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Development of artificial primary teeth for laboratory practices in Pediatric Dentistry

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Abstract
During Dentistry training, students undertake pre-clinical training to improve their techniques. The objective of this study is to report the experience of producing artificial deciduous teeth using three-dimensional (3D) printing, at low cost, for academic laboratory practices in Pediatric Dentistry. The starting point was laboratory and experimental research, and a bibliographic review was carried out to obtain data. The 3D images were obtained from the free Brenner permanent teeth library and edited in the Meshmixer program to incorporate the characteristics of deciduous teeth, followed by 3D printing using stereolithography. Subsequently, the root canals were filled with wax 7 and red polyvinyl acetate (PVA). The cementum and crown were also painted with brown and white enamel paint, respectively. The two resins exhibited external anatomical fidelity, however, for feasibility of use in Endodontics, the internal anatomy, radiographic image, printing time, production cost and cost/benefit were analyzed. The combination of Anycubic resin to represent mineralized tissues with wax 7 to simulate the pulp made it possible to adequately reproduce the internal anatomy of deciduous teeth.
Descriptors: Tooth, Deciduous. Endodontics. Printing, Three-Dimensional. Education, Dental.

Desarrollo de dientes temporales artificiales para prácticas de laboratorio en Odontopediatría
Resumen
En la formación en Odontología, los alumnos realizan una formación preclínica para mejorar sus técnicas. El objetivo de este estudio es relatar la experiencia de producción de dientes temporales artificiales por impresión tridimensional (3D), a bajo costo, para prácticas académicas de laboratorio en Odontopediatría. Se inició con una investigación de laboratorio y experimental, habiéndose realizado una revisión bibliográfica para la obtención de los datos. Las imágenes 3D se obtuvieran de la biblioteca gratuita de dientes permanentes de Brenner y se editó en el programa Meshmixer para incorporar las características de los dientes temporales, seguida de una impresión 3D mediante estereolitografía. Posteriormente se obturaron los conductos radiculares con cera 7 y acetato de polivinilo rojo (PVA). El cemento y la corona también se pintaron con pintura de esmalte marrón y blanco, respectivamente. Las dos resinas exhibieron fidelidad anatómica externa, sin embargo, para la factibilidad de uso en Endodoncia se analizó la anatomía interna, imagen radiográfica, tiempo de impresión, costo de producción y costo/beneficio. La combinación de la resina Anycubic para la representación de tejidos mineralizados con la cera 7 para la simulación de la pulpa permitió reproducir adecuadamente la anatomía interna de los dientes temporales.
Descriptores: Diente Primário. Endodoncia. Impresión Tridimensional. Educación en Odontología.

Desenvolvimento de dentes decíduos artificiais para práticas laboratoriais em Odontopediatria
Resumo Na formação em Odontologia os acadêmicos realizam treinos pré-clínicos para aperfeiçoar suas técnicas. O objetivo deste estudo é relatar a experiência de produção de dentes decíduos artificiais por impressão tridimensional (3D), com baixo custo, para práticas laboratoriais acadêmicas em Odontopediatria. Partiu-se de uma pesquisa laboratorial e experimental, tendo sido realizada uma revisão bibliográfica para obtenção dos dados. A obtenção das imagens 3D se deu a partir da biblioteca gratuita de dentes

permanentes Brenner e edição no programa Meshmixer para incorporação das características de dentes decíduos, seguida de impressão 3D utilizando estereolitografia. Posteriormente, foram preenchidos os condutos radiculares com cera 7 e poliacetato de vinila (PVA) vermelha. Foi realizada também a pintura do cemento e da coroa, com tinta de esmalte marrom e branca, respectivamente. As duas resinas exibiram fidelidade anatômica externa, entretanto, para viabilidade do uso na Endodontia, foi analisada a anatomia interna, imagem radiográfica, tempo de impressão, custo de produção e custo/benefício. A combinação de resina Anycubic para a representação dos tecidos mineralizados com cera 7 para simulação da polpa possibilitou a adequada reprodução da anatomia interna de dentes decíduos.
Descritores: Dente Decíduo. Endodontia. Impressão Tridimensional. Educação em Odontologia.

INTRODUCTION

The Dentistry course is a practical theoretical course, in which students develop the ability to integrate knowledge and practice through laboratory and pre-clinical activities, with the aim at training students in the execution of clinical techniques on patients[1].

In the specialty of Pediatric Dentistry, the success of endodontic treatment depends on several factors, mainly pre-clinical training, which will support the preparation of the dental surgeon to care for patients[2,3]. Anatomy knowledge of deciduous teeth, dental materials and manipulation and execution techniques are fundamental to the success of clinical practices[4].

