

# Multiple choice as formative assessment in dental education

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## Abstract

**Introduction:** The effectiveness of multiple-choice questions (MCQs) in dental education is pivotal to student performance and knowledge advancement. However, their optimal implementation requires exploration to enhance the benefits.

**Materials and Methods:** An educational tool incorporating MCQs was administered from the 5th to the 10th semester in a dental curriculum. The students filled out a questionnaire after the MCQ, which was linked to the learning management system. Four cohorts of four semesters generated 2300 data points analysed by Spearman correlation and mixed model regression analysis.

**Results:** Demonstrated a significant correlation between early exam preparation and improved student performance. Independent study hours and lecture attendance emerged as significant predictors, accounting for approximately 10.27% of the variance in student performance on MCQs. While the number of MCQs taken showed an inverse relationship with study hours, the perceived clarity of these questions positively correlated with academic achievement.

**Conclusion:** MCQs have proven effective in enhancing student learning and knowledge within the discipline. Our analysis underscores the important role of independent study and consistent lecture attendance in positively influencing MCQ scores. The study provides valuable insights into using MCQs as a practical tool for dental student learning. Moreover, the clarity of assessment tools, such as MCQs, remains pivotal in influencing student outcomes. This study underscores the multifaceted nature of learning experiences in dental education and the importance of bridging the gap between student expectations and actual performance.

## KEYWORDS

dental education, learning management platform, multiple-choice questions, student performance

## 1 | INTRODUCTION

Formative assessment is an essential component of any dental education programme. It provides a means of evaluating student learning, promoting student engagement and providing opportunities for

students to receive feedback on their performance. One form of assessment that has gained popularity in dental education is using multiple-choice questions (MCQs).<sup>1</sup> MCQs are a quick, efficient and cost-effective assessment form that can provide objective and immediate feedback to students. However, using MCQs in formative

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assessment in dental education is a topic of ongoing research and debate.<sup>2</sup> While many educators recognise the potential benefits of MCQs, some argue that there may be better assessment forms for evaluating and supporting learning in clinical and practical skills required in dentistry.

A critical factor in students' learning depends on how they are assessed.<sup>3-6</sup> This sometimes causes students to emphasise preparing for upcoming exams more than keeping previously acquired knowledge in educational programmes with high knowledge demands. Furthermore, significant knowledge requirements, particularly in high-stakes professional education, frequently pressure students to give up favoured learning activities, which are replaced by calculated actions that result in assessment success.<sup>7</sup> Therefore, a clear recommendation in the literature is to implement assessment activities that make students appraise productive and relevant approaches to learning. Formative and summative assessment concepts can illustrate these recommendations. Summative assessment is a final measure of what the student knows by the end of a course. In contrast, formative assessment provides information about performance during a course, allowing students to adjust their learning accordingly. A fundamental premise in successful assessment is to stimulate productive learning and provide supportive feedback to the learner rather than exclusively focusing on marking and measuring.

The current study focuses on developing an assessment strategy where students in a dental education programme are required to maintain previously attained knowledge. We were concerned that the dental students would graduate from our institute without mastering the most fundamental knowledge in each discipline since the written exams from different disciplines are spread throughout the whole education. Therefore, it was discussed how we could ensure that all the students who graduated from our programme would master particular knowledge demands. This assessment strategy is based on MCQs, testing students' knowledge from preceding course teaching and examinations. While the MCQ testing aims to refresh and maintain students' knowledge from previous courses in the dental education programme, the challenge with this MCQ-based approach is twofold. While MCQs can be valuable in testing the capacity to remember core contents and principles, they fail to measure more profound knowledge, encouraging surface learning.<sup>8</sup> Second, implementing MCQs is not conceived as a supportive measure by students as it needs to provide productive feedback to their learning.<sup>9</sup> Hence, MCQs are mainly perceived as summative assessment procedures implemented to control students' knowledge at the end of an educational process.

Implementing MCQ testing in the dental education programme aimed to assess what students remembered from previous courses and provide feedback, allowing them to refresh their knowledge productively; we were worried when we introduced an MCQ test in the middle of each clinical semester that each student had to pass, how to avoid adding MCQ as a supplementary exam and ensure that the student learnt from the MCQ test while guaranteeing quality

and correct implementation. This approach presupposes a sense of agency, enabling students to adjust their learning appropriately based on carrying out MCQs.

This research paper aims to explore how using MCQs as a formative assessment influences study skills and preparedness for examinations in dental education. The Faculty of Dentistry introduced MCQs in their new master's degree curriculum ('UiO ODONT 2010'). The questionnaire was implemented in each clinical semester (semesters 5 through 10), and students were required to achieve a minimum of 70% correct answers to be eligible for the end-of-semester exam. The MCQ was available for students to take multiple times over 2 weeks at mid-semester, with a 24-h waiting period between each attempt. The student behaviour was logged on a digital learning platform and linked to a questionnaire, resulting in a database with over 2200 data points analysed using SPSS. This paper provides insights into MCQs' experiences, potential benefits and limitations and recommendations for their practical use in dental education programmes. The results of this study can help dental educators make informed decisions about incorporating MCQs into their programmes.

## 2 | MATERIALS AND METHODS

### 2.1 | Setting and intervention

The MCQ design process was a collaborative effort between a team of experts consisting of three academics, one IT specialist, one administrator and one education specialist. The team utilised a Learning Management System, Fronter® (Itslearning AS, Bergen, Norway) to develop and administer the MCQs. The compulsory questionnaire used the University of Oslo forms (Nettskjema, <https://nettskjema.no/?lang=en>).

The MCQs design encompassed key elements such as creating plausible distractors, aligning questions with student learning objectives and maintaining consistent difficulty levels across subjects. We avoided negatively phrased questions and provided clear instructions. A pilot study with senior students was conducted to assess the MCQs' effectiveness, followed by student behaviour analysis linked to a questionnaire.

For the 5th semester, MCQ involved collecting MCQs; questions were sourced from the previous semester's second to the current semesters. Each clinical faculty department contributed eight questions, with one correct answer out of four options. These questions were aligned with specific learning outcomes, and new questions were added every semester. A student control group reviewed the questions for relevance and recognition.

In total, 449 MCQs are registered in the digital platform 'Classfronter', which selects questions randomly for each test, ensuring uniqueness. The number of questions per test increases from 30 in the 5th semester to 50 in the 10th semester, blending current semester questions with a fraction from previous semesters (Table S1). This method reinforces continuous learning and

knowledge retention. Although students had access to resources during the MCQs and received score feedback, specific question performance was not disclosed.

