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A critical evaluation of the material properties and clinical suitability of in-house printed and commercial tooth replicas for endodontic training

M. Reymus[1], **B. Stawarczyk**[2], **A. Winkler**[3], **J. Ludwig**[3], **S. Kess**[4], **G. Krastl**[3] & **R. Krug**[3]

[1]Department of Conservative Dentistry and Periodontology; [2]Department of Prosthetic Dentistry, University Hospital, Ludwig-Maximilians-University, Munich; [3]Department of Conservative Dentistry; and [4]Department of Orthodontics, University Hospital, Julius-Maximilians-University, Würzburg, Germany

Abstract

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Aim To assess the suitability of several 3D-printed resins for the manufacturing of tooth replicas for endodontic training in comparison with commercially available replicas by analysing the properties of the materials and comparing them with real teeth during endodontic training.

Methodology Tooth replicas were 3D-printed using four resins (NextDent Model, NextDent C&B, V-Print ee and Vero White Plus) and compared with two commercially available products (VDW and Smile Factory) as well as extracted human teeth. Martens hardness, indentation modulus and radiopacity were investigated on these tooth replicas. Experienced dentists evaluated the suitability of the replicas for endodontic training by comparing them with real teeth in terms of appearance, anatomy, radiopacity, similarity to dentine during access opening, canal gauging and canal instrumentation. Data were analysed using the Kolmogorov–Smirnov and Mann–Whitney *U*-test.

Results The greatest hardness values were recorded for human dentine ($P < 0.001$), followed by V-Print ee and the commercial tooth replica of Smile Factory. The greatest radiopacity was associated with VOC and dentine ($P < 0.001$) in comparison with the other materials tested. The appearance of the in-house printed tooth replicas was subjectively evaluated by the dentists as being more realistic than the commercially available products. No differences between the replicas was detected during mechanical instrumentation of root canals.

Conclusion None of the tooth replicas were able to simulate human dentine from the perspectives evaluated. V-Print ee had radiopacity comparable with dentine, but its hardness was not comparable with dentine.

Keywords: 3D Printing, dental education, replica, undergraduate training.

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Introduction

Endodontic procedures require dentists to become competent in a wide range of manual tasks. Enabling dental students to perform high-quality root canal treatment, as stated by the undergraduate guidelines of the European Society of Endodontology (ESE 2013), is an essential goal of endodontic education, and students need

Correspondence: Marcel Reymus, Department of Conservative Dentistry and Periodontology, University Hospital, Ludwig-Maximilians-University Munich, Goethestrasse 70, 80336 Munich, Germany (e-mail: mreymus@dent.med.uni-muenchen.de).

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extensive practice on pre-clinical repetitive exercises (Sonntag *et al.* 1997), typically achieved on extracted human teeth. These provide, by far, the most realistic training scenario. Their use, however, has several drawbacks, which have come to the fore in recent years: human teeth are difficult to collect and store, their use has potential cross-infection risks, ethical considerations including patient consent are required, and they do not offer standardization for student assessment (DeWald 1997). Using simulated canals in plastic blocks has been proposed as an alternative (Spenst & Kahn 1979); however, although they offer very good visualization, they simulate only a single root canal instead of an entire tooth with an often complex root canal system. Tooth replicas may overcome these limitations as their appearance is realistic, they are standardized, and they can be ordered in large quantities.

From a didactic point of view, the use of tooth replicas for training purposes might be considered controversial. Tchorz *et al.* (2015) stated that such replicas would prepare dental students for the clinical setting as effectively as extracted human teeth. However, Bitter *et al.* (2016) concluded that training on tooth replicas may not accurately predict student performance when they encountered real teeth in patients. In particular, they felt that the properties of such tooth replicas were different from those of dentine. Their hardness, as well as their radiopacity, has been rated as not being comparable with that of real human teeth (Nassri *et al.* 2008, Al-Sudani & Basudan 2017). With the development of additive manufacturing (AM), dental faculties have recently started to design and produce tooth replicas and entire training models in-house (Kröger *et al.* 2017, Reymus *et al.* 2019). In this way, customized training scenarios that are competitive with commercially available ones in terms of realism, costs and availability can be developed. A variety of powerful freeware and open-source software solutions are available for those wishing to design tooth replicas and models of jaws. Most of this software offer tutorials that give beginners an introduction on how to use the software for their own purpose, for example Blender (blender.org). A variety of 3D-printing technologies have been obtained by dental schools. Most are resin-processing printers: stereolithography (SLA) and digital light processing (DLP) polymerize liquid resin either by a single laser spot (using SLA) or by a beam (using DLP), whilst the Polyjet technology polymerizes single drops of resin applied on a surface (Kessler *et al.* 2019). All have in common that the desired object is built layer by layer. In contrast with milling procedures, this approach allows the reproduction of objects of complex geometry, such as hollow structures. Several 3D-printed resins are formulated for dental applications and include dental casts (Hazeveld *et al.* 2014), surgical guides and occlusal splints (Reyes *et al.* 2015, Krastl *et al.* 2016), and interim fixed prostheses (Li *et al.* 2018).

