Enhancing Manual Dexterity through Virtual Simulation: A Comparative Analysis of Depth Control and Lateral Movement Accuracy

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Introduction

Simulation technologies have become an integral component of modern dental education, providing valuable support for the development of practical and psychomotor skills. The implementation of virtual reality and haptic simulation systems has become increasingly important in undergraduate dental training. However, the successful introduction of such technologies requires careful curriculum planning. Simulation exercises should be appropriately integrated into the existing curriculum, provide students with sufficient time to become familiar with the simulator and practice individual tasks, while also considering the time constraints of undergraduate education.

Questions

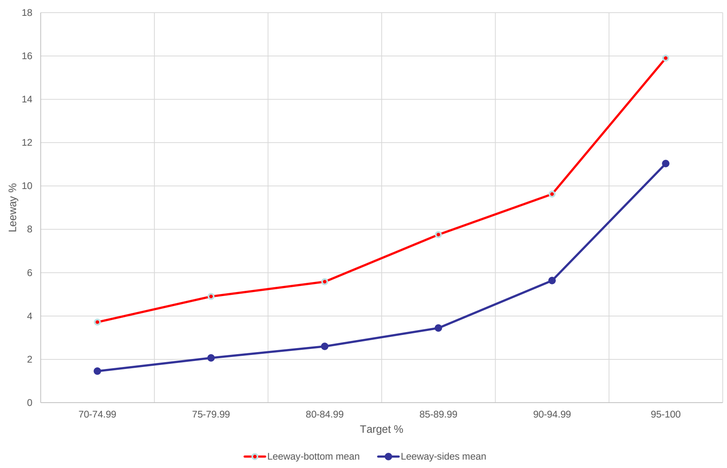
How should a simulation-based manual dexterity curriculum be optimally designed?
To what extent should time allocation be considered when planning such a course?
Which simulation exercises are easier or more challenging for undergraduate dental students?

Methods

The study was conducted involving undergraduate dental students (n =94) who had no previous experience using rotary dental instruments under either preclinical or clinical conditions. Manual dexterity was assessed using the **Simodont Dental Trainer**. Four standardized manual dexterity exercises were selected: **Channel (straight line), Cross, Circle, and Hollow Circle**. All exercises were performed under direct vision using a standardized **0.4 mm Leeway** setting for every task. Performance data generated by the simulator were collected and statistically analysed, focusing on lateral (Leeway-side) and depth-related (Leeway-bottom) deviations during target preparation.

Results: Leeway-bottom and side

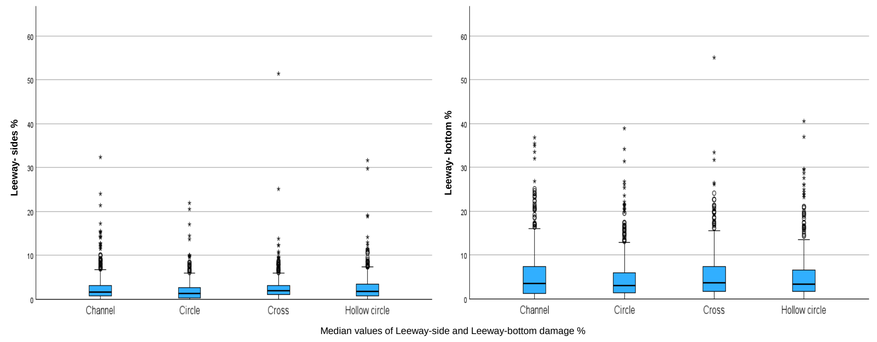
A total of **1,583 samples** were analysed. Across all four exercises (Channel, Cross, Circle, and Hollow Circle), students working under direct vision with a **0.4 mm Leeway** setting violated the **Leeway-bottom** significantly more frequently than the **Leeway-side** during target preparation. These findings indicate that depth control represents a greater challenge than lateral movement accuracy.



Plot of the reached target % of the sum of the four selected shapes against the Leeway %.

Results: More difficult task

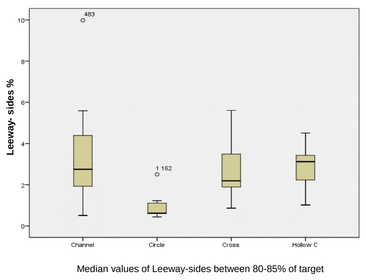
Based on the combined median values of Leeway-side and Leeway-bottom errors, the exercises could be ranked according to difficulty: **Circle < Channel < Cross < Hollow Circle**
Although no statistically significant differences were found between consecutive tasks, likely due to the limited sample size, significant differences were observed between: Circle vs. Cross, Circle vs. Hollow Circle, Channel vs. Hollow Circle.
These findings suggest that the geometric characteristics of individual exercises substantially influence task difficulty.



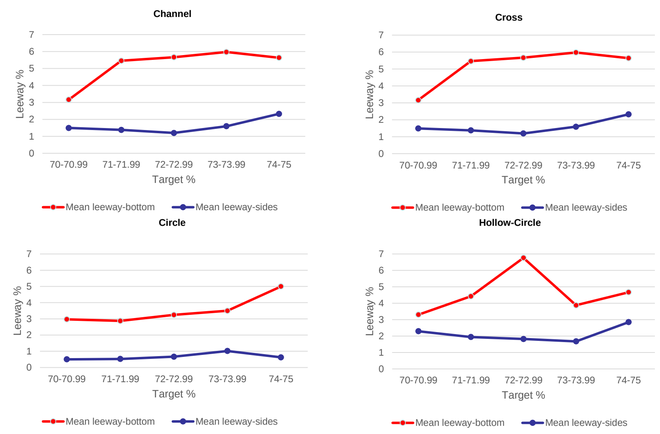
Median values of Leeway-side and Leeway-bottom damage %

Results: Student skills and improvements

If simulation exercises are intended to selectively improve specific psychomotor skills, student performance should be continuously monitored and target parameters should be adjusted according to the objectives of each exercise rather than relying solely on the manufacturer's default settings.
Median performance values within the **80–85% target score range** provided sufficient sensitivity to distinguish differences in lateral movement accuracy among the different exercise types and to identify students requiring additional practice in specific skill domains.



Median values of Leeway-sides between 80-85% of target



Plots of the reached target % of the 4 different tasks against the Leeway % of the buttom and the sides.

Discussion

The results demonstrate that the selected simulation exercises are not equally difficult for undergraduate dental students. Consequently, careful planning of simulation-based curricula is essential before implementation.
Our findings suggest that the development of **depth control** and **lateral movement accuracy** requires different training strategies, different exercises, and different amounts of practice time. Therefore, simulation tasks should be selected deliberately according to the psychomotor skill being developed instead of applying identical training protocols for all exercises.