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3D Printed denture resin reinforced with porosphere and zinc oxide nanoparticles

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Abstract

The 3D printed resins have been evolving in the field of dentistry. This also has some disadvantages like decreased strength when compared to conventional denture base resins. This 3D printed denture base resins, were reinforced with Porospheres and Zinc oxide nano particles to improve the compressive strength. Total of 15 samples were fabricated. These samples were designed in the software with the measurements of inner diameter of 20 mm and height of 40 mm for compressive strength according to the ISO standard. These sample were categorized into Group A - 3D printing denture resins; Group B- 3D printing denture resins reinforced with Porosphere; Group C- 3D printing denture resins reinforced with zinc oxide nanoparticles. These Glass spheres and Zinc oxide nanoparticles were added to the 3D printed denture base resins in the resin tank and printing was done after which samples were retrieved these obtained samples were tested using universal testing machine. The data obtained were statistically analyzed. 3D printing denture base resins reinforced with Porospheres and Zinc oxide showed improved compressive strength.

Keywords: 3D printing resins, Porospheres, Zinc oxide nanoparticles, universal testing, Additive technology.

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1. Introduction

Over past several decades PMMA was the only reliable material for fabrication of dentures in completely and partially edentulous patients which were fabricated using universally accepted compression molding and injection molding technique but these had some disadvantages on the technical part has well as patient with several appointment. These conventionally fabricated dentures were also heavy in-case of patients who require maxillofacial prosthesis, increase bacterial colonization, increased polymerization shrinkage were noticed. So many experiments were carried out to overcome the disadvantages.

Digitalized dentistry has become a very popular in past few decades. CAD-CAM was first introduced in the year 1990 and the person to introduce it was Goodacre. This technology was developed in-order to overcome disadvantages of conventional techniques. This rapid prototyping using additive manufacturing is used develop gross part of the model. In digital manufacturing there are two techniques which are additive and subtractive. The subtractive technique was first introduced, since it had some disadvantages additive process were it fabricates an object layer by layer although it is latest technology it is used in wide range in medical, engineering and dentistry. This additive technique is the CAM step which is defined has "The process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies." The person who introduced the additive manufacturing is C. Hull [7]. Through this technique various material such as polymers, metals and ceramics can be used without limitations when compared to subtractive technique. There are various methods for printing of which stereolithography with help of UV light is used.

Porospheres are glass spheres micro-glass soda silica spheres which has outer surface stiff glass and inner inert glass which also has low density and it acts as inorganic filler. This porospheres will have some advantages like decreased warpage and less shrinkage. It also decreases the flow of the materials, it is chemically resistant particles, high heat. These porospheres (glass sphere) are available in different sizes and density. These light weight glass spheres are non-porous, noncombustible, chemically stable. It is also resistant to water.

Zinc oxide nanoparticles ZnO-Np's are inorganic material it is semiconductor. The main property of ZnO-Np's is antimicrobial and antifungal properties[1]. It also has potential of UV absorption which can be used has protector in cosmetology and increase the response for antimicrobial property. So in this study the porosphere (glass spheres) nanoparticles and zinc oxide nanoparticles were incorporated into the 3D printing resins to improve the mechanical property.

2. Materials and methods

According to ISO standards the designing of models with the measurements of inner diameter 20 mm and height of 40 mm for compressive strength. Tinker cad is used to design these models. These models were then exported in STL file. After which STL file is opened in Chitu Box to process and slice the design for printing. During this slicing process each layer will be converted to PNG image. Finally all PNG image file were compressed into a single file. This single file is loaded onto pendrive which is inserted into printer for printing (Fig 1). Then to the 3 d printing denture resins 5% zinc oxide and 5% porospheres nanoparticles were added and mixed using magnetic stirrer 5000rpm for half an hour as recommended by the manufacturer. After mixing the material it is poured into resin tank which is followed by printing, the samples were then retrieved, agitated in alcohol to remove the uncured extra resin. These samples are 80% cured, they were then placed into UV chamber for maximum curing with wavelength 390 nm for 12 mins (Fig 2).
After which these samples were tested for compressive strength of each specimens (fig: 1) are tested using Universal Testing Machine (shimadzu) at a cross-head speed of (1 ± 0.3) mm/min. Compressive load is applied until the sample fractures(fig 3).

