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ORIGINAL ARTICLE

Evaluating a method of creating artificial caries in typodont teeth for teaching Class III cavity preparations

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ABSTRACT

Objectives: The purpose of the study was to report a step-by-step process of creating artificial caries typodont teeth and to determine the perception and efficacy of their use in preclinical operative training.

Methods: Artificial caries material comprised of commercially available hide glue and chocolate powder for more realistic coloring was embedded into the distolingual of #9 ModuPRO plastic typodont teeth. First-year dental students having no clinical experience in excavating Class III cavity preparations were divided into two groups. Group BA prepared conventional typodont teeth (CTT) first, then artificial caries typodont teeth. Group AB prepared the ACT first, then CTT. The preps were scored employing a rubric used in the operative dentistry course class. A feedback questionnaire was conducted to rate students' satisfaction regarding the use of ACT and CTT. The Mann–Whitney *U*-test was used to compare the scores between groups ACT–CTT and CTT–ACT and the Chi-Square test was used to evaluate the positive and negative questionnaire responses.

Results: The two groups showed no significant difference in grades and no significant changes in their scores regardless of which order they prepped the teeth ($P > 0.05$). The questionnaire heavily favored the use of artificial caries typodont teeth ($P < 0.05$).

Conclusions: The artificial caries typodont teeth protocol described in this study was feasible when implemented at the preclinical laboratory instruction level with positive questionnaire feedback from dental students.

KEYWORDS
artificial caries, dental education, operative laboratory

1 | INTRODUCTION

Laboratory simulations for operative dentistry and fixed prosthodontics are an essential part of preclinical dental education serving to develop hand skills, increase student confidence, and improve patient safety in later clinical situations.[1] Some previous studies have shown a positive correlation between preclinical and clinical performance,[2] while others have found little correlation,[3,4] due at least partly to the inherent disparity between preclinical and clinical situations. To align preclinical training as closely as possible with actual clinical scenarios continues to present a basic challenge for dental educators.

Conventional methods of providing preclinical training involve molded plastic typodont teeth and extracted human or animal teeth. The use of plastic typodont teeth has been a mainstay of preclinical dental education for decades. While these teeth help to develop essential hand skills,[1] they are inadequate to simulate tactile differences between sound and diseased tooth structure.[5] Extracted teeth have been shown to provide accurate tactile feedback,[6] however they can present with limited availability, challenges with infection control, and insufficient standardization issues due to significant variability in lesion size and consistency.[7]

These limitations have prompted the development of new methods including virtual reality (VR) simulation with haptic feedback, also new materials such as manufactured plastic teeth that incorporate artificial caries, and in-house 3D printed teeth programmed with simulated caries. Early efforts to simulate operative dental procedures in VR without tactile sensation, however, were found to produce less satisfactory results than traditional training techniques.[8] VR systems with haptic feedback have since been developed that provide tactile differentiation between various anatomic tooth structures and carious lesions. Although these systems have been shown to help improve student motor skills,[9] they can be prohibitively expensive.[10]

Manufacturers of dental educational materials have produced plastic teeth that are commercially available with simulated carious lesions. These allow students to sense tactile differences between sound tooth structure and simulated carious lesions. They also can aid students' ability to understand the use of non-ideal preparation designs that might be dictated by irregular caries location and extent.[11] One drawback that has been reported, however, is the significant potential for variation in the amount of caries between individual teeth that may negatively impact students' performance on their early practical examinations.[12] Another challenge was the significant cost per tooth that can preclude routine use in preclinical training.[11,13]

Advancement in the 3D printing technology within the last decade has prompted several schools to experiment with "in-house" 3D printed individual teeth or full arches with simulated carious lesions. These simulations have generally shown positive results in terms of student perception.[14–16] The materials and techniques employed for individual 3D printed teeth include varying the density of the resin within the simulated lesion,[17] using different material to simulate the lesion,[18] and using a PolyJet style printer to vary the characteristics of the material.[19] Potential drawbacks of 3D printed teeth are the lack of visual color differentiation between sound tooth structure and the lesion,[19,20] and the unrepresentative hardness characteristics of the 3D printed resin as compared to enamel.[14,18] However, it is anticipated that these issues will be addressed with future advancements in the printer technology.

Faculty and students at a Southern California Dental School developed a standardized method of creating artificial caries typodont teeth (ACT) for teaching ideal Class III preparations. This study presents a step-by-step process of creating ACT and evaluates the perception and efficacy of their use in preclinical operative training. We hypothesized that there would be no difference in students' perceptions on the use of conventional typodont teeth (CTT) and ACT and that there would be no difference in the overall preparation scores when comparing CTT and ACT.