The MCQ was evaluated after each period. A separate questionnaire assessed the students' perceptions of the MCQ test after each MCQ period. Items included the degree to which learning outcomes of the different subject areas are recognisable, the degree of difficulty, how clearly the questions are formulated, etc. Moreover, the questions address the amount of self-study per week, the percentage of lectures attended, the expected score when taking the test for the first time, the actual score and the highest score achieved. Lastly, students can comment on whether the test included questions that could not be recognised concerning previous lectures, which specific questions should be omitted and why, and add other comments.

Data were collected for the MCQ assessments through the digital learning platform the digital learning platform, Fronter®. In addition to the questionnaire results, Fronter® provided extensive information on students' behaviour during the MCQ period, including the frequency and timing of test-taking, scores and the number of times each answer option was selected. The platform also generated a list of results per question, which helped us determine the questions' clarity and identify any subject-specific misconceptions among the students. Finally, the analysis used this information to understand the MCQ's effectiveness in dental education programmes.

## 2.2 | Study cohort

Four student cohorts were followed for four clinical semesters over 4 years; each semester had 75 students on average. All students participating in this study signed a consent form. Students who did not sign the consent form (2%) were removed from the datasets. After each MCQ test, all students were given a questionnaire. Therefore, we could link student MCQ performance in CLASSFRONTER with this questionnaire. The compiled database had 2230 unique students' behaviours at the end of the project. The Norwegian Agency approved data collection from questionnaires and its link to student MCQ performance approved data collection from questionnaires and its link to student MCQ performance for Shared Services in Education and Research NSD (project number 37255), a national committee that reviews, approves and monitors studies involving human subjects. NSD did not allow to link the final year exam with the information above.

## 2.3 | Statistical analysis

Descriptive and statistical analysis of the database was performed using the computer software Statistical Package for Social Sciences (SPSS) version 20.0 for Windows and GraphPad Prism software version 10.0 (GRAPH PAD Software Inc, California,

USA). The Shapiro–Wilk test in GraphPad assessed the dataset for normality, and none of the datasets passed the normality. The effect of MCQ on student performance was investigated through both linear and multiple regression. The multiple regression model used the least squares approach, with MCQ score chosen as the dependent variable, and the variable parameters were (Student ID, Semester, Cohort, Time MCQ was taken, Number of MCQ). The goodness of fit for the regression model was evaluated using the  $R$ -squared ( $R^2$ ) value, which indicates the proportion of the variance in the dependent variable explained by the predictors. The variance inflation factor (VIF) and the  $R^2$  value with other variables were computed for each predictor. A high VIF value and a corresponding high  $R^2$  value with other variables suggest shared variance among predictors, indicating possible multicollinearity to examine potential multicollinearity among predictors.<sup>10</sup> The multiple comparison between groups was performed with ANOVA on ranks with Kruskal–Wallis, followed by Dunn's multiple comparisons test in GraphPad. Significance levels were noted as  $*p < .05$ ,  $**p < .01$ ,  $***p < .001$ ,  $****p < .0001$ . Since the datasets were non-parametric, a Spearman correlation analysis study was performed in SPSS. The results were interpreted as follows: no correlation if  $|r| < .2$ ; correlation if  $.2 < |r| < .5$ ; and strong correlation if  $.5 < |r| < 1$ . A negative correlation, whereas a positive  $r$  indicated a positive correlation.<sup>11</sup>

## 3 | RESULTS

### 3.1 | Student feedback

The study results indicate that most students found the MCQs to be a valuable tool for their learning. Specifically, more than 70% of the students reported that they found the MCQs to help promote their understanding of course content (Figure 1C). Additionally, 60% of the students reported that they found the questions well-formulated, accurately reflecting the course material (Figure 1A), and that the difficulty level was adequate (Figure 1B). The results also showed that the MCQs led the students to review their lecture notes and textbook, with many students (>55%) reporting that they used the MCQs to a 'considerable amount' and 20% 'to a very large extent' as a way to check their understanding of course material and identify areas where they needed further clarification (Figure 1D).

Additionally, to further confirm that the positive response from students was not just limited to those who scored the highest, a correlation analysis was performed between the student scores, the number of MCQs taken, and their reported level of usefulness. The results showed no significant correlation between these variables (MCQ score;  $r = .083$ ,  $p = .03$ , Number Of MCQ Taken:  $r = .009$ ,  $p = .04$ ), Table 1, indicating that regardless of their score, more than 70% of students found the MCQs to be helpful. This highlights the effectiveness of the MCQs as a formative assessment tool and suggests that they can benefit students at all levels of performance.