The aim of this study was to compare tooth replicas made with different 3D-printed resins with commercially available replicas and extracted human teeth. The properties of the different materials were investigated by evaluating the Martens parameters (Martens hardness HM, indentation modulus E_{IT}) and the radiopacity. As instrumented indentation tests, Martens hardness and indentation modulus describe the elastic–plastic property of one material (Shahdad *et al.* 2007). This property, in turn, influences cutting characteristic of an endodontic file working within the material (Lim & Webber 1985, Hülsmann *et al.* 2005). Furthermore, tooth replicas fabricated from different materials were evaluated by experienced endodontists in terms of appearance, anatomy, radiopacity, similarity to dentine during access opening, gauging and instrumentation. The null hypothesis stated that no difference would be found amongst the 3D-printed resins, commercially available replicas or extracted human teeth.

Materials and methods

The tested 3D-printed resins and commercial tooth replicas are shown in Table 1. Human teeth extracted for orthodontic reasons and free of caries and without restorative treatment were used as controls. These teeth were stored in 0.5 % chloramine T trihydrate (Carl Roth, Karlsruhe, Germany) at room temperature (23 °C) for a maximum of one week after extraction and then in distilled water at 5 °C.

Hardness and indentation modulus

A disc of 5 mm in height and 15 mm in diameter was digitally designed (Meshmixer; Autodesk, San Rafael, CA, USA) and additively manufactured ten times with each 3D resin material. The commercially available tooth replicas and the extracted human teeth were cut in half with a handpiece along the (simulated) cemento-enamel junction. The discs and the apical half of the commercially available and natural teeth were embedded in autopolymerizing acrylic resin (Scandi Quick A and B; ScanDia, Hagen,

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Table 1 3D-printed resins and commercial tooth replicas tested

Material	Indication	Manufacturer	3D Printer used
V-Print ee [VOC]	3D-printed resin for educational use	VOCO, Cuxhaven, Germany	Solflex 350, VOCO, Cuxhaven, Germany
NextDent Model [NDM]	3D-printed resin for dental models	NextDent, Soesterberg, Netherlands	D20II, Rapidshape, Heimsheim, German
NextDent C&B [NDC]	3D-printed resin for crowns and bridges	NextDent, Soesterberg, Netherlands	D20II, Rapidshape, Heimsheim, Germany
Vero White Plus [VWP]	3D-printed resin for prototypes	Sculpteo, Villejuif, France	Objet 30 Prime, Stratasys, Rechovot, Israel
Smile Factory [SMI]	Commercial tooth replica	Smile Factory, Bairro do Portao, Brazil	not applicable
Endo Training Tooth [VDW]	Commercial tooth replica	VDW, Munich, Germany	not applicable
Human Dentine [DEN]	Control	not applicable	not applicable

Germany) and polished semi-automatically (Tegramin-20; Struers) using consecutive silicon carbide papers up to P2000 under constant water cooling. On each specimen, a line crossing its surface was drawn. Measurements were taken at three predefined points, that is one in the middle and two at the periphery of the specimen, with a distance of approximately 5 mm from each other (measurements: $n = 210$). For the human teeth, special care was taken to measure only on dentine. Martens hardness and indentation modulus were determined using a Martens hardness machine (ZHU 0.2; ZwickRoell). The specimens were loaded with a Vickers diamond indenter (α = 136 degrees) with increasing force up to a maximum of 9.807 N, which was held for 10 s. The minimum indenter depth was always greater than 5 μm. Martens hardness (HM) and indentation modulus (E_{IT}) were calculated (testX-pert V12.3 Master; ZwickRoell) according to the ISO specification (www.iso.org/standard/56626.html?browse=tc):

