Development and evaluation of the use of a virtual learning object with virtual simulation on alginate

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ABSTRACT

The aim of the present study was to develop a Virtual Learning Object (VLO) on impression materials, with emphasis on alginate, and to evaluate the influence of its use on the theoretical learning and clinical skills of dental students, as well as on the physical properties and material mechanics. Sixty-four students received a theoretical lecture on alginate and were later divided into 2 groups, Control (n=30) and VLO (n=34). The VLO group had access to the educational tool composed of theoretical content and simulation of alginate mixing, and their ability was evaluated. All participants performed a pre-test after the theoretical class, as well as tests of ability to handle the material, which was subjected to a compressive strength test and detail reproduction. A post-test evaluation was performed after fifteen days. The results of the groups were compared by the t test, logistic regression model and significant variables were included in the multiple regression model. All analyzes were conducted with a significance of 5%. In the VLO simulation, 75% of the users obtained the maximum score and the results of the theoretical assessments did not indicate a statistical difference between the groups. The use of VLO is related to greater clinical skill, with 3.76 more chances of correct incorporation of the powder. In the compressive strength test, the mean of the groups was higher than that recommended by the standard, VLO 0.86±0.03 and Control 1.09±0.04. The developed tool has a positive influence on the clinical ability and mechanical property of the material studied, constituting itself as a promising strategy of virtual learning.

Descriptors: Dental Materials. Materials for Dental Impression. Distance Education. Interactive Learning. Simulation Training.

1 INTRODUCTION

The inclusion of Information and Communication Technologies (ICT) in the scope of education is a growing reality, made possible by the increase in the coverage of access to the internet. Its introduction is emerging in institutions and is related to encouraging active and meaningful learning through modern and accessible teaching environments, in which the learning process becomes more attractive and dynamic[1]. Digital resources represent a potential teaching tool, with a great contribution to the training of professionals from different areas[2], in addition to being a relevant alternative to the profile of current students, who present a natural approach and consumption of technology[3].

Virtual Learning Environments (VLE) can be understood as spaces that provide the distribution, use and interaction of technological multimedia and the internet in order to obtain an improvement in the quality of learning, as they facilitate access to resources and services for exchange and collaboration[4,5]. The Virtual Learning Objects (VLO) are part of the VLEs, which are educational tools that encourage the student to use technology for the sake of education. The use of virtual simulation is one of the modalities of interaction that contributes to the students' learning experiences, promotes the development of motor skills and has the role of providing an interface that simulates a clinical or laboratory environment, while stimulating the dissemination of knowledge autonomously without restrictions related to physical space or time[6,7]. Gamification techniques are often used in the VLO format to make learning more engaging compared to traditional educational practices. Gamification consists of the use of game elements (narrative, feedback system, competition, objectives, clear rules, trial and error) to create learning spaces mediated by challenge and entertainment[8].

In Dentistry, alginate has been a widely used impression material since its inception, due to its acceptance related to patient comfort, low cost, ease of use, for dismissing the use of sophisticated equipment for its preparation and for its ability to reproduction with good precision of detail, when used correctly[9,10]. However, the handling of alginate requires great technical sensitivity, it requires attention with regard to its specifications, such as the powder and liquid proportion, handling, molding and plaster casting, to guarantee its physical, chemical and mechanical properties[11]. Therefore, training is necessary on an ongoing basis through the use of e - learning tools, which have great popularity and approval among students. Therefore, the aim of the present study was to describe the development of an VLO on alginate and to evaluate the influence of its use on theoretical learning, clinical skill and physical and mechanical properties of alginate in undergraduate Dentistry students.

2 METHODS

VLO development

At first, the contents were selected and organized. In the next step, the media were developed and organized. In the elaboration of the layout, two software's were used: Adobe Photoshop CS6 (Adobe System, Inc., San Jose, California - USA) and Articulate Storyline 2 (Articulate Global, Inc., New York, NY - USA)[12]. The Articulate Storyline 2 software allowed the insertion of the material made in a digital platform, with access made available to students via a *link* in the VLE Moodle.

