

Flipped Classroom Versus Conventional Didactic Teaching and Examination Performance Among Dental Students: A Prospective Comparative Cohort Analysis

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Abstract

Background: Flipped classroom teaching moves initial exposure to instructional material before class and uses scheduled contact time for active learning, application and feedback. Evidence in health-professions and dental education suggests potential academic benefit, but effects vary by implementation and study design.

Objective: To compare preclinical prosthodontic examination performance across four annual dental student cohorts exposed to conventional/didactic or flipped classroom teaching.

Methods: This comparative cohort analysis included 400 undergraduate dental students from four annual cohorts of 100 students each. Conventional/didactic teaching was used in 2022 and 2024, and flipped classroom teaching in 2023 and 2025. Teaching occurred for approximately 6–8 hours per week from October to September. The primary outcome was a 0–100 preclinical complete-denture tooth-arrangement examination score. Because variances differed across cohorts, Welch's one-way ANOVA was used, followed by pairwise Welch tests with Holm adjustment. Cohen's d was used for standardized differences. A pooled comparison of conventional versus flipped cohorts was also performed.

Results: Mean scores were 64.35±6.56, 77.35±6.99, 68.44±11.34 and 86.41±5.75 for the 2022 conventional, 2023 flipped, 2024 conventional and 2025 flipped cohorts, respectively. Welch's ANOVA showed a significant difference across cohorts ($F(3,216.20) = 228.83$, $p < 0.001$). The pooled conventional mean was 66.40±9.47 and the pooled flipped mean was 81.88±7.83. The mean difference was 15.49 marks (95% CI 13.78–17.19), Welch's $t = 17.82$, $df = 384.57$, $p < 0.001$; Cohen's $d = 1.78$.

Conclusion: Higher examination scores were observed in the flipped classroom cohorts. However, teaching approach was completely confounded with academic year, and examination, faculty, student and temporal differences may explain part of the observed association. The findings therefore support further controlled evaluation rather than a definitive causal claim.

Keywords: flipped classroom; dental education; prosthodontics; didactic teaching; active learning; academic performance; examination scores; cohort study.

Introduction

Dental education requires integration of theoretical knowledge, psychomotor skills, clinical reasoning and professional competencies. Conventional teacher-directed instruction can efficiently transmit foundational content, whereas active-learning approaches provide greater opportunity for application, discussion, feedback and higher-order problem solving.^{1,2}

A flipped classroom is a blended instructional model in which students encounter core learning material before scheduled class time, while face-to-face time is redirected towards discussion, application, problem solving, demonstration and faculty-guided practice.^{1,2} A meta-analysis of 28 comparative health-professions studies reported an overall advantage for flipped learning (SMD 0.33, 95% CI 0.21–0.46).¹ A later systematic review involving 45 studies and 8,426 undergraduate health-professions students found higher academic performance with flipped learning (SMD 0.57, 95% CI 0.25–0.90), although certainty of evidence was low and heterogeneity was substantial. Dental education is particularly relevant because students must translate theoretical principles into technical and clinical decisions. A dental scoping review found generally favourable learner perceptions but noted that evidence for academic performance and skill development remained less consistent.³ A 2024 systematic review and meta-analysis of 29 randomized trials involving 3,502 dental students found improved academic performance with flipped classroom teaching compared with lecture-based learning (SMD 0.50, 95% CI 0.31–0.69).⁴ A 2026 systematic review

and meta-analysis similarly reported better academic performance and one-month retention with active teaching methods, while rating the certainty of evidence as low.⁵

Preclinical prosthodontics is well suited to active learning because students must integrate anatomical orientation, tooth selection, tooth arrangement, occlusion, aesthetics, laboratory procedures and error correction. A preclinical dental study using a WeChat-based flipped classroom reported improved test and root-canal-filling performance compared with lecture-based teaching.⁶

The present study compares examination performance across four annual dental cohorts taught using conventional/didactic or flipped classroom approaches. Because the instructional approach coincided with academic year, the study estimates an association rather than an independent causal effect.

2. RESEARCH QUESTION AND HYPOTHESIS

Research question: Is preclinical prosthodontic examination performance different among dental student cohorts taught using flipped classroom compared with conventional/didactic teaching?