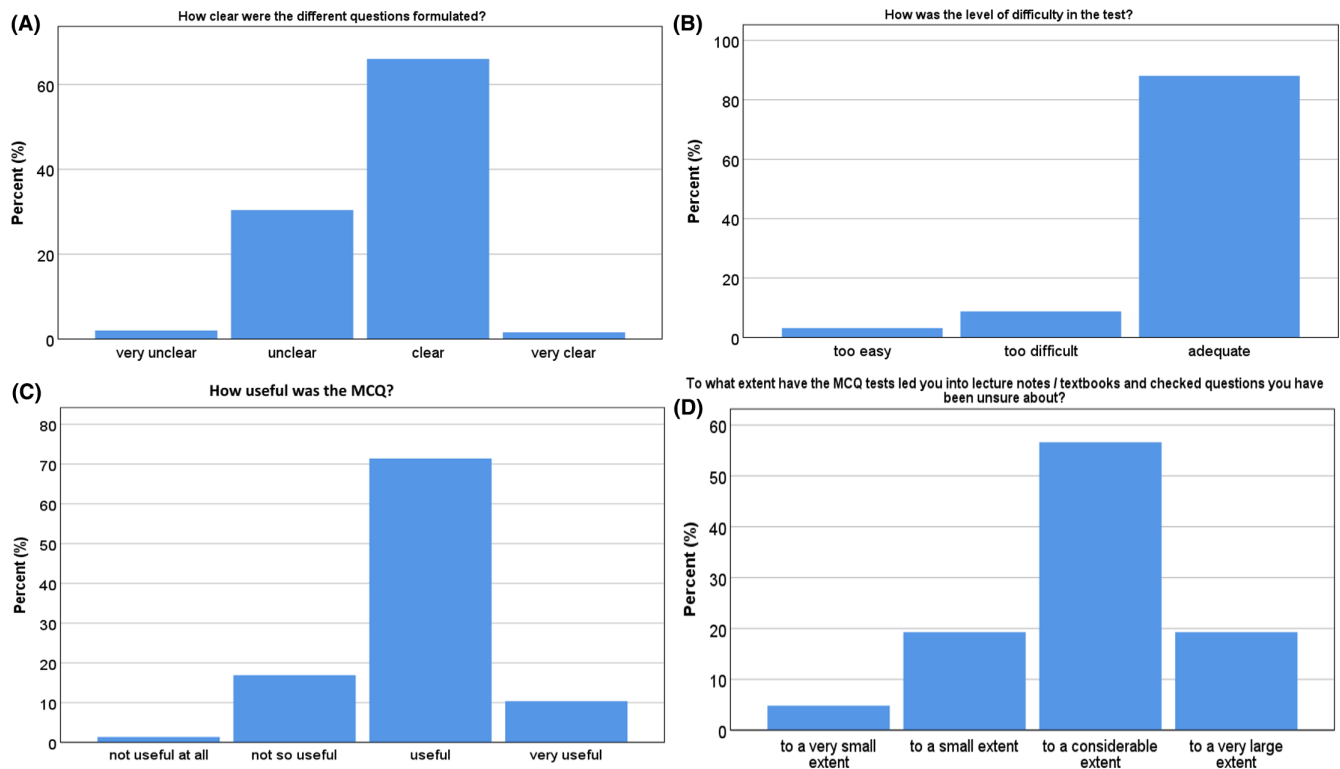


FIGURE 1 Student feedback on MCQ ( $n=468$ ).

TABLE 1 Spearman rank correlation on student assessment was independent of whom they scored; in other words, the better and less-performing students found the MCQ equally useful.

Spearman rank correlation	How useful is such an MCQ test?
Time MCQ	.029
MCQ score	.083*
Number Of MCQ taken	-.009

Note: Small correlation if  $.1 < |r| < .3$ , Medium corr. if  $.3 < |r| < .5$ , Strong corr. if  $0.5 < |r| < 1$ .<sup>11</sup>

\* $p > .05$  level (one-tailed).<sup>11</sup>

### 3.2 | Student behaviour

A histogram shows how the student scored for all the 2230 MCQ tests within the project period. The study results indicate that the use of MCQs as a formative assessment tool was well received by the students, with an average score of  $72.3\% \pm 12.5$  across all 2230 recorded answers (Figure 2A,B). The distribution of scores almost portrayed a bell-like curve, indicating that the MCQ questions were set at the appropriate level and that most students performed well on the tests. The pass threshold for each MCQ was set at 70%, and the results suggest that most students could meet this threshold. An analysis of the individual scores for each student (Figure 2B) showed that 45% of the students scored above 70% on their first trial but still retook the MCQ, 29% of the students

scored above 70% on their first trial and did not retake the MCQ, and 26% of the students scored below 70% and only retook the MCQ until they obtained the pass mark. On average, each student took each MCQ 3.9 times (Figure 2D). The results also showed that the MCQs were used by students throughout the day, indicating the need for an electronic platform to make MCQs available 24 h a day (Figure 2C).

The MCQ scores dropped between the 7th and 8th semesters (Figure 3A). However, the scores rose again for the last two semesters. Analysis revealed that the highest MCQ retakes occurred in the challenging 7th semester, with a subsequent decline in later semesters (Figure 3B). The 9th and 10th semesters showed fewer retakes despite their complexity. All semesters, they reported equal satisfaction with the MCQ's usefulness regardless final MCQ score (Table 1). Notably, students in the 9th and 10th semesters revised lecture notes earlier, reflecting a change in study behaviour (Figure 3D,E).

The study's results proved a correlation between student behaviour and the semester in which they took the MCQ. The analysis results showed a negative Spearman rank correlation of  $-.227$  ( $p = .02$ ) between the difficulty level in the MCQ tests and the corresponding semesters (Table 2). This suggests a weak inverse relationship between the difficulty of the MCQ tests and the semesters, where a decrease in difficulty was associated with an increase in semester number (Table 2). This suggests that the students adjusted to the increasing difficulty of the MCQ over time, which is also seen as the students required fewer retakes in the latter semesters (Figure 3A). However, the difficulty score is highest for the 7th and

