**RESEARCH ARTICLE**

# Results from a five-year clinical assessment of undergraduate-performed direct composite restorations

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## Abstract

Resin based dental composites offer significant benefits with regard to the minimally invasive management of dental caries. However, over a period of time such restorations may become susceptible to failure with secondary caries and marginal deterioration being common causes. A retrospective clinical study was conducted at the IMU University Oral Health Centre to assess the quality of direct resin composite restorations placed by dental undergraduates as judged by the modified United States Public Health Service (USPHS), criteria. This study aimed to evaluate the quality and the causes of the failure of direct resin composite restorations in permanent teeth placed by dental undergraduate students using modified USPHS criteria to assess failure. A total of 76 restorations were evaluated in this study. Descriptive statistics were collected, and the Chi-square test ($p < 0.05$) was used to determine statistically significant differences. A total of 42.1% of the composite resin restorations in the study were considered satisfactory. Of the restorations regarded as failures, the causes were colour mismatch (39.4%), followed by marginal discolouration (21%) and then restoration fracture (14.5%). The operator's year of study ($p = 0.039$) and the number of restoration surfaces ($p = 0.039$) showed statistically significant associations with the quality of the restorations. Composite resin restorations performed by dental undergraduates exhibited high failure rates, which were primarily attributed to colour mismatches, marginal dis-colourations, or fractures of the restoration.

## 1 Introduction

The International Caries Detection and Assessment System (ICDAS), as shown in Table 1, is a clinical scoring system that is used to assess the extent of dental caries (Gugnani et al. 2011). It can be used to assess all teeth surfaces, enamel or dentin tissue, as well as non-cavitated lesions, providing a detailed diagnosis to improve caries management (Gugnani et al. 2011). In the International Caries Classification and Management Guide (ICCMS), only moderate and extensive lesions between ICDAS codes 3 to 6, are managed operatively with tooth-preserving operative care (TPOC)

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(Pitts et al. 2014). Resin composite restorations have been widely used for ICDAS codes 3 to 6 lesions for almost half a century. They offer substantial benefits in preserving tooth structure by providing direct bonding of the restoration with the tooth. That step provides adequate strength for restorations being managed with a minimum intervention approach.

There have been an increasing number of composite resin restorations placed in clinical practice over the last few decades. (Pitts et al. 2014) While composite resins remain both an aesthetic and conservative approach for caries management, such restorations also require regular reviews for maintenance and for replacement of restorations that show failures (Schwendicke et al. 2018; Bartlett and Varma 2017). The longevity of resin composite restorations depends on both the material and the technique used in placing the restorations. The survival of composite resin restorations is also affected by the patient's age, habits, and oral hygiene maintenance. Location of the tooth in the arch and the size of the restoration have been found to play a role in the lifespan of these restorations (Alonso et al. 2024) (Demarco et al. 2023). It is therefore important for all dentists, and also

**Table 1** International caries detection and assessment system (ICDAS) ( Gugnani et al. 2011)

| Code | Description |
|------|-------------|
| 0 | Sound tooth surface: No evidence of caries after air drying for 5 seconds |
| 1 | First visual change in enamel: opacity or discolouration (white or brown) is visible at the entrance to the pit or fissure seen after prolonged air drying |
| 2 | Distinct visual change in enamel visible when wet, lesion must be visible when dry |
| 3 | Localized enamel breakdown (without clinical visual signs of dentinal involvement) seen when wet and after prolonged drying |
| 4 | Underlying dark shadow from dentine |
| 5 | Distinct cavity with visible dentine |
| 6 | Extensive distinct cavity with visible dentine (involving more than half the surface) |

dental students upon graduation, to have the clinical skills to place high-quality restorations, ones that are long-lasting and meet the most exacting criteria for such restorations.

The common reasons for failure include discolouration, fracture of the restoration, and persistent post-operative sensitivity. These elements may indicate microleakage, which can lead to secondary decay or pulpal irritation. (Demarco et al. 2023) Several factors play a crucial role in the success and failure of composite resin restorations. They include cavity preparation techniques, choice of restorative material and placement methods.

One of the notable disadvantages of direct composite resin restorations is their tendency to develop bond failure, leading to marginal deterioration. Also, composite resins are known to produce shrinkage stress on curing. Furthermore, bonding is a technique-sensitive step in the placement procedure that requires a specific moisture level within the dentine to prevent collapse of collagen structure in the hybrid layer. Failure to follow the techniques to achieve such a correct level during bonding and composite curing can lead to bond failure and microleakage. That subsequently can result in secondary caries (Szczesio-Wlodarczyk et al. 2020). Hence, it is essential to follow up on patients with composite resin restorations at periodic intervals and evaluate the integrity of dental composite restorations. If patients fail to present at scheduled follow-up visits, the result can be failure to identify and manage failed restorations in a timely fashion.

