Abstract: The aim of the present study was to analyze the parameters recorded by the Simodont dental trainer and methacrylate block grades during preclinical practicums to validate whether manual skills can be assessed by both methodologies, over a period of two years and to obtain a preclinical evaluation methodology for all the parameters that measure Simodont performance in each of the prepared figures. To this end, the methacrylate block practice’s criteria and evaluation scale were used as predictors. A total of 82 students who completed the first year of dentistry were followed for 2 years. Their performance on the same task (i.e., cavity preparation of three figures in the Simodont and methacrylate blocks) was then reevaluated in the third year. Manual skill improvement was detected in all the students. The parameters measured by the Simodont were used as predictors of the methacrylate block evaluation’s results, performed by a professor. Multiple linear regression models for each of the figures and years evaluated in the study were proposed. The present study demonstrates that both methodologies can detect manual skill improvement in dental students. Additionally, the Simodont practice can be reliably evaluated.

Keywords: competencies, dental trainer, methacrylate blocks, operative dentistry, preclinical assessment

Introduction

Dentistry students’ training is directed toward the acquisition of professional skills [1]. These include diagnosis, prognosis, prevention, planning, and execution of dental treatment [2,3]. During their professional and personal development, which is the basis for incorporating fundamental skills (cross-cutting and specific), students integrate all of this knowledge [3]. Professors play key roles in skills acquisition by dentistry students. The development of students’ clinical abilities while students obtain a dentistry degree has always been performed with the support of preclinical practice [4-8]. The latter serves as training for students and assessment of their abilities [5,6,7]. In the School of Dentistry of Complutense University of Madrid (UCM), during the first and third years of the dentistry program, preclinical practices are organized into two basic types of teaching environment: traditional laboratory practicums [practice in methacrylate blocks (MBs) and in typodonts mounted on the head of a mannequin] and dental simulators. Through this new technology, students obtain immediate feedback. This allows them to correct errors performed during their practice. Consequently, students can gain experience until the goal is met. Additionally, students may repeat their training as many times as necessary to improve the learning curves based on simulation [1,3].

Preclinical practices in the Simodont Dental Trainer (SDT) and MB are complementary [8-10]. Of note, practice in MB can be evaluated quantitatively, allowing the teacher to measure a student’s development both over an academic year or throughout the training [2,3,5-8,10]. Importantly, practice using the SDT provides error percentages for each parameter of practice, without numerical evaluation [3]. The aim of the present study was to establish an equation that uses a numerical scale from 0 to 10 to quantify the percentage results provided by the SDT.

Materials and Methods

Study design
A longitudinal panel study was designed from November 2014 to February 2016. A total of 82 students were selected from the dentistry program at UCM. Enrolled students had performed preclinical practice first in MBs and then in the SDT. The designs of these two tests are identical and consist of preparation of three cavities with geometric forms (i.e., bar, circle, and cross), performed sequentially within 15 minutes. Students received a brief explanation. The study was approved by the Hospital Clínico San Carlos Ethical Advisory Committee (C.I. 17/358-E).

Traditional preclinical practice: methacrylate blocks
A transparent MB (PT Polimer Tecnic SLU, Gerona, Spain) was used. It has the silhouettes of three figures (drawn in black with a width of 4 mm). Each figure design had a length of 15 mm and width of 7-15 mm (excluding the silhouette). After completing the task and preparing all cavities, the students provided the MBs to a single professor who evaluated the three figures. To avoid evaluation bias, the same professor evaluated all the participants in the first and third grades. Each figure was evaluated on a scale to obtain the methacrylate block grade (MBG) ranging from 0 (not performed) to 10 (excellent).

Simodont preclinical practice: manual dexterity
An SDT (Moog Inc., Nieuw-Vennep, Netherlands) with software 3.18.4 was used. Through the software, each student was tasked with removing simulated caries (red) in three figures, similarly to MBs. The SDT software recorded the following parameters (%): 1. percentage drilled segment target, which represents the percentage of caries to be completely removed within the time limit; 2. percentage drilled leeway bottom (PDSLb); 3. percentage drilled leeway sides (PDSLs); 4. percentage drilled container bottom (PDSCb) and 5. percentage drilled container sides (PDSCs), where variables 2 to 5 reflect students’ errors (i.e., the variables present the percentage of simulated healthy tooth structure unnecessarily removed, the leeway (healthy surface structure, green), and the container (healthy deeper structure, beige) in the floor (bottom) and in the walls (sides)); and 6. session time, which is real time (seconds), i.e., time used by the student during the practice.

Statistical analysis
A statistical analysis was performed using SPSS 22.0 for Windows (SPSS, Chicago, IL, USA). The Wilcoxon signed-rank test was used to compare parameters between the first and third years. An overall score of the SDT practices based on the evaluation of the MB was obtained by multiple linear regressions.