$$\mathrm{HM} = \frac{F}{A_s(h)} = \frac{F}{26.43 \times h^2}$$

$$H_{IT} = \frac{F_{max}}{A_p}$$

$$E_{IT} = (1 - v_s^2) \times \left(\frac{1}{E_r} - \frac{(1-v_i^2)}{E_i}\right)^{-1} \text{ with } E_r = \frac{\sqrt{\pi}}{2C\sqrt{A_p}}$$

with HM in N mm^{-2}, F (test force) in N, A_s (h) (surface area of the indenter at distance h from the tip) in mm^2, h (indentation depth under applied test force) in mm, H_{IT} in N mm^{-2}, F_{max} (maximum test force) in N, A_p (projected [cross-sectional] area of contact between the indenter and the test piece determined from the force–displacement curve and a knowledge of the area function of the indenter) in mm^2, E_{IT} in kN mm^{-2}, E_r (reduced modulus of the indentation contact) in N mm^{-2}, E_i (elastic modulus of the indenter) in N mm^{-2}, C (compliance of the contact), v_s (Poisson ratio of the test piece) = 0.35 (Greaves *et al.* 2011) and v_i (Poisson ratio of the indenter) = 0.3.

Radiographic absorption

A disc of 1 mm in height and 15 mm in diameter was digitally designed (Meshmixer; Autodesk) and additively manufactured ten times with each 3D-printed resin material. For the extracted human teeth and the commercially available tooth replicas, the specimens from the investigation of the Martens parameters were used. For this purpose, the specimens were cut into discs of 1 mm thickness (Secotom 50; Struers, Ballerup, Denmark). Subsequently, all specimens were polished semi-automatically (Tegramin-20; Struers) using consecutive silicon carbide papers up to P2000 under constant water cooling. For calibration, a step wedge (1-mm increments, 10 steps) made of 99.5% pure aluminium (AluKeil; PEHA Medikal Geräte GmbH, Sulzbach, Germany) was used. Radiographs of each specimen with the step wedge next to it were exposed (Fig. 1) using a dental X-ray machine (Heliodont DS Dental X-ray Unit; Dentsply Sirona, York, PA, USA). The machine was operated at 7 mA and 60 kV at a 30-cm distance from the digital sensor with an exposure time of 0.1 s. The raw digital images were saved in 8-bit TIFF format and exported. The grey values of the step wedge and the specimens were analysed using the software Fiji (Schindelin *et al.* 2012). For this purpose, five regions of 10 × 10 pixels were selected per specimen ($n = 50$ per material) in each step of the step wedge ($n = 350$ per step). Care was taken that no root canals were present in the investigated region. The grey value per

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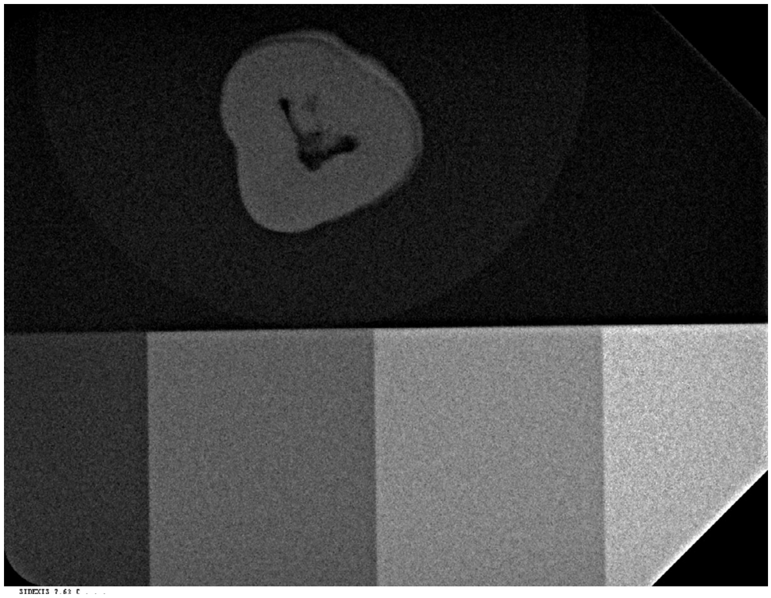

Figure 1 Radiograph of a specimen of an extracted human tooth next to the aluminium step wedge.

specimen was recorded as the mean of those five readings. The grey value was then converted into absorbance using the following equation:

$$A = -\log(T) = -\log\left(1 - \frac{G}{255}\right)$$

where A is the absorbance, T is the transmission, and G is the recorded grey value (0–255). The converted absorption was plotted against the number of aluminium steps. Subsequently, those plots were linearly regressed, and the regressions were used to correlate absorbance with the thickness of 99.5% pure aluminium in millimetres.