Null hypothesis: There is no difference in examination performance among the four annual cohorts or between pooled conventional and flipped classroom cohorts.

3. MATERIALS AND METHODS

A. Study design and reporting

This was a Prospective comparative cohort analysis of examination-performance data from four completed annual undergraduate dental cohorts. The original description as a prospective comparative cohort was corrected because the available analysis concerns completed historical cohorts without prospective allocation to teaching method. Reporting was structured according to STROBE recommendations for observational cohort studies.⁷

B. Study population

Academic year	Teaching approach	n
2022	Conventional/didactic	100
2023	Flipped classroom	100
2024	Conventional/didactic	100
2025	Flipped classroom	100
Total		400

The analytic dataset contained 400 students, with 100 students represented in each annual cohort. No personally identifying information was required for the statistical analysis.

C. Educational intervention

Curriculum and duration

Teaching was delivered over one complete academic year, from October to September, with approximately 6–8 hours of prosthodontic teaching per week. The curriculum addressed complete-denture prosthodontic principles, including edentulous-arch analysis, identification and marking of anatomical landmarks, artificial-tooth selection, anterior and posterior tooth arrangement, occlusal development, laboratory procedures, error identification and correction, laboratory safety, professional ethics and patient-centred considerations.

I. Conventional/didactic method:

The conventional cohorts received predominantly faculty-directed classroom and preclinical instruction. Faculty introduced and explained theoretical concepts during scheduled teaching sessions, followed by demonstration, clarification, supervised practical application and feedback. Four MDS faculty members in Prosthodontics and Crown & Bridge were involved; the approximate faculty-to-student ratio was 1:50 for theory and 1:25 for practical sessions. The same faculty pool taught the cohorts. No specific additional training was reported for the conventional teaching protocol. The institutional attendance requirement was 80%; attendance was recorded digitally through the ERP, with a reported mean attendance of approximately 83%.

II. Flipped classroom method :

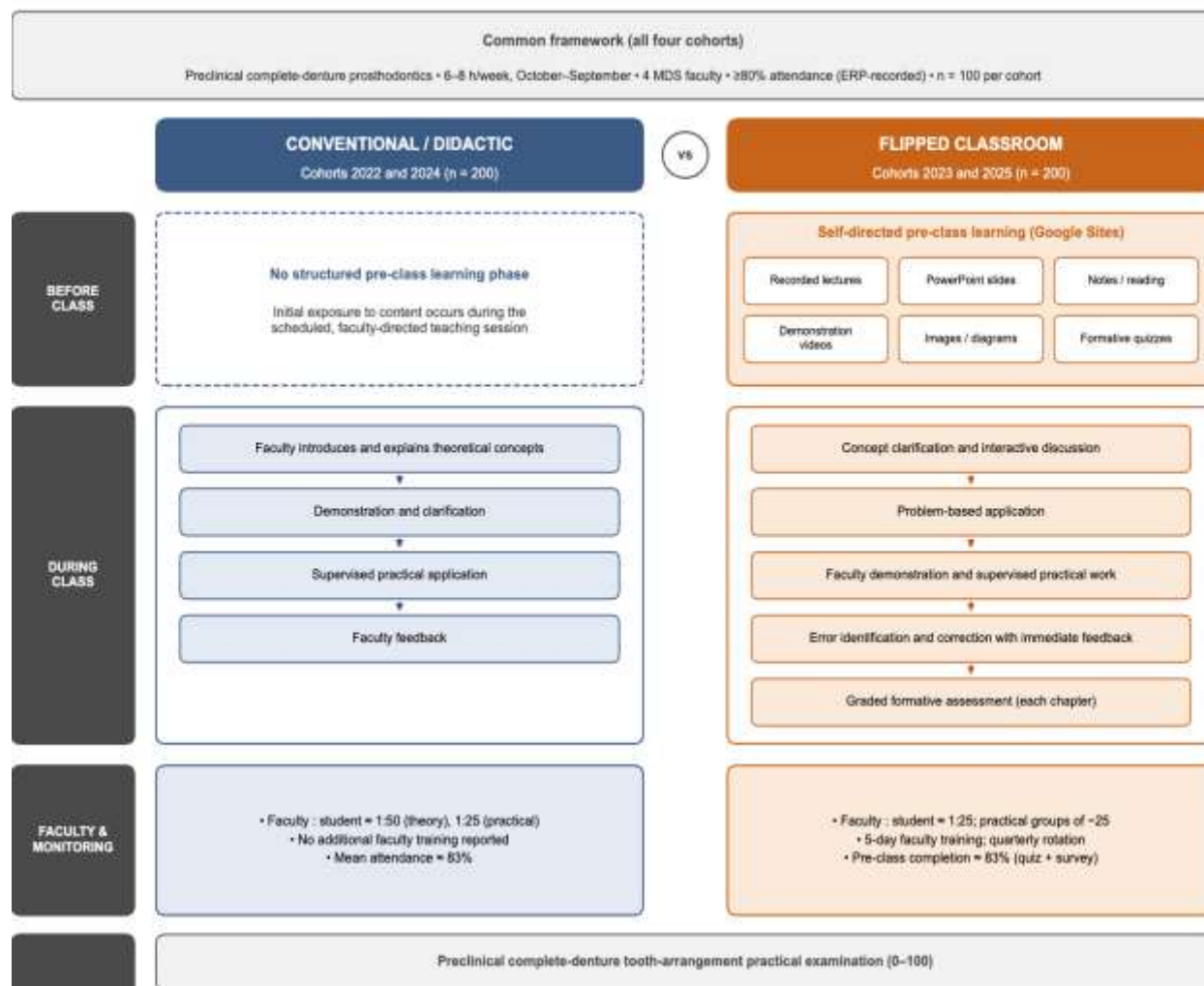
The flipped cohorts received initial exposure to instructional material before scheduled classroom sessions. Pre-class resources included recorded lectures, PowerPoint presentations, faculty-prepared notes/reading material,

