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Patient Awareness of Additive Manufacturing in Dentistry – A Survey

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Abstract

BACKGROUND: Additive manufacturing or 3D printing technology creates the object layer by layer. Its development in dentistry has been particularly rapid over the past 10 years and covers more and more dental fields.

AIM: The aim of this article is to demonstrate the patient's awareness of additive manufacturing and their opinion about the price and application of 3D-printed products in dentistry.

MATERIALS AND METHODS: The survey was distributed to a total of 111 patients, of whom 49.5% were men and 50.5% were women. The majority of respondents have higher education. Their age varies from 34 to 76. Students do not participate in the survey. More than half of the respondents (55.5%) are retired.

RESULTS AND CONCLUSION: Patients are mainly informed by dentists but consider themselves insufficiently informed. 3D-printed versions are rarely offered, especially for temporary constructions. Patients rate the price as too high but would not give up treatment only for that reason. They are hesitant in their choice for treatment with a classic or 3D-printed technique.

Introduction

3D printing or additive manufacturing technology is a practice of making three-dimensional objects through layer-by-layer printing of melt material [1]. 3D printing technology is an interdisciplinary technology which includes machinery, computer technique, numerical control, and material technology [2]. Generalized additive manufacturing process includes the following steps: Object, STL file, Slicing software, Layer slices and tool path, additive manufacturing process (building), and ready 3D object [3].

Compared to conventional (lost-wax technique) and subtractive computer numeric controlled methods, 3D printing offers process engineering advantages. Materials such as plastics, metals, and ceramics can be manufactured using various techniques [4]. Its applications stretch across the fields of medical modeling, fabrication of surgical guides, prosthodontics, restorative dentistry, orthodontics, implantology, and instrument manufacturing [5]. 3D printing technology also can be used to replace, restore, maintain, or improve the tissues and their function. The replacement tissues produced by 3D printing technology have the interconnected pore network, biocompatible, appropriate surface chemistry, and have good mechanical properties [6].

3D printing is the best way to achieve personalized manufacturing, which matches the characteristic of biological tissue. Photopolymerization 3D printing, which has high printing precision and high speed, has a good application prospect in biological tissue. However, the biocompatibility of materials is very important for biomaterials. Thus, it is important to develop biocompatible materials for photopolymerization 3D printing [7]. Photocuring 3D printing is a model-free manufacturing technology. However, the limited performance of the photosensitive resin and the bottlenecks of 3D printing technology restrict the application of photocuring 3D printing. Once the technical problems such as rapid curing, large size, and high viscosity resin printing were solved, as well as the development of high-performance materials, biocompatible materials, and degradable materials, the photocuring 3D printing will have a broad prospect [8]. 3D printing technology has recently extended to metallic materials and allows now to produce 3D models directly from metallic powders. There are several methods of 3D metal printing and compared to conventional technologies of casting, forging, and machining, these methods offer many advantages. The most important is shape variety allowing preparation of very complicated shapes and designs, which would be impossible to reach by classical techniques. There is practically no material loss, since the remaining powder can be recycled and reused in other manufacturing processes that are one of the important cost savings. However, for now, the metal 3D printing is unable to compete the price of large-lot production [9].

The pricing strategies of Sun *et al.* (2020) for such platforms are quite complicated since different kinds of products/services could be provided on the same platform at the same time. The optimal pricing strategy for a 3D printing platform sells standard and customized products, taking products' differentiation into account, where the platform and designer seek to maximize their profits, while the customer wishes to maximize their utility gained from the product purchase. In the basic model, the platform's optimal prices allow the designer to add a mark-up for the standard product. The standard product's final price increases with its own quality and decreases with the customized product's quality. When labor cost is low, the customized product's final price increases with its own quality and decreases with the standard product's quality. The authors also found that the designer's optimal mark-up for the standard product increases with the printing cost of the standard product and quality of the customized product, and decreases with the interaction cost, printing cost of the customized product, and quality of the standard product. Comparison of the platform's profit in the case of "partial price power", where the platform allows the designer to add a mark-up, with that in the case of "full price power", where the platform determines the final price of a standard product and charges commission as revenue. If the difference in the quality between the standard and customized products is high, then the strategy of charging a commission fee at a rate of more than 25% is more profitable than the strategy of allowing the designer to add a mark-up to the reservation price [10].

The price of the printer is of primary importance in pricing. It is determined by the precision of work, the size of the objects, and the type of used materials – polymers, ceramics, metal, and more. The price of the materials used also varies widely [11].