In a report by Sidhu et al. (Sidhu et al. 2021) 74% of posterior restorations placed by Malaysian undergraduate dental students were found to be composite resins. IMU University dental undergraduates are taught preparation and restoration of teeth using dental composite resins in their pre-clinical years. This is taught on extracted teeth, before the students progress to their supervised clinical training on real patients. Thus, the undergraduate dental students perform clinical procedures under the direct supervision of dental specialists at the Oral Health Centre. However, due to their lack of clinical experience in performing restorative procedures, there is a greater chance of failure of composite resin restorations over time. It is therefore important to recall patients for review at regular intervals to assess the restored dentition. This is to minimize failure of restorations and early identification and management.

Although dental composite resins have been used in clinical practice for a long time, there is only a limited literature on the clinical quality and longevity of composite resin restorations performed by dental undergraduate students. Dental undergraduate students perform a limited number of restorations during their undergraduate training (Alonso et al. 2024). Composite resin restorations, like many other restorative skills, is technique sensitive and mastered over time with repeated practice. Retrospective clinical studies are important for quality assessment and can regulate processes required for enhancements designed to improve patient care. In this study, the evaluation of direct composite resin restorations was based on the modified USPHS criteria, as shown in Table 2 (Lempel et al. 2017). The Federation Dentaire Internationale (FDI) two-digit notation was used for tooth numbering (Yaren Tekin et al. 2022). This study aimed to report the quality of direct composite resin restorations performed by dental undergraduates, to investigate the reasons for any failures as indicated according to USPHS criteria and thereby make recommendations to improve the standards of care delivered during undergraduate clinical instruction.

## 2 Materials & methods

### 2.1 Study design & setting

The inclusion of the restorations selected in this study ensured a minimum observation period of one year and a maximum of five years. The research was conducted at the Oral Health Centre at IMU University in Malaysia. The study protocol was approved by the IMU Joint Committee on Research and Ethics as well as IMU Healthcare which is the entity responsible for the operation of clinical facilities used for clinical instruction.

**Table 2** Modified united states public health service (USPHS) criteria ( Lempel et al. 2017)

| Category | Criteria | Score |
|---|---|---|
| Marginal adaptation | 0 Smooth margin<br>1 All margins closed or poses minor voids, defects (enamel exposed) | Acceptable |
| | 2 Obvious crevice at margin, dentin or base exposed<br>3 De-bonded from one end<br>4 De-bonded from both ends | Unacceptable |
| Colour match | 0 Very good colour match<br>1 Good colour match | Acceptable |
| | 2 Slight mismatch in colour or shade<br>3 Obvious mismatch, outside the normal range<br>4 Gross mismatch | Unacceptable |
| Marginal discoloration | 0 No discolouration evident<br>1 Slight staining, can be polished away | Acceptable |
| | 2 Obvious staining, cannot be polished away<br>3 Gross staining | Unacceptable |
| Surface roughness | 0 Smooth surface<br>1 Slightly rough or pitted | Acceptable |
| | 2 Rough, cannot be refinished<br>3 Surface deeply pitted, irregular grooves | Unacceptable |
| Fracture of restoration | 0 No fracture | Acceptable |
| | 1 Minor crack lines or tiny chipping ($< 1/4$ of restoration)<br>2 Partial fracture of restoration ($> 1/4$ of restoration)<br>3 Debonding of restoration | Unacceptable |
| Fracture of tooth | 0 No fracture of tooth<br>1 Minor crack lines in tooth | Acceptable |
| | 2 Partial fracture of tooth ($> 1/4$ of crown)<br>3 Crown-root fracture (extraction) | Unacceptable |
| Wear of restoration | 0 No wear | Acceptable |
| | 1 Wear of restoration | Unacceptable |
| Wear of antagonist | 0 No wear | Acceptable |
| | 1 Wear of antagonist | Unacceptable |
| Caries | 0 No evidence of caries along the margin of the restoration | Acceptable |
| | 1 Caries evident continuous with the margin of the restoration | Unacceptable |
| Post-operative sensitivity | 0 No symptoms<br>1 Slight sensitivity | Acceptable |
| | 2 Moderate sensitivity<br>3 Severe pain | Unacceptable |

## 2.2 Sample size

A total of 3189 composite resin restorations in 1302 patients were identified that had been placed between the years 2018 and 2023 by dental undergraduate students. They were identified using records retrieved from Open Dental practice management software (Open Dental Software—Practice Management Software (https://opendental.com).