demonstration videos, digital images/diagrams and formative quizzes. Material was distributed through Google Sites.

The intervention lasted one academic year from October to September, with approximately 6–8 hours of teaching per week. In-class time emphasized concept clarification, interactive discussion, problem-based application, faculty demonstration, supervised practical work, error identification and correction, immediate feedback and formative assessment. Each chapter included formative assessment activities that were graded and recorded.

Four MDS faculty members participated. The faculty-to-student ratio was approximately 1:25 during classroom and practical activities. Faculty received a 5-day orientation/training programme in innovative teaching and learning methodologies. The same faculty pool delivered the intervention, rotating on a quarterly basis.

The minimum attendance requirement was 80%, with attendance recorded through electronic attendance management software in the ERP. Practical students were organized in groups of approximately 25. Completion of pre-class learning was monitored using formative assessment within Google Sites together with a pre-class survey; approximately 83% completion was reported.



D. Outcome assessment

Academic performance was assessed using the preclinical complete-denture tooth-arrangement practical examination. Students arranged artificial teeth for an edentulous arch and demonstrated application of complete-denture principles to the specified preclinical scenario. The examination assessed the final practical outcome together with relevant theoretical understanding and justification.

Domain	Competency assessed
1. Tooth selection and anatomical orientation	Appropriate tooth selection; identification and

	marking of anatomical landmarks and index/reference lines.
2. Anterior tooth arrangement	Correct anterior positioning, alignment, inclination and aesthetic integration.
3. Posterior arrangement and occlusion	Posterior arrangement, appropriate occlusal scheme, functional occlusion and justification.
4. Prosthodontic knowledge and error management	Tooth-arrangement principles; identification, prevention and correction of errors.
5. Laboratory procedures and safety	Complete-denture laboratory procedures, material/instrument handling and laboratory safety.
6. Aesthetics, ethics and patient care	Aesthetic-functional integration, professional conduct, ethical awareness and patient-welfare considerations.

The examination score was recorded on a 0–100 scale. The available manuscript does not document the exact mark allocation among domains, examination duration, number of examiners, examiner calibration, pass mark, or formal validity/reliability testing. These details must be verified before submission. Equivalence of the assessment across academic years should also be confirmed; if different examinations were used, this is a major potential source of measurement confounding.