Deciduous teeth undergo a continuous process of rhizolysis until the succession of their permanent tooth, which is why using natural deciduous teeth is practically impossible for academic practices. The high commercial cost of artificial deciduous teeth makes it difficult to acquire them for student training. Therefore, digitally printed deciduous teeth can meet this need[4].

Digital dentistry allows three-dimensional (3D) printing and the use of proprietary editing software, allowing the researcher to faithfully model and print anatomical structures, including teeth[5].

CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) technology is present in different areas of Dentistry. When creating a work in CAD/CAM, the process begins with CAD in obtaining the image, which can come from digital libraries of files in STL (Standard Tessellation Language), the standard format for 3D files, or by digital scanning followed by editing in specific software[6-9].

Consequently, the process of creating a part is completed through CAM and one of the affordable ways to produce artificial deciduous teeth is 3D[6-10] printing. Used in the Stereolithography (SLA) technique, it consists of a printer that works using a liquid base (liquid photopolymer resins) that solidifies upon contact with ultraviolet light. It has a platform to hold the pending pieces, thereby the UV laser is applied, solidifying each specific region of the applied resin layers. At the end, excess resin is drained, which allows it to be reused[11].

Therefore, the objective of this study is to present artificial deciduous teeth obtained at low cost by 3D printing for use in academic laboratory practices in Pediatric Dentistry.

EXPERIENCE REPORT

As an instrument for obtaining data, a bibliographical review was carried out in books and scientific articles from the databases: SciELO, Google Scholar, Periódicos Capes, PubMed and Science Direct, using the keywords three-dimensional impression, deciduous tooth and dental anatomy.

The 3D image was obtained by downloading the free teeth library Brenner[12], as it has permanent teeth files in STL format, and was imported and installed in the free Meshmixer software for 3D modeling. The permanent teeth files were modeled, respecting all the anatomical characteristics described in the literature for deciduous teeth[13] regarding size, width, number of roots and root canal, focusing on the main differences. An orifice located at the apex or crown that gives access to the root canal was also modeled, to enable the subsequent filling of the canal with a material that simulates the dental pulp.

Guiding support was sought for modeling teeth in the Meshmixer program, the methodology used in the study by Cunha et al. (2019)[8] and Goulart et al. (2019)[14] in which these processes were detailed step by step.

Thus, deciduous teeth 51 (central incisor), 53 (canine), 54 (upper first molar) and 84 (lower first molar) were created in STL files, simulating pulp chamber and root canals (Figure 1).

The STL files were exported and sent to be printed by using the Photon Mono 3D printer (Anycubic, Shenzhen, Guangdong, China) - Stereolithography (SLA), according to the product's instructions for use. In view of this, the teeth were printed according to the printing parameters corresponding to each 3D resin according to its manufacturers.

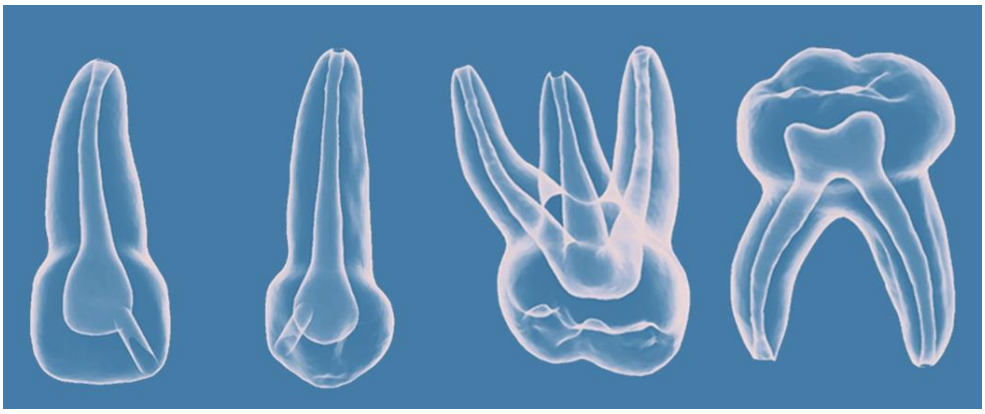

Figure 1. Models of teeth 51, 53, 54 and 84 created using the Meshmixer program.

Teeth models were printed using 2 types of photo-polymerizable 3D resins: gray model resin (Anycubic, Shenzhen, Guangdong, China) and Bio Crown Prizma A1 resin (Makertech, Tatuí, São Paulo, Brazil) (Figure 2). Since they are new resins on the market, the reference for their use was based on the manufacturer's own laboratory research.

