Preparation Time and Perceptions of Brazilian Specialists and Dental Students Regarding Simulated Root Canals for Endodontic Teaching: A Preliminary Study

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Abstract: The aim of this preliminary study was to evaluate the desirability of alternative models of artificial teeth versus extracted natural teeth for use in preclinical dental education. Specifically, the study was designed to compare the preparation time and perceptions of difficulty of undergraduate dental students and endodontists in carrying out root canal preparations on resin models (both clear and opaque) and extracted natural teeth. Twenty participants—ten fifth-year students at a Brazilian dental school and ten endodontists with at least five years’ experience in the specialty—performed root canal instrumentation on two samples of each model. Preparation times were recorded, and the participants completed a questionnaire about the anatomical and physical characteristics of these models. The results showed that the time required for performing endodontic procedures in the natural teeth was higher than in the alternative models. The perceptions of the students and specialists regarding some topics on the questionnaire were significantly different. The students had more positive opinions about artificial teeth made of opaque resin, while the specialists had more positive opinions about simulated root canals in clear resin blocks. This study suggests that neither of the alternative models fulfilled requirements to replace natural teeth in endodontic teaching; improvements are still necessary to accomplish this goal.

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Preclinical disciplines represent an important stage of learning in dental schools since they enable students to acquire manual skills essential to clinical practice.1 For many years, extracted human teeth were used almost exclusively for teaching endodontic procedures. However, this use has disadvantages, such as the possibility of cross-infection.2 Dental students and dental investigators who use extracted teeth for learning and research purposes are exposed to potentially harmful organisms and need to follow infection control guidelines.2 However, concerns have been raised that following these guidelines may cause confounding effects on the extracted teeth to be prepared or tested.2

Another disadvantage of using human teeth includes difficulties in obtaining them. These drawbacks, along with ethical factors, have stimulated the development of alternative simulation methods for endodontic teaching.1,3-9 A simulation is an experiential learning tool to depict a “real-life” situation, and dental simulations may be defined as those practices that reproduce or imitate clinical conditions in dentistry.10 Traditionally, these have included training for clinical procedures using extracted or artificial teeth placed in static manikin jaws or phantom heads.7,11

Another alternative method involves the use of simulated root canals made in clear resin blocks, allowing standardization of length, diameter, and degree of curvature.3 Accordingly, simulated canals that play single-rooted teeth present straight configurations, while molars are best represented by curved simulated canals.12 However, dentin hardness and
some aspects of internal and external anatomy of teeth are not accurately reproduced in these blocks. Moreover, their characteristics of transparency and lack of radiopacity do not allow the development of some technical skills related to radiographic interpretation, making their use limited in some phases of learning.

As a result, some researchers have sought to reproduce the anatomical and physical characteristics of dental tissues in artificial teeth.1,3,4 Recently, the construction of models made of opaque resin has been cited as an alternative to better reproduce the features of natural teeth.5 The replacement of natural teeth by resin teeth is justified for two reasons. The first is related to the current conservative philosophy of preserving natural teeth as much as possible, which directly interferes with tooth removal and makes it increasingly difficult to obtain natural teeth for teaching purposes. The second reason is related to ethics committees’ recommendation regarding teeth origin, as in many cases teeth are obtained from popular dental offices without any official record.1 This practice reveals a concern about the way teeth are being obtained and leads to strategies to curb unjustified extraction and lack of record about the origin of teeth to be used in dental research and education.15

Although the similarities between artificial teeth made of opaque resin and natural teeth are often emphasized, previous evaluation of the use of artificial teeth has been limited to the observations of experts in endodontics.1 However, a number of issues have to be resolved if extracted human teeth are to be replaced with artificial ones in preclinical education in endodontics. Therefore, the aim of this preliminary study was to compare the perceptions of dental students and endodontists regarding the two alternative models (artificial teeth made of opaque resin and simulated root canals in clear resin blocks) to natural human teeth. Another objective was to compare the time required to perform root canal preparation in the three models.

Methods

This study was approved by the Ethics and Research Committee of Pontifical Catholic University of Rio Grande do Sul, Porto Alegre, Brazil (protocol no. 322.742/2013). All participants in the study signed an informed consent form before starting practical procedures.