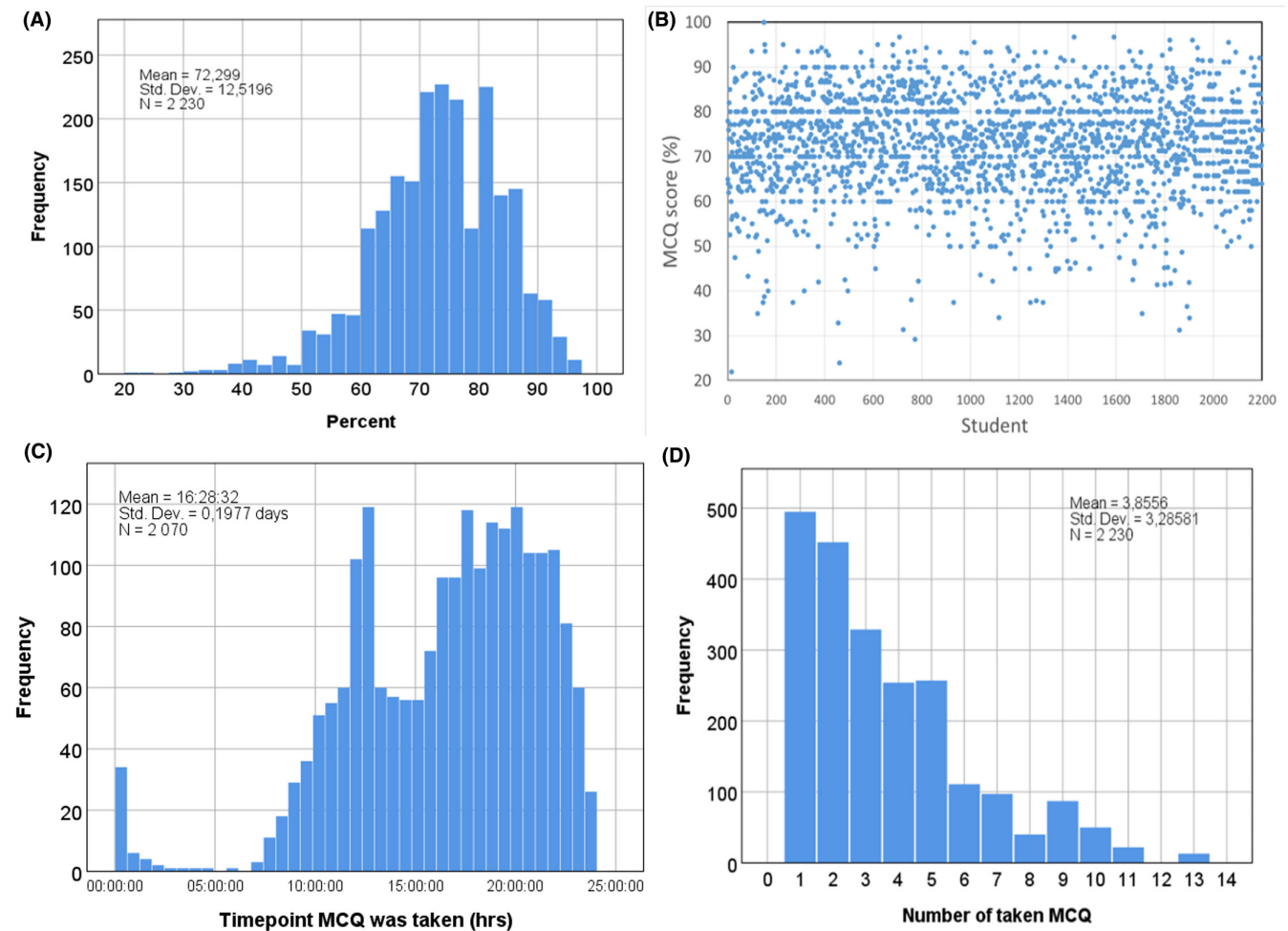


FIGURE 2 Student behaviour and a test score of the MCQ ( $n=2230$ ).

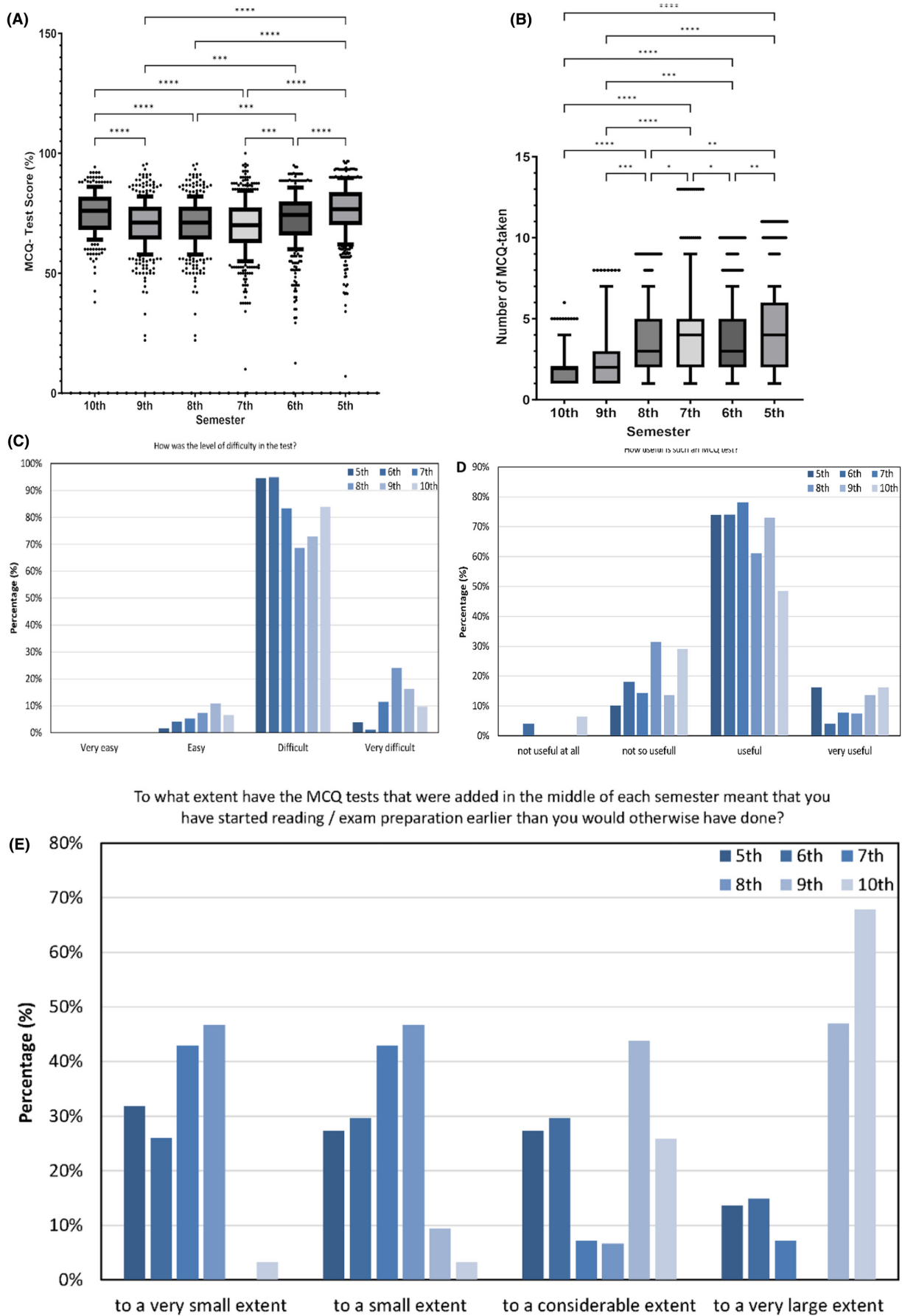
8th semesters (Figure 3C). We found no significant difference between the study cohorts on these parameters.

All students were asked what they thought they would score on the MCS, and we measured this against the actual MCQ score. There was a correlation between the expected MCQ score and the achieved MCQ score at the higher semester ( $r: .485, p=.002$ ), suggesting that the students were more aware of their level at the higher semester. The Spearman correlation between the variable 'have you started reading/exam preparation earlier than you would otherwise have done' and 'semester' was 0.477 with a significant one-tailed  $p$ -value of less than .01. This indicates a moderate positive correlation between the two variables, meaning that as the number of semesters progressed, the likelihood of students starting their reading/exam preparation earlier also increased (Table 1). This data suggested that MCQ changes student behaviour towards exam preparations.