Evaluation of tooth replicas by dentists

A molar was digitally designed according to the workflow recently presented (Reymus *et al.* 2019) and additively manufactured ten times with each 3D-printed resin material (NDM, NDC, VOC, VWP). Each tooth replica had three root canals. Ten dentists of several years of clinical experience received one specimen each of the 3D-printed tooth replicas and one specimen each of the commercially available replicas (VDW, SMI) (Fig. 2). The operators perform root canal treatments on a regular basis. They are all involved in the university curriculum to teach endodontics to undergraduate students. They were asked to fill out a questionnaire regarding the comparability of the tooth replicas with real teeth. They evaluated the appearance of the tooth replicas and their anatomy, that is position and extent of the pulp cavity as well as course of the root canals. Furthermore, radiopacity and similarity to dentine during access opening, canal gauging and canal instrumentation were rated on a subjective basis. For drawing a comparison in each of these aspects, they marked a cross on a 10-cm-long scale anchored from very realistic (0 cm) to not realistic at all (10 cm; Appendix). Finally, they rated each tooth replica as whole. For root canal preparation, all participants negotiated the canals with size 10 hand files and carried out mechanical root canal instrumentation using a reciproc file system (R25 & R40; VDW, Munich, Germany).

For this purpose, they rated the comparability by marking a 10-cm-long scale anchored from very realistic (0 cm) to not realistic at all (10 cm). Finally, they evaluated the performance of each tooth replica in total by summing up all factors.

The data derived from the measurements on radiopacity and hardness as well as from the evaluation by dentists were analysed (SPSS Version 25; IBM, New York, USA) using the Kolmogorov–Smirnov and Mann–Whitney U-test. The level of statistical significance was set at $\alpha = 0.05$.

Results

The Kolmogorov–Smirnov test revealed a violation of normal distribution for up to 75% of the groups.

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Figure 2 Appearance of replicas from left to right: NDM, NDC, VOC, VWP, SMI and VDW.

Consequently, the data were analysed with a non-parametric approach. The Mann–Whitney *U*-test revealed significant differences between the various materials in terms of radiopacity, Martens hardness and indentation modulus. Those differences are shown in Table 2. The highest Martens hardness and indentation modulus (HM and E_{IT}) were recorded for DEN, followed by SMI and VOC, whilst NDM revealed the lowest values. The highest radiopacity was associated with VOC and DEN, followed by SMI. NDC had the lowest radiopacity.

The appearance of the 3D-printed tooth replicas (VOC, NDM, NDC, VWP) was assessed as being more realistic than the commercially available products (Fig. 3). Significant differences between the evaluated tooth replicas are shown in Table 3. In terms of radiopacity, VOC was considered to be the most comparable with human dentine, followed by NDM, NDC and SMI, whilst VDW and VWP had the lowest radiopacity. VWP demonstrated the lowest hardness during access opening, whilst the other tooth replicas ranged in the same values. For VDW, the evaluation of hardness was not applicable since the replica already had an access opening. In terms of internal anatomy, that is position and extent of the pulp chamber as well as course of the root canals, SMI was rated to be the most unrealistic, whilst the other tooth replicas were not different from each other. Before mechanical root canal preparation, all participants negotiated the canals with size 10 hand files. For this aspect (i.e. root canal gauging), VWP and VDW were evaluated to be the most realistic. Regarding mechanical root canal instrumentation, no differences between the tooth replicas could be detected. Considering the results for the evaluation for each tooth replica in total, SMI was rated to be the most unrealistic replica. The other tooth replicas were not different from each other.

Discussion

Tooth replicas should be as realistic as possible to provide dental students with the best simulation of an endodontic treatment procedure. The aim of this study was to compare tooth replicas made with various 3D-printed resins with commercially available replicas and extracted human teeth. The null hypothesis, which stated that no difference would be found amongst those, was rejected.