Figure 2. Teeth 51, 53, 54 and 84 printed in Anycubic Model resin (gray) and Bio Crown resin (white).

After printing, as indicated by the resin manufacturer, the resin residue present in the root canals was cleaned with the injection of 98% isopropyl alcohol (IPA) (Quimidrol, Joinville, Santa Catarina, Brazil), into the hole located at the apex or on the crown, using a 5ml disposable syringe with needle (Lifelong Meditech Pvt. Ltd., Gurgaon, Haryana, India). Unclogging was effective in teeth printed with Modelo resin, but in Bio Crown resin, IPA was unable to remove residue from the canal, which makes it impossible to use for endodontic practice.

To simulate the dental pulp, the root canal was filled with wax 7 (ASFER, São Caetano do Sul, São Paulo, Brazil) and polyvinyl acetate (PVA) (Tek Bond, Cotia, São Paulo, Brazil), as they were malleable and reddish in color, with the aim at simulating the pulp of a natural tooth. Filling took place using a 5ml disposable syringe with a dark gray needle (0.70mm x 30mm long), for injecting the material through the hole located at the apex or crown. To fill with wax 7, it was heated to a liquid state for deposition in the syringe and better flow in the ducts (Figure 3).

Figure 3. Filling of the tooth root canal, to simulate the dental pulp with red PVA.

The makeup of the teeth was then carried out by means of manual painting, using enamel paint (Savoy industria de cosmeticos S.A, Goiânia, Goiás, Brazil) in brown color to represent the cementum and in white color for differentiation of the crown (Figure 4).

Figure 4. Manual painting of the cementum and crown, with brown and white enamel paint respectively.

Therefore, it was analyzed which material presents the best registration in the radiographic image (radiopacity of the resin and radiolucency of the simulated root canal). Based on the parameters used in the study by Silva et al. (2021) [15], who evaluated artificial deciduous teeth using the Focus™ X-ray device (Kavo, Biberach, Bade-Württemberg, Germany), operating at 60 kV, 7mA and 0.160s of exposure. The teeth were placed on the semi-direct digital radiographic sensor, with size 02 phosphor plates (Kavo, Biberach, Bade-Wurtemberg, Germany) with the buccal side facing the X-ray source and the parallelism technique was performed. Finally, the radiographic plate was digitized using a scanner (Scan eXam, Kavo, Biberach, Bade-Wurtemberg, Germany). The two resins presented similar and acceptable images in terms of radiopacity, however the Bio Crown resin provided the best result. In teeth printed in Model resin, it was possible to see the internal anatomy of the root canals, free of resin residues, when filled with wax 7, which was not possible in teeth filled with PVA, which proved to be radiopaque. The teeth printed in Bio Crown resin, as their canals were not completely unobstructed, did not allow complete visualization of the root canals (Figure 5).