E. Statistical analysis

Continuous scores were summarized using mean, standard deviation, median, minimum and maximum. Variance heterogeneity was assessed using Levene's test. Because equal variances were not assumed, Welch's one-way ANOVA was used for the four-cohort comparison. Pairwise comparisons used Welch's independent-samples t-test with Holm adjustment. Cohen's d was used for standardized differences. The two conventional cohorts were pooled and compared with the two flipped cohorts using Welch's independent-samples t-test. Two-sided $p < 0.05$ was considered statistically significant. The reported analysis should be rerun using the original student-level dataset before submission.

4. Results

A. Descriptive statistics

Cohort	Method	n	Mean $\pm$ SD	Median	Minimum	Maximum
2022	Conventional	100	64.35 $\pm$ 6.56	63.50	38.0	81.0
2023	Flipped	100	77.35 $\pm$ 6.99	77.25	41.5	92.5
2024	Conventional	100	68.44 $\pm$ 11.34	70.00	32.0	90.0
2025	Flipped	100	86.41 $\pm$ 5.75	86.50	49.0	97.5
			74.14 $\pm$ 10.02*			

*Overall SD from the cohort summary statistics and equal cohort sizes.

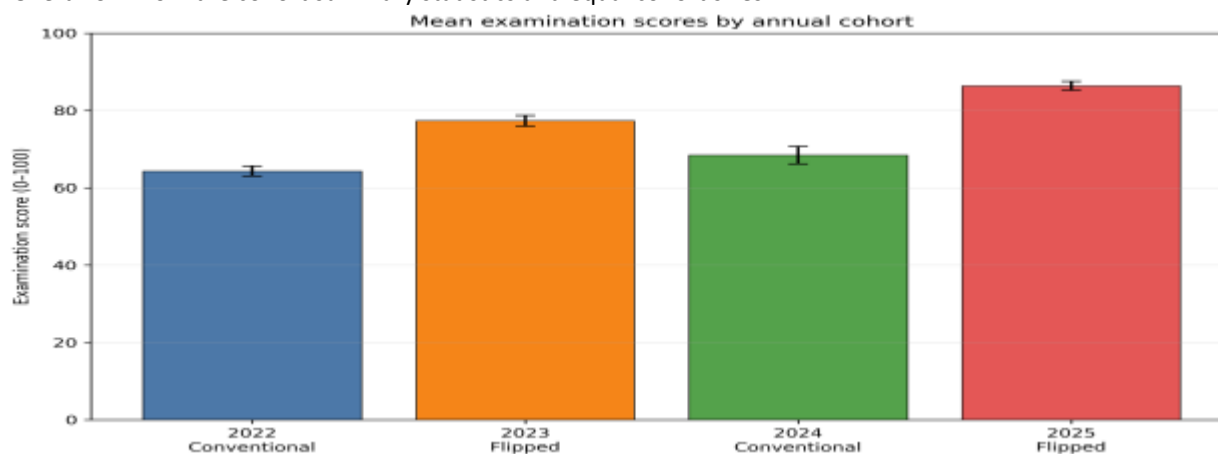


Figure 1. Mean preclinical prosthodontic examination score by annual cohort. Error bars represent 95% confidence intervals.

B. Four-cohort comparison:

Levene's test indicated unequal variances ($p < 0.001$). Welch's ANOVA demonstrated a statistically significant difference among cohorts, $F(3,216.20) = 228.83$, $p < 0.001$. Descriptive η^2 and ω^2 estimates were 0.535 and 0.531, respectively. These are descriptive between-cohort measures and should not be interpreted as causal treatment effects.

C. Pairwise comparisons :

Comparison	Mean difference	95% CI	Welch df	Holm-adjusted p	Cohen's d
2022 vs 2023	-13.00	-14.89 to -11.11	197.21	<0.001	-1.92
2022 vs 2024	-4.09	-6.68 to -1.50	158.59	0.002	-0.44
2022 vs 2025	-22.06	-23.78 to -20.34	194.66	<0.001	-3.58
2023 vs 2024	+8.91	+6.28 to +11.54	164.74	<0.001	+0.95
2023 vs 2025	-9.06	-10.85 to -7.27	190.90	<0.001	-1.42
2024 vs 2025	-17.97	-20.48 to -15.46	146.75	<0.001	-2.00

All six pairwise comparisons remained statistically significant after Holm adjustment.

