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Highlights

The influence of a learning object with virtual simulation for dentistry: A randomized controlled trial

Rodrigo Alves Tubelo, Vicente Leitune Castelo Branco, Alessandra Dahmer, Susana Maria Werner Samuel, Fabrício Mezzomo Collares

- The influence of virtual learning objects with virtual simulation was evaluated in the theoretical learning and laboratory performance of dentistry students.
- The students using virtual learning objects achieved better results than the control students.
- Virtual learning object use improved zinc phosphate cement handling.
The influence of a learning object with virtual simulation for dentistry: A randomized controlled trial

Q1 Rodrigo Alves Tubelo, Vicente Leitune Castelo Branco, Alessandra Dahmer, Susana Maria Werner Samuel, Fabrício Mezzomo Collares.

Q2 Laboratório de Materiais Dentários, Faculdade de Odontologia da Universidade Federal do, Rio Grande do Sul, Rua Ramiro Barcelos, 2492—4o andar, CEP: 90035-004, Brazil

Laboratório de Materiais Dentários—Bairro Rio Branco, Porto Alegre

Departamento de Ensino em Saúde, Universidade Federal de Ciências da Saúde de Porto Alegre, Rua Sarmiento Leite, 245/212—Bairro Centro, Porto Alegre

Q3 Rodrigo Alves Tubelo, Vicente Leitune Castelo Branco, Alessandra Dahmer, Susana Maria Werner Samuel, Fabrício Mezzomo Collares.

Objective: The study aimed to evaluate the influence of virtual learning object (VLO) in the theoretical knowledge and skill practice of undergraduate dentistry students as it relates to zinc phosphate cement (ZPC).

Methods: Only students enrolled in the dentistry course the course were included in the trial. Forty-six students received a live class regarding ZPC and were randomized by electronic sorting into the following 4 groups: VLO Immediate (GIVLO n=9), VLO longitudinal (GIVLO n=15) and two control groups without VLO (GC n=9 and GLC n=13). The immediate groups had access to VLO or a book for 20 min before the ability assessment, whereas the longitudinal groups had access to VLO or a book for 15 days.

Results: A pre- and posttest on theoretical knowledge and two laboratory skill tests, evaluated by blinded examiners, were performed regarding zinc phosphate cement manipulation in all groups. The students who used the VLO obtained better results in all the tests performed than the control students. The theoretical posttest showed a significant difference between the longitudinal groups, GLC (6.0 ± 1.15) and GIVLO (7.33 ± 1.43). The lower film thickness presented with a significant difference in the VLO groups: (GIVLO 25 ± 9.3) and GIVLO (16.24 ± 5.17); GIVLO (50 ± 27.08) and GIVLO (22.5 ± 9.65). The higher setting time occurred in the VLO groups, and the immediate group showed a significant difference (GIC 896 ± 218.90) and GIVLO (1138.5 ± 177.95).

Conclusions: The ZPC manipulated by the students who used the VLO had better mechanical properties in the laboratory tests. Therefore, the groups that used the VLO had clinical handling skills superior to its controls and greater retention of knowledge after 15 days.

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1. Introduction

Distance learning has existed for over a century, and its media diversity has evolved during this time, from mailing to web-based technologies that enable the use of more sophisticated teaching tools [1]. Distance learning using the web has broken the paradigm of learning in place and reinforced the idea of student-centered learning without the presence of a teacher [1]. Regarding health education, distance learning has been an effective way to enhance the knowledge of professionals in continuing education [2]. Compared to traditional education methods, distance learning shows inconsistency and heterogeneous results because of the various interventions applied; however, Internet-Based Learning is associated with positive outcomes [3], principally when use VLO as a resource learning.

Learning objects are reusable digital resources attainable for distribution throughout the network to achieve various population interventions applied; however, Internet-Based Learning is associated with positive outcomes [3], principally when use VLO as a resource learning. Learning objects are reusable digital resources attainable for distribution throughout the network to achieve various population sizes [4]. These objects, comprising texts, graphics and animations, should facilitate the learning process by creating an attractive, interactive environment of easy navigation in electronic media [5]. In this context, virtual reality has been shown to be a potential tool in the teaching-learning process [6], being able to overcome traditional teaching methods [7]. To assist the educational process, gamification techniques have been used as elements with design.