2 | MATERIALS AND METHODS

This retrospective data review from the Dental Fundamentals course with first-year dental students was approved by the University's Institutional Review Board (IRB #5230060).

2.1 | Fabrication of artificial caries typodont teeth (ACT)

A maxillary left central incisor typodont tooth (#9, ModuPro One, Acadental, Inc, Overland Park, KS, USA) was selected to have simulated caries placed on the distal surface requiring a Class III cavity preparation. A Craftsman drill platform was equipped with a dental bur to drill a hole in a standardized location to represent caries with a depth of 1.25 mm and diameter of 1 mm on the distal of a #9 ModuPro typodont tooth.

Armamentarium:

- Typodont teeth
- Drill press

FIGURE 1 ACT fabrication sequence and usage in preclinical operative training. (A) A Craftsman drill platform was equipped with a straight handpiece bur to standardize the location with a depth of 1.25 mm and diameter of 1 mm on the distal surface of #9, ModuPro typodont tooth. (B) Artificial caries was made with Titebond Hide glue mixed with chocolate powder in 10:1 weight ratio, respectively. (C) A small injection syringe was used to insert the mixture into the cavities. (D) Teeth were mounted on a spacer board, made to hold at least 100 teeth, for the glue mixture to set. (E) A Hollenbeck carver was used to remove excess flash that was present after drying. (F) Completed ACT of #9. (G) ACT mounted on typodont showing the artificial caries when viewed from the facial. (H) Initiation of the Class III cavity preparation with artificial caries remaining on the facial wall.

- Adjustable customized holding jig secured in position on the drill press platform
- Splash putty to form the impression of the typodont tooth being drilled
- Straight handpiece type #1 round bur (or whatever is suitable for the artificial caries size)
- Small lumen TB syringe and needle
- Titebond hide glue
- Hershey's (or Nestle's) brand dark chocolate (cocoa) powder
- Pegboard paneling with the proper number of holes is recommended to hold the artificial caries teeth while the glue is setting
- Hollenback carver or reasonable substitute instrument for removing excess dried glue

The sequence of ACT fabrication and implementation in the pre-clinical student laboratory is illustrated in Figure 1. A mixture of titebond hide glue and Hershey's brand dark chocolate powder (10:1 weight ratio) was injected using a small-lumen TB syringe and needle into the typodont teeth cavity sites created using the drill press platform with the installed bur. The tooth preps were moderately over-filled until the material formed a dome in order to compensate for expected shrinkage back to flat when it hardened. A sufficient size of ordinary pegboard material was used to hold the teeth while the glue set. The costs for the Hershey's brand dark chocolate powder (8 oz, 226 g) and Titebond Hide Glue (8 oz, 237 mL), were US$ 4.44 around US$ 5 and 10, respectively. The cost for creating artificial caries in these typodont teeth was negligible as only about two tablespoons (< 30 mL) of glue mixture were needed for 100 cavitated typodont teeth and the cost of each typodont tooth was around US$ 1.50. Excluding the waiting period for the mixture to set, the fabrication of 100 ACT teeth required about 2 h in total (equivalent to ~1.2 min per tooth).

2.2 | Comparison of artificial caries in typodont teeth versus conventional typodont teeth

First-year (D1) dental students attended a lecture on ideal Class III cavity preparations including the step-by-step preparation sequence and proper dimension. Students

($N = 99$) were then required to excavate the artificial caries teeth and complete two Class III cavity preparations during the two and a half-hour laboratory session. Students were divided into groups ACT–CTT ($N = 50$) and CTT–ACT ($N = 49$). Group ACT–CTT was given ACT first, while group CTT–ACT was given CTT first. Students had 70 min to complete each preparation.

2.3 | Students' perception on the use of artificial caries in typodont teeth versus conventional typodont teeth

After the completion of two preparations, an 8-item questionnaire was distributed on the perception of the use of ACT versus CTT. The first four questions pertained specifically to the students' perceptions on the use of ACT in preparing ideal Class III preparations followed by two questions addressing general perceptions on the use of ACT versus CTT. Responses were on a 5-point Likert scale ranging from "Strongly agree" to "Strongly disagree." At the end, two open-ended questions were included about what students liked about ACT teeth and what type of improvements could be made in the future.

