Section: Dentistry

Original Research Article

EFFECTIVENESS OF SIMULATION-BASED TEACHING OF DENTAL MATERIALS IN IMPROVING CLINICAL COMPETENCE IN REMOVABLE PROSTHODONTICS AMONG UNDERGRADUATE DENTAL STUDENTS: A QUASI-EXPERIMENTAL STUDY

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ABSTRACT

Background: Objective: To evaluate the effectiveness of simulation-based teaching (SBT) compared to traditional teaching (TT) in improving clinical competence and confidence among undergraduate dental students. **Materials and Methods:** A quasi-experimental study was conducted at PIMS School of Dentistry, Islamabad, from January to August 2024. Sixty third-year BDS students were divided into a Simulation Group (n=30) and a Traditional Group (n=30). Clinical competence was assessed using pre- and post-intervention OSCE scores, while student confidence was evaluated using a structured 5-point Likert scale questionnaire. Data were analyzed using paired and independent t-tests. **Results:** Baseline OSCE scores were comparable between groups ($p=0.582$). Post-intervention, the Simulation Group achieved significantly higher scores (16.8 ± 1.4) compared to the Traditional Group (12.2 ± 2.1, $p<0.001$). Domain-specific analysis showed greatest improvement in tray loading and impression accuracy. Confidence scores were also significantly higher in the Simulation Group ($p=0.004$). A large effect size was observed (Cohen's $d=2.54$). **Conclusion:** Simulation-based teaching significantly improves both clinical competence and student confidence. It provides an effective bridge between theoretical learning and clinical practice in prosthodontics.

INTRODUCTION

The transition from preclinical training to clinical patient care is a critical stage in undergraduate dental education. In removable prosthodontics, this transition is particularly challenging because students must develop both cognitive understanding and psychomotor skills for handling dental materials. Materials such as irreversible hydrocolloids (alginate) and gypsum products are highly technique-sensitive, and even minor errors in manipulation can significantly affect the accuracy of impressions and the final prosthesis.[1] Therefore, competence in dental material handling is essential for successful clinical outcomes.

Traditional teaching (TT) methods in dental education usually include didactic lectures and bench-top demonstrations. While these methods are effective for delivering theoretical knowledge, they often fail to replicate real clinical conditions. Students usually remain passive observers during demonstrations and have limited opportunities for hands-on practice before encountering real patients.[2] This creates a gap between knowledge and application, which may result in procedural errors, increased anxiety, and reduced confidence during initial clinical exposure.

Simulation-based teaching (SBT) has emerged as an innovative educational strategy to address this gap. It allows students to practice clinical procedures in a

controlled, safe, and risk-free environment before treating patients. High-fidelity simulation models, such as phantom heads, are designed to mimic intraoral conditions, including restricted access, patient positioning, and time constraints.[3] These features enable students to develop both technical skills and clinical judgment without compromising patient safety.

SBT is grounded in experiential learning theory, where students actively engage in performing tasks and receive immediate feedback. This approach enhances retention of knowledge and improves skill acquisition compared to passive learning methods.[4] In dental education, simulation has been shown to improve psychomotor skills, reduce performance anxiety, and enhance overall clinical preparedness.[5] Furthermore, repeated practice in simulation environments allows students to refine their techniques and correct errors before transitioning to clinical settings.

Despite the growing global adoption of simulation in health professions education, its integration into dental curricula in Pakistan remains limited. Most institutions continue to rely heavily on traditional teaching methods, with minimal structured simulation training. This lack of exposure may contribute to variability in student competence and confidence levels during clinical rotations. There is also a lack of local evidence evaluating the effectiveness of simulation-based teaching specifically in the context of dental materials and removable prosthodontics.

Given the importance of accurate material manipulation in prosthodontic procedures, it is essential to explore teaching strategies that can enhance student performance. Simulation-based training has the potential to bridge the gap between theoretical learning and clinical practice by providing a realistic and structured learning environment.

Therefore, this study aims to evaluate the effectiveness of simulation-based teaching compared to traditional teaching in improving clinical competence and confidence among undergraduate dental students in removable prosthodontics at PIMS School of Dentistry, Islamabad.

