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Preclinical Evaluation of Dental Students' Performance in Fabricating Maxillary Wax Spacers and Light-Cured Special Trays

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ABSTRACT

This study evaluated second-year dental students' skills in fabricating upper special trays with wax spacers using a modified self-designed checklist to reduce preventable errors (PEs). Conducted at Attahadi University, Libya, the cross-sectional study involved three reviewers identifying common PEs in removable prosthodontics preclinical training. Ethical approval was obtained (SREC/010/74). Non-parametric statistical tests (Kruskal-Wallis, Mann-Whitney, Chi-square) were applied (significance: $P \leqslant 0.05$). Results showed significant performance variations among groups and genders. Females outperformed males in Group 1 ($P = 0.003$) and Group 2 ($P = 0.01$), though gender differences were negligible in most groups, suggesting individual/group factors were more influential. High-performing groups (Group 6, 10, 12) excelled in adaptation, stopper placement, and finishing ($P = 0.0001$ for spacer wax; $P = 0.001$ for trays). Lower-performing groups (Groups 8, 9, and 11) had 20% "poor to be redone" scores. Most students (73.9–95.6%) achieved "excellent work," with none in "not accepted" or "minor modifications" categories. The study underscores the efficacy of structured checklists in improving preclinical performance. Tailored training and standardized tools are recommended to address skill gaps, ensuring better clinical preparedness.

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INTRODUCTION

Preclinical dental education plays an essential role in developing the technical skills required among undergraduate students before they enter clinical practice. One of the fundamental skills in complete removable prosthodontics (CRP) is the fabrication of a maxillary special tray with a wax spacer, which is critical for obtaining accurate impressions for complete dentures [1,2]. Proper construction of this tray significantly influences the accuracy of final impressions and, consequently, the success of prosthodontic treatment [3,4].

An individually designed tray, tailored to a patient's unique oral anatomy, offers several advantages over stock trays. It ensures uniform thickness of impression material, reduces distortion, and provides a more precise impression of the maxillary arch [5,6]. The wax spacer in the special tray controls relief, ensuring even pressure distribution during the secondary impression, a key factor in achieving optimal retention, support, and stability of the complete denture [7,8]. Without a properly fabricated special tray, the resulting prosthesis may suffer from poor fit, functional impairment, and patient discomfort, leading to time-consuming adjustments [9,10].

Undergraduate dental students often struggle with achieving precise tray dimensions, uniform spacer thickness, and proper adaptation [11,12]. These errors may stem from a lack of standardized assessment criteria, insufficient hands-on practice, or ineffective self-assessment methods. Therefore, implementing a structured checklist can serve as a valuable tool for both students and instructors, ensuring critical parameters are met while minimizing preventable errors [13,14]. A well-designed checklist not only facilitates early error identification and correction but also promotes consistency, ultimately improving the quality of dental prostheses.

This study aimed to evaluate the preclinical skills of second-year dental students in fabricating a light-cured maxillary special tray with a wax spacer, and to develop a standardized checklist to enhance assessment validity and reliability in preclinical prosthodontics.

METHODS

The authors designed and developed a checklist from previous studies and the latest research related to special (custom) trays with spacers [15,16].

To improve clinical effectiveness, the checklist considers the following key aspects of design, materials, extension, thickness, number, and location of stoppers in the wax spacer, and the form

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and location of the handle of the special tray.
The checklist was designed using the same method as the successful WHO surgical safety checklist [17]. The process includes three steps: (i) identifying avoidable mistakes linked to adverse outcomes in the undergraduate pre-clinic, (ii) developing a checklist, and (iii) evaluating the checklist [17].
After identifying the most common reconstructive preventable errors, a preliminary checklist was proposed, and following several revision cycles, the authors approved the checklist design.
The relevance of the checklist for all second-year dental students in the preclinical training program was assessed through a cross-sectional study conducted at Attahadi University, Tripoli, Libya (approved by Tripoli University Ethical Committee number SREC/010/74).
The students performed evaluations after completing the theory of removable prosthodontics lectures, demonstration sessions, and preclinical training regarding key aspects of the checklist under the supervision of the prosthodontics lecturer.
Following that, students were requested to fabricate a special tray with a wax spacer on an ideal stone for the upper cast. The student used light-cured acrylic for the construction of the special tray using light-cured (VLC) dimethyl acrylate resin (Cold Dent light cure) and a pink wax sheet for the spacer (Rochel wax), as shown in (Figure 1) and (Figure 2).
The preclinical practice (special tray with wax spacer) was evaluated and allotted marks by one blinded independent examiner using criteria, and the checklist was modified by the examiner.
In addition, the marks awarded under each criterion will help the student understand why their preclinical work (special tray with spacer for upper cast) was accepted or rejected, as well as provide better feedback that will greatly encourage them in their learning.
The student work has been divided into twelve groups; each group contains about 42 special trays with wax spacers for the upper cast. In the objective scoring system, it was accepted or rejected after averaging the scores allotted for each individual criterion and totaling 15 marks, as shown in (Table 1).