The Spearman correlation analysis assessed the relationship between the number of hours spent reading and studying independently during the week and several other factors related to MCQ performance. The results showed a strong positive correlation between the number of hours spent reading and studying on one's own and the percent score on MCQ ( $r=.425, p<.01$ ), as well as the clarity

of the questions formulated ( $r=.416, p<.01$ ). A moderate negative correlation was found between the number of hours spent reading and studying on one's own and the number of MCQ taken ( $r=-.357, p<.01$ ) (Table 3). Additionally, a moderate positive correlation was found between the number of hours spent reading and studying independently and the percentage of lectures participated in ( $r=.403, p<.01$ , Table 3). Not surprisingly, these results show that the amount of time spent reading and studying on one's own can significantly impact a student's performance on MCQ and their perceptions of the clarity of questions.

A linear correlation confirmed the Spearman rank correlation finding and showed little difference between the tested cohorts (Figure 4). In the present analysis, the effect of MCQ on student performance was investigated through a regression model using the least squares approach, with MCQ score as the dependent variable (Figure 5A–C). The regression model was statistically significant, explaining a proportion of the variance in student performance ( $F(5, 2063)=47.25, p<.0001$  (Table 4a). From the predictors, 'Cohort', 'Semester' and 'Number of MCQs taken' emerged as significant factors with  $p$ -values of  $<.0001$ ,  $.0259$ , and  $<.0001$  respectively. Conversely, 'Student' and 'Time-When-MCQ-Was Taken' did not exhibit statistical significance with  $p$ -values of  $.8773$  and  $.3220$



**FIGURE 3** Student behaviour and a test score of the MCQ depending on each semester. (A) MCQ test score versus the different semesters, (B) Number of MCQ Taken versus different semesters, ( $*p < .05$ ,  $**p < .01$ ,  $***p < .001$ ,  $****p < .0001$ ,  $n = 2230$ ) Answer from Questionnaire not following questions (C): 'How was the level of difficulty in the test?', (D) 'How useful is such an MCQ test?', (E) 'To what extent have the MCQ tests led you into lecture notes/textbooks and checked questions you have been unsure about?'

**TABLE 2** Spearman rank correlation on student behaviour versus semester.

Spearman rank correlation	Semester
What score did you expect to achieve the first time you completed the test?	.271**
What score did you get the first time you completed the test?	-.485**
What was your maximum score?	.477**
Have MCQ tests led you to check questions and lecture notes you are unsure about?	.271**

Note: Small correlation if  $.1 < |r| < .3$ , Medium corr. if  $.3 < |r| < .5$ , Strong corr. if  $.5 < |r| < 1$ .

\* $p > .05$  level (one-tailed), \*\* $p > .01$  level (one-tailed).<sup>11</sup>

respectively (Table 4a, Figure 5C). The intercept showcased an estimate of 66.53 with a 95% CI ranging from 66.03 to 67.03 and a  $p$ -value of  $< .0001$ . Analysing the predictors, 'Cohort' had the most pronounced coefficient valued at 1.188 (95% CI: 0.7505 to 1.626,  $p < .0001$ ), suggesting a potent association with student performance. The 'Number of MCQs taken' predictor displayed a negative coefficient of  $-0.9557$  (95% CI:  $-1.166$  to  $-0.7457$ ,  $p < .0001$ ) (Table 4b). In contrast, both 'Student' and 'Time-When-MCQ-Was Taken' showed no substantial association with the dependent variable. The Goodness of Fit for the model provided an  $R^2$  value that showed the predictors included in the model (such as Student, Semester, Cohort, Time-When-MCQ-Was Taken and Number of MCQs) accounted for only a tiny portion, 10.27%, of the variability seen in the MCQ scores of students. While the predictors correlate with student performance, the model does not account for substantial performance variability (Table 4c). None of the predictors showed severe multicollinearity, with all VIF values relatively close to 1 (Table 4d, Figure 5C). A VIF value close to 1 indicates little to no multicollinearity, while a value above 10 (some use a threshold of 5) suggests high multicollinearity. The analysis highlights the significant predictors affecting student performance, specifically focusing on the influence of MCQ.

## 4 | DISCUSSION

Students appear to be implementing this assessment strategy to enhance knowledge retention, with data indicating improved recall of foundational concepts from earlier courses. This suggests a positive impact on knowledge retention. The MCQ format, selected for its efficiency and immediate feedback, was designed to encourage ongoing engagement with key concepts.<sup>12,13</sup> Critically evaluating the tests' structure and content, the student appeared congruent with the initial intention of refreshing and maintaining students'

knowledge from preceding courses. However, any assessment method's true efficacy depends on its alignment with the learning outcomes.<sup>14</sup> Thus, regular reviews and refinements to the test design might be required to ensure their ongoing relevance. The administration of a preliminary test to gauge a student's readiness for another test may seem redundant at first glance. However, this approach is anchored in the idea of 'assessment for learning' rather than 'assessment of learning'. The formative nature of the preliminary tests allows students to identify their strengths and weaknesses.<sup>15-17</sup> One of the primary goals of education is to promote student learning and ensure that students acquire the knowledge and skills they need to succeed in their chosen fields.<sup>18</sup> In recent years, there has been increased interest in using formative assessment to increase student learning and improve student outcomes.<sup>19</sup> One form of assessment that has gained popularity in various educational contexts is using MCQs.<sup>17</sup> MCQs offer several advantages over other forms of formative assessment, including their ability to quickly and efficiently assess a wide range of knowledge and skills, objective and impartial nature and capacity to provide immediate feedback to students.<sup>20</sup> By leveraging the benefits of MCQs, educators can extend the scope of formative assessment and create new opportunities for students to engage with course content and receive meaningful feedback on their learning progress.

The objective of the MCQ was to facilitate a more stable learning process for students and to ensure a minimum level of knowledge during exams at the end of each semester.

This study aims to:

- (i) Monitor the implementation of the MCQ and the student's behaviour and achievements during the tests
- (ii) Analyse student experiences with the MCQ and to what extent they perceive it as a supportive measure for learning

The quality of assessment is an essential aspect of the educational experience that significantly impacts both students and teachers.<sup>13,21</sup> How the quality of the evaluation is perceived and evaluated can vary greatly depending on various contextual factors, such as the discipline, the teaching-learning environment and the type of assessment.<sup>22,23</sup> The quality of an assessment can vary significantly based on the specific context in which it takes place. This can be influenced by factors such as the type of assessment (e.g. formative or summative), the teaching methods employed, the learning goals and the resources available.<sup>24,25</sup>

In recent years, digital technologies have greatly impacted education and significantly impacted student learning.<sup>26,27</sup> In addition, the flexibility and reachability provided by digital resources have greatly improved how formative and summative assessments can be delivered to students.<sup>28</sup> This approach aids student learning

Spearman rank correlation	How many hours do you use to read/study independently during the week?	How many percent of the lectures this year have you participated in?
Percent MCQ score	.425**	.383**
Number Of MCQ Taken	-.357**	.076
How clear were the different questions formulated?	.416**	.240**
How many percent of the lectures this year have you participated in?	.403**	-

TABLE 3 Studying hours versus scoring on MCQ test.