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techniques and game mechanics in different contexts. E-learning platforms have the potential to increase students’ motivation with aspects of gaming [8,9]. These digital games have a positive effect on education, although more randomized clinical trials are needed to provide more rigorous evidence of their effectiveness [8,10]. In the health area, research should be conducted to evaluate a static methodology with an active learning approach such as games and virtual simulations [11,12]. In dentistry, there is research positively associating the interactivity of learning objects to undergraduate teaching [13]. However, there are no studies evaluating the relationship between virtual simulation and gamification in the learning process for dentistry students.

In dentistry, there are a variety of dental materials that could be used in patients, and these materials include zinc phosphate cement. Zinc Phosphate Cement (ZPC) is a water-based cement, in use for over one-hundred years in dentistry; it provides retainment of prosthetic devices on the remaining tooth structure [14]. Proper adaptation between a prosthesis and tooth interface requires cement with ideal properties. An appropriate amount of powder and liquid, associated with correct handling of the mixture of these components, is essential. These properties are the film thickness and setting time. Proper handling includes the disposal and cement adaptation at the interface, and the latter is the time in which a dentist will have from the beginning of handling to the moment of the hardening of the cement. A low film thickness leads to a lower interface between the prosthesis and tooth, preventing recurrent caries.

In the setting time, a longer time yields a better result because of the extra working time the professional have to place the material in the prosthesis device and cement it to the patients’ tooth. Both properties are directly linked to the correct manipulation of ZPC, and there is no studies evaluating the influence of different teaching methodologies at handling skills and cement properties.

In the literature, several studies have compared the outcomes of different teaching methodologies, as “e-learning” and instruction in the classroom [15–18]; virtual simulations have been used for teaching in medicine [9], highlighted by anatomy and surgery disciplines [19,20]. However, those studies failed to appraise the clinical performance of these students [21]. Other studies showed the effectiveness of VLO in health care for medical students as instruction tool in the analysis exams [22]. Many studies using Information Technology have been developed for health education as virtual simulation with serious game [23,24] intending to qualify clinical practice not only for trainees but also as a quick reference guide to support clinical decisionmaking [25]. However, these studies are predominantly related to users and not applied to dentistry undergraduates [24]. The use of e-learning tools in dental materials has shown popularity and approval among students [26]. The influence of VLO in association with the theoretical and clinical performance of undergraduate students it is not properly known. As the outcome, we evaluated the influence of a VLO in theoretical knowledge and skill practice in undergraduate dentistry students, relative to zinc phosphate cement.

2. Methodology

2.1. Design

This study used the CONSORT Statement to develop the randomized controlled trial (RCT) [27] performed with undergraduate students of dental materials at the Dental Materials Laboratory of Federal University of Rio Grande do Sul. The exclusion criteria were participation in all stages of the study and not having had previous access to the content. The local Ethics in Research Committee approved the study, and all students signed a consent form (CAAE: 37347214.6.0000.5347).

All current students enrolled in a dental materials class were eligible for this study; the forty-six undergraduates were allocated by coin flip to the following two blocks: the immediate and longitudinal groups, after they were divided by electronic random allocation into four groups. The group distributions are shown in Fig. 1. The four groups are as follows: GIC (use of a traditional teaching method and tested immediately, n = 9), GIVLO (use of VLO and tested immediately, n = 9), GIVLO (use of a traditional teaching method for 15 days, n = 13), GILO (use of VLO for 15 days, n = 15). A 50-min live class showed the basic fundamentals regarding the agents in dental cementation, with an emphasis on zinc phosphate cement, for all groups. After the class, a theoretical knowledge pretest was given, which consisted of 10 true or false questions about the properties and characteristics of zinc phosphate cement. Four students did not attend the class and were excluded from the research.

Next, a practical lesson was presented, in which the students manipulated zinc phosphate cement for the first time. Two groups received intervention, as follows: the GILO group was given a chapter of a standard reference book [28], and the GIVLO received a VLO available for laptop computers. Both groups had 20 min with their study materials. Then, they manipulated the zinc phosphate cement.