The production of digital didactic content was developed from the *storyboard* according to the lesson plan present in the course syllabus and approved by the faculty (figure 1). The demonstration video of the alginate's manipulation that was incorporated into the tool was developed from the SEAD public notice nº 19 and produced at the Laboratory of Dental Materials (LAMAD) of the Federal University of Rio Grande do Sul (UFRGS). For the immersive experience of alginate manipulation, gamification techniques were applied in order to promote motivation for use, repetition and competition. A virtual simulator was developed using non-immersive virtual reality, which can be understood as the articulation of 3D images that can be interactively explored using cell phone screens, keyboard, *mouse*, headphones and the like[13].

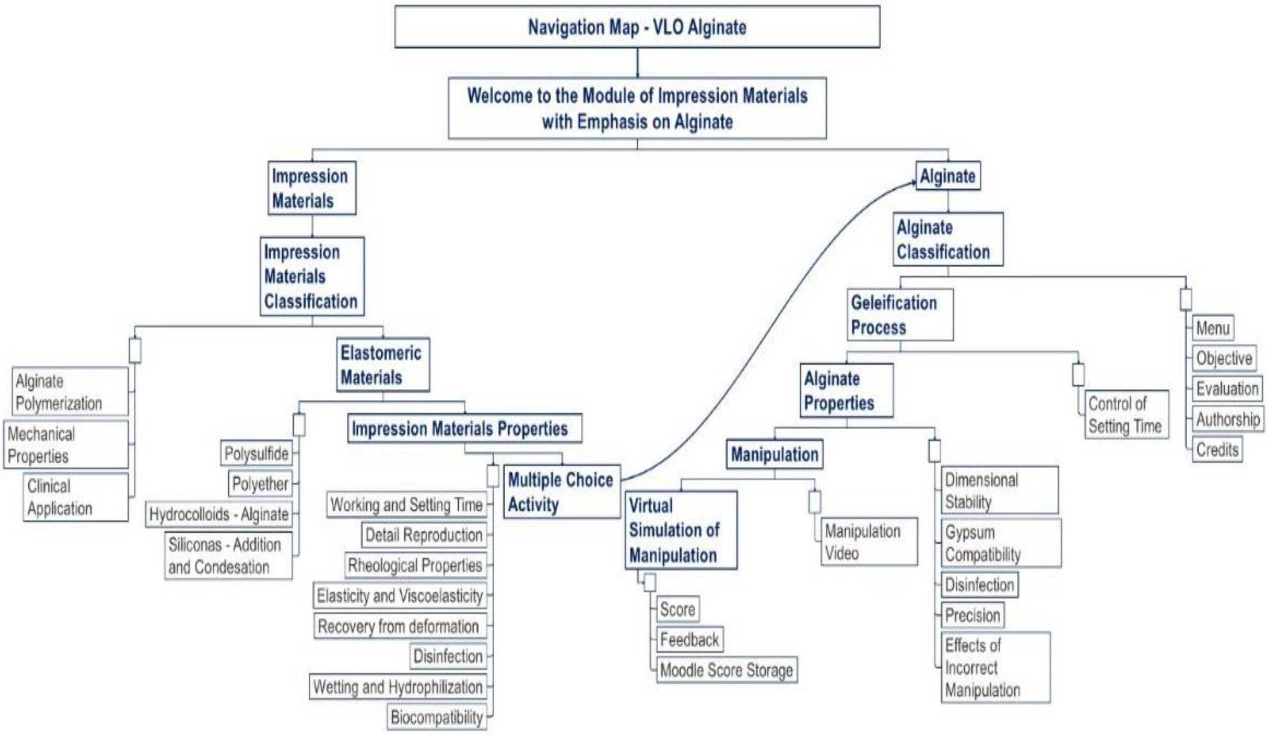

Figure 1. Storyboard VLO production

Study Design

It is a technological production and non-randomized clinical trial. The trials were carried out in partnership between LAMAD/UFRGS, Universidade Aberta do SUS, Universidade Federal de Ciências da Saúde de Porto Alegre, and SEAD/UFRGS. This study was registered in Plataforma Brasil CAAE: 37069220.6.0000.5347 and approved by the institutional ethics committee under the no. 4.396.043.

Sixty-four dental students participated in the study, divided into two groups: VLO (n=34) and Control (n=30) (figure 2). The inclusion criterion was to be taking the Dental Materials course and the exclusion criteria were not complying with any of the stages of the study, having previous contact with the course or having previously handled the material under study.

Evaluation

For evaluation purposes, pre-test and post-test theoretical questionnaires were considered (figures 3 and 4), evaluation of the mean obtained in the simulator present in the VLO, laboratory performance and quality of the sample produced (detail reproduction and compressive strength).