These patients were contacted to return for a review, and 69 patients agreed to follow up with a total of 76 restorations. A number of patients were not contactable for various reasons.

## 2.3 Inclusion & exclusion criteria

After screening each record, based on the inclusion and exclusion criteria set for the study, only 266 restorations placed in 222 patients were selected. These restorations were included according to the specific criteria outlined in Table 3.

## 2.4 Data collection

The first ten patients included were used for examiner training and calibration. Four selected examiners, of which two were undergraduate dental students and two faculty

**Table 3** Inclusion and exclusion criteria for screening

| Inclusion Criteria | Exclusion Criteria |
|---|---|
| • Direct composite restorations placed for ICDAS code 4 and 5 carious lesions<br>• Restorations performed under dental dam isolation<br>• Restorations placed on posterior permanent teeth between June 2018 and June 2022<br>• Restorations involving the proximal surface | • Any indirect restorations<br>• ICDAS code 1, 2, 3 and 6 restorations<br>• Restorations placed on primary teeth<br>• Restorations placed on anterior permanent teeth<br>• Restorations placed on posterior permanent teeth involving only occlusal/buccal/lingual surface<br>• Restorations placed on endodontically treated teeth<br>• Any restorations placed before June 2018<br>• Restorations performed by IMU dental officers/lecturers |

members from the restorative dentistry department, underwent examiner calibration. These first ten patients used for calibration were not included in the data collection and analysis. Throughout the data collection process, two supervisors were continuously present to ensure that the evaluation of the direct composite restorations was accurate, and any uncertainties were clarified (Fig. 1).

Cohen's kappa statistic was calculated to determine inter-rater reliability and gave a kappa value of $\kappa = 0.864$, indicating an almost perfect agreement between the examiners. The process flow for the calibration exercise is shown in Fig. 2, while Fig. 3 shows the form that was used for data collection.

## 2.5 Statistical analysis

Data entry and statistical analysis were performed using IBM Statistical Package for Social Science Software version 29 (SPSS, Chicago, IL). A restoration was deemed 'unsatisfactory' when it displayed at least one category of the criteria that had an unacceptable score; a restoration was 'satisfactory' when all categories achieved an acceptable score.

Descriptive statistics were used to describe the independent variables, such as socio-demographic data of operators, patients, quality of restorations, and reasons for restoration failure. The Chi-square test was used to determine the association between the variables and the quality of the restorations, with statistical significance set at $p < 0.05$.

## 3 Results

In this study, a total of 76 composite resin restorations that were placed by dental undergraduate students between 2018 and 2023 in IMU were evaluated. Quantitative analysis of the socio-demographic data of operators, the socio-demographic data of patients, tooth/restoration-related variables, and quality of composite resin restorations based on the modified USPHS criteria are presented in Figs. 3, 4, 5, and 6, respectively. Based on the USPHS criteria, only 42.1% of the composite restorations were satisfactory.

As shown in Table 4 and Fig. 7, the failure of restorations was mainly due to unacceptable scores in colour match (39.4%), marginal discolouration (21%), and fracture of restoration (14.5%). There was no restoration found to be unsatisfactory due to the fracture of the tooth.