Note: Small correlation if  $.1 < |r| < .3$ , Medium corr. if  $.3 < |r| < .5$ , Strong corr. if  $.5 < |r| < 1$ .

\* $p > .05$  level (one-tailed), \*\*  $p > .01$  level (one-tailed).<sup>11</sup>

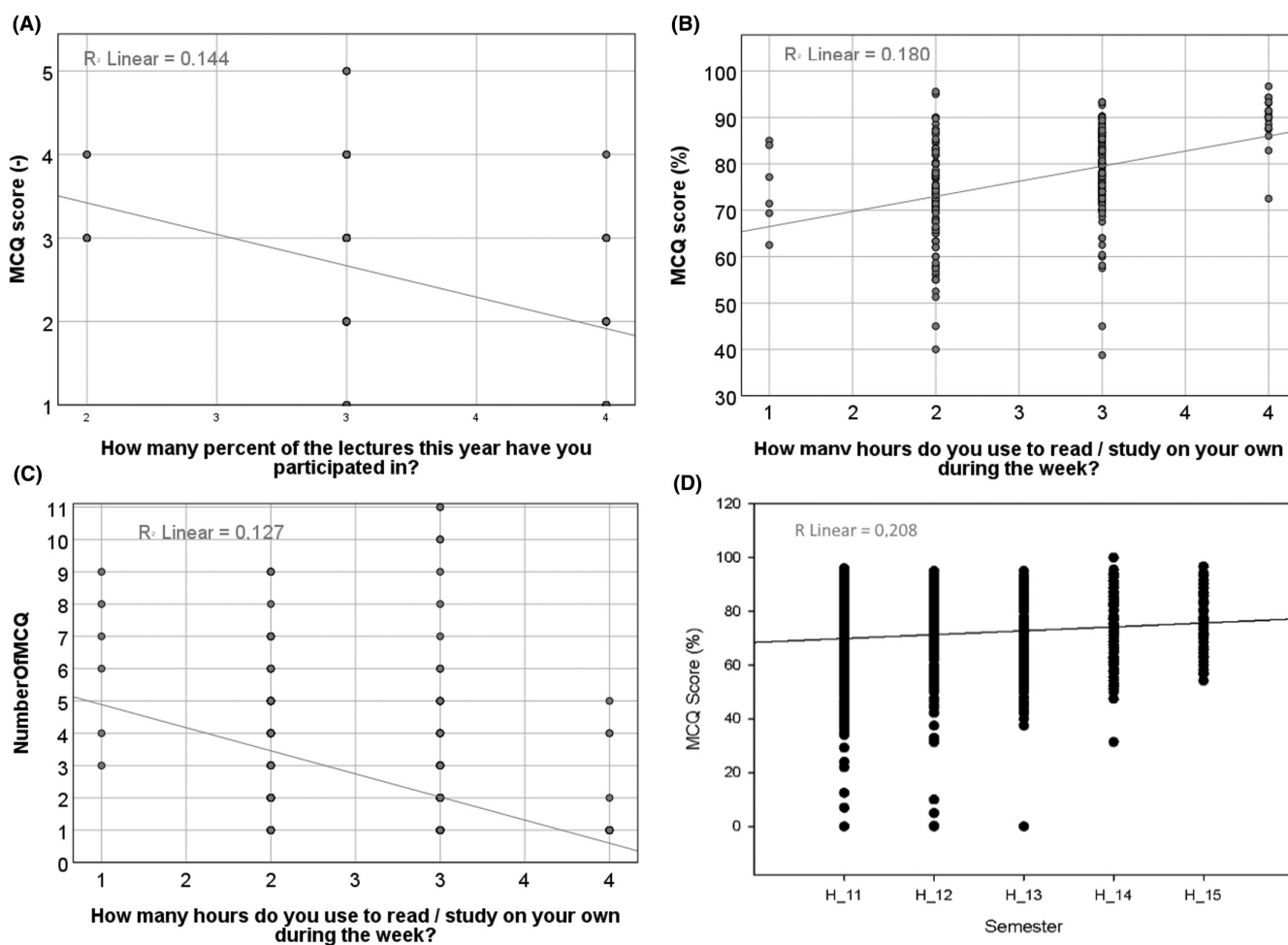


FIGURE 4 Linear regression on selected parameters in the study.

and maintains knowledge standards for future dental professionals. Digital platforms offer online lectures, quizzes and interactive materials, facilitating anytime, anywhere access to coursework. Formative assessments, such as online quizzes and activities, can assess student progress and understanding, providing valuable feedback to students and dental instructors.<sup>29,30</sup> Summative assessments, such as online exams, can also be delivered through digital platforms, providing a reliable and secure assessment. Digital

assessments benefit both students and instructors. Students enjoy convenient, flexible access, improving time and workload management. Instructors can consistently and reliably deliver assessments to multiple students, reducing the workload compared to traditional paper-based methods.<sup>28</sup>

Moreover, digital resources allow students to create more interactive and engaging assessment practices by providing them with more flexible, meaningful and beneficial learning experiences.<sup>31</sup>