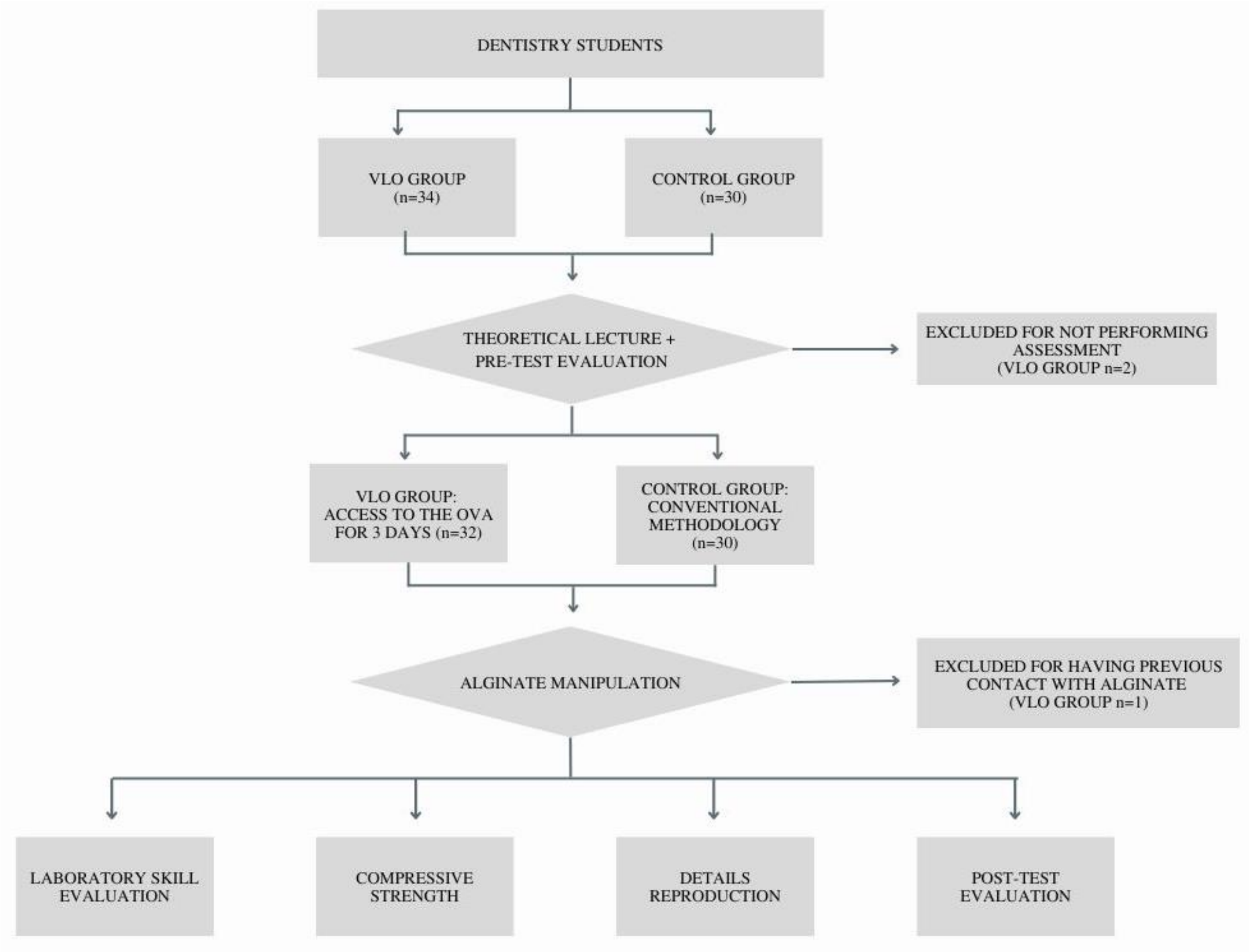

Figure 2. Study design organization chart

Theoretical questionnaires

Developed from the lesson plan administered to the two groups and approved by the professors of the area, the first evaluation (called pre-test) was carried out with the research participants immediately after receiving the expository lecture on molding materials and alginate, in which the objective was to measure the understanding of the class. After fifteen days, a new assessment was carried out (called a post-test) consisting of questions relevant to the previously studied content and the laboratory experience, with the objective of verifying whether the use of the VLO influences learning retention.