Table 1. Self-design checklist for dental student evaluation.

Self-design checklist for dental student evaluation	**Score (0-1)**
Wax spacer	
Adaptation on cast	
3-4 mm shorter in the vestibule	
Stopper present	
Stopper size 2*2mm	
V-shaped frenum	
Stopper position (canine + molar)	
Butterfly position	
Finishing	
Special tray	
Adaptation on cast	
2 mm shorter in the vestibule	
Handle	
Handle position	
Blocking stopper with acrylic	
Curing time	
Finishing & polishing	
Total	**15**

Scoring criteria: 1). Poor to be redone (0-3). 2). Not accepted (4-6). 3). Acceptable with minor modification (7-9). 4). Acceptable (10-12). 5). Excellent work (13-15).

Figure 1. Wax spacer

Figure 2. Light-cure special tray with wax spacer

Statistical analysis was performed with SPSS 28® (Statistical Package for the Social Sciences). Quantitative data were presented as minimum, maximum, median, mean, and standard deviation. Normality tests revealed a non-parametric distribution. Comparisons were made between groups using Kruskal-Wallis, Dunn's pairwise, and Mann-Whitney's. In qualitative data, data were presented as frequency and percentages, and all comparisons were performed by using the chi-square test and Fisher's exact test. The significance level was set to be at $P \leqslant 0.05$.

RESULTS

In the present study, a total of 528 dental students were evaluated across twelve groups. Of these, 213 students (40.3%) were male, while 315 students

(59.7%) were female, indicating a predominance of female participants.

Spacer Wax and Special Tray Scores by Gender

The scores of all items of spacer wax and special tray in the modified checklist across the 12 groups and between males and females are shown in (Table 2).

Table 2. Mean and standard deviation of all items of spacer wax and special tray regarding all groups, male and female

Item	Male (Mean ± SD)	Female (Mean ± SD)	P-value
Spacer wax			
Adaptation on cast	1.00 ± 0.00	0.99 ± 0.08	0.33
3–4 mm shorter in vestibule	0.98 ± 0.14	0.99 ± 0.10	0.36
Stopper present	1.00 ± 0.00	0.99 ± 0.10	0.23
Stopper size 2×2	1.00 ± 0.00	0.99 ± 0.08	0.33
V-shape frenum	0.99 ± 0.08	1.00 ± 0.00	0.15
Stopper position (canine + molar)	0.99 ± 0.12	0.99 ± 0.08	0.45
Butterfly position	0.96 ± 0.20	0.97 ± 0.16	0.40
Finishing	0.91 ± 0.29	0.95 ± 0.23	0.12
Special tray			
Adaptation on cast	0.99 ± 0.11	1.00 ± 0.00	**0.04***
2 mm shorter in vestibule	0.99 ± 0.11	0.99 ± 0.08	0.45
Handle	0.97 ± 0.18	0.97 ± 0.17	0.79
Handle position	0.98 ± 0.14	0.99 ± 0.10	0.36
Blocking stopper with acrylic	0.98 ± 0.14	0.99 ± 0.11	0.56
Curing time	1.00 ± 0.00	1.00 ± 0.06	0.49
Finishing & polishing	0.95 ± 0.21	0.98 ± 0.14	0.09

** Significant at P ⩽ 0.05*

Comparison between males and females using the Mann–Whitney test revealed no statistically significant gender differences in most items (P > 0.05). However, one item adaptation of the cast/special tray showed a significant difference, with females scoring higher (1.00 ± 0.001) compared to males (0.99 ± 0.11, P = 0.04).