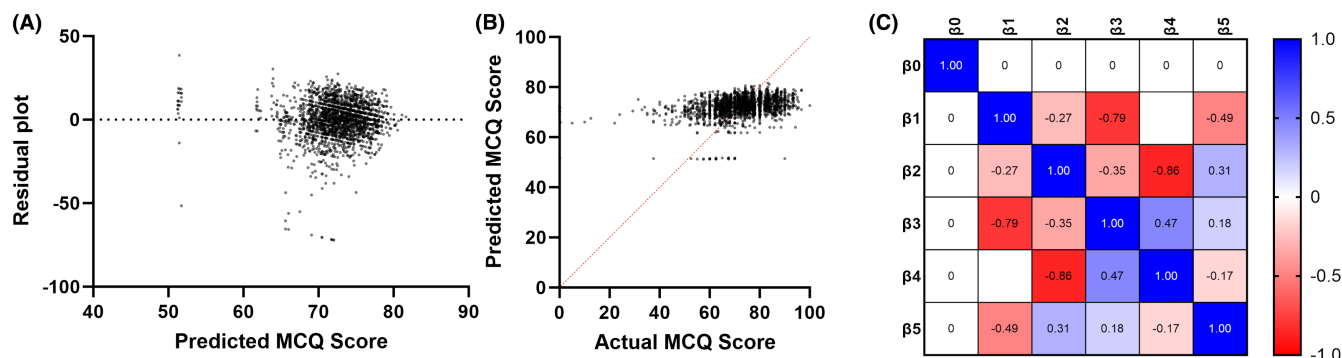


FIGURE 5 Multi-regression analysis with MCQ score as the dependent variable. (A) Residual plot versus predicted MCQ score, (B) predicted MCQ score versus actual MCQ score, (C) multicollinearity variance inflation factor (VIF) heatmap,  $\beta_0$ : intercept,  $\beta_1$ : student,  $\beta_2$ : semester,  $\beta_3$ : cohort,  $\beta_4$ : Time-When-MCQ-Was Taken,  $\beta_5$ : number of MCQs.

TABLE 4 Multi-regression analysis with (a) Analysis of Variance, (b) Parameter estimates, (c) Goodness of Fit and (d) Multicollinearity analysis using the least squares approach, with MCQ score as the dependent variable.

a	Analysis of variance	SS	df	MS	F (dfn, dfd)	p value	
	Regression	31842	5	6368	$F(5, 2064) = 47.25$	<.0001	
	Student	3.216	1	3.216	$F(1, 2064) = 0.02386$	.8773	
	Semester	670	1	670	$F(1, 2064) = 4.971$	.0259	
	Cohort	3822	1	3822	$F(1, 2064) = 28.35$	<.0001	
	Time-When-MCQ-Was Taken	132.3	1	132.3	$F(1, 2064) = 0.9814$	0.3220	
	Number of MCQs	10739	1	10739	$F(1, 2064) = 79.67$	<.0001	
	Residual	277590	2063	134.6			
	Total	310055	2069				
b	Parameter estimates	Variable	Estimate	Standard err.	95% CI (asymptotic)	t	p Value
	$\beta_0$	Intercept	<b>66.53</b>	0.255	<b>66.03 to 67.03</b>	260.7	<.0001
	$\beta_1$	Student	2.51E-25	1.62E-24	-2.9e-024 to 3.4e-024	0.1545	.8773
	$\beta_2$	Semester	<b>-0.7898</b>	0.354	<b>-1.48 to -0.095</b>	2.23	.0259
	$\beta_3$	Cohort	<b>1.188</b>	0.223	<b>0.75 to 1.63</b>	5.325	<.0001
	$\beta_4$	Time-When-MCQ-Was Taken	-1.184	1.195	-3.53 to 1.160	0.9907	.322
	$\beta_5$	Number of MCQs	<b>-0.9557</b>	0.107	<b>-1.16 to -0.745</b>	8.926	<.0001
c	Goodness of fit						
	Degrees of freedom					2063	
	$R^2$					.1027	
d	Multicollinearity	Variable	VIF		$R^2$ with other variables		
		$\beta_0$	Intercept				
		$\beta_1$	Student		1.042	.04035	
		$\beta_2$	Semester		1.181	.1532	
		$\beta_3$	Cohort		1.219	.1794	
		$\beta_4$	Time-When-MCQ-Was Taken		1.005	.005216	
		$\beta_5$	Number of MCQs		1.027	.02672	

Note: Significant ( $p < .05$ ) parameter estimates are highlighted in bold.

Abbreviations: CI, confidence interval; df, degrees of freedom; dfd, denominator degrees of freedom; F, F-statistic (or F-value); MS, mean square; SS, sum of squares; VIF, variance inflation factor.

In addition, using digital technologies in assessments has numerous benefits for students and instructors and offers the opportunity to improve the quality of assessments in dental education.<sup>32</sup> MCQ has been proven productive in several dental educational programmes.<sup>20,33</sup> Consistent with the findings of Shaikh et al.'s findings, faculty development programmes positively impact MCQ quality, evidenced by fewer low-discrimination MCQs, more high-discrimination ones and fewer non-functional distractors. This underscores the effectiveness of such programmes in dental education and highlights the vital role of active dental education departments in enhancing assessment quality.<sup>34</sup> Critics may argue that this assessment strategy focuses on test-taking skills rather than proper understanding. However, it is vital to consider the broader educational context. MCQs are designed to supplement, not replace, other learning methods.<sup>35,36</sup> Their use for reinforcing core content aids long-term retention and practical application. A balanced mix of various assessments is essential for a comprehensive educational experience. The strategy, showing potential in knowledge retention, should be viewed as a dynamic tool, evolving with feedback and educational needs.

In the ever-evolving landscape of dental education, understanding the factors influencing student performance is pivotal.<sup>37</sup> This study shows that students find MCQs beneficial for learning and knowledge retention. They appreciated the MCQs' design and reported that these assessments motivated them to review materials and seek additional resources. These results indicate that MCQs as formative assessments can effectively enhance learning. Although a direct link between formative MCQ performance and final exams wasn't established due to restrictions from the Norwegian Agency for Shared Services in Education and Research (NSD), the positive influence of MCQs on student learning is evident.

This alignment reinforces the notion that consistent engagement with course content, as prompted by the formative assessments, can lead to better summative performance. However, a deeper dive into individual student trajectories and other potential confounding factors is recommended to solidify this observation. Our study further explored the intricate associations between student behaviour and their performance via the Spearman rank correlation, providing nuanced insights into the dynamics of dental education. The study revealed a significant drop in MCQ scores for the 7th and 8th semesters; this trend can be attributed to the increasing number of questions for the MCQ throughout the semesters, making it more challenging for the students. Another notable finding is the medium positive correlation between the percent MCQ score and the hours students devote to independent reading/studying during the week ( $r = .425$ ,  $**p < .01$ ). This aligns with conventional pedagogical wisdom, suggesting that diligent independent study can bolster academic performance.

Similarly, students' lecture attendance positively correlated with their MCQ scores ( $r = .383$ ,  $**p < .01$ ). This underscores the importance of classroom interactions and the potential benefits of face-to-face learning experiences. Interestingly, while the number

of MCQs taken exhibited a negative correlation with study hours ( $r = -.357$ ,  $**p < .01$ ), its relationship with lecture attendance was not statistically significant. This suggests that while frequent exposure to MCQs might reduce the perceived need for extensive independent study, it does not necessarily correlate with increased lecture participation.