Evaluation of the virtual simulation

In the virtual simulation step of the alginate manipulation, the images of a mortar and a water dispenser are shown to the student, who must add water to the mortar to proceed to the next task. Then is shown an alginate dispenser loaded with a portion of the powder to be incremented (figure 5). In the next step, with the spatula, it is necessary to vigorously manipulate the entire available area in the mortar. The higher the manipulation frequency, the higher the score, until the pre-defined number of times as the maximum incorporation *score* is reached. The incorporation of powder during handling is also evaluated by checking the spatula's passage through four checkpoints arranged in the mortar. Through evolution bars it is possible to follow the performance in each of the variables over the simulation time, which is sixty seconds, starting after the contact of the water with the powder. At the end of the simulation, *feedback* is sent with the following information: average powder incorporation from 0-100%, average handling frequency from 0-100%, and a performance report. To ensure that all students in the VLO Group used the tool, a supervised simulation was performed and their final grade was recorded moments before the user underwent the laboratory evaluation.

PRE-TEST

1) Alginate has in its composition 4 groups of materials. They are: reagent, reaction accelerator, set retarder and charge particles. Choose an option: ( ) True ( ) False

2) Which of these alternatives are requirements of an impression material.
A) Long working time, difficult removal, excellent print quality, low cost, easy disinfection, unpleasant taste.
B) Long working time, easy removal, good print quality, unpleasant taste and odor, tissue irritant.
C) Short working time, easy removal, good impression quality, high cost, easy disinfection, pleasant taste and odor, tissue irritant.
D) Short working time, easy removal, good impression quality, low cost, easy disinfection, pleasant taste and odor, non-irritating to tissue.
E) Excellent impression quality, high cost, difficult to disinfect, pleasant taste and odor, non-irritating to tissue.

3) The alginate should be mixed slowly against the alginate mixing wall until the consistency is rough, homogeneous and uniform in color. Its objective is to form a three-dimensional network of polymers: Choose an option: ( ) True ( ) False

4) What is syneresis and alginate imbibition?
A) Syneresis: Gain of water to the environment (contraction), Imbibition: Loss of water from the environment (expansion).
B) Syneresis: Gain of water to the environment (contraction), Imbibition: Gain of water from the environment (expansion).
C) Syneresis: Loss of water to the environment (contraction), Imbibition: Loss of water from the environment (expansion).
D) Syneresis: Loss of water to the environment (expansion), Imbibition: Gain of water to the environment (contraction).
E) Syneresis: Loss of water to the environment (contraction), Imbibition: Gain of water from the environment (expansion).

5) Choose which mechanical property correctly fills the gap, according to the explanation.
_______________ maximum stress that can be supported by a structure.
_______________ ability to absorb and dissipate energy.
_______________ ability of a material to absorb energy until it fractures.

A) Resistance or Elasticity.
B) Resilience or Viscosity.
C) Tenacity or hardness.

6) What are the possible failures in the manipulation of alginate? Choose one.
A) Incorrect handling, tearing and Imbibition.
B) Anelastic, rigid material and air bubbles.
C) Viscosity, tearing and syneresis.
D) Tearing, premature removal and air bubbles.
E) Elastic, viscous and tearing material.

7) Among the elastomers, polysulfide and condensation silicone present polymerization shrinkage due to the loss of by-products and require the plaster to be poured immediately after the polymerization reaction. Choose an option: ( ) True ( ) False

8) Regarding the manipulation of alginate: Handling the powder must avoid contact with the walls of the alginate mixing. Choose an option: ( ) True ( ) False

Figure 3. Pre-test theoretical questionnaire

POST-TEST

1) Alginate is an impression material that can be defined as a type of:
A) Reversible hydrocolloid.
B) Resin-modified heavy silicone.
C) Stone plaster.
D) Irreversible hydrocolloid.
E) None of the alternatives.

2) Tick the correct option:
A) Alginate is an elastic material.
B) Alginate is a material that undergoes an exothermic reaction.
C) Alginate is a material that does not require disinfection.
D) Alginates are no longer used due to the difficulty of handling.
E) None of the alternatives.