3. Results and Discussions

Table 1 shows the mean and standard deviation values for compressive strength for reinforced and non-reinforced 3D printing denture resins. The mean compressive strength was 75.11±5.37, 90.61±3.19, 106.76± 9.97. among which Group C shows the high compressive strength. Using one way ANOVA the compressive strength of Groups A, B, C mean values were calculated. The sum of squares obtained between groups is 2504.02 and within the Groups were 554.04. the F value was calculated as 27.17 which was calculated from the mean values. The significant values of P was < 0.001, hence there was significant difference in compressive strength between group A, B and C. Tables 2 describes post hoc test or multiple comparison test where Group C and B showed a statistically significant value when compared to Group A. This graph shows the mean and standard deviation of all the three groups in the study by plotting the groups on X axis and values measured on Y axis. The mean compressive strength of Group C exhibited higher range of 106.76 followed by Group B 90.61 respectively. This graph shows the mean and standard deviation of all the three groups in the study by plotting the groups on X axis and values measured on Y axis. The mean compressive strength of Group C exhibited a higher range of 106.76 followed by Group B 90.61 respectively. The concoction of this study was to find out the effect of zinc oxide and porosphere NP's into the 3D printing resin and to find the improved mechanical properties. The results obtained were significant so thereby null hypothesis was rejected. Usually metal oxide nanoparticles with decreased filler size, increase in condensation of the particles has proved to improve the mechanical properties of conventional PMMA resin. Since these nanoparticles were used in 3D printing resins to find out the improvement. Studies have proven that ZnO'NP's have Photocatalytic activity which enhances the conductivity of the material in-turn increases the interaction between ZnO and bacteria with good antibacterial activity. Similarly in the present study these ZnO and Porosphere NP'S were incorporated to 3D printed resins to improve its mechanical properties [1]. Various studies have been conducted by incorporating nanoparticles such as silver, copper, titanium, nickel, zirconia etc into conventional denture base resins and have found that improved mechanical properties. Similarly a study was done by incorporating porospheres onto polymer composites, these glass spheres where surface modified using silane treatment and ferkote treatment which in order improved the fracture toughness and elastic modulus [22,13]. So these porospheres were incorporated in our study. In our present study we have added 5 wg% of ZnO and porospheres to the 3D printed resin similar to the study done by incorporating ZrO_2 into 3D printed resin were it showed a improved flexural strength, impact strength and hardness [5]. In this study also there was an improved compressive strength. Many studies were conducted using ZnO NP'S since they have a very good antimicrobial property, antifungal property and mechanical property. In previous studies when the ZnO NP'S added to the heat cure acrylic resin it has improved the flexural properties. A study done by incorporating the silver nanoparticles to the 3D printing denture base resin it did not affect the biocompatibility has well as it showed a good antimicrobial and anti-fungal properties along with improved mechanical properties [8].