For the study, we wanted to compare the perceptions of two groups with differing amounts of experience in endodontics. Thus, the participants were convenience samples of ten fifth-year dental students at the Pontifical Catholic University of Rio Grande do Sul, Porto Alegre, Brazil (PUCRS) and ten endodontists (with at least five years of experience in the specialty) in Porto Alegre, Brazil. These 20 participants performed root canal preparation and evaluated the characteristics of three models: 1) extracted human teeth provided by the PUCRS Bank of Teeth, which were submitted to autoclave sterilization; 2) artificial teeth made of opaque resin (Smile Factory, Mogi das Cruzes, SP, Brazil); and 3) simulated root canals in clear resin blocks (Endo-Block, Dentsply-Maillefer, Ballaigues, Switzerland) (Figure 1). Aiming for the evaluation of curved canals, only the mesiobuccal canal (MB1) of first maxillary molars was used in models 1 and 2. MB2 canals were not considered in order to simplify the procedures, especially for the inexperienced students. Natural teeth with moderate curvatures (approximately 10° to 20°) were selected visually, considering the study of Schneider et al.12 In the third model, simulated canals with standardized curvature (35°) were used, also corresponding to MB canals of maxillary molars.

Each operator received two specimens of each model. Thus, the sample consisted of 120 specimens: 40 extracted human teeth, 40 artificial teeth made of opaque resin, and 40 simulated canals in clear resin blocks. This research was considered a pilot study, and a further investigation with a large number of samples per model is planned, as performed in previous studies.1,14,15

Endodontic Procedures

Natural and artificial teeth were included in acrylic resin blocks. Thus, they could be introduced and fixed on a special platform developed by the authors for radiographic exposure (Figure 2). The participants were instructed to adopt a specific technical sequence for each model, as follows: Models 1 and 2—initial radiograph, endodontic access, MB canal scouting, coronal preflaring, manual instrumentation by crown-down technique, including radiographic working length (WL) determination, and final radiograph; Model 3—MB canal scouting, coronal preflaring, manual instrumentation by crown-down technique, and WL standardized at 15 mm.

For all three models, 2% sodium hypochlorite (VirexPlus, Johnson Diversey Brasil Ltda, São Paulo, SP, Brazil) was employed as the irrigating solution, and 1mL of this substance was used after each instrument change. Irrigation was carried out
WL determination was accomplished by Ingle’s technique, 1 mm short of the radiographic apex. For simulated root canals in clear resin blocks, WL was visually set at 15 mm.

The root canals were prepared by crown-down technique using LA Axxess burs (SybronEndo, Anaheim, CA, USA) and hand flexible K-files (Medin, NovéMěsto na Moravě, Czech Republic). One pack of files (#15-40) was used for each model. Preparation was initiated with a large diameter instrument by using a 30G needle (NaviTip, Ultradent Products Inc., South Jordan, UT, USA) attached to a plastic syringe (Ultradent Products Inc., South Jordan, UT, USA). Also, a suction cannula was used to remove extruded liquid.

In order to obtain the WL in natural and artificial teeth, MB canals were explored with size #15 hand instruments. Sizes #08 and #10 hand instruments were also available for initial exploration and establishing patency in severely narrow canals.

Figure 1. Alternative models for endodontic teaching: (A) artificial teeth made of opaque resin; (B) simulated root canals in clear resin blocks
adjusted to the canal orifice, penetrating about 2 mm, using slight watch winding movements, to the right and left, without apical pressure, followed by traction. Subsequently, this procedure was repeated with smaller diameter instruments, progressing toward the apex. The apical stop was established with a size #30 instrument. Operators were instructed to make the procedures in the following sequence: model 1, model 2, and model 3, in order to obtain a standardized and immediate comparison of models 2 and 3 with model 1. The time elapsed from the start of each sequence to its completion was recorded with the aid of a digital timer, in order to compare the three models and the two participating groups (students vs. specialists).

**Survey Questionnaire**

After conducting preparations in the three proposed models, all the participants completed a questionnaire with objective and subjective sections, which included questions regarding their perceptions of the similarity between the alternative models and natural human teeth. For artificial teeth, the following topics were addressed: anatomy, endodontic access, canal exploration, length determination, and canal preparation. For simulated canals in clear resin blocks, only exploring and preparation stages were considered.

The participants also answered questions about the quality of the models regarding each topic using four response options: excellent, satisfactory, unsatisfactory, and poor. This part of the questionnaire was adapted from a previous study, with modifications. At the end of each question, the participant assigned a grade from 0 to 10 for each aspect, guided by the following scale: 0-2 for poor feature, 3-5 for unsatisfactory feature, 6-8 for satisfactory feature, and 9-10 for excellent feature.

**Statistical Analysis**

The test of homogeneity of variances (Levene’s test) was applied to evaluate the feasibility of using parametric tests. Data concerning the time required to complete the technical sequences were analyzed by one-way ANOVA and Dunnett’s post hoc test for comparing the three models and Student’s t-test for comparing the two groups (students vs. specialists).
The results of the perceptions were analyzed with a Mann-Whitney test, which compared the responses of the students and the specialists in the qualitative analysis. Each answer choice was transformed into a number: 1=poor, 2=unsatisfactory, 3=satisfactory, and 4=excellent. Afterwards, data from the quantitative analysis (grades 0-10) were evaluated by Student’s t-test. The significance level was set at 5%.