The rise of 3D printing and additive manufacturing will replace the competitive dynamics of traditional economies-of-scale production with an economies-of-one production model enabled by 3D printing and additive manufacturing, at least for some industries and products. In essence, future manufacturers will be governed by two sets of rules: Economies of scale for interchangeable parts produced at high volumes and economies of one for highly customizable products that can be built layer by layer. Each model brings its own sources of competitive advantage and economic factors (Table 1) [12].

The integrated model can be developed to analyze the impact of 3D printing on retail product offering, prices for online and in-store channels, as well as inventory decisions. Table 2 summarizes the main insights we have obtained from the model analysis. There are two major effects of 3D printing: The substitution effect and the supply chain structural effect. Adopting 3D printing for the online channel gives rise to a substitution effect of technological innovation. Such technology substitution leads to the variety effect, enabled by 3D printing's natural elimination of the production setup cost, and allows the firm to offer perfect customization and charge a price premium for online customers. At the same time, the firm offers a smaller product variety in the store at a reduced price. Moreover, when 3D printing is used in the online channel, the effect of enhanced customization in the online channel must be balanced against the opposite effect induced by the BTO/BTS (build-to-order/traditional build-to-stock) difference of the online and in-store channels. Specifically, for functional products with low demand uncertainty, the firm should charge a price premium for the 3D-printed products. However, for innovative products with high demand uncertainty, the firm should set the online price lower than the in-store price to attract more demand to the online channel. Thus, different pricing strategies are needed for different product characteristics in this case (Table 2) [13].

Economies of scale and economies of one will continue to coexist, but they will not be used for the same things. Companies based on economies of scale will still support commodity and high-volume production, but in instances where end-user customization is highly desirable, where production is single unit or very small volume, or where the end product requires features that cannot be manufactured by traditional means, 3D printing and additive manufacturing will become a viable and competitive option [12], [14].

Table 1: Economies of scale versus economies of one [12]

	Economies of Scale	Economies of One
Source of competitive advantage	Low cost, high volume, high variety	End-user customization
Supply chain	Sequential linear handoffs between distributed manufacturers with well-defi ned roles and responsibilities	Non-linear, localized collaboration with ill-defined roles and responsibilities
Distribution	High volume covers transportation costs	Direct interaction between local consumer/client and producer
Economic model	Fixed costs + variable costs	Nearly all costs become variable
Design	Simplified designs dictated by manufacturing constraints	Complex and unique designs afford customization
Competition	Well-defined set of competitors	Continuously changing set of competitors

Table 2: Summary of effects of 3D printing [13]

	Functional Products (Small σ)	Innovative Products (Large σ)	
Traditional System With Dual Channels (Case 1)	• Online price *same as* in-store price • Online price determines product variety • No customers are left unserved	• Online price *less than* in-store price • Online price determines product variety • Some customers are left unserved	
3D Printing Online (Case 2)	• Online price *greater than* in--store price • In-store price determines product variety • No customers are left unserved	• Online price *less than* in-store price • In-store price determines product variety • When both channels are in use, no customers are left unserved; may shut off in-store channel	Substitution effect: • In-store product offering decreases • Online price increases, in-store price decreases • In-store safety-stock factor (for FG) decreases • Customers are steered from in-store to online if online purchasing waiting cost is small (if σ is small)/medium (if σ is large)
3D Printing In-Store (Case 3)	• Online price *same as* in-store price • No customers are left unserved	• Online price *less than* in-store price • No customers are left unserved	Structural effect: • Both channels offer highest product variety • Both online and in-store prices are highest • In-store safety-stock factor (for RM) is highest • Customers are steered from in-store to online if online purchasing waiting cost is large • Cost-sharing contracts can help coordinate the in-store channel in a decentralized setting

The aim of this article is to demonstrate the patient's awareness of additive manufacturing and their opinion about the price and application of 3D-printed products in dentistry.

Material and Methods

The survey was distributed to a total of 111 patients, with 49.5% being men and 50.5% being women. The majority of respondents have higher education. This implies an interest in current trends and one's own health. Their age varies from 34 to 76 years and can be visualized at intervals - 34–44 years with 17.3%, 45–54 - 28.4%, 55–64 - 36.9%, and 65–76 - 17.4%. The main contingent is over the age of 45. This is the age at which clinically chronic diseases appear. It is assumed that due to deteriorating health, these people are beginning to be interested in other treatments not only routinely offered to them. Their social status was also taken into account. Students did not participate in the survey. More than half of the respondents (55.5%) are retired. This contingent is keenly interested in what is happening around them and due to the available free time is looking for ways to improve. The other groups are employees 14.8%, workers 17.6%, and unemployed 12.1%.

