CBCT-Based 3-D Printed Simulation Model for Pediatric Dental Trauma Training

Anthony Leisure, DDS | Simon Lin, DDS, MS | Thomas Tanbonliong, DDS | Lloyd Mancl, MS, PhD

Background

Traumatic dental injuries (TDIs) are common in pediatric patients, affecting approximately 33% of children and 25% of adolescents [1, 4]. These injuries require rapid, evidence-based management to prevent unfavorable outcomes such as pulpal necrosis, root resorption, and tooth loss [3, 4]. Clinical outcomes are highly dependent on timely decision-making and accurate procedural execution.

Despite established guidelines from the International Association of Dental Traumatology, a persistent gap exists between theoretical knowledge and clinical application, as dentists report limited exposure to trauma cases and low preparedness in managing these high-stakes clinical situations [2, 3, 4].

Simulation-based education provides a controlled environment for skill development and has been shown to enhance clinical learning; however, more advanced models are needed to replicate the complexity of pediatric dental trauma [3, 4].

Purpose

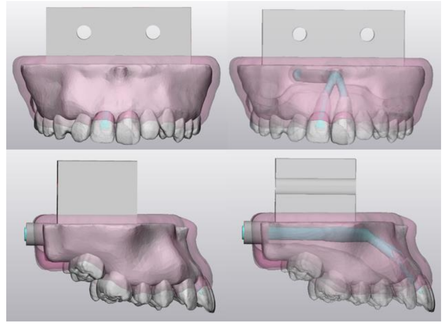
Develop and evaluate a CBCT-based, 3D-printed high-fidelity simulation model for pediatric dental trauma management. Assess the impact of a single-session simulation on dental students' theoretical knowledge, self-reported confidence and preparedness, objective clinical performance, and physiological stress responses.

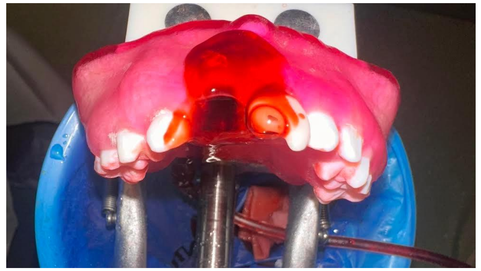
Methods

Twenty-five third and fourth-year dental students at the University of Washington were randomly selected to participate in a single-group pre-post study design. We developed a pediatric dental trauma simulation model using CBCT-based 3D printing, incorporating avulsion, complicated crown fracture (Cvek pulpotomy), splinting, and simulated bleeding to replicate real clinical scenarios.

Participants completed pre- and post-simulation assessments evaluating trauma knowledge and self-reported confidence across multiple domains using 0-10 a Likert scale. Objective performance was measured using case-based multiple-choice questions and a procedural accuracy score during simulation.

Statistical analysis included paired t-tests for continuous outcomes and McNemar's tests for categorical data, with significance set at $p < 0.05$.





Results

Variable	N = 25
Trauma	
Mean (SD)	9.0 (1.6)
Median (IQR)	10.0 (8.0, 10.0)
Min to Max	3.0, 10.0
Skewness	-2.3
Recommend	
Mean (SD)	9.6 (0.8)
Median (IQR)	10.0 (10.0, 10.0)
Min to Max	8.0, 10.0
Skewness	-1.6
Realistic	
Mean (SD)	9.4 (1.2)
Median (IQR)	10.0 (9.0, 10.0)
Min to Max	5.0, 10.0
Skewness	-2.1
Engagement	
Mean (SD)	8.8 (1.8)
Median (IQR)	10.0 (8.0, 10.0)
Min to Max	5.0, 10.0
Skewness	-1.1
Bleeding Stress	
Mean (SD)	6.5 (3.1)
Median (IQR)	7.0 (5.0, 9.0)
Min to Max	1.0, 10.0
Skewness	-0.4
Increased Stress	
Mean (SD)	9.1 (1.3)
Median (IQR)	10.0 (8.0, 10.0)
Min to Max	5.0, 10.0
Skewness	-1.4
Lecture vs Simulation	
Mean (SD)	9.7 (0.9)
Median (IQR)	10.0 (10.0, 10.0)
Min to Max	6.0, 10.0
Skewness	-2.8

Overall model assessment table: the simulation was highly rated across all domains, with near-perfect scores for realism, recommendation, and preference over lecture.

