STUDY

Modern Moulage

Evaluating the Use of 3-Dimensional Prosthetic Mimics in a Dermatology Teaching Program for Second-Year Medical Students

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Objectives: To evaluate the effectiveness of a teaching method that uses 3-dimensional (3D) silicone-based prosthetic mimics of common serious lesions and eruptions and to compare learning outcomes with those achieved through the conventional method of lectures with 2-dimensional (2D) images.

Design: Prospective and comparative.

Setting: University of Massachusetts Medical School.

Participants: Ninety second-year medical students.

Intervention: A 1-hour teaching intervention using a lecture with 2D images (2D group) or using 3D prosthetic mimics of lesions and eruptions (3D group).

Main Outcome Measures: Mean scores in the domains of morphology, lesion and rash recognition, lesion and rash management, and overall performance assessed at baseline, immediately after, and 3 months after each group's respective teaching intervention.

Results: Immediately after the teaching intervention, the 3D group had significantly higher mean percentage scores than did the 2D group for overall performance (71 vs 65, $P=.03$), lesion recognition (65 vs 56, $P=.02$), and rash management (80 vs 67, $P=.01$). Three months later, the 3D group still had significantly higher mean percentage scores than did the 2D group for lesion recognition (47 vs 40, $P=.03$). The 3D group better recognized lesions at 3 months compared with at baseline, whereas the 2D group was no better at recognizing lesions at 3 months compared with at baseline.

Conclusions: Despite limited curricular time, the novel teaching method using 3D prosthetic mimics of lesions and eruptions improves immediate and long-term learning outcomes, in particular, lesion recognition. It is also a preferred teaching format among second-year medical students.

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In most medical schools, limited training time is dedicated to skin biology and clinical dermatology. Sixty-nine percent of medical students surveyed agreed that insufficient emphasis in their medical training was placed on learning the skin examination, and only 28.2% rated themselves as somewhat or very skilled in the skin examination.[1] Furthermore, core curricula are based on print media and lectures with 2-dimensional (2D) images, and it is unknown whether content learned through this approach transfers to practical long-term recognition of important lesions and eruptions. It has been shown that although medical students accurately identify melanoma in clinical photographs, they may not transfer this knowledge into identification of suspicious lesions during standardized patient examinations.[2] As such, it is important to develop effective standardized methods that improve long-term learner outcomes without using more curricular time and resources to ensure that medical students graduate with specific and standardized competencies in dermatology.

Clinical instruction reaching an entire class typically occurs in the form of large-capacity lectures with projected 2D images. However, lesions and eruptions are 3-dimensional (3D) structures with clinical features best appreciated by touch and subtle visual clues that are often lost in 2D photographs. Based on this concept, mouleurs of the Renaissance era produced detailed morphologic wax casts that were used as teaching tools throughout Europe.[3,4] Although now an almost forgotten art, instruction through moulage paralleled the growth of dermatology as an independent specialty during the 19th century. Similarly, we explore a teaching