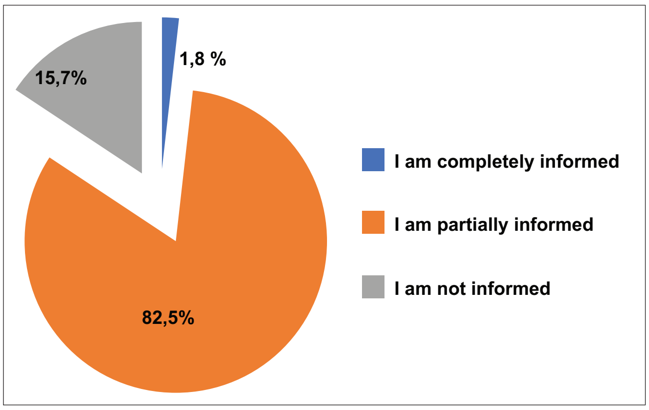

Figure 1: Distribution by level of awareness

Results

The answers to the question "Are you informed about the application of 3D printers for dental purposes?" are shown in Figure 1. Most of them, 82.5%, admit that they are partially informed about the problem. Only two of the respondents (1.8%) feel completely familiar with 3D printing. This shows that despite the desire to be competent, there is scarce information.

The question "Who are you informed of?" is mostly indicated by the dentist (58.3%) followed by information from relatives (23.4%). The dentist is the face of dentistry and it is logical that the information comes from him. Commenting between acquaintances and friends also explains the high percentage of information received in this way. Receiving information from dental technicians and the media is almost the same. Dental technicians do not have direct contact with patients, which limit the exchange of information with them. Articles about this innovative technology are rare in the daily press, except in the case of targeted patient search, Figure 2.

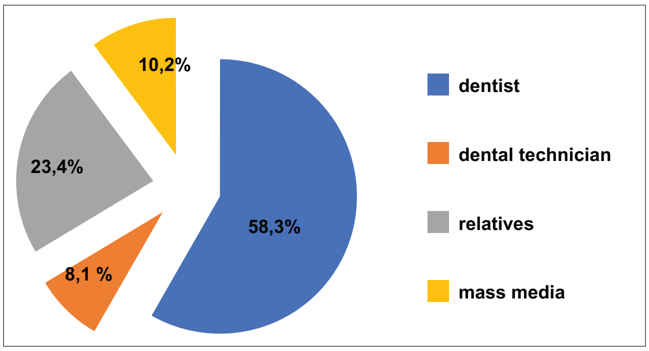

Figure 2: Distribution by source of information

When asked "Have you been offered similar products during your dental treatment?" the majority of patients (64.6%) stated that they have not been offered such products, 27.2% – that they have been offered them. A commercial trick even in dentistry is to offer innovative products to consent to treatment, Figure 3.

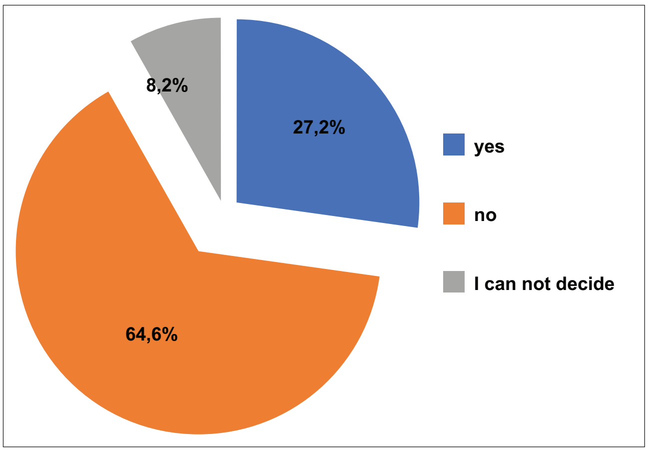

Figure 3: Distribution by offering of 3D-printed products

Figure 4 shows the types of constructions that are proposed. Temporary constructions are the most popular product offered (56.4%). This high percentage may be due to the easy fabrication and the short period (not more than 15-20 days) of use and stay in the oral cavity. Splints are also an easy-to-make product with a basic night stay in the patient's mouth (34.5%). The materials of removable prostheses were almost the last to be patented on the market and are still poorly offered (5.4%) due to difficulties in the laboratory protocol (poor knowledge of digital design software and lack of materials). Fixed structures, crowns, and bridges are made mainly by combined methods (3D printing of metal and application of ceramic masses; 3D printing of a wax prototype with subsequent casting of metal, etc.). In its pure 3D form, the printing of fixed prostheses is only possible for all-metal crowns or all-ceramic (materials are still being tested). Dentists still refrain from mass supply of printed products.