3) In alginates, dimensional stability is related to the characteristic of the GEL to absorb water from the medium. Choose an option: ( ) True ( ) False

4) When mixing the alginate: First, put the powder and then the water alginate mixing bowl according to the proportion 1:1, after that, vigorous mixing against the walls of the alginate mixing begins until a homogeneous, smooth and shiny mixture is obtained called GEL. Choose an option: ( ) True ( ) False

5) During the manipulation of alginate, some precautions are essential and must be followed, check the (s).
( ) Shake the powder before use.
( ) Use vinyl gloves to avoid interfering with the setting.
( ) Use of a mask to avoid silica inhalation.
( ) Close the container tightly after use.
( ) Add extra water until you get the desired consistency for impression.

6) When making an impression with alginate, it is recommended that the gypsum be poured as soon as possible because the alginate suffers the phenomena of:
A) Syneresis and gelation.
B) Crystallization and imbibition.
C) Gelation and crystallization.
D) Syneresis and imbibition.
E) Exothermic setting and gelation.

7) The function of alginates is to produce a negative copy of the structures of the oral cavity and also extraoral, which will be reproduced in a model (positive copy of the structure). There are two types of alginate to copy these structures: Type 1 of normal setting that varies from 1.5 to 3 minutes and Type 2 of fast setting that varies from 3 to 4.5 minutes. Choose an option: ( ) True ( ) False

8) The purpose of vigorous mixing against the walls of the alginate mixing is to form a three-dimensional network of polymers. Choose an option: ( ) True ( ) False

9) List the columns:
1- Imbibition ( ) Do not drain from the spatula.
2- Syneresis ( ) Gain of water from the environment.
3- Viscosity ( ) Loss of water to the environment.

10) The alginate gelation reaction can be influenced by the temperature of the environment or water, the higher the temperature, the shorter the working time.
Choose an option: ( ) True ( ) False

Figure 4. Post-test theoretical questionnaire

Figure 5. Screenshot of the OVA with virtual simulation of alginate manipulation

Laboratory evaluation

For the purpose of evaluating clinical skills in a laboratory environment, in the intermediate stage of the evaluation, participants were asked to prepare a portion of alginate as exemplified in the theoretical class and in the content of the educational tool, used by the VLO group. During the preparation of the material, the students were evaluated according to the following criteria: Agitation of the powder inside the alginate storage container, so that the levels of filler particles are guaranteed; Powder-water order, regarding the placement of inputs in order in the mortar; Respect to the proportion recommended by the manufacturer; Handling time between 45 and 60 seconds; Handling/manipulation is defined here as vigorous mixing against the walls of the mortar; Incorporation of powder at the end of mixing and Use of personal protective equipment (PPE).

Detail Reproduction

For the detail reproduction test, the alginate sample manipulated by the student was inserted into a matrix with 30 mm in diameter and 6 mm in height. Immediately after receiving the hydrocolloid material, the matrix was placed in a water bath at 35°C ± 1°C, under a weight of 1Kg. After a period of 3 minutes the alginate sample was removed from the metal ring and excess water was removed. Detail reproduction will be considered positive if the 50 µm line is fully reproduced over the 25 mm length between the intersecting lines[14].

Compressive Strength

After handling the impression material by the student, the alginate was introduced into a metallic matrix, with a diameter of 12.5 mm and a height of 20 mm, positioned on a glass plate. Then, a second plate was fixed over the matrix to form the upper surface of the sample. The matrix was placed in a water bath at 35°C ± 1°C, weighing 1Kg. After a period of 3 minutes, the alginate sample was removed from the metallic ring and submitted to the compressive strength test (DL-2000, EMIC, São José dos Pinhais, Brazil). The samples were continuously and uniformly loaded to produce an average compression ratio of 100 N.min-1 ± 20 N.min-1 until the first graphic sign of fracture was recorded. The compressive strength is calculated in megapascals (MPa), according to the formula: $K= 4F / \pi d^2$ where F is the fracture force (N) and d is the diameter of the specimen (mm)[15].

Statistical analysis

Data normality was assessed by the Shapiro-Wilk test. The different groups were compared by the t test for pre- and post-theoretical test results and compressive strength. Response variables were used in a logistic regression model with different groups as the predictor variable. The variables response, compressive strength and detail reproduction were submitted to univariate analysis, and significant variables were included in the multiple regression model. All analyzes were conducted with a significance of 5%.