Variable	Pre (N=25)	Post (N=25)	Post-Pre	95% CI	P-value
Trauma management					
Mean (SD)	3.6 (2.0)	8.6 (1.0)	5.0 (2.1)	4.1, 5.8	<.001
Min to Max	1.0, 8.0	7.0, 10.0	0.0, 9.0		
Bleeding control					
Mean (SD)	4.1 (2.3)	8.6 (1.0)	4.5 (2.0)	3.6, 5.3	<.001
Min to Max	1.0, 8.0	7.0, 10.0	0.0, 7.0		
Decision making					
Mean (SD)	5.2 (1.9)	8.5 (1.0)	3.3 (1.7)	2.6, 4.0	<.001
Min to Max	2.0, 9.0	7.0, 10.0	1.0, 7.0		
Communication					
Mean (SD)	6.3 (2.3)	7.8 (1.9)	1.4 (2.0)	0.6, 2.3	.001
Min to Max	2.0, 10.0	2.0, 10.0	-2.0, 7.0		
Protocol knowledge					
Mean (SD)	3.7 (1.9)	9.0 (0.8)	5.2 (1.9)	4.4, 6.0	<.001
Min to Max	1.0, 7.0	8.0, 10.0	2.0, 8.0		

All domains improved significantly after simulation ($p \leq 0.001$), with large effect sizes and confidence intervals confirming consistent, clinically meaningful gains.

Variable	N = 25
Bleeding Realism	
Mean (SD)	9.2 (1.4)
Median (IQR)	10.0 (9.0, 10.0)
Min to Max	5.0, 10.0
Skewness	-1.7
Bleeding Trauma	
Mean (SD)	9.0 (1.5)
Median (IQR)	10.0 (8.0, 10.0)
Min to Max	5.0, 10.0
Skewness	-1.3
Bleeding Stress	
Mean (SD)	8.3 (1.7)
Median (IQR)	8.0 (7.0, 10.0)
Min to Max	4.0, 10.0
Skewness	-0.8

Simulated bleeding achieved near-perfect ratings for realism and trauma (median = 10), with strong consensus and appropriate stress induction, supporting high simulation fidelity.

Variable	N = 25
Replanting	
Mean (SD)	9.4 (1.1)
Median (IQR)	10.0 (9.0, 10.0)
Min to Max	6.0, 10.0
Skewness	-1.8
Avulsed Tooth	
Mean (SD)	9.5 (1.0)
Median (IQR)	10.0 (10.0, 10.0)
Min to Max	6.0, 10.0
Skewness	-2.2
Splint	
Mean (SD)	9.3 (1.3)
Median (IQR)	10.0 (9.0, 10.0)
Min to Max	4.0, 10.0
Skewness	-2.6

Key procedural components—replantation, avulsed tooth handling, and splinting—received near-perfect ratings (median = 10), supporting high procedural realism and educational value.

Variable	N = 25
Cvek	
Mean (SD)	9.1 (1.3)
Median (IQR)	10.0 (8.0, 10.0)
Min to Max	6.0, 10.0
Skewness	-1.0
Pulpotomy Materials	
Mean (SD)	9.0 (1.3)
Median (IQR)	10.0 (8.0, 10.0)
Min to Max	6.0, 10.0
Skewness	-0.7
Pulp Removal	
Mean (SD)	9.2 (1.3)
Median (IQR)	10.0 (8.0, 10.0)
Min to Max	6.0, 10.0
Skewness	-1.1

The Cvek pulpotomy component received near-perfect ratings (median = 10), supporting high procedural fidelity and realistic replication of materials and technique.

Conclusions

- A high-fidelity, CBCT-based simulation model significantly improved dental students' trauma knowledge and confidence across all domains
- Participants rated the model highly for realism and its educational value
- Supports the needs for repeated high realism simulation-based training
- Integration of advanced simulation into dental school curriculum represents a valuable strategy for bridging the gap between theoretical knowledge and clinical practice
- Future studies should include larger cohorts and control groups, while continuing to refine simulation models to further enhance clinical realism and training effectiveness