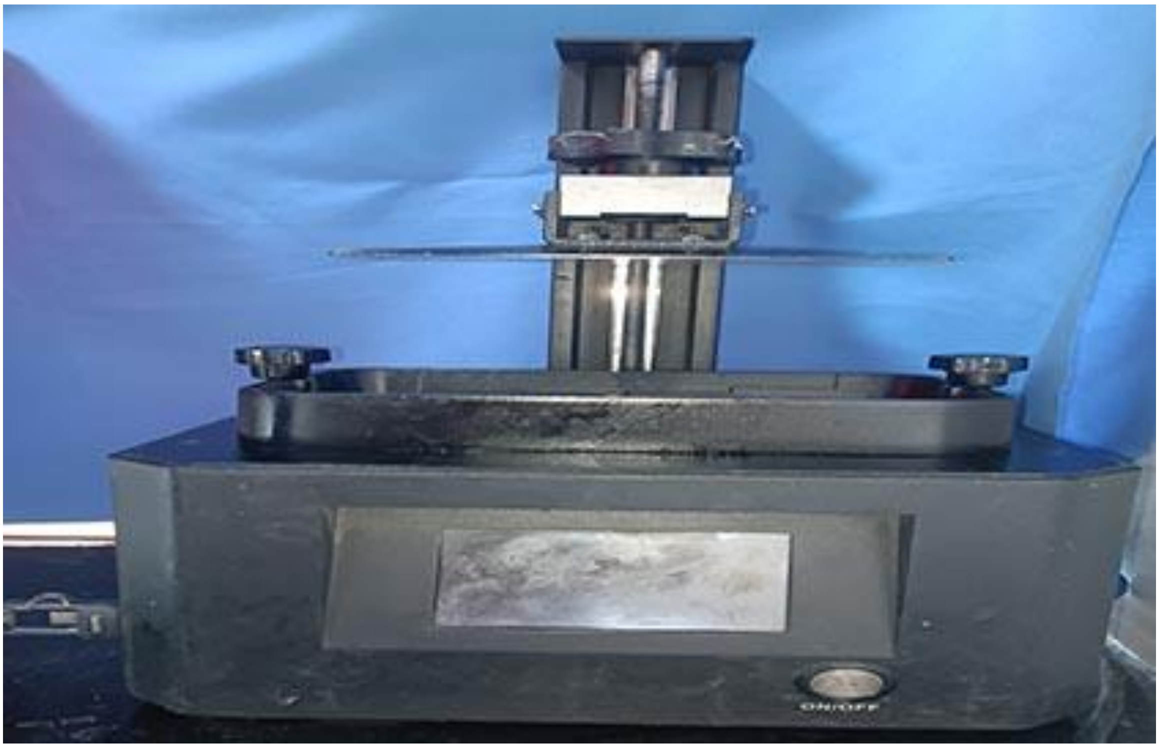


Figure 1: 3D Printer

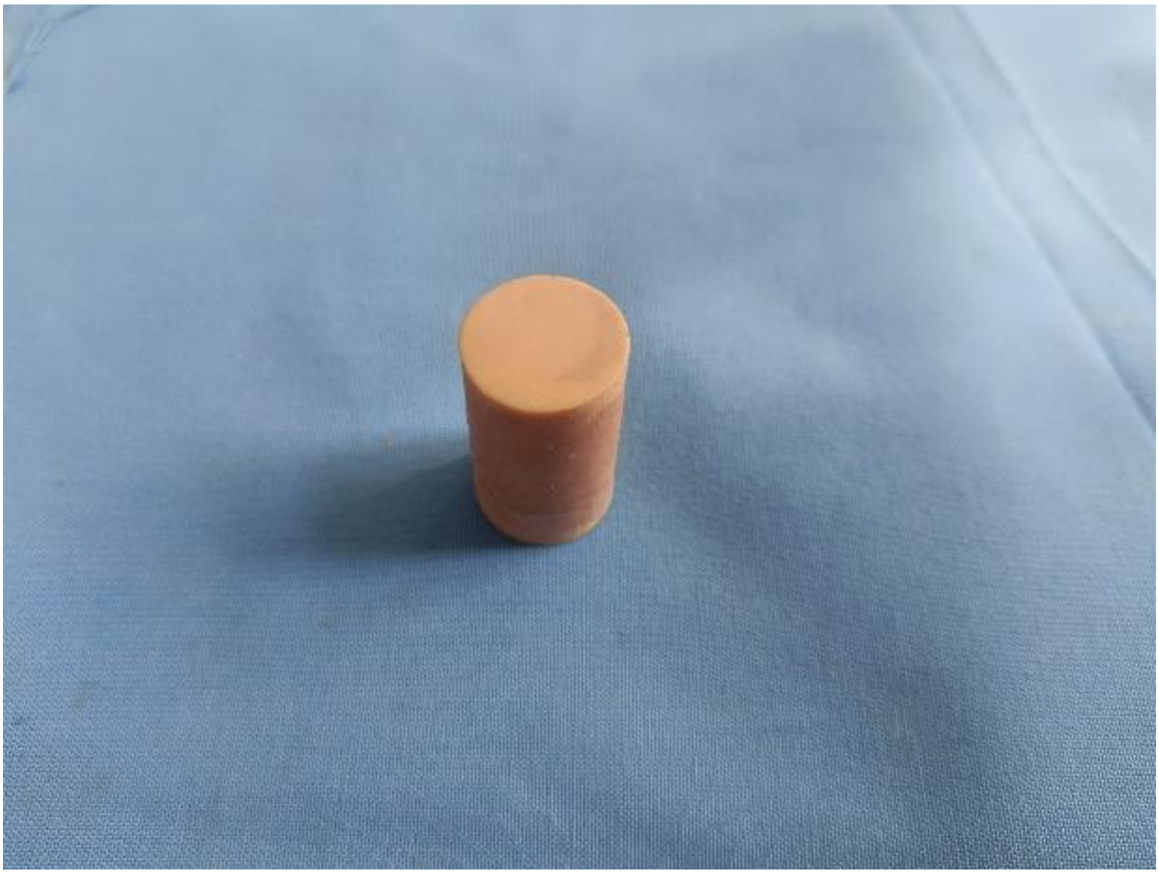


Figure 2: Finished and polished reinforced 3D printing resin

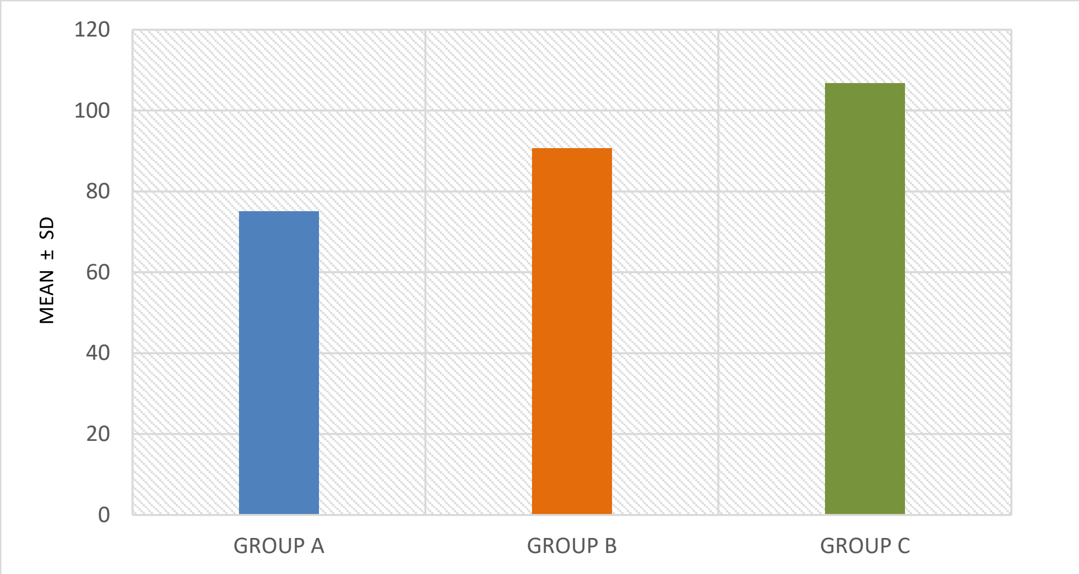
Figure 3: A compressive strength test of reinforced sample

Tables 1: Mean and Standard Deviations of Compressive Strength of Group A, B and C and One Way ANOVA of Mean Compressive Strength within the Groups A, B, C

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2504.025	2	1252.013	27.117	.000
Within Groups	554.046	12	46.171		
Total	3058.072	14			

Table 2. Intergroup Comparison of Compressive Strength of Group A, B ,C Using Tukey's Post Hoc Test

(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.
GROUP A	GROUP B	-15.49800*	4.29747	.009
	GROUP C	-31.64600*	4.29747	.000
GROUP B	GROUP A	15.49800*	4.29747	.009
	GROUP C	-16.14800*	4.29747	.007
GROUP C	GROUP A	31.64600*	4.29747	.000
	GROUP B	16.14800*	4.29747	.007



Graph 1. Graphical Representation of Compressive Strength of Group A, B, C

4. Conclusions

Basically 3D printed resins had a decreased mechanical property when compared to conventional heat polymerized PMMA but on addition of porospheres and zinc oxide particles has shown improved compressive strength of the material.

LIST OF ABBREVIATIONS:

PS – Porospheres

ZnO' NP- Zinc oxide Nanoparticles.

PMMA- Polymethyl methacrylate.

ISO – International Organization of Standardization.

CAD-CAM – Computer Aided Designing and Computer Aided Tomography.

UVC – Ultra Violet Chamber.

STL- Standard Stellation Language.

PNG – Portable Network Graphics.

UTI – Universal Testing Machine.

ANOVA – Analysis Of Variance.