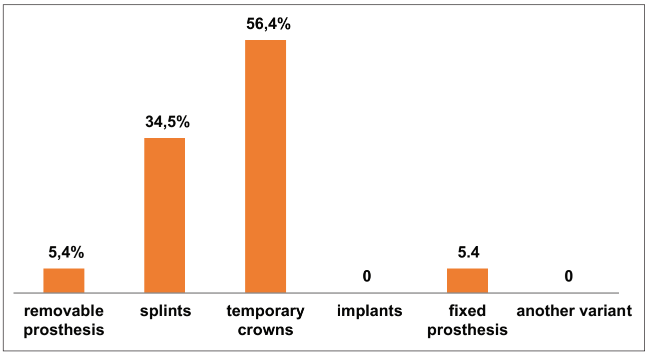

Figure 4: Type of constructions proposed for treatment

To the question "How do you assess the price of this type of product?" the majority believes that the price is high, no one answered that it is low. Offering new and improved products are often combined with a higher price than previous treatment with the same dentist or another dental office, Figure 5.

The question "Would you prefer 3D printed objects to classic ones?" shows a large fluctuation

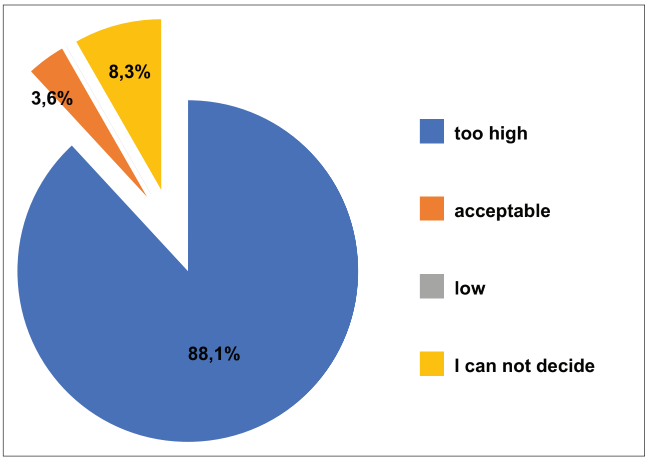

Figure 5: Distribution by price

of respondents – 58.3% cannot decide. Lack of information could be the main reason. Another reason for hesitation may be the memory of past treatment by classical methods, which was unsatisfactory for esthetic, functional, and other reasons. Fluctuation can also be seen as a desire for better treatment, Figure 6.

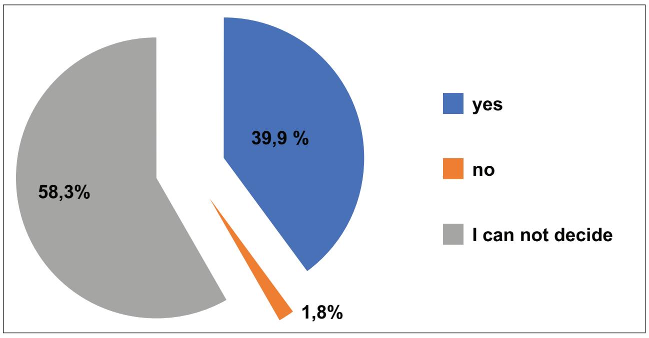

Figure 6: Distribution of preferably a 3D-printed object over a classic one

The question "Would you refuse 3D-printed objects just because of the high price?" surprisingly shows that this is not a reason for rejection in 41.7% of respondents. Most people think that quality treatment is more important than the money invested in it. Given the adult age of the majority of respondents, their main idea is to be healthy and non-disabled, Figure 7.

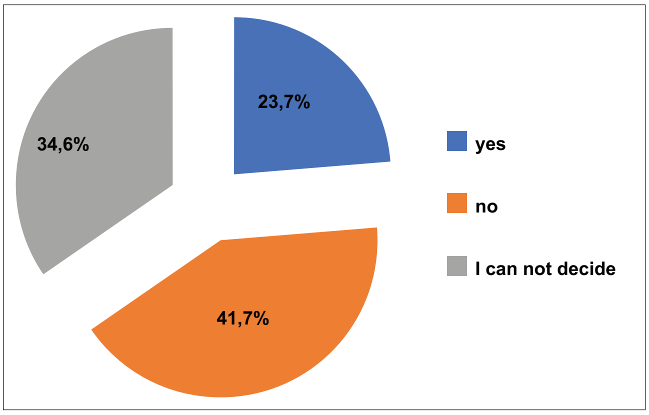

Figure 7: Would you refuse 3D-printed objects just because of the high price?