2.4 | Assessment of preparation

All preparations were assessed by a blinded examiner using a rubric for assessing an ideal Class III tooth preparation on a central incisor (Table 2). It covered three major categories of the preparation: (1) external outline—including the angle of the cavosurface margin, outline smoothness, damage to adjacent teeth, and soft tissue damage; (2) internal form—including the axial wall depth and sharpness/roundness of the internal line angles; and (3) finish—including wall and margin smoothness and removal of all caries and debris. Each category was graded on a scale ranging from ideal (3) to major/unacceptable (0), providing a comprehensive framework for assessing and improving tooth preparations in the dental laboratory class. The total score for each preparation could range from 0 to 9.

Data Analysis: Descriptive statistics were generated to show the average score of the first and second cavity preparation and characterize students' perceptions on the use of ACT versus CTT. The Mann–Whitney *U*-test was used to compare the scores between groups ACT–CTT and CTT–ACT and the Chi-square test was used to compare positive and negative responses from the questionnaire. All analysis of data was performed at alpha = 0.05 with jamovi version 1.6 (Jamovi, Sydney, Australia).

3 | RESULTS

3.1 | Students' perception on the use of artificial caries in typodont teeth versus conventional typodont teeth

Ninety-nine students completed the questionnaire. The distribution of positive and negative responses for each question is outlined in Figure 2. A statistically significant difference was noted in the assessment of positive and negative feedbacks between ACT and CTT, with a clear preference for ACT evident throughout all six questions ($p < 0.05$). For the open-ended question on what students liked about ACT, 93 students provided positive feedback such as:

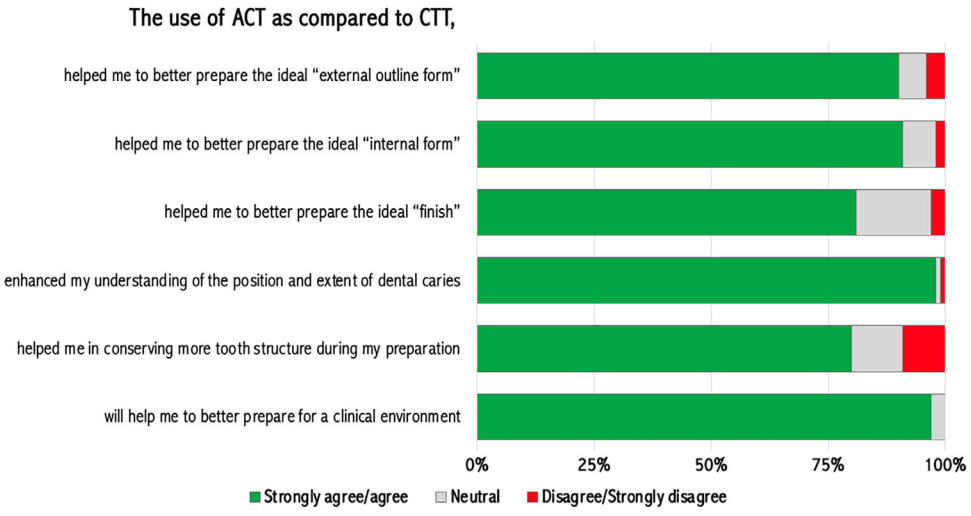

FIGURE 2 Summary of Students' responses to questionnaire ($N = 99$).

TABLE 1 Summary of project scores by group (mean ± SD).

	ACT–CTT	CTT–ACT	*p*-Value
1st Prep	5.7 ± 1.9	5.7 ± 1.0	0.844
2nd Prep	6.2 ± 1.4	5.9 ± 1.7	0.254
*Difference	0.5 ± 1.3	0.2 ± 2.1	0.206

Note: Difference: 2nd prep – 1st prep.

- *"it made the exercise fun"*
- *"the caries lesion smelled like chocolate"*
- *"I liked that it helped me visualize the caries lesion and be more conservative"*
- *"I love that the texture was similar to real decay and that it was visually obvious"*
- *"I liked seeing how deep we have to go to remove decay"*
- *"It helped me determine the correct position incisocervically. On the blank typodont, I made my prep too far incisally. This ACT tooth made me realize that the cavity is located more cervical. It was also interesting to focus on getting rid of the lesion, as opposed to just focusing on making ideal preparations"*
- *"I love it. I wish we could use these teeth for our future projects"*

A total of 25 students addressed the final question regarding potential future enhancements, primarily suggesting varying the size of the lesion and improving the adherence of artificial caries lesion material to the typodont teeth.

3.2 | Assessment of Class III preparation

The scores for the Class III preparations by the group are summarized in Table 1, averaging from 5.7 to 6.2. There was no statistically significant difference between the two groups for the first prep ($P = 0.844$), second prep ($P = 0.254$), and the improvement from first to second prep ($P = 0.206$). For the ACT–CTT group, students on average improved by 6% while for the CTT–ACT group students improved by 2%, which was not statistically significantly different ($P = 0.206$).