3 RESULTS

Of the 64 students selected for the study, two were excluded because they did not accept to perform the initial assessment and one participant was excluded because he had already taken the Dental Materials course and had experience in handling the material studied. Thus, 31 students remained in the VLO Group and 30 students in the Control Group. Students in the experimental group, who had free access to the VLO for 3 days, performed a supervised simulation stage and the result was recorded. Regarding the frequency of manipulation, 100% of the users obtained maximum use, grade 100. For the incorporation of the powder, 75% of the users reached the maximum grade. There was no statistically significant difference between the groups in the results of pre- and post-test theoretical assessments ($p>0.05\%$). There was also no statistically significant difference between the moments evaluated within each group ($p>0.05\%$). Compressive strength was significantly higher for samples obtained from the Control group (table 1).

Table 1. Pre- and post-test results for the VLO and Control groups. The compressive strength for the different groups was presented in MPa.

	Theoretical Assessment		**Compressive Strength**
Group	Pre-test	Post-test	(MPa)
Control	7.33 (±0.33) Aa	7.90 (±0.25) Aa	1.09 (± 0.04) A
VLO	7.47 (±0.19) Aa	8.09 (±0.23) Aa	0.86 (± 0.03) B

Different capital letters indicate a statistically significant difference in the same column ($p<0.05$). Equal lowercase letters indicate that there is no statistically significant difference in the same row, between pre- and post-test ($p> 0.05$).

At univariate analysis (table 2) the results of the dust-water order were not included, as all subjects in both groups performed the manipulation in the correct order. Powder agitation, handling time, handling/manipulation, powder incorporation and detail reproduction were statistically significant in the univariate analysis. The variables of detail reproduction and handling/manipulation resulted in multicollinearity and were not included in the adjusted multiple logistic regression model.

Table 2. Univariate analysis for different variables after interventions with VLO or control

Variable	P
Dust	0.036
Water: powder ratio	0.668
Handling time	0.031
Handling / Handling	0.000
Powder agitation	0.006
Use of PPE	0.530
Compressive strength	0.284
Detail reproduction	0.005

Table 3 shows the multiple logistic regression with the VLO group as the predictor variable. The Control group was used as a reference for the analysis. The incorporation of the powder showed statistically significant coefficient values in the adjusted model. The use of VLO increased the chance of adequate incorporation of the powder by 3,76 times when compared to the control group. The time for stirring and handling the powder was not statistically significant in the fitted model.

Table 3. Odds Adjusted ratio for powder agitation, handling time and powder incorporation between VLO and Control used in a multiple logistic analysis

Variable	Multiple logistic regression					
				Number of observations: 61		
				Pseudo R^2: 0.2918		
	OR	Std. error	z	P	95% Confidence Interval	
Dust	2.533	1.593	1.48	0.139	0.738	8.691
Handling time	3.100	2.168	1.62	0.106	0.787	12.214
Powder Incorporation	3.768	2.234	2.24	0.025	1.178	12.048
_cons	0.191	0.128	-2.46	0.014	0.051	0.715

4 DISCUSSION

The influence of the use of an VLO on theoretical learning, clinical skill, and physical and mechanical properties of alginate was evaluated in this research. The VLO composed of narration, animation and texts, also has a video tutorial and virtual simulation, in which gamification techniques were applied, such as instant feedback, progress bars, time delimitation and final score. In this study, the use of VLO with virtual simulation had a positive influence on the clinical ability of undergraduate students of

Dentistry and on the mechanical property of alginate.

The use of VLO has shown advantages in face-to-face classes, functioning as a facilitator, as well as in distance learning, promoting student motivation[16]. It has already been seen that its use improves the learning experience in clinical simulation scenarios and contributes to the development of competences for providing health care, and skills training [12,17-19.] The VLO developed follows the recommendations presented in Kavadella *et al*. (2003)[20], is simple, can be used in different contexts and equipment's, has clear learning objectives, addresses the individual needs of students, as it allows navigation in modules, is visually attractive, interactive and provides *feedback*. In the simulation present in the OVA, 75% of the users obtained a maximum average, taking into account the two evaluated items. This result indicates that there was great use of the tool and easy development of skills and abilities required for its use, despite the limited time of prior access available.

There was no statistically significant difference in the pre-test average scores between students in the two groups, showing homogeneity in the distribution of the sample[21]. The average of the final (post-test) assessment scores also indicates similar levels of learning retention in the two groups. However, a study with a similar methodology, which provided more time to use the VLO, showed better theoretical performance of users, when compared to the Control group[12].