Previous studies on commercially available tooth replicas stated that their mechanical properties were not similar to that of real human teeth, although their appearance was quite realistic (Nassri *et al.* 2008, Bitter *et al.* 2016). Especially, the hardness of the materials was regarded as a drawback, providing a completely different sensation during root canal instrumentation. These results are consistent with those of the present study. None of the investigated 3D-printed resins nor the commercially available tooth replicas had hardness values that were comparable with that of dentine. They were all much softer. The hardness of dentine as measured in this

Table 2 Descriptive statistics of Martens hardness (HM in N mm^{-2}), indentation modulus (E_{IT} in kN mm^{-2}) and absorption (in mm aluminium)

	HM		E_{IT}		Absorption	
	Mean ± SD	95% CI	Mean ± SD	95% CI	Mean ± SD	95% CI
DEN	500 ± 46.4^{a}	[466.7;533.1]	16.3 ± 3.0^{a}	[14.1;18.5]	1.48 ± 0.035^{a}	[1.452;1.501]
VOC	144 ± 17.2^{b}	[131.4;156.0]	3.6 ± 0.3^{b}	[3.4;3.8]	1.50 ± 0.003^{a}	[1.493;1.497]
NDM	67 ± 4.4^{e}	[64.1;70.3]	1.8 ± 0.3^{d}	[1.6;2.1]	0.83 ± 0.002c	[0.833;0.835]
NDC	137 ± 0.9^{c}	[135.9;137.1]	3.5 ± 0.3^{b}	[3.3;3.8]	0.82 ± 0.001^{c}	[0.822;0.824]
VWP	133 ± 4.7^{d}	[129.6;136.3]	3.6 ± 0.2^{b}	[3.5;3.8]	0.85 ± 0.004^{c}	[0.849;0.855]
VDW	106 ± 1.8^{f}	[104.9;107.5]	3.1 ± 0.1^{c}	[3.0;3.1]	0.85 ± 0.003^{c}	[0.848;0.868]
SMI	$155 \pm 26.4^{b,c,d}$	[136.3;174.1]	4.2 ± 0.1^{b}	[3.7;4.8]	1.30 ± 0.010^{b}	[1.290;1.320]

a,b,c,d indicate groups with significant differences to each other.

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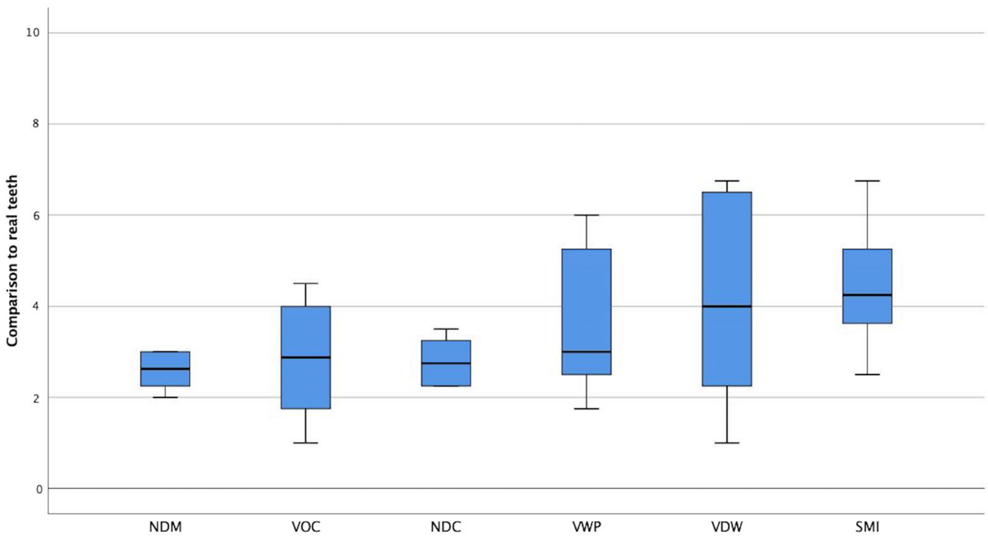

Figure 3 Comparison to real teeth as stated by experienced dentists (measured in cm on a scale reaching from very realistic [0 cm] to not realistic at all [10 cm]).