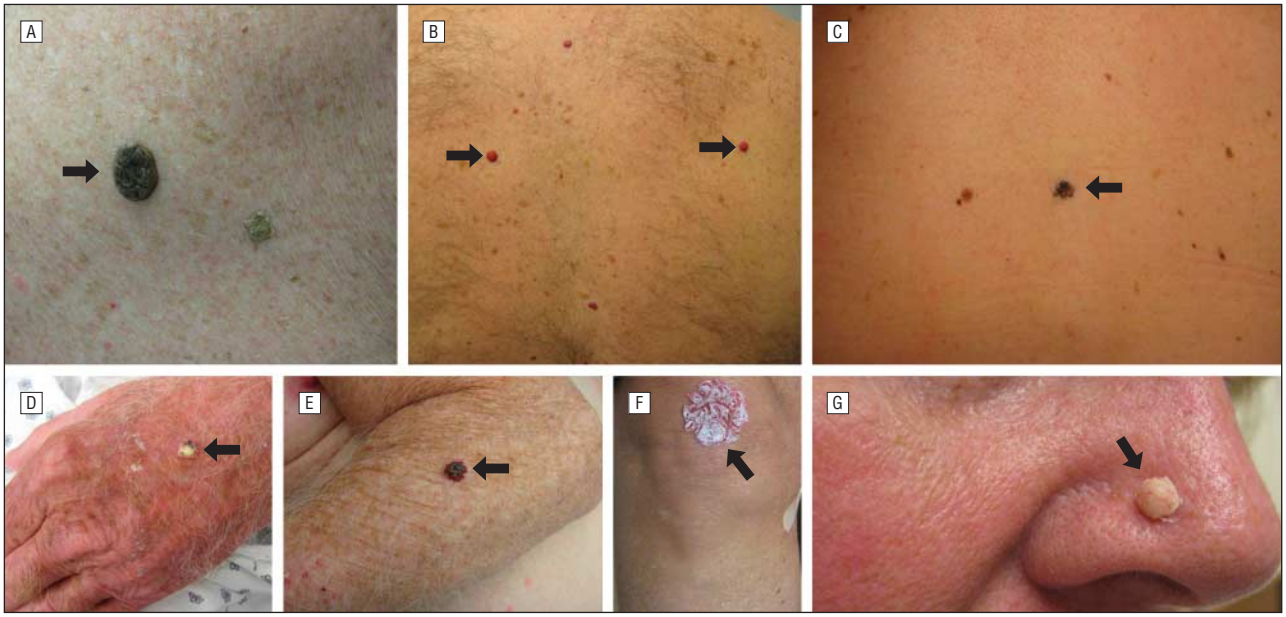

Figure. Examples of 3-dimensional prosthetic mimics of lesions and eruptions, including seborrheic keratosis (A), cherry angioma (B), melanoma (C), hypertrophic actinic keratosis (D), squamous cell carcinoma (E), psoriasis (F), and basal cell carcinoma (G). Arrows point to prostheses.

Table 1. Prosthetic Mimics of Lesions and Eruptions Used in the Learning Modules

Lesions
Acrochordon
Actinic keratosis
Angioma
Basal cell carcinoma
Melanoma
Nevus: junctional, compound, and intradermal
Seborrheic keratosis
Squamous cell carcinoma
Verruca vulgaris
Eruptions
Contact dermatitis
Folliculitis
Herpes simplex
Herpes zoster
Psoriasis
Tinea corporis

method that uses 3D virtual mimics of common serious lesions and eruptions to train preclinical students in acquiring dermatologic recognition and initial management skills. The aims of the present study are to evaluate the student learning response to using 3D models, to compare that response to evaluation of traditional lectures using 2D images, and to measure learning outcomes before, immediately after, and 3 months after the teaching interventions.

METHODS

This study received approval by the human subjects committee of the institutional review board at the University of Massachusetts Medical School. This study represents a collaboration between the Biology of Disease course, an organ-based course focused on the basic science, physiology, and clinical spectrum of normal and abnormal integumentary processes, and the Physical Diagnosis II course, which teaches the principles and practice of physical examination.

Second-year students at the University of Massachusetts Medical School were randomly assigned to 1 of 2 intervention groups: 3D (n=49) or 2D (n=41). Both cohorts underwent baseline assessment (T0) using 2D images that assessed recognition and basic management skills for several common serious lesions and eruptions. This pretraining assessment was followed by a single 1-hour clinical teaching intervention in which the 2D cohort underwent a traditional content-based lecture using projected 2D images and in which the 3D cohort underwent a clinical teaching session using 3D nontoxic, hypoallergenic platinum-based silicone prosthetic mimics (MEDART-FX Inc, New York, New York) of lesions and eruptions affixed to a standardized patient (**Figure**). All the students were assessed using a computer-based module and 2D images immediately (T1) and 3 months (T2) after their respective teaching intervention. Students took assessments at individual computer terminals. The order of the questions was the same for all the students, and each module contained unique clinical images. All 3 modules consisted of only multiple-choice questions, and the modules were equivalent in their level of difficulty. The T2 assessment was expanded to include more questions to better discriminate between the cohorts' retention of content across time.