4 | DISCUSSION

Developing a process for improvising more realistic caries on typodont teeth involved some preliminary experimentation. During the selection of the appropriate material to simulate caries in the typodont teeth, multiple varieties of adhesive products were tried and evaluated for color and consistency. Aleene's Quick Dry Tacky Glue had a translucent white color and Aleene's Aliphatic Wood Glue (Duncan Enterprises, Fresno, CA, USA) was pinkish tan. They both hardened to a consistency that made light flakes when cut with a slow-speed #1 round bur. Both glues contracted significantly upon setting typically requiring the addition of more glue afterward to nearer to the level of the original surface. Titebond Hide Glue was light honey colored and seemed most favorable because of having less contraction shrinkage after hardening and most representative dental-bur tactile characteristics upon excavation. Hide glue is basically comprised of collagen, which may aid in its resemblance to dental caries. Other materials tested were Loctite Repair Extreme, Henkel Corporation, Avon, OH (clear silicone type adhesive) and Loctite Epoxy Clear, Henkel Corporation, Rocky Hill, CT (clear epoxy adhesive). They offered a more rubbery or chewy texture when excavated with a bur. Nestle brand chocolate powder (Nestle Toll House Cocoa, Nestle USA, Inc., Solon, OH) mixed in an approximately 1:10 wt/wt ratio with Titebond Hide Glue produced acceptable appearance characteristics for the present study.

Overall, there were strongly positive responses from the students on the use of ACT. Students' feedback comments stated that such use of artificial caries offered them greater realism and understanding of caries. Other literature studies similarly showed that students strongly favored using artificial caries, instead of blank typodont teeth,[14,18,21] indicating that students prefer more realistic scenarios in their operative dental education. An overwhelming majority of the students in this present study agreed that using the artificial caries embedded teeth reinforced their understanding and practice of the concepts that they had learned from their didactic operative lectures. This resulted in more conservative outline form with reduced loss of the tooth structure. Students felt that this enhanced their preparation for the follow-on clinical phase of their education with actual live patients. A considerable number also wished that the use of artificial caries would be generally adopted as a standard method for the laboratory course. Since students strongly favored the use of artificial caries compared to using a blank typodont tooth, the first null hypothesis was rejected.

A limited number of studies have been conducted to determine educational outcomes other than students' perceptions when using teeth with artificial caries. Chevalier et al. found that preclinical exercises with artificial caries can help to student anxiety-related stress associated with caries removal. However, they reported that the exercises did not tend to help to increase student knowledge regarding the procedures.[7] Delgado et al. found a statistically significant decrease in performance among the students who used typodont teeth with simulated caries on preclinical practical exams.[12] The authors attributed this decrease to variance in manufacturing consistency of the typodont

TABLE 2 Ideal Class III preparation assessment Rubric.

Class III Prep	**Tooth: #9 (DL)** **Ideal: 3**	**Date:** **Slight: 2**	**Student initials:** **Moderate: 1**	**Box #:** **Major/unacceptable:0**
External outline	Extended for convenience. Broken contact facially (hair line). Broken contact gingivally Max 0.5 mm. I–G is 1.5– 2 mm. 90° exit angles.	Over/Under extended: I, F, G. Facial clearance is 0.5 mm. Gingival clearance more than 0.5 mm less than 1 mm.	Over/under extended: I, F, G. Facial clearance is between 0.5–1 mm. Gingival clearance is 1 mm.	Over/under extended: I, F, G. Facial clearance is more than 1 mm. Not open facially or gingivally. Gingival clearance is more than 1 mm.
		Angle of departure: less than/greater than 90°.	Angle of departure: less than/greater than 90°.	Angle of departure: less than/greater than 90°.
	Smooth flowing outline.	Slight irregular outline.	Moderate irregular outline.	Severe irregular outline.
	No damage to adjacent tooth.	Slight damage to adjacent tooth.	Moderate damage to the adjacent tooth.	Non repairable adjacent tooth damage.
	Soft tissue is free from damage.	Slight soft tissue damage.	Moderate soft tissue damage.	Severe soft tissue damage.
Internal form	Axial wall depth is 1–1.2 mm. Rounded internal line angles.	Axial wall depth is slightly less than 1 mm or at 1.5 mm.	Axial wall depth is more than 1.5 mm and less than 2 mm.	Axial wall depth is more than 2.0 mm. Jeopardized incisal angle.
Finish	Walls and margins smooth and well defined.	Rough walls or margins.	Rough walls or margins.	Rough walls or margins.
		Lacking internal definition.	**L**acking internal definition.	Loose or undermined enamel margins/ walls.
	Cavity is clean and no caries visible.	Cavity with slight debris and caries.	Moderate debris and caries present.	Internal of cavity poorly defined/devoid of form. Major debris and caries present.
2nd Class III prep	**Tooth: #9 (DL)** **Ideal: 3**	**Date: February 1, 2023** **Slight: 2**	**Student Initials:** **Moderate: 1**	**Box #:** **Major/Unacceptable:0**
External Outline	Extended for convenience. Broken contact facially (hair line). Broken contact gingivally Max 0.5 mm. I–G is 1.5– 2 mm. 90° exit angles.	Over/under extended: I, F, G. Facial clearance is 0.5 mm. Gingival clearance more than 0.5 mm less than 1 mm.	Over/under extended: I, F, G. Facial clearance is between 0.5–1 mm. Gingival clearance is 1 mm.	Over/under extended: I, F, G. Facial clearance is more than 1 mm. Not open facially or gingivally. Gingival clearance is more than 1 mm.
		Angle of departure: less than/greater than 90°.	Angle of departure: less than/greater than 90°.	Angle of departure: less than/greater than 90°.