Results

Means and standard deviations of root canal preparation time are listed in Table 1, considering groups (students vs. specialists) and models. In the subjective part of the questionnaire, the participants reported their opinion about the quality of the alternative models compared to natural teeth.

The results showed that 70% of the students and 30% of the specialists did not feel the sensation of reaching the pulp chamber during the endodontic access preparation of artificial teeth. In addition, 30% of the students and 50% of the specialists reported unsuitable anatomy of artificial teeth, both external and internal, the last being mainly related to the incorrect position of the pulp chamber and root canals, as well as their incompatible diameter. Among these participants, 40% of the students and 20% of the specialists reported difficulty in irrigating simulated root canals, while 30% of the students and 10% of the specialists reported that the filling of artificial teeth with wax did not simulate reality, which may facilitate instrument fracture due to its sticky consistence, and may impair irrigation procedures. Further, 40% of the students and 30% of the specialists reported that artificial teeth showed the lowest wear resistance; 10% of the students and 20% of the specialists reported difficulties in radiographic interpretation using artificial teeth; and 10% of the students and 10% of the specialists reported that clear resin blocks with simulated canals had higher wear resistance than natural teeth. Finally, none of the students and only 10% of the specialists reported a repeated occurrence of the sensation of reaching the pulp chamber in artificial teeth: one in the enamel-dentin transition and another in the actual pulp chamber.

In the objective part of the questionnaire, the students and specialists reported on their qualitative analyses of the alternative models. The percentages of positive responses (excellent or satisfactory options) are shown, in descending order, in Figure 3 for artificial teeth in opaque resin and Figure 4 for simulated canals in clear resin blocks. The results of the quantitative analyses, in which the operator assigned grades from 0 to 10 for each item on the questionnaire, are shown in Table 2.

Discussion

This study compared the perceptions of two groups of dental practitioners with different levels of experience regarding the possible replacement of natural teeth with alternative models in preclinical endodontic training. The results showed an acceptance of these models by the students, although both groups (students and specialists) pointed out features that were inconsistent with natural teeth.

Regarding artificial teeth made of opaque resin, statistical differences were detected between the students and specialists in their evaluations of the following characteristics: internal anatomy, pulp chamber shape, canal shape, canal size, and radiographic image. A remarkably unsatisfactory evaluation (less than 50% positive responses) was noted for the specialists. On the other hand, the students’ assessments had more than 50% positive rating on all questions, indicating good acceptance, probably due to the lower difficulty in applying endodontic techniques in this standardized model.

Both groups of operators, although with different frequencies, pointed out characteristics related to artificial teeth that differed from natural teeth, such

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Table 1. Means and standard deviations of root canal preparation time, in minutes, by group (students vs. specialists) and dental model

<table>
<thead>
<tr>
<th>Group</th>
<th>Natural Teeth</th>
<th>Artificial Teeth</th>
<th>Simulated Root Canals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fifth-year dental students</td>
<td>42.81±12.14\textsuperscript{aA}</td>
<td>31.90±8.34\textsuperscript{aA}</td>
<td>10.90±3.29\textsuperscript{aA}</td>
</tr>
<tr>
<td>Specialists</td>
<td>30.52±9.17\textsuperscript{aA}</td>
<td>25.52±6.83\textsuperscript{aA}</td>
<td>12.85±6.50\textsuperscript{aA}</td>
</tr>
</tbody>
</table>

Note: Distinct lower-case letters in the same row indicate significant difference between models (p<0.05). Distinct capital letters in the same column indicate significant difference between groups (p<0.05).
as the material within the pulp space. This finding corroborates the results of a previous study in which the same brand of artificial teeth was evaluated, indicating the need for improvement in the content of the pulp chamber and root canals, since it has different viscosity in comparison to pulp tissue, which makes it more difficult to remove. Another limitation of this model is the radiographic image. The previous study noted that it has low contrast, despite hard and soft tissues being clearly distinguishable. However, the main difficulty pointed out in that study was resin hardness, which does not reproduce dentin characteristics, giving the wrong impression that there is not much resistance in the access to pulp space in a natural tooth. Such problems were also detected by the participants in our study, notably the specialists.

Simulated root canals in clear resin blocks were evaluated more positively by the specialists in comparison to artificial teeth in opaque resin, considering the hardness offered by the material as well as canal

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**Figure 3.** Percentage of positive perceptions for each question regarding artificial teeth made of opaque resin: comparison between students and specialists

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**Figure 4.** Percentage of positive perceptions for each question regarding simulated root canals in clear resin blocks: comparison between students and specialists
size and shape. On the contrary, the students rated that model as inferior when compared to artificial teeth. These blocks with simulated canals more closely resemble complex clinical cases—in other words, narrow and severely curved canals. This fact may explain why the specialists’ evaluation was better.