Primary outcome measures at each assessment included morphology recognition, lesion and rash recognition, lesion and rash initial management, and overall performance, which is an aggregate score of all the performance measures. Morphology questions assessed a student's ability to correctly identify primary morphologic features from images. Lesion and rash recognition questions assessed a student's ability to correctly identify common serious diagnoses from 2D images. Lesion management questions assessed a student's ability to correctly identify the initial management (ie, biopsy or reassure) of a lesion. Rash management questions assessed a student's ability to correctly identify the initial management (ie, administration of an anti-inflammatory, antibiotic, or antiviral medication) of an eruption. **Table 1** lists common serious lesions and eruptions on which the

Table 2. Analysis of Variance Between Mean 3D and 2D Scores at Each of 3 Periods for Overall Performance, Morphology, Lesion and Rash Recognition, and Lesion and Rash Management

	Correct, %								
	Baseline			Immediate Postassessment			3-mo Postassessment		
Educational Outcome	3D	2D	*P* Value	3D	2D	*P* Value	3D	2D	*P* Value
Overall performance	52	50	.55	71	65	.03	60	55	.08
Morphology	50	52	.77	60	60	.99	52	47	.13
Recognition									
Lesion	40	36	.31	65	56	.02	47	40	.03
Rash	59	58	.79	78	73	.15	65	63	.51
Management									
Lesion	70	69	.69	84	83	.73	81	79	.39
Rash	67	60	.20	80	67	.01	61	59	.56

Abbreviations: 2D, 2 dimensional; 3D, 3 dimensional.

teaching content and assessments were based. Along with the T1 assessment, students were surveyed anonymously regarding general impressions of their respective instructional sessions using a 5-point Likert scale.

One-way analyses of variance were conducted to determine differences between the 2D and 3D groups in each period. Improvement across time was calculated for each group using paired *t* tests. Subject content, teaching time, and assessments were the same for both cohorts. To minimize repeated testing bias, students were not given correct responses or scores for any of the 3 assessments. None of the study participants had previous instruction in dermatology. After the final assessment, each cohort was offered the other's training intervention so that each student would ultimately have had the same learning experiences.

RESULTS

All T0, T1, and T2 outcomes are summarized in **Table 2**. At baseline (T0), tests of knowledge showed that mean percentage scores for overall performance, morphology, lesion and rash recognition, and lesion and rash management were similar and not significantly different between the 3D and 2D groups before any teaching intervention, as tested using analysis of variance.

Both groups showed a similar pattern of significant improvement from T0 to T1 in paired *t* tests. One-way analysis of variance found that the 3D group had significantly higher T1 mean percentage scores than the 2D group for overall performance, lesion recognition, and rash management (Table 2). The mean percentage scores at T1 for morphology, rash recognition, and lesion management were the same or higher in the 3D group than in the 2D group, but these differences did not reach statistical significance.

Both groups showed a similar decrease in scores 3 months after the single teaching intervention (Table 2). At T2, the 3D group still had a significantly higher mean percentage score than the 2D group for lesion recognition and a higher mean percentage score for overall performance that neared significance compared with the 2D group. The mean percentage scores for morphology, rash recognition, lesion management, and rash management were higher in the 3D group compared with the 2D group, but an analysis of variance indicated that these differences did not reach statistical significance.

Paired *t* test subanalysis of lesion recognition scores showed that the 3D group had a significant increase in mean score from T0 to T1 and a significant decrease in mean score from T1 to T2. The 3D group also showed a significant increase in mean score from T0 to T2, suggesting that the 3D group was better able to recognize lesions at 3 months compared with at baseline. Likewise, the 2D group showed a significant increase in mean score from T0 to T1 and a significant decrease in mean score from T1 to T2. However, the difference in 2D mean scores between T0 and T2 was not significant, suggesting that the 2D group was no better at recognizing lesions at 3 months compared with at baseline.