investigation was consistent with that found in a previous study, which reported the hardness of sound dentine to be approximately 500 N mm^{-2} (Lai *et al.* 2014). There were differences amongst the various materials tested. NDM had the lowest hardness values, which suggests it is less suitable for the manufacturing of tooth replicas for endodontic training. VOC and SMI had the greatest hardness. Whilst SMI is a commercially available tooth replica, VOC was specifically developed for the additive manufacturing of tooth replicas. Nevertheless, a greater hardness was apparently not achievable, thus demonstrating one crucial drawback of this type of 3D-printing technology, that is digital light processing (DLP). This technology polymerizes liquid resin which is hold in a vat. The chemical composition of such a resin must adhere to several requirements. It must have a low viscosity, so that it can flow underneath the printer's platform when it rises for the next layer to be polymerized. Additives, such as filler particles, can be used to supplement the basic resin to improve the material properties, but those will also increase its viscosity. Therefore, the opportunity for increasing the hardness using fillers is limited (Stansbury & Idacavage 2016). The indentation modulus (E_{IT}) describes the elastic performance of a material and is comparable with the Young modulus (www.iso.org/standard/30104.html). Concerning the elastic performance, none of the investigated materials achieved comparable results with that of dentine. Although the low hardness of tooth replicas has been criticized in previous studies from a subjective point of view, objective hardness measurement in terms of a laboratory investigation has not been analysed. The authors are unaware of previous studies highlighting this specific material property in 3D-printing technology for the purposes of dental education.

The correct interpretation of periapical radiographs is fundamental for the success of root canal treatment. Especially in a training scenario, the trainee needs to get used to recognize and correctly interpret various radiographic findings. These can, for example, provide an informative basis for assessing the working length of a root canal or for rating the quality of the root canal filling. Misinterpretations can lead to problems during root canal treatment. Consequently, tooth replicas should also be appropriate for this purpose. If their radiopacity is too low, a lack of contrast in the image makes interpretation quite difficult or completely unrealistic (Bitter *et al.* 2016). The relevance of adequate radiopacity in tooth replicas for their use in endodontic training has been emphasized before. Gancedo-Caravia *et al.* (2020) compared different commercially available tooth replicas by evaluating the performance of dental students and that of experienced instructors. They stated that no material had sufficient radiopacity for correctly evaluating the apical anatomy of the tooth replicas. From the results of the present study, only VOC showed radiopacity comparable with that of dentine. Whilst SMI came close to this radiopacity, all

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Table 3 Descriptive statistics on the evaluation of experienced dentists about the appearance of the tooth replicas, their radiopacity, the inner anatomy and similarity to human's dentine during access opening, root canal gauging and mechanical instrumentation (measured in cm on a scale reaching from very realistic [0 cm] to not realistic at all [10 cm])

	Appearance		Radiopacity		Access opening		Anatomy		Gauging		Instrumentation	
	Mean ± SD	95% CI	Mean ± SD	95% CI	Mean ± SD	95% CI	Mean ± SD	95% CI	Mean ± SD	95% CI	Mean ± SD	95% CI
VOC	2.20 ± 1.1^{a}	[1.4;2.9]	2.02 ± 1.1^{a}	[1.2;2.9]	2.82 ± 1.4^{a}	[1.8;3.8]	2.50 ± 1.0^{a}	[1.7;3.2]	3.92 ± 2.3^{b}	[2.3;5.6]	3.45 ± 1.6	[2.3;4.6]
NDM	2.25 ± 1.3^{a}	[1.3;3.2]	3.1 ± 0.9^{b}	[2.4;3.7]	3.67 ± 1.7^{a}	[2.4;4.9]	2.37 ± 0.8^{a}	[1.8;2.9]	4.72 ± 1.5^{b}	[3.6;5.8]	3.20 ± 1.4	[2.1;4.2]
NDC	1.85 ± 0.9^{a}	[1.2;2.4]	3.10 ± 0.9^{b}	[2.4;3.8]	3.45 ± 2.2^{a}	[1.9;5.0]	2.37 ± 1.1^{a}	[1.6;3.2]	4.25 ± 1.8^{b}	[2.9;5.5]	3.37 ± 1.9	[2.0;4.7]
VWP	2.35 ± 0.8^{a}	[1.7;2.9]	6.37 ± 1.6^{c}	[5.2;7.6]	6.62 ± 1.6^{b}	[5.3;7.9]	3.20 ± 1.1^{a}	[2.4;4.0]	2.20 ± 1.6^{a}	[1.0;3.3]	3.60 ± 2.0	[2.1;5.0]
VDW	2.50 ± 1.a^{b}	[1.5;3.4]	6.5 ± 1.8^{c}	[5.3;7.7]	n.a.	n.a.	2.67 ± 1.6^{a}	[1.5;3.8]	2.25 ± 1.7^{a}	[1.0;3.4]	3.00 ± 2.5	[1.1;4.8]
SMI	4.84 ± 2.1^{b}	[3.4;6.3]	3.25 ± 1.5^{b}	[2.2;4.2]	3.00 ± 1.4^{a}	[2.0;3.9]	5.18 ± 1.4^{b}	[4.1;6.1]	4.59 ± 2.9^{b}	[2.6;6.6]	4.70 ± 1.9	[3.4;6.0]