MATERIALS AND METHODS

2.1 Study Design and Setting

Quasi-experimental study conducted at PIMS School of Dentistry, Islamabad (Jan–Aug 2024).

2.2 Participants

60 third-year BDS students

1. Simulation Group (n=30)
2. Traditional Group (n=30)

2.3 Intervention

- SBT: Phantom head training + feedback
- TT: Lecture + demonstration

2.4 Tools

- OSCE checklist (20 marks)
- Likert confidence scale

2.5 Analysis

- Paired t-test
- Independent t-test
- Effect size (Cohen's d)

RESULTS

A total of 60 undergraduate dental students participated in the study. All participants completed both pre-test and post-test assessments. Students were equally divided into two groups: Simulation Group (n=30) and Traditional Teaching Group (n=30).

3.1 Comparative Analysis of OSCE Scores

At baseline, both groups demonstrated comparable clinical competence. The mean pre-test OSCE score for the Simulation Group was 8.2 ± 1.5, while the Traditional Group scored 8.4 ± 1.3, with no statistically significant difference ($p = 0.582$). This indicates similar foundational knowledge and skill levels before the intervention.

Following the intervention, both groups showed improvement in OSCE scores. However, the magnitude of improvement was significantly greater in the Simulation Group. The post-test mean score for the Simulation Group was 16.8 ± 1.4, compared to 12.2 ± 2.1 in the Traditional Group. This difference was highly statistically significant ($p < 0.001$).

The Simulation Group demonstrated a mean improvement (Δ) of +8.6, while the Traditional Group showed an improvement of +3.8, indicating a substantially greater gain in clinical competence among students trained using simulation-based teaching.

Table 1: Pre- and Post-Test OSCE Score Distribution (N = 60)

Assessment Phase	Simulation Group (Mean ± SD)	Traditional Group (Mean ± SD)	Mean Difference	p-value
Pre-Test	8.2 ± 1.5	8.4 ± 1.3	-0.2	0.582
Post-Test	16.8 ± 1.4	12.2 ± 2.1	+4.6	<0.001*
Improvement (Δ)	+8.6	+3.8	—	—

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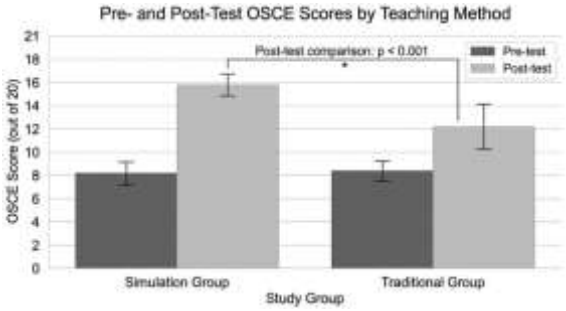

3.2 Evaluation of Clinical Competence by Domain

The OSCE assessment was further divided into five key domains related to prosthodontic material handling. The Simulation Group consistently achieved higher mean scores across all domains compared to the Traditional Group.

The most pronounced differences were observed in:

- **Tray Selection and Loading**
- **Impression Placement and Accuracy**

These domains require spatial awareness and real-time material handling, which were better developed through simulation training.

Table 2: Domain-Specific Competence Scores (Mean Score out of 4 per Domain)

OSCE Domain	Simulation Group (n=30)	Traditional Group (n=30)	% Difference
Material Selection & W:P Ratio	3.8 ± 0.3	3.1 ± 0.6	+22.5%
Mixing Technique & Consistency	3.6 ± 0.4	2.8 ± 0.7	+28.6%
Tray Selection & Loading	3.4 ± 0.5	2.1 ± 0.8	+61.9%
Impression Placement & Accuracy	3.2 ± 0.6	1.9 ± 0.9	+68.4%
Infection Control Protocols	2.8 ± 0.5	2.3 ± 0.6	+21.7%

3.3 Student Self-Reported Confidence (Secondary Outcome)

Post-intervention confidence levels were assessed using a 5-point Likert scale. Students in the Simulation Group reported significantly higher confidence compared to the Traditional Group.