The 3D cohort agreed or strongly agreed that the 3D session was (1) more enjoyable than classroom lectures (96%), (2) effective in facilitating recognition of lesions and rashes (94%), and (3) perceived to be a more effective teaching method than lectures with 2D images (94%). The 3D cohort also believed that the prosthetic pieces (1) appeared realistic enough to learn from (79%), (2) facilitated close examination of specific morphologic features (92%), and (3) had a learning benefit that outweighed their artificiality (96%). In the 2D cohort, 42% of the students agreed or strongly agreed that it was difficult to examine specific morphologic features of lesions and rashes projected as 2D images, and another 30% were neutral on this issue.

COMMENT

As a modern perspective on the practice of moulage, the present method using silicone-based 3D prosthetic mimics of common serious lesions and eruptions resulted in significantly improved immediate clinical skills acquisition with respect to lesion recognition, rash management, and overall performance compared directly with traditional lecture-based teaching with projected 2D images. Regarding long-term skills retention, the 3D group significantly outperformed the 2D group with respect to lesion recognition 3 months after a single teaching intervention. Furthermore, the 3D group better recognized lesions at 3 months compared with at baseline, whereas the 2D group was no better at recognizing le-

sions at 3 months compared with at baseline. We took particular notice of lesion recognition performance for 2 reasons. First, we believed that any 1-hour teaching intervention, regardless of method, would be limited in its ability to demonstrate long-term retention of knowledge 3 months after the intervention. This result suggests that despite limited curricular time, use of the 3D method may effectively facilitate long-term retention of lesion recognition skills. Second, we believed that long-term retention of lesion recognition skills was the most essential of all the skills because initial recognition of melanoma or basal cell carcinoma, for example, would ultimately lead to intervention, either by a primary care physician or via referral to a dermatologist. The remaining immediate and long-term learner outcomes in the 3D group were at least as good as those in the 2D group. This study reinforces that lesion management, rash recognition, and rash management are likely higher-order skills that require a "higher dose" of intervention to facilitate acquisition and retention of knowledge. These skills should continue to be targeted in later years of medical school. Although the 3D group realized statistically significant improvements at 3 months, absolute scores at 3 months (T2) for both cohorts were lower than were scores immediately after the teaching session (T1). We believe that this finding underscores the need for additional teaching and reinforcement of dermatologic skills after students complete the core curriculum in the second year. Because most students do not take a clinical elective in dermatology, we advocate including this 3D session in third-year clerkships as part of the Objective Structured Clinical Examination.

The general impressions and attitudes toward the 3D method were highly favorable among students. The 3D method was thought to be enjoyable, effective, and authentic, and it was also believed to have offered advantages over 2D learning.

There are several limitations to this study. Prostheses do not represent exact replicas of clinical lesions or eruptions. Prosthetic lesions were of higher fidelity than were eruptions, and this may, in part, account for why students performed better with prosthetic lesions. It is also possible that the unique experience of the novel 3D teaching method may have encouraged students to pay more attention and, consequently, learn more than they otherwise might have through a 2D-based lecture, similar to the way a student may better recall a basal cell carcinoma after having experienced a clinical encounter with such a lesion on a patient. The improvement in 3D learning is modest in some areas. It is also important to underscore that the 3D group scored the same or better than the 2D group in all outcome domains at T1 and T2 despite assessments having been performed via 2D, which we would expect to have favored the 2D group. Outcome measures may become more disparate between the groups with the second-generation of improved prosthetics, an increased number of study participants, more discriminating assessments that are not skewed to favor either group, and an assessment interval that reasonably measures long-term learning resulting from a single 1-hour intervention. Although students were not given answers to assessments and each assessment was composed of unique images, we cannot exclude the possibility of learning due to repeated testing in either group. The most appropriate assessment would have involved clinical evaluation of actual lesions, but this would have been difficult to coordinate for melanoma, for example. Finally, results in this study require further validation in other medical student classes.

To our knowledge, this study is the first of its kind to rigorously assess and demonstrate the value of a prosthetics-based teaching method in dermatology. These findings are important especially in the context of limited curricular time allotments for dermatology. These results provide a framework to further develop and evaluate an undergraduate teaching program that incorporates the prosthetics method across an experience vertically oriented across 4 years.

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