The coefficient of determination ($R^2$) and an adjusted coefficient of determination ($R^2_a$) were used to check the power of the equation proposed to calculate the MBG based on the SDT. Additionally, the Durbin-Watson
test for auto-correlation was conducted and variance inflation factor (VIF) was calculated. A model with VIF>5 was considered indicative of serious collinearity. Simple correlation coefficients (Spearman) between the SDT results and MBGs for the assessed figures and years were measured.

**Results**

A statistical improvement of both the mean MBGs and the MBG scores was observed in all the studied parameters from the first to the third years (\(P < 0.05\) in all cases). In the first year, a mean MBG score of 6.3 ± 0.9 was obtained. The score increased to 7.3 ± 1.2 in the third year for the bar figure (\(P < 0.00\)). Such result represents a mean increase of 15.87%. Similarly, increases of 13.43% and 11.76% for the circle and the cross figure, respectively (\(P < 0.00\)) were reported.

The MBGs were significantly and negatively correlated with the SDT parameters (Table 1). For PDSLB, the highest correlation coefficient was observed for the circle figure during the first year (\(r = −0.837; P < 0.001\)). Of note, PDSL was better correlated with the circle figure during the first year (\(r = −0.819; P < 0.001\)). Notably, the highest correlation coefficient between PDSCB and MBG was observed for the bar figure during the first year (\(r = −0.696; P < 0.001\)). Finally, for PDSCS the highest correlation was observed with the bar figure during the third year (\(r = −0.566; P < 0.001\)).

Table 2 highlights the six regression models of MBG proposed. The majority of the proposed models were recommended because of their very high adjusted coefficients of determination (R²a). Results of the present study indicate no significant multicollinearity between the variables derived from the regression models for the MBG.

**Discussion**

In this study, the manual skills of the same students through preclinical practice in the first and third years were assessed by evaluating their performance on the same geometric figures in MBs and the SDT. Notably, similar investigations have been conducted with different figures after several hours of training in both practices [6,9]. Results reported here confirm those by Bakker et al. [6], Urbankova et al. [9], and Rhenmora et al. [7]. Specifically, the authors demonstrated that the measured variables (i.e., PDSLS, PDSLB, PDSCS, PDSCB, and MBG) improved longitudinally and in sequential order of figure preparation, for the parameters measured with both the SDT and MBs [6,7,9].

As Urbankova et al. [9] suggested, it is believed that the improvements in all the parameters measured in both practices are due to the acquisition of theoretical concepts. Specifically, when students know the goal of the treatment simulation they are performing, they gain confidence and improved manual dexterity. These results are achieved despite having improved during the second student contact in both practices. Of note, such an improvement could be higher if students could practice during the second year [11]. In the SDT practice, the students can improve their performance exclusively by practice repetition. Specifically, the professor’s presence is not necessary for students to access the SDT. Consequently, the students’ curricular model relaxes, enabling the students to have free access to the SDT during their second year and allowing them to develop their full potential in skill development [10-12]. This methodology cannot be achieved in MB practice because the environment is different in terms of safety. Additionally, in the MB practice, the professor’s presence is needed both during practice and for evaluation, as concluded by Perry et al. [3], Bakker et al. [6], and Burlui et al. [2]. Therefore, it appears that the traditional methodology model is not as effective as the SDT because of the following aspects: creation of good learning habits, promotion of a culture of self-learning, and acquisition of new information [2,3,6].

MB’s evaluation was used to obtain a reliable methodology to evaluate the SDT practice with a strength linear association. In earlier studies, Leblanc et al. [4] and Jasinevicius et al. [6] proposed a different methodology to evaluate and compare practice in a simulator (DentSim, DenX, Jerusalem, Israel). Specifically, in this methodology, there was the need for a professor’s evaluation of a cavity prepared by a student in the simulator. The professor evaluated the student on a scale of 0-100, in intervals of 5 points, with the lowest grade being 60 and the highest being 95. The present study has several limitations. In earlier studies from Bakker et al. [6] and Urbankova et al. [9], two evaluators were used to evaluate preclinical laboratory practice. However, subjectivity during the methacrylate evaluation, attributable to a reliance on the evaluator’s own criteria may influence the evaluation. Consequently, it was attempted to reduce that error by using the evaluation by exclusively one professor. A second limitation of this study is the lack of control for inherent dexterity or clumsiness of the students. However, initially poor manual ability does not seem to be a discriminating factor for the success of anyone who wishes to become a professional dentist [1].