For the GIC and GIVLO, the practice lesson took place after 15 days, so it relinquished the book and the VLO, respectively, for that period. The GILO had access to the VLO via the virtual learning environment Moodle 2.5 and made use of the discussion forum, which had been taught by the teacher who had taught the live class. After the 15-day period, the practice class occurred, and GILO and GIVLO manipulated zinc phosphate cement for the first time. Four students did not attend the practical class and were excluded from the research. The study design is shown in Fig. 2.

2.2. Development of the virtual learning object

The VLO was developed in partnership with the Open University of the Brazilian Public Health System of Federal University of Health Science of Porto Alegre. The VLO content was exactly the same as that of the live class and was developed by the same teacher in Articulate Storyline 2 (Articulate Global, Inc., New York, NY—USA) software. The object was composed of narrated illustrations, a video demonstration and virtual simulation of cement handling (http://www.ufrgs.br/lamad/fosfato-de-zinco/fosfato-de-zinco/view).

2.2.1. Virtual simulation

Virtual simulation was the last stage of the VLO. After attending to all classroom content and seeing the manipulation video, each student was expected to perform the simulation. A video tutorial explained the simulation, which was the use of a spatula held with a click and dragged over a glass plate. The following two variables were considered: the handling frequency and the used area of the plate. The student should receive maximum points for these two blocks. The following two variables were considered: the handling frequency and the used area of the plate. The student should receive maximum points for these two blocks.
test. The pretest was applied after the live class, and the posttest was applied 21 days after the live class.

2.4. Skill test

The handling skills of the students were evaluated with laboratory tests by blinded examiners. After their first manipulation of zinc phosphate cement, the content was collected and conducted according to film thickness and setting time tests. These cement properties are directly affected by the quality of the handling.

2.4.1. Film thickness

The thickness measurements were conducted according to ISO 9917-1 (ISO 9917-1:2003). Initially, the students measured the
Fig. 3. (A) First screen of virtual simulation of zinc phosphate cement manipulation, there are the powder divided into six sections, three drops of fluid and the manipulation spatula; (B) Manipulation screen of the fourth powder increment. It is seen three bars of progression: 1—time progression of the manipulation, 2—progression of use of the plate area, 3—progression of powder incorporation; (C) Instant feedback screen about manipulating the powder increment: positive message for homogeneous mixture and negative message for plate area underused; (D) Feedback screen with final score of the mix, counting all increments.

Fig. 4. Film thickness test scheme.
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There was no significant difference between GIC and GLC.

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the G IVLO (1138.5 ± 9.65 B,a) had a lower film thickness than the GIC (25 ± 9.3 A,a) and the other plate was applied over the drop. A load of 150 ± 3 N was placed for 10 min. After this period, the thickness of the cement boards together was measured by subtracting the values that had been obtained for the thickness of the concrete film (Fig. 4).

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Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>GIC 9.3 A,a</th>
<th>GIVLO 27.08 A,b</th>
<th>GLC 22.5 ± 9.65 B,a</th>
<th>GLVLO 25.5 ± 9.61 B,a</th>
<th>* Different capital letters in the same column show differences between groups (p &lt; 0.05).</th>
<th>* Different lowercase letters on the same line show differences between groups (p &lt; 0.05).</th>
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<tr>
<td>Group</td>
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<td>Longitudinal</td>
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<tr>
<td>Control</td>
<td>25 ± 9.3 A,a</td>
<td>50 ± 27.08 A,b</td>
<td>22.5 ± 9.65 B,a</td>
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thickness of two combined glass plates (40 mm × 40 mm × 5 mm). After the student handled the material, a drop of cement was applied to one of the plates and the other plate was applied over the drop. A load of 150 ± 3 N was placed for 10 min. After this period, the thickness of the cement boards together was measured by subtracting the values that had been obtained for the thickness of the concrete film (Fig. 4).

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2.4.2. Setting time

The initial setting time test was conducted according to ISO 9917-1 (ISO 9917-1:2003). After 90 s of material preparation, the material was placed in a metal matrix with an inner diameter of 10 mm and a height of 1 mm. Then, a needle with a mass of 400 g (± 5 g) and a flat end, with a 1 mm (± 0.1 mm) diameter, was placed vertically on the horizontal surface of the material for 5 s, and this surface was visually inspected to verify indentations (Fig. 5). This measurement was repeated every 10 s, until it had not scored a full circle in the material. The time was clocked from the beginning of the material preparation until no indentations appeared during the repetition of the process.