SPSS – Statistical Package Of Social Sciences.

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There is no actual or potential conflict of interest in relation to this article.

References

[1] A.Sirelkhatim., S.Mahmud, A.Seeni *et al.*(2015). Review on Zinc Oxide Nanoparticles: Antibacterial Activity and Toxicity Mechanism. *Nano-MicroLett.*.7:219–242. https://doi.org/10.1007/s40820-015-0040-x

[2] S.G..Chen, J. Yang, Y.G. Jia, B.Lu, L. Ren (2019). TiO2 and PEEK reinforced 3D printing PMMA composite resin for dental denture base applications.Nanomaterials.9(7):1049; https://doi.org/10.3390/nano9071049

[3] Y.J. Chung, J.M. Park, T.H. Kim, J.S. Ahn, H.S. Cha, J.H Lee. (2018). 3D printing of resin material

for denture artificial teeth: chipping and indirect tensile fracture resistance. Materials. 11(10):1798. https://doi.org/10.3390/ma11101798

[4] S. Aati, S. Aneja, M.Kassar, R. Leung, A.Nguyen, S .Tran, B.Shrestha, A. Fawzy.(2022). Silver-loaded mesoporous silica nanoparticles enhanced the mechanical and antimicrobial properties of 3D printed denture base resin. Journal of the mechanical behavior of biomedical materials. 134:105421. https://doi.org/10.1016/j.jmbbm.2022.105421

[5] A.A Alshaikh, A. Khattar, I..A Almindil, M.H Alsaif, S.Akhtar, S.Q Khan, M.M Gad.(2022). 3D-printed nanocomposite denture-base resins: effect of ZrO2 nanoparticles on the mechanical and surface properties in vitro. Nanomaterials. 12(14):2451. https://doi.org/10.3390/nano12142451

[6] J.S Shim, J.E.Kim, S.H. Jeong, Y.J Choi, J.J Ryu.(2020) Printing accuracy, mechanical properties, surface characteristics, and microbial adhesion of 3D-printed resins with various printing orientations. The Journal of prosthetic dentistry.124(4):468-75. https://doi.org/10.1016/j.prosdent.2019.05.034

[7] N.Gligorijević, T.Mihajlov-Krstev, M.Kostić, L Nikolić, N.Stanković, V.Nikolić, A.Dinić, M. Igić, N.Bernstein. (2022).Antimicrobial properties of silver-modified denture base resins. Nanomaterials.12(14):2453. https://doi.org/10.3390/nano12142453

[8] A.Aruniit, J.Kers, J.Majak, A. Krumme, K.Tall. (2012). Influence of hollow glass microspheres on the mechanical and physical properties and cost of particle reinforced polymer composites. Proceedings of the Estonian Academy of Sciences. 61(3):160. doi: 10.3176/proc.2012.3.03

[9] F.D. Al-Qarni, M.M. Gad. (2022). Printing Accuracy and Flexural Properties of Different 3D-Printed Denture Base Resins. Materials. 15(7):2410. https://doi.org/10.3390/ma15072410

[10] M.Dimitrova, M.Corsalini, R. Kazakova, A. Vlahova, B.Chuchulska, G.Barile, S.Capodiferro, S. Kazakov. (2022). Comparison between conventional PMMA and 3D printed resins for denture bases: A narrative review. Journal of Composites Science. 6(3):87. https://doi.org/10.3390/jcs6030087

[11] L. Al Deeb, K. Al Ahdal, G.Alotaibi, A.Alshehri, B. Alotaibi, F.Alabdulwahab, M.Al Deeb, Y.F. AlFawaz, F.Vohra, T.Abduljabbar.(2019). Marginal Integrity, Internal Adaptation and Compressive Strength of 3D Printed, Computer Aided Design and Computer Aided Manufacture and Conventional Interim Fixed Partial Dentures. Journal of Biomaterials and Tissue Engineering.9(12):1745-50. https://doi.org/10.1166/jbt.2019.2196

[12] T.H. Hsieh, M.Y. Shen, Y.S. Huang, Q.Q. He, H.C. Chen.(2018). Mechanical properties of glass bead-modified polymer composite. Polymers and Polymer Composites.26(1):35-44. https://doi.org/10.1177/096739111802600105