Discussion

Awareness of 3D printing is mainly related to its application in many industries. The supply of printed objects in dentistry is related to the progress in the detection of biomaterials that are not harmful, allergenic, or lead to disability and death [5], [8]. The requirements for biomaterials are mainly implemented of good biodegradability and biocompatibility. Some physicians still have doubts about the safety of these materials and limit their availability in practice [6], [7], [8]. The work of the dentist is directly related to dental technology and the lack of a quality laboratory also limits their application [3], [9].

Pricing in dentistry is a complex process. In addition to the visible costs of materials, equipment, and services, there are costs for tools, depreciation of equipment, fees to dental unions, routine costs for electricity, water, staff, accountant, and more. All of them should be calculated in the price of the final product. In the case of innovations, an amount should be provided for errors, for test constructions, for clearing the technical settings, etc. [10], [11].

Conclusion

Patients are mainly informed by dentists, but consider themselves insufficiently informed. 3D-printed versions are rarely offered, especially for temporary constructions. Patients rate the price as too high, but would not give up treatment for that reason alone. They are hesitant in their choice for treatment with a classic or 3D-printed technique.

References

1. Tay YW, Panda B, Paul SC, Tan MJ, Qian SZ, Leong KF, *et al.* Processing and properties of construction materials for 3D printing. Mater Sci Forum. 2016;861:177-81. https://doi.org/10.4028/www.scientific.net/msf.861.177
2. Umair M, Kim WS. An Online 3d Printing Portal for General and Medical Fields. In: 2015 International Conference on Computational Intelligence and Communication Networks (CICN), IEEE; 2015. p. 278-82. https://doi.org/10.1109/cicn.2015.62
3. Campbell T, Williams C, Ivanova O, Garrett B. Could 3D Printing Change the World. Technologies, Potential, and Implications of Additive Manufacturing. Washington, DC: Atlantic Council; 2011. p. 3.
4. Kessler A, Hickel R, Reymus M. 3D printing in dentistry-state of the art. Oper Dent 2020;45(1):30-40. https://doi.org/10.2341/18-229-l

   PMid:31172871
5. Prasad S, Kader NA, Sujatha G, Raj T, Patil S. 3D printing in dentistry. J 3D Print Med. 2018;2(3):89-91. https://doi.org/10.2217/3dp-2018-0012
6. Shahrubudin N, Lee TC, Ramlan R. An overview on 3d printing technology: Technological, materials, and applications. Proc Manuf. 2019;35:1286-96.
7. Shuoping C, Heping Y, Zhihong L. The 3D printing polymers and their printing technologies. J Mater Rep. 2016;30(4):54-9.
8. Quan H, Zhang T, Xu H, Luo S, Nie J, Zhu X. Photo-curing 3D printing technique and its challenges. Bioact Mater. 2020;5(1):110-5. https://doi.org/10.1016/j.bioactmat.2019.12.003

   PMid:32021945
9. Fousová M, Vojtěch D, Kubásek J, Dvorský D, Machová M. 3D printing as an alternative to casting, forging and machining technologies? Manuf Technol. 2015;15(5):809-14. https://doi.org/10.21062/ujep/x.2015/a/1213-2489/mt/15/5/809
10. Sun L, Hua G, Cheng TC, Wang Y. How to price 3D-printed products? Pricing strategy for 3D printing platforms. Int J Prod Econ. 2020;226:107600. https://doi.org/10.1016/j.ijpe.2019.107600
11. Pîrjan A, Petroşanu DM. The impact of 3D printing technology on the society and economy. J Inform Syst Oper Manag. 2013;7(2):360-70.
12. Petrick IJ, Simpson TW. 3D printing disrupts manufacturing: How economies of one create new rules of competition. Res Technol Manag. 2013;56(6):12-6. https://doi.org/10.5437/08956308x5606193
13. Chen L, Cui Y, Lee HL. Retailing with 3d printing. Prod Oper Manag. 2021;30(7):1986-2007.
14. Matias E, Rao B. 3D Printing: On its Historical Evolution and the Implications for Business. Proceedings of Porland International Conference on Management of Engineering and Technology (PICMET). 2015. p. 551-8. https://doi.org/10.1109/picmet.2015.7273052