Alginate is an irreversible, viscoelastic molding material. Its gelation process occurs through a sol-gel reaction, in which, in the presence of water, sodium (or potassium) alginate reacts with calcium sulfate forming a cross-linked molecular network. At first, it is difficult to be successful in its manipulation, normally the failures and the need for repetition are associated with non-compliance with the basic principles for molding, low understanding of its properties or inadequate manipulation by the operator[22,23]. In this study, seven items were evaluated regarding the handling and the result is that the use of VLO increases the chances of correct incorporation of the powder by 3.76 times, defined here as obtaining a homogeneous mixture at the end of the mixing time. In order to obtain success in this variable, the variables of powder agitation inside the alginate storage container are also related, so that the levels of filler particles are guaranteed; water-powder ratio; respecting the handling and handling time through vigorous mixing against the walls of the mortar. The mastery of the evaluated points is essential for the minimization of flaws such as granular material and inadequate dissolution of the components, which can affect their properties of dimensional stability, detail reproduction and compressive strength.

Compressive strength is an important mechanical property of alginate, it is related to the removal of the impression and the production of the plaster model. When removed from the mouth, the alginate must have sufficient strength to prevent breakage and the impression must resist the weight of the plaster without distorting to ensure dimensional fidelity in the copied area[24]. In the present study, the Control group and the VLO group obtained means above 0.35 Mpa, a result recommended by the ADA standard n°18, 1.09 (±0.04) and 0.86 (±0.03), respectively. The control group presented higher compressive strength results, and it can be thought that they obtained better results for clinical application. On the other hand, a high compressive strength in the gelled alginate may represent that it has less elasticity, influencing the dimensions of the final model or its fracture at the time of impression removal[15].

The tool developed was able to exert a

positive influence on the clinical ability, since it improved the incorporation of the powder, as well as obtaining a better mechanical property, through the most adequate mean value of compressive strength when compared to its control. According to the results obtained, the VLO is a promising tool for the insertion of virtual learning strategies in Dentistry.

5 CONCLUSION

The VLO with virtual simulation on alginate in Dentistry was successfully developed, according to the planning of the manufacturing steps. From the results obtained in the study, it is concluded that the VLO has a positive influence on the clinical ability of its users, on the mechanical property of the material studied and shows itself as a simple, objective and promising tool for the introduction of virtual learning strategies in Dentistry.

RESUMO

Desenvolvimento e avaliação do uso de um objeto virtual de aprendizagem com simulação virtual sobre alginato

O objetivo do presente estudo foi desenvolver um Objeto Virtual de Aprendizagem (OVA) sobre materiais de moldagem, com ênfase no alginato, e avaliar a influência do seu uso sobre o aprendizado teórico e habilidade clínica de estudantes de Odontologia, assim como sobre as propriedades física e mecânica material. Sessenta e quatro estudantes receberam aula teórica expositiva sobre alginato e posteriormente foram divididos em 2 grupos, Controle (n=30) e OVA (n=34). O grupo OVA teve acesso à ferramenta educacional composta de conteúdo teórico e simulação de espatulação do alginato, sendo sua habilidade avaliada. Todos os participantes realizaram um pré-teste após a aula teórica, assim como testes de habilidade de manipulação do material, o qual foi submetido a ensaio de resistência à compressão e reprodução de detalhes. Uma avaliação pós-teste foi realizada após quinze dias. Os resultados dos grupos foram comparados pelo teste t, modelo de regressão logística e as variáveis significativas foram incluídas no modelo de regressão múltipla. Todas as análises foram conduzidas com significância de 5%. Na simulação do OVA 75% dos usuários obtiveram nota máxima e os resultados das avaliações teóricas não indicaram diferença estatística entre os grupos. O uso do OVA está relacionado à maior habilidade clínica, com 3,76 mais chances de correta incorporação do pó. No ensaio de resistência à compressão a média dos grupos foi superior ao preconizado pela norma, OVA 0,86±0,03 e Controle 1,09±0,04. A ferramenta desenvolvida exerce influência positiva sobre a habilidade clínica e propriedade mecânica do material estudado, constituindo-se como promissora estratégia de aprendizagem virtual.

Descritores: Materiais Dentários. Materiais para Moldagem Odontológica. Educação a Distância. Aprendizagem Interativa. Treinamento por Simulação.

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