Upon investigating the relationship between the quality of restorations and a list of variables, the operator's year of study and number of restoration surfaces exhibited statistically significant correlations ($p = 0.039$) with the outcome. As portrayed in Table 5, the prevalence of satisfactory restorations is higher when performed by Year Five students (50.9%) than Year Three (40.0%) and Year Four (16.7%) students. The failure rate of restorations increased in relation to the number of surfaces, from 37.5% in one-surface restorations, 52.7% in two-surface restorations, 90.0% in three-surface restorations, and 100% in four-surface restorations.
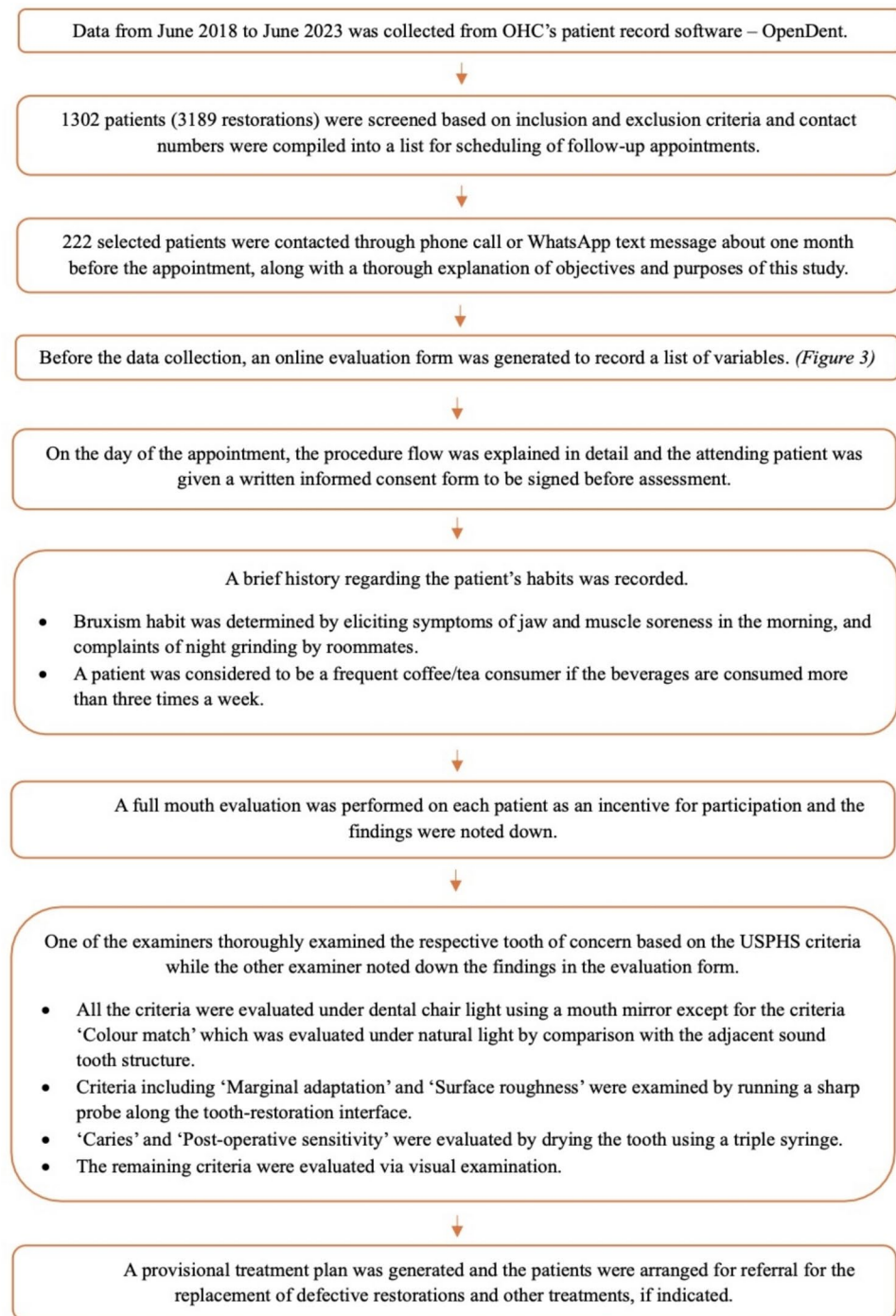
## 4 Discussion

A meta-analysis conducted on the longevity of posterior composite resin restorations in 2014 by Opdam et. al concluded that composite resin restorations in posterior teeth show annual failure rates of 1.8% at 5 years and 2.4% after 10 years of service (Opdam et al. 2014). Due to advancements in materials and instruments, resin composites have shown significant improvement in bond strengths, and reductions in technique sensitivity, as well as better compressive and tensile strengths of the materials (Demarco et al. 2023). However, several factors play a role in the success and failure of composite resin restorations. These can be broadly grouped together as a) predominantly operator-related factors and b) predominantly patient-related factors.

### 4.1 Operator-related factors

Teaching of composite resin restorations begins in the pre-clinical years, on plastic teeth, followed by extracted teeth. Once the students have achieved a high level of competence, they are permitted to perform, under supervision, these restorations on patients during their clinical training.

**Fig. 1** Summary of steps involved in data collection



*Fig. 1 flowchart:*

Data from June 2018 to June 2023 was collected from OHC's patient record software – OpenDent.

↓

1302 patients (3189 restorations) were screened based on inclusion and exclusion criteria and contact numbers were compiled into a list for scheduling of follow-up appointments.

↓

222 selected patients were contacted through phone call or WhatsApp text message about one month before the appointment, along with a thorough explanation of objectives and purposes of this study.

↓

Before the data collection, an online evaluation form was generated to record a list of variables. *(Figure 3)*

↓

On the day of the appointment, the procedure flow was explained in detail and the attending patient was given a written informed consent form to be signed before assessment.