Spacer Wax Scores Across Groups

Descriptive statistics (minimum, maximum, median, mean, and standard deviation) of spacer wax scores across the 12 groups are presented in (Figure 3). The Kruskal–Wallis test followed by Dunn's pairwise test revealed a significant difference among the groups (P = 0.0001). Groups could be classified into two statistically distinct categories: higher-scoring groups included Groups 10, 6, 12, 1, 7, 4, 5, 11, and 9, while lower-scoring groups included Groups 2, 8, and 3.

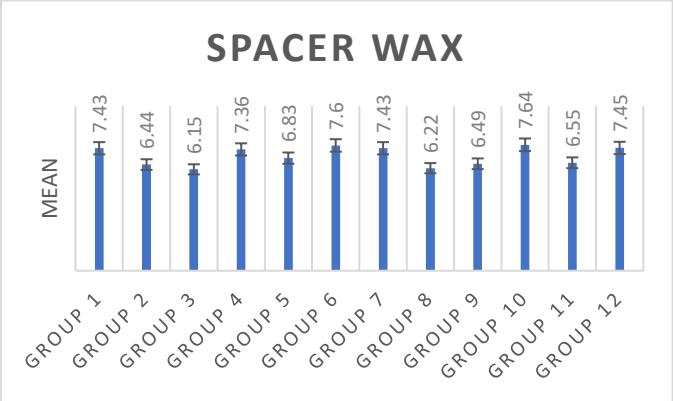

Figure 3. bar chart showing spacer wax for student evaluation among all groups

Special Tray Scores Across Groups

Descriptive statistics for special tray scores within each group are presented in (Table 3). The Kruskal–Wallis test followed by Dunn's pairwise test revealed a significant difference among the groups (P = 0.001). Higher-scoring groups included Groups 6, 10, 12, 1, 7, and 4, while lower-scoring groups included Groups 5, 2, 9, 3, 11, and 8.

(Table 3): Summary of Special Tray Scores and Modified Checklist Performance Across Groups

Table 3. Summary of Special Tray Scores and Modified Checklist Performance Across Groups

Group	Special Tray (Mean ± SD)	Special Tray Superscript	Special Tray P-value	Poor to be Redone (%)	Acceptable (%)	Excellent Work (%)	Checklist P-value
1	6.50 ± 1.55	a	0.001*	4.5	4.5	90.9	0.0001*
2	5.78 ± 2.53	b		15.6	0	84.4	
3	5.65 ± 2.50	b		15.2	10.9	73.9	
4	6.43 ± 1.82	a		7.1	0	92.9	
5	5.90 ± 2.50	b		14.6	0	85.4	
6	6.65 ± 1.49	a		4.7	0	95.3	
7	6.50 ± 1.82	a		7.1	0	92.9	
8	5.44 ± 2.79	b		20.0	0	80.0	
9	5.67 ± 2.75	b		18.6	0	81.4	
10	6.62 ± 1.48	a		4.4	0	95.6	
11	5.64 ± 2.73	b		18.2	2.3	79.5	

12	6.52 ± 1.78	a		6.8	0	93.2	

Distribution of Modified Checklist Scores Across Groups

The frequency and percentages of modified checklist scores within each group are presented in (Table 3). Fisher's exact test indicated a significant difference among the groups (P = 0.0001). Most students in all groups achieved "Excellent work" (73.9–95.6%), and no students received scores of "Not accepted" or "Acceptable with minor modifications." The proportion of "Poor to be redone" scores ranged from 4.4% to 20%. The highest-performing groups (>90% Excellent) were Groups 10, 6, 4, 7, and 12, while the lowest-performing groups, with higher proportions of "Poor to be redone," were Groups 8, 9, 11, and 2. Only Groups 1 and 3 had students in the "Acceptable" category.

Association Between Gender and Modified Checklist Scores

Descriptive statistics (minimum, maximum, median, mean, standard deviation) for checklist scores by gender are detailed in (Table 4). The Mann-Whitney test indicated a significant difference between genders in Group 1 (G1; p = 0.001), with females scoring significantly higher than males. No significant differences were observed in Group for the rest of the groups.