Student feedback on the clarity of MCQs also exhibited a medium positive correlation with independent study hours ( $r = .416$ ,  $**p < .01$ ) and a slight correlation with lecture attendance ( $r = .240$ ,  $**p < .01$ ). Straightforward questions can enhance students' study experiences, possibly motivating them to engage more deeply with the material.

The correlation metrics about students' expectations and performance in MCQs yielded exciting insights. The negative correlation between initial MCQ scores and what they achieved in their first attempt ( $r = -.485$ ,  $**p < .01$ ) suggests that there is a misalignment between students' perceptions and actual performance, a facet that educators need to address. However, the data also reveal that students' maximum scores positively correlated with lecture attendance ( $r = .477$ ,  $**p < .01$ ). These results suggest that the students struggled the most with the MCQ during the 7th semester but adjusted to the increasing difficulty in the last semesters (Figure 3C). This underlines the instrumental role of regular lecture attendance in achieving peak academic performance. Lastly, the perceived utility of MCQ tests did not exhibit significant correlations with MCQ timings, scores, or the number of MCQs taken. This suggests that while MCQs serve as an assessment tool, their perceived value from a student's perspective might be multifactorial and not solely contingent on performance metrics, as observed previously.

In the overarching context of dental education, these findings emphasise the significance of self-study, classroom participation and the alignment of assessment tools with learning objectives. The diverse correlations underscore the need for an integrated pedagogical approach holistically addressing academic and behavioural aspects of student learning.<sup>38</sup> The present study employed regression analysis to delve into the predictors that might have a bearing on student MCQ scores, a prevalent assessment metric in dental faculties. Our findings reveal that the current model accounts for approximately 10.27% of the variability in student MCQ scores, as indicated by the  $R$ -squared value. While this percentage is modest, it underscores the partial influence of the incorporated predictors, such as Student, Semester, Cohort, Time-When-MCQ-Was Taken and Number of MCQs, on performance outcomes. One could surmise that myriad other factors not encapsulated within this model play a significant role in student performance. This notion aligns with previous research highlighting the multifaceted nature of student assessment outcomes, encompassing both academic and non-academic determinants such as psychological well-being, teaching methodologies and curriculum design.<sup>35,39</sup>

Variance inflation factors (VIF) and  $R^2$  values with other variables were examined to address multicollinearity. An integral aspect of this analysis was to ensure that multicollinearity did not confound our findings. VIF of the predictors were notably close to 1, suggesting a

minimal presence of multicollinearity.<sup>40</sup> Since there is no severe multicollinearity, each predictor's coefficient can be interpreted more confidently about its effect on student MCQ scores without concern about overlapping influences from other predictors. However, because only 10.27% of the variability is explained, it implies there might be other significant factors affecting the MCQ scores that have yet to be included in this model.

In summary, while the predictors offer some insights into factors influencing student MCQ scores, the majority of the variability in scores remains unexplained by this model. The absence of multicollinearity ensures that the predictors are trustworthy. This is important as high multicollinearity can obfuscate the genuine relationship between predictors and the dependent variable, leading to potentially misleading conclusions.<sup>41</sup> Hence, we can interpret our results with a heightened degree of confidence regarding the distinct influence of each predictor on the MCQ scores. However, the study is full of limitations. The modest *R*-squared value signifies that the chosen model might benefit from including additional predictors.<sup>12,42</sup> Future research could consider factors such as student engagement levels, quality of teaching materials and even more nuanced aspects like the psychological preparedness of students for examinations. However, avoiding overfitting the model by including too many independent variables is essential. The adjusted *R*-squared value can be used to compare models and select the one that provides the best balance between model fit and complexity.<sup>43-45</sup> While our findings provide valuable insights into specific determinants of student performance in MCQs, they also highlight the intricate nature of academic success in dental education.

The shortcomings of recent studies are longitudinal data as it does not track long-term outcomes or follow-up with students post-graduation, potentially missing substantial impacts of the MCQ-based learning approach on longer-term career success or retention of knowledge longevity.<sup>46</sup> The study might have needed to adequately incorporate student suggestions for improvement, limiting the opportunities for optimisation and adaptation of the MCQs based on student feedback. The study needs a control or comparative group, making it difficult to draw definitive conclusions about the effectiveness of the intervention.<sup>18</sup> The study primarily focused on the 5th to 10th semesters of the curriculum, which may limit its applicability to the entire duration of dental education.

## 5 | CONCLUSIONS

This study emphasises the nuances of student learning, assessment and behaviour in dental education. Incorporating MCQs as formative assessments has proven effective in fostering knowledge retention and aligning with pedagogical best practices. The correlations underline the intricate dynamics between student habits, attendance and performance. While digital technologies, including online MCQ platforms, offer unprecedented flexibility and accessibility, they also bring forth pedagogical challenges that must be addressed holistically.

Our research underscores the importance of lecture attendance, independent study and well-constructed assessments in promoting student success. The correlations between student behaviours, such as separate study hours and lecture attendance, and their performance metrics offer valuable insights for educators to refine their teaching and assessment strategies. The positive correlation between lecture attendance and academic performance underlines the significance of in-person educational experiences, suggesting dental educators should prioritise classroom interactions and possibly employ strategies to increase student participation. While engagement with MCQs offers benefits, the frequency of MCQ exposure may inversely relate to the time dedicated to self-study. Moreover, the observed disconnect between students' performance expectations and scores warrant attention, suggesting educators must bridge this perception gap. Nevertheless, the clarity of MCQs and the frequency of lectures attended consistently emerged as instrumental in enhancing student performance.

This study showcases the importance of aligning expectations and outcomes, a task that both educators and students share. The need for more transparent communication and consistent feedback to bridge this gap between students' perception of their performance and their actual scores indicates a need for clear communication and consistent feedback to bridge this gap. By fostering an environment where students can gauge their understanding and receive constant, constructive feedback, educators can pave the way for improved student performance and satisfaction. While MCQ offers a robust tool for assessment in dental education, it is imperative to approach them as part of a broader educational strategy. Given the ever-changing dynamics of dental education, continual reflection, adaptation and research are essential to ensure the best results for students and the broader dental community. Therefore, this study provides a steppingstone in understanding the intricacies of student performance and offers insights that could be valuable for dental educators.

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## DATA AVAILABILITY STATEMENT

The data supporting this study's findings are available on request from the corresponding author. The data are not publicly available

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#### SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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