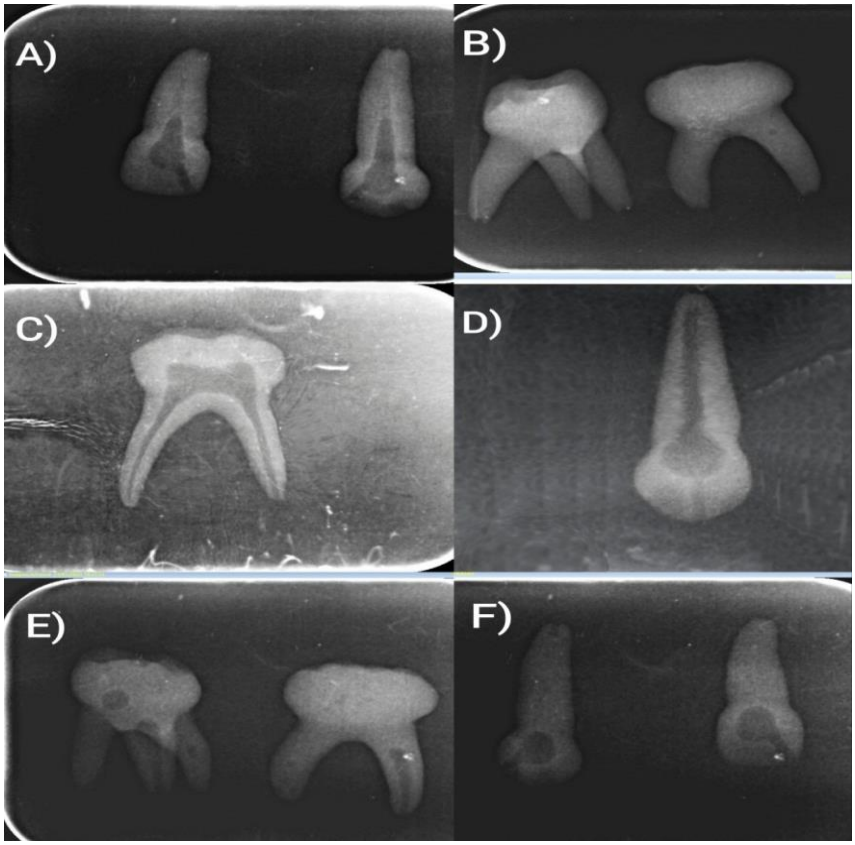

Figure 5. Radiographic images of artificial teeth. A) 51 and 53 in Bio Crown resin; B) 54 and 84 in Bio Crown resin; C) 84 in Model resin free of residues in the ducts; D) 53 in wax-filled Model resin 7; E) 54 and 84 in Model resin filled with PVA; F) 53 and 51 in Model resin filled with PVA.

The printing time for the materials varied from 1 to 2 hours, for the Modelo and Bio Crown resins, respectively. The first resin was considered ideal for good and quick printing of parts. Regarding the amount of material for impression, 1g of resin was used for each tooth. Therefore, a bottle of Anycubic resin (1,000g) and Bio Crown (250g) has a production capacity of 1,000 and 250 teeth, respectively.

Regarding the cost of this production, the virtual planning CAD system was run using a free Brenner tooth library and editing program. For 3D printing, there was a pre-operational investment (initial cost) of ~ R$ 6,150.00: acquisition of a notebook (~ R$ 3,200.00) and Anycubic Photon Mono 3D printer (~ R$ 2,700.00), as well as the professional working time (~ R$ 250.00). The costing resources (consumable materials) were ~ R$ 1,650.78: enamel paint (~ R$ 10.78), wax 7 (~ R$ 20.00), red PVA (~ R$ 20.00), Bio Crown resin 250g (~ R$ 1,300.00) and Anycubic Model resin (~ R$ 300.00). The cost totaled ~ R$ 7,800.78, with an average value of R$ 6.25 per tooth.

Subsequently, subtracting the initial cost values (printer and notebook), production costs per tooth are estimated at ~ R$ 7.61 using Bio Crown resin and ~ R$ 1.91 using Anycubic resin. Thus, both presented excellent cost/benefit compared to the current commercial value of a kit of 6 artificial deciduous teeth (~ R$ 240.00, ~ R$ 40.00 per tooth). Thus, 3D printing with Anycubic Model resin and the use of wax 7 to simulate dental pulp brings great advantages for the production of artificial deciduous teeth, with external and internal anatomical fidelity, acceptable radiopacity of the material, low production cost, good cost/benefit to college students and capacity to produce more teeth in less time, when compared to Bio Crown resin (Table 1).

Table 1. Comparative evaluation of resins.

Resina	Quantidade da embalagem (em gramas)	Preço aproximado da embalagem (em reais)	Capacidade de produção (Unidades)	Custo aproximado por dente (em reais)	Tempo de Impressão (em horas)
Resina Bio Crown	250	1.300,00	250	7,61	2
Resina de Modelo Anycubic	1.000	300, 00	1.000	1,91	1

Resin	Packaging quantity (in grams)	Approximate packaging price (in Brazilian reais)	Production capacity (Units)	Approximate cost per tooth (in Brazilian reais)	Printing Time (in hours)
Bio Crown Resin	250	1,300.00	250	7.61	2
Anycubic Modelo Resin	1,000	300.00	1,000	1.91	1

Due to the complexity of endodontic treatment in Pediatric Dentistry, which requires awareness of anatomy, execution techniques and manipulation of materials, success will depend on laboratory practice on artificial deciduous teeth. Execution via CAD/CAM system provides ease and agility, allowing 3D printing of artificial deciduous teeth in Dentistry courses, with cost reduction[4,8,14,16]. Innovation has the potential to improve accessibility to an item that will assist in the professional training process[17], favoring academic training with a profile that meets the need to align with the new reality[18] and qualified for the future job market[19].

FINAL CONSIDERATIONS

It is possible to produce artificial deciduous teeth for laboratory practices in pediatric dentistry by using CAD/CAM technology. The combination of Anycubic resin to represent mineralized tissues with wax 7 to simulate the pulp made it possible to adequately reproduce the internal anatomy of deciduous teeth. Due to the scarcity of publications on the production of artificial deciduous teeth, studies that aim to contribute to the endodontic technique in Pediatric Dentistry are necessary.

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