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2.5. Survey

The evaluation of the VLO was prepared as a survey composed of thirteen questions. Five-point Likert scale items (responses 1 Never to 5 Very Frequently) ascertained the student’s perspective regarding the technological and technical aspects. The survey was based on the Guidelines for Learning Objects assessment [29]. To estimate the reliability of the survey, Cronbach’s alpha was applied.

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2.6. Statistical analysis

A paired t-test was used to compare the pre/posttest theoretical knowledge within the same group. A t-test was used for the analysis between the groups. Two-way ANOVA was used to compare the laboratory tests with the use or not of the VLO. The p-value was set at <0.05 significance.

3. Results

The values for the film thickness are shown in Table 1, the measure is given in micrometers (ISO9917-1:2003). In the immediate groups, the GIVLO (16.24 ± 5.17) had a lower film thickness than the GIC (25 ± 9.3) (p < 0.05). The GIVLO (22.5 ± 9.65) had a lower film thickness than the GIC (50 ± 27.08) (p < 0.05). When the traditional teaching methodology was used, GIC had a film thickness lower than that of the 15-day group (p < 0.05). There was no significant difference between GIVLO and GLVLO. The values for the setting time are given in Table 2, in seconds. In the immediate groups, the GIVLO (1138.5 ± 177.95) had a higher setting time than the GIC (896 ± 218.90) (p < 0.05). There was no difference between the groups within 15 days. When the VLO was used, the GIVLO showed a higher setting time than the GLVLO (999.16 ± 189.45) (p < 0.05). There was no significant difference between GIC and GIC-

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Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>GIC 896 ± 218.90 A,a</th>
<th>GIVLO 1138.5 ± 177.95 B,a</th>
<th>GLC 999.16 ± 189.45 B,a</th>
<th>GLVLO 955.4 ± 354.87 A,a</th>
<th>* Different capital letters in the same column show differences between groups (p &lt; 0.05).</th>
<th>* Different lowercase letters on the same line show differences between groups (p &lt; 0.05).</th>
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<td>VLO</td>
<td>896 ± 218.90 A,a</td>
<td>1138.5 ± 177.95 B,a</td>
<td>999.16 ± 189.45 B,a</td>
<td>955.4 ± 354.87 A,a</td>
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4. Discussion

The learning virtual object’s influence on the theoretical knowledge and laboratory skill manipulation of zinc phosphate cement was evaluated in this research. The VLO was composed of pictures and narration regarding cementing agents with emphasis on zinc phosphate cement. Video and virtual simulation of zinc phosphate cement handling was developed in the object. Gamification elements were added to the virtual simulation as instant feedback, with a progress bar of the mix, delimitation of the time and the final score. In this study, the use of VLO with virtual simulation improved the performance of the undergraduate students on the test of theoretical knowledge and manipulation skills of zinc-phosphate cement.

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In the pretest assessment, there was no difference between the students of the two groups, showing homogeneity in the distribution of the sample [21]. In the posttest, the GIVLO showed better results than GIC, with a significant difference (p-value < 0.05). This difference could be explained by the easiest access to VLO during the period of 15 days, with access by the web and with mobile devices. There was no significant difference between the GIVLO and GIC in the posttest. The reason for this lack of difference is probably that GIVLO used the VLO for only 15 min whereas the average operating time of GIVLO was approximately 24 min. Another reason for the lack of difference might be the correlation with access time because the students with greater access to the VLO performed better in the posttest [11,30]. In our study, this correlation was not statistically significant. In general, the groups that used the VLO performed better, and these results were due to the cognitive response of these students to a visually appealing and interactive methodology as opposed to a book, which is a static teaching material [17].