In the Simulation Group, **90% (n=27)** of students rated their confidence as "High" or "Very High" (scores 4–5), whereas only **40% (n=12)** of students in the Traditional Group reported similar confidence levels.

The mean confidence score for performing clinical impressions was **4.6 ± 0.5** in the Simulation Group compared to **3.2 ± 0.9** in the Traditional Group. This difference was statistically significant (**p = 0.004**).

Table 3: Post-Intervention Confidence Levels (Likert Scale 1–5)

Confidence Parameter	Simulation Group (Mean ± SD)	Traditional Group (Mean ± SD)	p-value
Handling Alginate/Gypsum	4.7 ± 0.4	3.5 ± 0.8	0.002
Performing Impressions	4.5 ± 0.6	2.9 ± 1.1	<0.001
Identifying Procedural Errors	4.2 ± 0.7	3.1 ± 0.9	0.005
Overall Readiness for Clinic	4.6 ± 0.5	3.2 ± 0.9	0.004

3.4 Summary of Statistical Findings

Independent t-test analysis demonstrated a statistically significant difference between the two groups in post-test scores ($p < 0.001$). The calculated Cohen's d effect size was 2.54, indicating a large effect of simulation-based teaching on clinical competence.

Additionally, paired t-tests within each group showed that both teaching methods resulted in improvement; however, the Simulation Group achieved significantly greater gains and demonstrated reduced variability in performance, suggesting a more standardized level of clinical readiness.

DISCUSSION

This study evaluated the effectiveness of simulation-based teaching (SBT) in improving clinical competence and confidence among undergraduate dental students in removable prosthodontics. The findings clearly demonstrate that students exposed to simulation-based training achieved significantly higher OSCE scores and reported greater confidence compared to those who underwent traditional teaching (TT). These results highlight the value of active, hands-on learning approaches in dental education.

A key finding of this study is the significant improvement in post-test OSCE scores in the Simulation Group. Although both groups showed improvement after the teaching intervention, the magnitude of improvement was substantially greater in the SBT group. This suggests that while traditional teaching can enhance theoretical understanding, it is less effective in developing practical clinical skills. These findings are consistent with previous studies in medical and dental education, which have shown that simulation-based learning improves psychomotor performance and clinical competence more effectively than passive learning methods.[3,4]

The comparable baseline scores between the two groups confirm that both groups started at a similar level of knowledge and skill. Therefore, the observed differences in post-test performance can be attributed to the teaching intervention rather than pre-existing differences. This strengthens the internal validity of the study and supports the effectiveness of simulation-based teaching.

Domain-specific analysis provides further insight into how simulation enhances learning. The Simulation Group showed the greatest improvement in tasks such as tray loading and impression accuracy. These tasks require spatial awareness, hand–eye coordination, and time-sensitive manipulation of

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materials. Traditional teaching methods, which rely mainly on observation, are limited in their ability to develop these skills. In contrast, simulation allows students to practice repeatedly under conditions that closely resemble the clinical environment. This finding is supported by earlier research, which suggests that simulation improves procedural accuracy and reduces technical errors.[5]

Another important finding is the improvement in material manipulation skills, including water-powder ratio accuracy and mixing consistency. These skills are critical in prosthodontics, as improper manipulation can compromise the quality of impressions and final prostheses. The higher scores in the Simulation Group indicate that hands-on practice with immediate feedback plays a key role in mastering these techniques. This aligns with experiential learning theory, which emphasizes active participation and reflection as essential components of skill acquisition.[4]

The results of this study also demonstrate a significant increase in student confidence following simulation-based training. Confidence is an important factor in clinical performance, especially during the early stages of patient care. Students who lack confidence may hesitate, make errors, or require more supervision. In this study, a large proportion of students in the Simulation Group reported high levels of confidence in performing clinical procedures. This finding is consistent with previous studies that have shown that simulation reduces anxiety and improves self-efficacy among students.[3,5]

The relationship between competence and confidence observed in this study is particularly important. Students who performed better in OSCE assessments also reported higher confidence levels. This suggests that simulation not only improves technical skills but also enhances students' readiness to apply these skills in real clinical settings. As a result, simulation-based teaching can facilitate a smoother transition from preclinical to clinical training.