[13] Y.J Chung, J.M. Park, T.H Kim, J.S. Ahn, H.S. Cha, J.H. Lee. (2018). 3D Printing of Resin Material for Denture Artificial Teeth: Chipping and Indirect Tensile Fracture Resistance. Materials.11(10):1798. https://doi.org/10.3390/ma11101798

[14] V.Prpić, Z.Schauperl, A.Ćatić, N. Dulčić, S. Čimić. (2020). Comparison of mechanical properties of 3D-printed, CAD/CAM, and conventional denture base materials. Journal of Prosthodontics.29(6):524-8. https://doi.org/10.1111/jopr.13175

[15] A.Di Fiore, R.Meneghello, P.Brun, S.Rosso, A Gattazzo, E.Stellini, B.Yilmaz.(2022) Comparison of the flexural and surface properties of milled, 3D-printed, and heat polymerized PMMA resins for denture bases: An in vitro study. Journal of prosthodontic research..66(3):502-8. https://doi.org/10.2186/jpr.JPR_D_21_00116

[16] H.Salgado, A.T.Gomes, A.S.Duarte, J.M.Ferreira, C. Fernandes, M.H.Figueiral, P.Mesquita.(2022) Antimicrobial Activity of a 3D-Printed Polymethylmethacrylate Dental Resin Enhanced with Graphene. Biomedicines. 10(10):2607. https://doi.org/10.3390/biomedicines10102607

[17] W.Liao, S.Zheng, S.Chen, L.Zhao, X.Huang, L .Huang, S.Kang.(2020) Surface silanization and grafting reaction of nano-silver loaded zirconium phosphate and properties strengthen in 3D-printable dental base composites. Journal of the Mechanical Behavior of Biomedical Materials.110:103864. https://doi.org/10.1016/j.jmbbm.2020.103864

[18] C.Herpel, A.Tasaka, S. Higuchi, D.Finke, R. Kühle, K.Odaka, S.Rues, C.J Lux, S.Yamashita, P. Rammelsberg, F.S.Schwindling. (2021). Accuracy of 3D printing compared with milling—A multi-center analysis of try-in dentures. Journal of Dentistry. 110:103681. https://doi.org/10.1016/j.jdent.2021.103681

[19] J.J Choi, R.S. Ramani, R. Ganjigatti, C.E. Uy, P. Plaksina, J.N. Waddell.(2021). Adhesion of denture characterizing composites to heat-cured, CAD/CAM and 3D printed denture base resins. Journal of Prosthodontics.30(1):83-90. https://doi.org/10.1111/jopr.13291

[20] M.M. Gad, S.Z. Alshehri, S.A. Alhamid, A. Albarrak, S.Q. Khan, F.A. Alshahrani, F.K. Alqarawi. Water sorption, solubility, and translucency of 3D-printed denture base resins.(2022). Dentistry Journal.. 10(3):42. https://doi.org/10.3390/dj10030042

[21] S.An, J.L. Evans, S. Hamlet, R.M. Love.(2021). Incorporation of antimicrobial agents in denture base resin: A systematic review. The Journal of Prosthetic Dentistry. 126(2):188-95. https://doi.org/10.1016/j.prosdent.2020.03.033

[22] B.A.Kschinka, S.Perrella, (1986). Strengths of glass spheres in compression. Journal of the American Ceramic Society.69(6):467-72. https://doi.org/10.1111/j.1151-2916.1986.tb07447.x

[23] E. Anadioti, L. Musharbash, M.B Blatz, G. Papavasiliou, P. Kamposiora. (2020). 3D printed complete removable dental prostheses: A narrative review. BMC Oral Health. 20(1):1-9. https://doi.org/10.1186/s12903-020-01328-8

[24] A.Barazanchi, K.C. Li, B.Al-Amleh, K.Lyons, J.N Waddell.(2017). Additive technology: update on current materials and applications in dentistry. Journal of Prosthodontics. 26(2):156-63. https://doi.org/10.1111/jopr.12510

[25] J.Yue, P.Zhao, J.Y. Gerasimov, M .van de Lagemaat, A. Grotenhuis, M. Rustema-Abbing, H.C van der Mei, H.J Busscher, A .Herrmann, Y.Ren.(2015). 3D-printable antimicrobial composite resins. Advanced functional materials.. 25(43):6756-67. https://doi.org/10.1002/adfm.201502384