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In addition to the best theoretical performance, the students who used the VLO showed a better manipulation ability. Regarding the film thickness test, the GIVLO and GLVLO obtained a lower film thickness value than the GIC and GIC, (p-value < 0.05). This dif-

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Table 3 shows the mean and standard deviation of the theoretical knowledge tests. There was a significant difference in the test of theoretical knowledge tests. There was a significant difference in the posttest score of GIC (6.0 ± 1.15) and GIVLO (7.33 ± 1.43). The students in the VLO longitudinal mode scored better in the posttest than did the students in the traditional mode. There was no significant difference between the other groups. For the VLO evaluations, 84.6% of the responses were 5 (very frequently), and 15.4% of the responses were 4-(frequently). The Cronbach’s alpha value was 0.57.

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Table 3

<table>
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<th>Variable</th>
<th>GIC 6.0 ± 1.15 A,a</th>
<th>GIVLO 7.33 ± 1.43 A,a</th>
<th>GLC 7.1 ± 1.10 A,#</th>
<th>GLVLO 7.41 ± 0.9 A,#</th>
<th>* Different capital letters in the same column show differences between groups (p &lt; 0.05).</th>
<th>* Different lowercase letters on the same line show differences between groups (p &lt; 0.05).</th>
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<td>Pretest</td>
<td>7.37 ± 1.18 A,a</td>
<td>7.12 ± 1.18 A,a</td>
<td>7.1 ± 1.10 A,#</td>
<td>7.41 ± 0.9 A,#</td>
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<tr>
<td>Posttest</td>
<td>7.37 ± 1.68 A,a</td>
<td>8.12 ± 1.45 A,a</td>
<td>6.0 ± 1.15 A,#</td>
<td>7.33 ± 1.43 A,#</td>
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The results obtained in this VLO with virtual simulation should not imply positive outcomes in other topics of dental materials science. Since dental clinicians use a wide spectrum of materials, such as impression and restorative materials, should have its efficacy investigated. Further, future studies should evaluate longer periods before manipulation and present demonstrations of ZPC manipulation as control groups. VLO of dental materials and techniques with efficacy could be a supporting tool at telehealth system reaching clinicians in rural areas and increasing the efficacy of continual educational programs.

Equivalent use of digital media for education to that used in the traditional method at different levels is assured in the literature [36]. The use of VLOs as teaching tools in the classroom has become important when the contents of the VLO have a close relationship with the course curriculum [37]. Serious games are useful tools for many pedagogical goals, regardless of the social class, gender and age of the student [38]. This study showed that an interactive VLO, with stories, pictures, videos and virtual reality simulation was able to improve the theoretical knowledge and handling ability in dentistry undergraduate students. In the future, with the development of effective dental materials VLOs, schools of Dentistry could integrate the virtual reality as a part of the undergraduate and graduate curriculum reducing the time spent with classroom.

5. Conclusion

The use of VLO with virtual simulation improved the performance of undergraduate students in a zinc phosphate cement handling procedure. The students who used the VLO produced ZPC
material with better characteristics. For an extended time (15 days), the VLO provided greater retention of the acquired knowledge. VLO might be a useful tool for improving the learning process in dentistry. Further clinical trials involving other dental materials and population, such as clinicians of public health system are needed to confirm these findings. The use of VLO in Dentistry could enhance continual educational programs increasing the quality of health assistance.

Authors contributions

Rodrigo Alves Tubelo, DDS, MSc

- drafting of the manuscript;
- conception and design;
- analysis and interpretation of data;

Vicente Leitune Castelo Branco, DDS, MSc, PhD

- critical revision of the manuscript for important intellectual content;

Alessandra Dahmer, BCS, MSc, PhD

- critical revision of the manuscript for important intellectual content;
- technical and material support;

Susana Maria Werner Samuel, DDS, MSc, PhD

- supervision of study;

Fábio Mezzomo Collares, DDS, MSc, PhD

- conception and design;
- drafting of the manuscript;
- statistical analysis;
- analysis and interpretation of data;

Conflict of interest

The authors report no conflict of interest. The authors alone are responsible for the content and writing of the article.

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References


Silvia Maria Werner Samuel, DDS, MSc, PhD

- conception and design;
- statistical analysis;
- analysis and interpretation of data;

A learning object with audio, video, animation and simulation improve theoretical learning of dentistry students.

The use of virtual reality complemented by gamification elements improve the ability of dental materials manipulation in dentistry students.