In the present study, preclinical methodologies of MBs and SDT detected improvements in the manual skills of first- and third-year dentistry students. Equations for each figure and year tested were developed and allowed the students to obtain practice reliably. Students’ evaluation was based on the grade they obtained for practice in MBs with similar geometric figures.

**Conflict of interest**

None declared.

**References**

1. Giuliani M, Lajolo C, Clemente L, Querqui A, Viotti R, Boari A et al. (2007) Is manual dexterity essential in the selection of dental students? Br Dent J 203, 149-155.
2. Burlui V, Gbirue C, Stadoleanu C, Roman M, Dusculescu R (2014) Advantages and difficulties in the practical application of the concept of continuing dexterity education. International Journal of Medical Dentistry 4, 196-201.
3. Perry S, Bridges SM, Burrow MF (2015) A review of the use of simulation in dental educa-

---

**Table 1** Bivariate correlation coefficients (Spearman) between methacrylate block grade and Simodont parameters at the years assessed.

| Variable | Bar | Circle | Cross |
|----------|-----|--------|-------|
| PDSLB    | -0.753 | -0.837 | -0.805 |
| PDSL     | -0.669 | -0.721 | -0.819 |
| PDSCB    | -0.696 | -0.574 | -0.632 |
| PDSCS    | -0.496 | -0.566 | -0.550 |

All the coefficients were significant (\(P < 0.001\)).

**Table 2** Models of equation for MBG determination, based on the Simodont parameters in dentistry students.

| Year | Figure | Regression equation | \(P\)-value | R | \(R^2\) | \(R^a\) | DW |
|------|--------|---------------------|-------------|---|---------|---------|-----|
| First | Bar    | 9.360 − 0.042 (PDSLB) − 0.038 (PDSL) + 0.007 (PDSCB) − 0.003 (PDSCS) | < 0.001 | 0.946 | 0.895 | 0.892 | 1.596 |
|       | Circle | 9.789 − 0.050 (PDSLB) − 0.049 (PDSL) + 0.009 (PDSCB) + 0.128 (PDSCS) | < 0.001 | 0.961 | 0.923 | 0.920 | 1.844 |
|       | Cross  | 9.406 − 0.040 (PDSLB) − 0.044 (PDSL) − 0.015 (PDSCB) − 0.044 (PDSCS) | < 0.001 | 0.925 | 0.855 | 0.851 | 1.951 |
| Third  | Bar    | 9.833 − 0.053 (PDSLB) − 0.042 (PDSL) | < 0.001 | 0.897 | 0.804 | 0.799 | 1.361 |
|        | Circle | 9.880 − 0.052 (PDSL) − 0.048 (PDSLB) | < 0.001 | 0.949 | 0.900 | 0.898 | 1.029 |
|        | Cross  | 9.851 − 0.052 (PDSL) − 0.048 (PDSLB) | < 0.001 | 0.884 | 0.782 | 0.776 | 1.141 |

DW, Durbin-Watson values.
4. LeBlanc VR, Urbankova A, Hadavi F, Lichtenhal RM (2004) A preliminary study in using virtual reality to train dental students. J Dent Educ 68, 378-383.
5. Jasinevicius TR, Landers M, Nelson S, Urbankova A (2004) An evaluation of two dental simulation systems: virtual reality versus contemporary non-computer-assisted. J Dent Educ 68, 1151-1162.
6. Bakker D, Lagerweij M, Wesseling P, Vervoorn M (2010) Transfer of manual dexterity skills acquired on the Simodont, a dental haptic trainer with a virtual environment, to reality. A pilot study. Bio-Algorithms and Med-Systems 6, 21-24.
7. Rhenmora P, Haddawy P, Suebnukarn S, Dailey MN (2011) Intelligent dental training simulator with objective skill assessment and feedback. Artif Intell Med 52, 115-121.
8. Wang D, Zhao S, Li T, Zhang Y, Wang X (2015) Preliminary evaluation of a virtual reality dental simulation system on drilling operation. Biomed Mater Eng 26 Suppl 1, 747-756.
9. Urbankova A, Engebretson SP (2011) The use of haptics to predict preclinical operative dentistry performance and Perceptual Ability. J Dent Educ 75, 1548-1557.
10. de Boer IR, Wesseling PE, Vervoorn JM (2013) The creation of virtual teeth with and without tooth pathology for a virtual learning environment in dental education. Eur J Dent Educ 17, 191-197.
11. Gal GB, Weiss EL, Gafni N, Ziv A (2011) Preliminary assessment of faculty and student perception of a haptic virtual reality simulator for training dental manual dexterity. J Dent Educ 75, 496-504.
12. Imber S, Shapiro G, Gordon M, Judes H, Metzger Z (2003) A virtual reality dental simulator predicts performance in an operative dentistry manikin course. Eur J Dent Educ 7, 160-163.