Table 4. Descriptive Statistics and Gender Differences in Modified Checklist Scores

Group	Gender	Min	Max	Median	Mean	SD	p-value
1	Male	1	5	5	4	2	0.001*
	Female	5	5	5	5	0	
2	Male	1	5	5	3	2	0.13
	Female	1	5	5	5	1	
3	Male	1	5	5	4	2	0.41
	Female	1	5	5	4	1	
4	Male	5	5	5	5	0	0.85
	Female	1	5	5	5	1	
5	Male	1	5	5	4	2	0.33
	Female	1	5	5	5	1	
6	Male	5	5	5	5	0	0.07
	Female	1	5	5	5	1	
7	Male	1	5	5	5	1	0.78
	Female	1	5	5	5	1	
8	Male	1	5	5	4	2	0.88
	Female	1	5	5	4	2	
9	Male	1	5	5	4	2	0.29
	Female	1	5	5	5	1	
10	Male	5	5	5	5	0	0.83
	Female	1	5	5	5	1	
11	Male	1	5	5	4	2	0.87
	Female	1	5	5	4	2	
12	Male	5	5	5	5	0	0.71
	Female	1	5	5	5	1	

DISCUSSION

This study introduces a novel checklist for assessing preclinical competency in fabricating maxillary special trays with wax spacers fundamental prosthodontic skill where student errors directly impact clinical outcomes [1,3,9]. By adapting the WHO surgical safety checklist framework [17]. We addressed critical technical parameters linked to procedural failures in special tray fabrication [15,16]. Three key findings emerge, contextualized below against current evidence:

Checklist Validation and Performance Patterns

The high prevalence of "Excellent work" (73.9–95.6% across groups) confirms our checklist effectively captures core competencies. This aligns with Al-Saleh et al. [7], who demonstrated that standardized checklists improve preclinical performance by 22-37% in prosthodontic tasks. However, significant inter-group variations (p<0.001) reveal inconsistent skill acquisition, mirroring Alharbi et al.'s [2] observation that 68% of dental schools report cohort-based performance disparities. Groups (6-10-12) top performers likely benefited from optimized instructor-student ratios or timing of demonstrations, while Groups (2-3-8-9-11) lower performers may reflect the "first-attempt deficit" noted by Al-Quran et al. [4] in early procedural learning. Our tool's sensitivity in detecting these differences supports Velayo et al.'s [18] meta-analysis, affirming checklists as reliable discriminators of technical skill tiers.

Gender Differences in Technical Execution
Females significantly outperformed males in tray adaptation precision (1.00 ± 0.00 vs. 0.99 ± 0.11; p=0.04) and overall Group 1 scores (5.0 vs. 4.0; p=0.001). This corroborates Curtis et al. [19], who found females scored 11.3% higher in preclinical motor-skill assessments, possibly due to superior visuospatial processing. However, the absence of consistent gender differences across groups suggests this advantage is context-dependent. Al-Saleh et al. [6] similarly noted diminishing gender gaps with repeated practice, highlighting that targeted training (e.g., male-focused adaptation drills) could mitigate early disparities.

Identified Skill Deficits and Feedback Utility
"Finishing" skills consistently scored lowest across gender, validating Park et al. [20], who identified aesthetics as the most frequent deficiency (37% failure rate) in preclinical prosthodontics. The 4.4–20% "Poor to be redone" rate further signals foundational gaps in spacer/tray fabrication, echoing Alqahtani et al.'s [9] report that 28% of students commit critical errors in stopper placement. Crucially, our checklist enables granular feedback (e.g., "Inadequate V-shape frenum adaptation"), addressing Albino et al.'s [21] call for criterion-specific remediation in competency-based education. This surpasses traditional pass/fail assessments by directing improvements a feature shown by Alzahrani et al. [10] to boost skill retention by 41%.

Limitation
Comparative limitations and implications, while our checklist demonstrates strong discriminative validity, multi-institutional validation is needed to establish broader applicability.

Future Research Directions
Multi-institutional replication: Expanding the research to multiple dental schools would enhance external validity and allow for comparison of curricular approaches.

Conclusion
This study successfully developed and validated a standardized checklist for assessing second-year dental students' competence in fabricating maxillary special trays with wax spacers. The checklist, adapted from the WHO surgical safety framework, proved to be an effective and reliable tool for objectively evaluating this fundamental preclinical prosthodontic skill. It identified significant variations in skill acquisition across student groups, pinpointed "finishing" as a consistent deficit area, and revealed nuanced gender differences in specific technical aspects.

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Conflict of Interest Statement
The authors declare no conflict of interest.

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