Regarding preparation time, it was expected that the more experienced operators would complete the procedures more quickly.16 This outcome was observed for the natural and artificial teeth in opaque resin. On the other hand, in the simulated root canals in clear resin blocks, no significant difference was observed between the students and specialists. It is worth mentioning that this model does not contemplate operative phases such as access cavity preparation and working length determination by radiographs. Moreover, the quality of the instrumentation was not evaluated in this study. Students may have instrumented simulated canals as quickly as specialists but with more operative procedural errors; this possibility remains unclear and points to a possible limitation of this study. Another limitation is that the study included a small number of students in one dental school and a small number of practicing endodontists, so the findings may not be generalizable to all dental students and endodontists.

When the three models were compared regarding time required, the time was longer for natural teeth, followed by artificial teeth and blocks with simulated canals. For the students, a significant difference was detected among those three models, indicating a major difficulty in the endodontic preparation on natural teeth. However, for the specialists, there was no difference between preparation time of natural and artificial teeth, but only between these two models and the simulated canals in clear resin blocks.

Based on the results and limitations of this study, the perception of specialists about artificial teeth was unsatisfactory and did not support the replacement of natural teeth. However, it is believed that exposing predoctoral students to such artificial models is also beneficial. Experimental studies addressing the comparison of different root canal instrumentation systems usually utilize such standardized models.17,18 Thus, the inclusion of such

| Table 2. Grades (mean and standard deviation) assigned to each requirement on the perception questionnaire: comparison between students and specialists in alternative models |
|-----------------|-----------------|-----------------|
| Model            | Requirement       | Students         | Specialists      | p-value |
| Artificial teeth | External anatomy  | 7.00±2.05        | 5.00±2.16        | 0.048*  |
|                  | Internal anatomy  | 6.20±1.75        | 3.80±2.74        | 0.034*  |
|                  | Pulp chamber size | 7.30±1.25        | 6.00±2.21        | 0.128   |
|                  | Pulp chamber shape| 7.00±1.41        | 4.20±2.57        | 0.009*  |
|                  | Endodontic access | 7.90±0.87        | 6.80±1.93        | 0.126   |
|                  | Fulfillment of the pulp chamber and root canal | 6.10±2.13 | 4.70±1.33 | 0.099 |
|                  | Radiographic image| 6.90±2.42        | 4.30±2.11        | 0.020*  |
|                  | Root canal size   | 8.10±0.73        | 4.80±1.68        | <0.001* |
|                  | Root canal shape  | 7.60±0.84        | 5.50±1.35        | 0.001*  |
|                  | Hardness          | 5.60±1.50        | 4.80±1.98        | 0.325   |
| Simulated root canals | Root canal size | 5.70±1.82        | 7.10±2.02        | 0.122   |
|                  | Root canal shape  | 6.70±1.70        | 7.30±1.76        | 0.449   |
|                  | Hardness          | 5.80±2.15        | 5.10±2.60        | 0.520   |

*Statistically significant difference (p<0.05) detected by Student’s t-test.
models as a part of dental curricula may pave the way for better exposure towards both clinical practice and research.

Considering ethical issues in obtaining natural teeth in Brazil (Federal Law no. 9,434, February 4, 1997), as well as the possibility of standardizing anatomical features and optimizing the academic time, the alternative models demonstrated good ability to elucidate endodontic techniques, but did not accurately reproduce natural teeth. For an approximation to clinical practice, we suggest using a teaching approach in which students have contact with natural teeth at least once while still in the preclinical laboratory stage.

This study contributes to the understanding of the state of the art of alternative dental models available for endodontic education in Brazil, from the perspective of the main beneficiaries of these models—undergraduate dental students—and also considering the opinion of experts in endodontics. The results may serve to give information to educators and manufacturers of existing models that may contribute to improvement of these educational tools. Data produced in this pilot study should be complemented by the analysis of more specimens. Also, shaping ability (incidence of transportation) and materials hardness, among other properties, should be evaluated, thereby providing a complete characterization of these alternative models in comparison to natural teeth.

**Conclusion**

This study found that the time required for performing endodontic procedures in natural teeth was higher than in the alternative models. The perceptions of the students and specialists regarding some features of these models were significantly different. The students had a more favorable judgment on artificial teeth made of opaque resin, while the specialists showed positive opinions about simulated root canals in clear resin blocks. Neither of these alternative models fulfills the requirements to replace natural teeth in endodontic teaching; improvements are still necessary to accomplish this goal.

**REFERENCES**