(Continues)

TABLE 2 (Continued)

2nd Class III prep	Tooth: #9 (DL) Ideal: 3	Date: February 1, 2023 Slight: 2	Student Initials: Moderate: 1	Box #: Major/Unacceptable:0
	Smooth flowing outline.	Slight irregular outline.	Moderate irregular outline.	Severe irregular outline.
	No damage to adjacent tooth.	Slight damage to adjacent tooth.	Moderate damage to the adjacent tooth.	Non repairable adjacent tooth damage.
	Soft tissue is free from damage.	Slight soft tissue damage.	Moderate soft tissue damage.	Severe soft tissue damage.
Internal form	Axial wall depth is 1–1.2 mm. Rounded internal line angles.	Axial wall depth is slightly less than 1 mm or at 1.5 mm.	Axial wall depth is more than 1.5 mmand less than 2 mm.	Axial wall depth is more than 2.0 mm. Jeopardized incisal angle.
Finish	Walls and margins smooth and well defined.	Rough walls or margins.	Rough walls or margins.	Rough walls or margins.
		Lacking internal definition.	Lacking internal definition.	Loose or undermined enamel margins/walls.
	Cavity is clean.	Cavity with slight debris.	Moderate debris present.	Internal of cavity poorly defined/ devoid of form. Major debris present.

teeth which led to overextension of the caries.[12] These findings were in contrast to the present study which showed no statistically difference in subsequent exam performance between the two groups. Therefore, our second hypothesis was accepted. Based on these results, the use of artificial caries in typodont teeth appears to be at least as well suited to aiding students in preparing for practical clinical situations as it is a means of improving preclinical laboratory examination scores.

The use of ACT is a cost-effective way of simulating artificial caries lesions compared to commercially available typodont teeth with factory-incorporated artificial caries. According to the students' questionnaire responses, the distinctive contrasting color of the caries lesions helped them to visualize caries removal and perform cavity preparation more efficiently than with regular typodont teeth. These results were generally consistent with the findings of other published studies.[14,18,21]

Upon conducting a critical self-evaluation, several limitations inherent in the present study were identified. Because evaluating the consistency of the simulated lesion was not included in the protocol of the present study, slight variations among teeth may have been present. However, because the lesion size was considerably smaller than the recommended preparation outline form, any possible inconsistencies were considered unlikely to have altered student performance. ACT in the present study did not exhibit as realistic and penetrable tugback properties as some commercially available teeth when tested using a dental explorer. However, lacking actual tactile sensation did not appear to affect the students' ability to remove caries. The hide glue and chocolate powder mixture used in this study to simulate caries did not totally adhere to or integrate with the typodont tooth which may have influenced the experience of some of the students when performing caries excavation adjacent to the sound tooth structure. The assessment rubric of this study was designed to evaluate the ideal Class II preparation and it may actually have been of further benefit to include the assessment of some of the critical thinking skills involved with caries removal.

Further studies might investigate the use of posterior ACT for Class II cavity preparations to create more suitable levels of caries simulation. Also, caries removal from the ACT could be evaluated to acadental teeth ((DTX (First Generation) carious teeth) and other brands having factory-incorporated artificial caries. Furthermore, there is a need for a more extensive evaluation into the translation of skills gained through the use of these ACT to actual clinical situations.

5 | CONCLUSION

The ACT protocol described in this study was feasible when implemented at the preclinical laboratory instruction level and received positive feedback from dental students.

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