a,b,c indicate groups with significant differences to each other.

other materials were inferior. Consequently, for training radiographic diagnostics, NDM, NDC, VWP and VDW do not seem to be suitable. The experimental set-up to evaluate the materials' radiopacity has been used in previous studies (Gu *et al.* 2006, Dukic *et al.* 2012, An *et al.* 2018). It provides an effective way of investigating absorbance with digital radiographs. Therefore, the results presented in this study are suitable for a comparison between dentine and the different materials tested.

The comparability of the different materials with real teeth was evaluated by experienced dentists. The in-house printed tooth replicas were rated as having the most realistic appearance. This finding emphasizes the suitability of the digital design process for the manufacturing of tooth replicas and the appropriateness of the 3D printer used. VOC was rated to show the most realistic radiopacity. This was consistent with the investigation of radiopacity described previously. VWP and VDW, in contrast, were rated as having unrealistic radiopacity. As seen in Fig. 4, VWP cannot be radiographically distinguished from the support material that fills the root canal. Thus, the anatomy of the root canal cannot be evaluated, which is a serious drawback for endodontic training and questions the materials' use for training purposes. Except for VWP, all materials had realistic hardness during access opening from the dentists' subjective point of view. For VDW, this factor could not be evaluated since this tooth replica is provided with an existing access opening, which makes it unsuitable for the training of this step of the root canal treatment. The most realistic gauging of the root canals was found for VDW and VWP. This might be explained by the fact that there is material inside the root canals: for VDW, it is wax, and for VWP, it is a soft support structure. These materials provoke resistance during manual instrumentation that imitates the resistance of pulp tissue in real teeth. For the other tooth replicas, the root canals were free of any residual material. Most interestingly, no difference was detected amongst the replicas for mechanical instrumentation, which is a crucial point for training purposes. This might explain why, in general, all tooth replicas except SMI were reported to be equally comparable with real teeth. Further studies with a larger number of operators (e.g. in a study setting with undergraduate students) must be conducted to confirm the reliability of the clinical evaluation using selected in-house manufactured tooth replicas in endodontic training.

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Figure 4 Radiographs of one extracted human tooth (a) and the various tooth replicas (b = NDC, c = NDM, d = VOC, e = VWP, f = VDW and g = SMI).

Conclusion

No material was able to simulate human dentine from all perspectives tested. Only VOC had comparable radiopacity to that of dentine. The hardness of all tested tooth replicas was lower than that of human dentine. Nevertheless, 3D-printed tooth replicas seem to be equivalent to commercially available tooth replicas in terms of specifications of the materials and their evaluation during training.

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Conflict of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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Appendix: Questionnaire for evaluation of clinical feasibility.

1. How realistic is the appearance of the replica tooth (please rate by marking the line)?

Very

Not at all

2. How much does the radiopacity of the replica tooth resemble an actual human tooth?

Very

Not at all

3. How much does the hardness of the replica tooth resemble an actual human tooth during access opening?

Very

Not at all

4. How much does the inner anatomy of the replica tooth resemble an actual human tooth?

Very

Not at all

5. How much does the manual instrumentation of the replica tooth resemble an actual human tooth?

Very

Not at all

6. How much does the mechanical instrumentation of the replica tooth resemble an actual human tooth?

Very

Not at all

7. How much does the replica tooth resemble an actual human tooth in total?

Very

Not at all

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