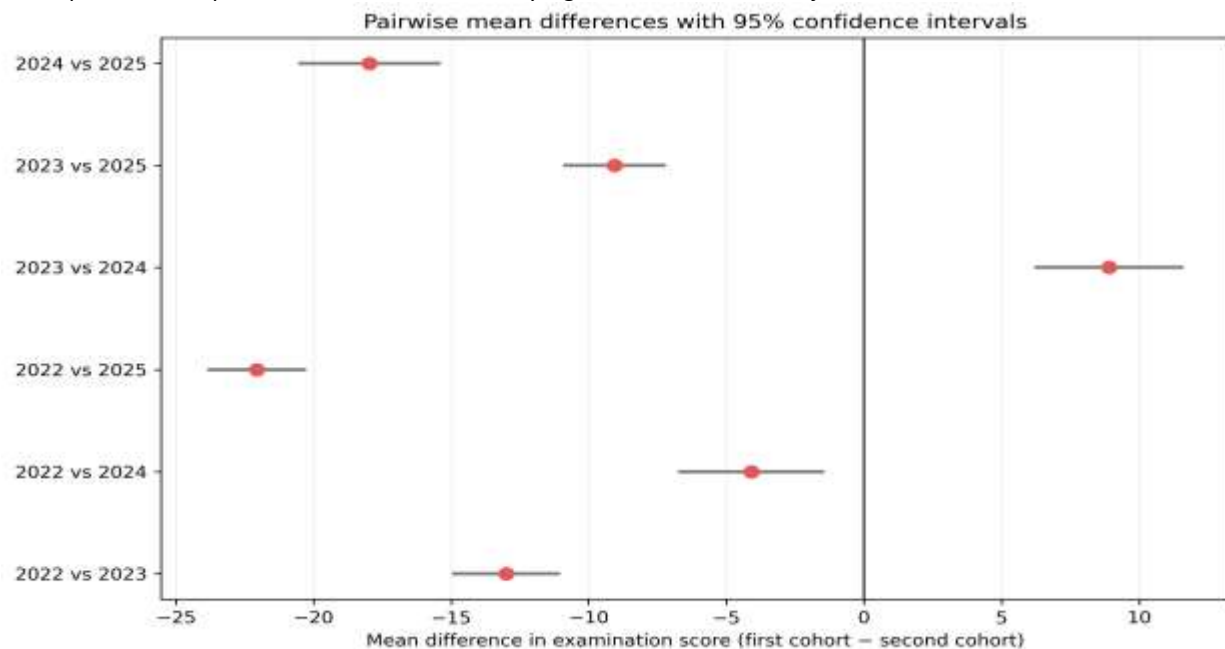


Figure 2. Pairwise cohort mean differences with 95% confidence intervals. Negative values indicate a lower mean for the first-listed cohort

D. Pooled comparison by teaching approach:

The pooled conventional mean was 66.40 ± 9.47 ($n = 200$) and the pooled flipped mean was 81.88 ± 7.83 ($n = 200$). The mean difference was 15.49 marks (95% CI 13.78–17.19). Welch's t-test yielded $t(384.57) = 17.82$, $p < 0.001$. Cohen's d was 1.78 and Hedges' g was approximately 1.78.

