kessler A, Hickel R, Reymus M. 3D Printing in Dentistry-State of the Art. Oper Dent 2020; 45: 30-40.
7. Liqcreate. Dostępny w Internecie: https://www.liqcreate.com/supportarticles/explained-2k-4k-8k-resolution-3d-printers-and-resins/
8. HUBS A PROTOLABS COMPANY. Dostępny w Internecie: https://www.hubs.com/knowledge-base/types-of-3d-printing/
9. Zhang J, Hu Q, Wang S, Tao J, Gou M. Digital Light Processing Based Three-dimensional Printing for Medical Applications. Int J Bioprint 2019; 6: 242.
10. Tsolakis IA, Gizani S, Panayi N, Antonopoulos G, Tsolakis AI. Three-Dimensional Printing Technology in Orthodontics for Dental Models: A Systematic Review. Children (Basel) 2022; 9: 1106.
11. Lo Giudice A, Ronsivalle V, Rustico L, Aboulazm K, Isola G, Palazzo G. Evaluation of the accuracy of orthodontic models prototyped with entry-level LCD-based 3D printers: a study using surface-based superimposition and deviation analysis. Clin Oral Investig 2022; 26: 303-12.
12. Park JM, Jeon J, Koak JY, Kim SK, Heo SJ. Dimensional accuracy and surface characteristics of 3D-printed dental casts. J Prosthet Dent 2021; 126: 427-37.
13. Stefaniak AB, Bowers LN, Knepp AK, Luxton TP, Peloquin DM, Baumann EJ, Ham JE, Wells JR, Johnson AR, LeBouf RF, Su FC, Martin SB, Virji MA. Particle and vapor emissions from vat polymerization desktop-scale 3-dimensional printers. J Occup Environ Hyg 2019; 16: 519-31.
14. PubChem, Methyl methacrylate. Dostępny w Internecie: https://pubchem.ncbi.nlm.nih.gov/compound/Methyl-methacrylate/
15. POLYMERS, Introduction to Resin 3D Printing. Dostępny w Internecie: https://www.polymers.lv/introduction-to-3d-printing/.
16. Tartaglia GM, Mapelli A, Maspero C, Santaniello T, Serafin M, Farronato M, Caprioglio A. Direct 3D Printing of Clear Orthodontic Aligners: Current State and Future Possibilities. Materials (Basel) 2021; 14: 1799.
17. Gange P. The evolution of bonding in orthodontics. Am J Orthod Dentofacial Orthop 2015; 147: 56-63.
18. Panayi NC. In-house customization of lingual orthodontic brackets using Ubrackets computer-aided design orthodontic software. AJO-DO Clinical Companion 2022; 2: 325-34.
19. Ahsanuddin S, Ahmed M, Slowikowski L, Heitzler J. Recent Advances in Nasoalveolar Molding Therapy Using 3D Technology. Craniomaxillofac Trauma Reconstr 2022; 15: 387-96.
20. Chou PY, Hallac RR, Ajiwe T, Xie XJ, Liao YF, Kane AA, Park YJ. The role of Nasoalveolar molding: A 3D Prospective analysis. Sci Rep 2017; 7: 9901.
21. Bauer FX, Schönberger M, Gattinger J, Eblenkamp M, Wintermantel E, Rau A, Güll FD, Wolff KD, Loeffelbein DJ. RapidNAM: generative manufacturing approach of nasoalveolar molding devices for presurgical cleft lip and palate treatment. Biomed Tech (Berl). 2017; 62: 407-14.
22. Graf S, Tarraf NE, Vasudavan S. Direct printed removable appliances: A new approach for the Twin-block appliance. Am J Orthod Dentofacial Orthop 2022; 162: 103-7.
23. Clark WJ. The twin block traction technique. Eur J Orthod 1982; 4: 129-38.
24. Koukou M, Damanakis G, Tsolakis AI. Orthodontic Management of Skeletal Class II Malocclusion with the Invisalign Mandibular Advancement Feature Appliance: A Case Report and Review of the Literature. Case Rep Dent 2022; 2022: 7095467.

25. Laing E, Ashley P, Naini FB, Gill DS. Space maintenance. Int J Paediatr Dent 2009; 19: 155-62.
26. Khanna S, Rao D, Panwar S, Pawar BA, Ameen S. 3D printed band and loop space maintainer: A digital game changer in preventive orthodontics. Int J Paediatr Dent 2021; 45: 147-51.
27. Chaudhary V, Batra P, Sharma K, Raghavan S, Gandhi V, Srivastava A. A comparative assessment of transfer accuracy of two indirect bonding techniques in patients undergoing fixed mechanotherapy: A randomised clinical trial. J Orthod 2021; 48: 13-23.
28. Wang M, Shi X, Cheng WP, Ma FH, Cheng SM, Kang X. Clinical Study on Efficiency of Using Traditional Direct Bonding or OrthGuide Computer-Aided Indirect Bonding in Orthodontic Patients. Dis Markers 2022; 2022: 9965190.
29. Hazra R, Srivastava A, Kumar D, Khattak A. Current trends in temporomandibular disorder management: A prosthodontist's perspective. J Dent Def Sect 2022; 16: 146-50.
30. Sirbu A, Bordea R, Lucaciu O, Braitoru C, Szuhanek C, Campian R. 3D Printed Splints an Innovative Method to Treat Temporomandibular Joint Pathology. Rev Chim 2018; 69: 3087-9.