The large effect size (Cohen's d = 2.54) observed in this study indicates a strong educational impact of simulation-based teaching. Effect sizes of this magnitude are rarely seen in educational research and highlight the practical significance of the findings. In addition, the Simulation Group showed reduced variability in performance compared to the Traditional Group. This suggests that simulation-based training leads to more consistent outcomes among students, resulting in a more standardized level of competence.

From a clinical perspective, these findings have important implications. In prosthodontics, accurate impressions are essential for the success of treatment. Errors in impression making can lead to ill-fitting prostheses, patient discomfort, and increased need for adjustments. By improving students' competence before they enter clinical settings, simulation-based teaching can contribute to better patient outcomes and more efficient clinical workflows.

The findings of this study are particularly relevant in the context of dental education in Pakistan. Many dental institutions rely heavily on traditional teaching methods, with limited integration of simulation-based learning. Resource constraints, lack of infrastructure, and limited faculty training may be contributing factors. However, the results of this study suggest that investing in simulation-based education can significantly enhance the quality of training and improve student performance.

Despite its strengths, this study has certain limitations. First, it was conducted at a single institution, which may limit the generalizability of the findings to other settings. Second, the sample size was relatively small, although sufficient to demonstrate statistically significant differences. Third, the study assessed short-term outcomes, and long-term retention of skills was not evaluated. Future studies should include multicenter designs, larger sample sizes, and longitudinal follow-up to assess skill retention over time.

5. Limitations

Despite its strengths, this study has certain limitations.

1. First, the study was conducted at a single institution, which may limit the generalizability of the findings to other dental schools with different teaching environments or resources.
2. Second, the sample size was relatively small (n=60), although it was sufficient to detect statistically significant differences between groups. Larger studies are needed to confirm these findings.
3. Third, the study used a non-probability convenient sampling technique, which may introduce selection bias and limit external validity.
4. Fourth, the duration of follow-up was short, and the study assessed only immediate post-intervention outcomes. Long-term retention of skills and knowledge was not evaluated.
5. Fifth, although the OSCE is a reliable assessment tool, there may still be some observer-related bias in scoring, especially if blinding of examiners was not implemented.
6. Finally, the study focused on undergraduate students in a specific year, and the findings may not be directly applicable to students at different levels of training or to postgraduate trainees.

5. Future Recommendations

Based on the findings of this study, several recommendations can be made for future research and educational practice.

1. First, multi-center studies should be conducted across different dental institutions in Pakistan to improve the generalizability of the results. Including both public and private sector colleges will provide a broader understanding of the effectiveness of simulation-based teaching.
2. Second, future research should focus on the long-term retention of clinical skills. Follow-up assessments after several months of clinical

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exposure can help determine whether the benefits of simulation-based teaching are sustained over time.

3. Third, studies can explore the integration of simulation-based teaching into different areas of dentistry, such as operative dentistry, endodontics, and oral surgery. This will help assess whether similar improvements are observed across various clinical disciplines.
4. Fourth, future studies may compare different levels of simulation fidelity (low-fidelity vs high-fidelity models) to determine the most cost-effective and practical approach for resource-limited settings.
5. Fifth, it is recommended to evaluate the cost-effectiveness of simulation-based teaching, especially in developing countries where financial and infrastructural limitations may affect implementation.
6. Sixth, qualitative research can be conducted to explore students' perceptions, learning experiences, and challenges associated with simulation-based training. This will provide deeper insights into how simulation influences learning behavior.
7. Finally, future studies should consider including faculty training and standardization of teaching methods, as instructor expertise and feedback play a critical role in the success of simulation-based education.

CONCLUSION

Simulation-based teaching is significantly more effective than traditional methods in improving clinical competence and confidence. It should be integrated into the undergraduate prosthodontics curriculum as a standard teaching approach.

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