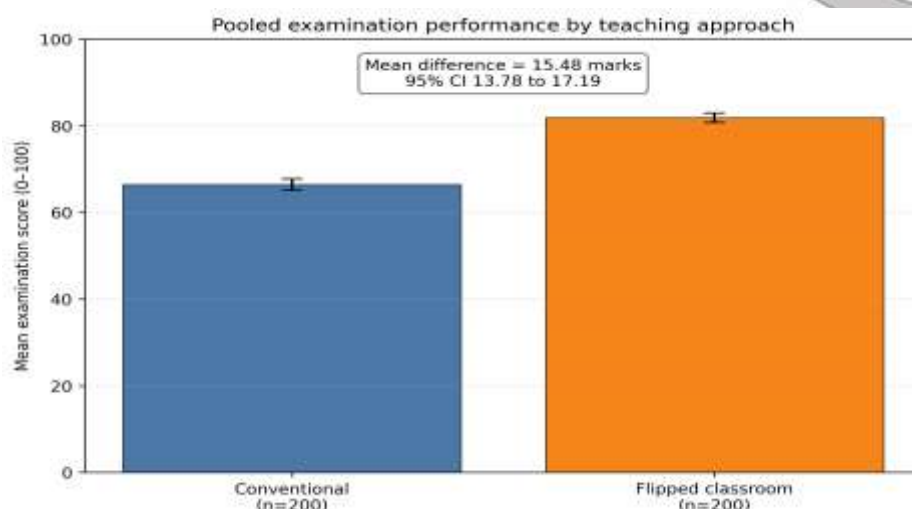


Figure 3. Pooled examination performance by teaching approach. Error bars represent 95% confidence intervals.

5. DISCUSSION

This retrospective cohort analysis identified substantially higher preclinical prosthodontic examination scores in the flipped classroom cohorts. The pooled difference was 15.49 marks, with a large standardized difference (Cohen's $d=1.78$). This is larger than pooled effects reported in broader health-professions and dental education syntheses and should therefore be interpreted cautiously.

The direction of the finding is consistent with previous evidence. Hew and Lo reported SMD 0.33 across 28 comparative health-professions studies, while Naing et al. reported SMD 0.57 across 44 studies contributing academic-performance data.^{1,2} Pang et al. reported SMD 0.50 for flipped classroom teaching in dental education.⁴ A 2026 systematic review of active teaching methods in undergraduate dental education also found improved academic performance and one-month retention, but rated the certainty of evidence as low.⁵

The central interpretive problem is confounding by academic year. Conventional teaching occurred in 2022 and 2024, whereas flipped teaching occurred in 2023 and 2025. Teaching method and year are therefore inseparable in this dataset. Differences in cohort composition, faculty, examination difficulty or blueprinting, attendance, technology exposure, curriculum delivery and other temporal factors could contribute to the observed difference. The higher scores in 2024 than 2022 among conventional cohorts and in 2025 than 2023 among flipped cohorts further support the possibility of secular or cohort effects.

Potential mechanisms include earlier exposure to content, increased opportunity for retrieval and application, greater classroom interaction and immediate feedback. These mechanisms were not directly measured and should not be presented as outcomes of this study.

Strengths include 400 students, balanced annual cohort sizes, an objective numerical outcome, variance-robust statistical testing, multiplicity adjustment and effect-size reporting. Limitations include the historical non-randomized design, complete confounding of method with year, lack of baseline academic-performance data, incomplete documentation of examination equivalence and absence of additional outcomes such as retention, satisfaction or clinical competence.

6. CONCLUSION

In this retrospective comparative cohort analysis of 400 dental students, flipped classroom cohorts had higher preclinical prosthodontic examination scores than conventional/didactic cohorts. The pooled mean difference was 15.49 marks (95% CI 13.78–17.19), with Cohen's $d=1.78$. However, teaching approach was inseparable from academic year and important potential confounders were not measured. The results should therefore be interpreted as an association between cohort-level teaching approach and examination performance rather than proof of causation. Prospective controlled or randomized studies with standardized assessments and baseline academic measures are warranted.

7. DECLARATIONS

Funding

No external funding was reported in the supplied manuscript.

Competing interests

The authors declared no conflict of interest in the given manuscript.

Author contributions

Dr. Yeshwanth Krishna L: Conceptualization, Methodology, Investigation, Supervision, Writing – Review & Editing. Dr. Rohit M: Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft. Dr. Hemamalini Balaji: Conceptualization, Methodology, Investigation, Visualization, Writing – Original Draft, Writing – Review & Editing. Dr. Reshika GA: Investigation, Data Curation, Formal Analysis, Visualization, Writing – Original Draft. Dr. Annapoorani B: Investigation, Data Curation, Validation, Writing – Review & Editing.

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