↓

A brief history regarding the patient's habits was recorded.

- Bruxism habit was determined by eliciting symptoms of jaw and muscle soreness in the morning, and complaints of night grinding by roommates.
- A patient was considered to be a frequent coffee/tea consumer if the beverages are consumed more than three times a week.

↓

A full mouth evaluation was performed on each patient as an incentive for participation and the findings were noted down.

↓

One of the examiners thoroughly examined the respective tooth of concern based on the USPHS criteria while the other examiner noted down the findings in the evaluation form.

- All the criteria were evaluated under dental chair light using a mouth mirror except for the criteria 'Colour match' which was evaluated under natural light by comparison with the adjacent sound tooth structure.
- Criteria including 'Marginal adaptation' and 'Surface roughness' were examined by running a sharp probe along the tooth-restoration interface.
- 'Caries' and 'Post-operative sensitivity' were evaluated by drying the tooth using a triple syringe.
- The remaining criteria were evaluated via visual examination.

↓

A provisional treatment plan was generated and the patients were arranged for referral for the replacement of defective restorations and other treatments, if indicated.

Santos et al. (Santos et al. 2023) suggested that a more accurate depiction of the clinical performance of composite resin restorations done by dental undergraduates was obtained in retrospective studies, as compared to that found with prospective studies performed on selected patients by calibrated operators. The level of competency the students achieve within their clinical years directly affects the quality of restorations performed. This is evident in the dental students' clinical training years, as they progress through the clinical semesters. However, there are limitations in assessing the extent of the improvement including the absence of baseline information for comparison, and lack of standardized documentation, indications, and treatment protocols in studies where data is accessed retrospectively (Lempel et al. 2017).

**DATA COLLECTION EVALUATION FORM**

EXAMINER: NKY / WHS / KRN / OME                                  DATE:

INITIAL:
RN:
AGE:
GENDER:

| OPENDENT | | | | | | | |
|---|---|---|---|---|---|---|---|
| OPERATOR'S YEAR OF STUDY | 2 | 3 | 4 | 5 | | | |
| RESTORATION DONE ON (DD/MM/YY) | | | | | | | |
| FOLLOW-UP PERIOD (YEAR) | Less than 3 0 | At least 3 1 | | | | | |
| TOOTH NUMBER (FDI) | | | | | | | |
| ICDAS | 4 | 5 | | | | | |
| NO. OF SURFACES | 1 | 2 | 3 | 4 | | | |
| MATRIX BAND | None 0 | Tofflemire 1 | Siqveland 2 | Sectional 3 | | | |
| HISTORY TAKING | | | | | | | |
| SMOKING HABIT | Yes 0 | No 1 | | | | | |
| BRUXISM | Yes 0 | No 1 | | | | | |
| COFFEE/TEA CONSUMPTION | Yes 0 | No 1 | | | | | |
| USPHS CRITERIA | | | | | | | |
| MARGINAL ADAPTATION | 0 | 1 | 2 | 3 | 4 | | |
| COLOR MATCH | 0 | 1 | 2 | 3 | 4 | | |
| MARGINAL DISCOLORATION | 0 | 1 | 2 | 3 | | | |
| SURFACE ROUGHNESS | 0 | 1 | 2 | 3 | | | |
| FRACTURE OF RESTORATION | 0 | 1 | 2 | 3 | | | |
| FRACTURE OF TOOTH | 0 | 1 | 2 | 3 | | | |
| WEAR OF RESTORATION | 0 | 1 | | | | | |
| WEAR OF ANTAGONIST | 0 | 1 | | | | | |
| CARIES | 0 | 1 | | | | | |
| POST-OPERATIVE SENSITIVITY | 0 | 1 | 2 | 3 | | | |
| QUALITY | SATISFACTORY | | | UNSATISFACTORY | | | |

**Fig. 2** Data collection form

Only a limited number of teeth were included in this study, because a considerable number of patients were difficult to reach due to relocation or unavailability. Additionally, many restorations could not be included due to incomplete data in the patient records. Restorations were excluded when the student operator did not document details in the records, such as the reason for placement of the restoration or whether proper isolation techniques with a dental dam were used when restorations were placed. This further reduced the number of teeth that could have been included in the study.

A similar situation arose in the study conducted by Santos et. al (Santos et al. 2022) where missing patient records and details of the procedure lead to many restorations being excluded from the study. One factor contributing to incomplete documentation was failure to record the usage of

**Fig. 3** Socio-demographic data of operators
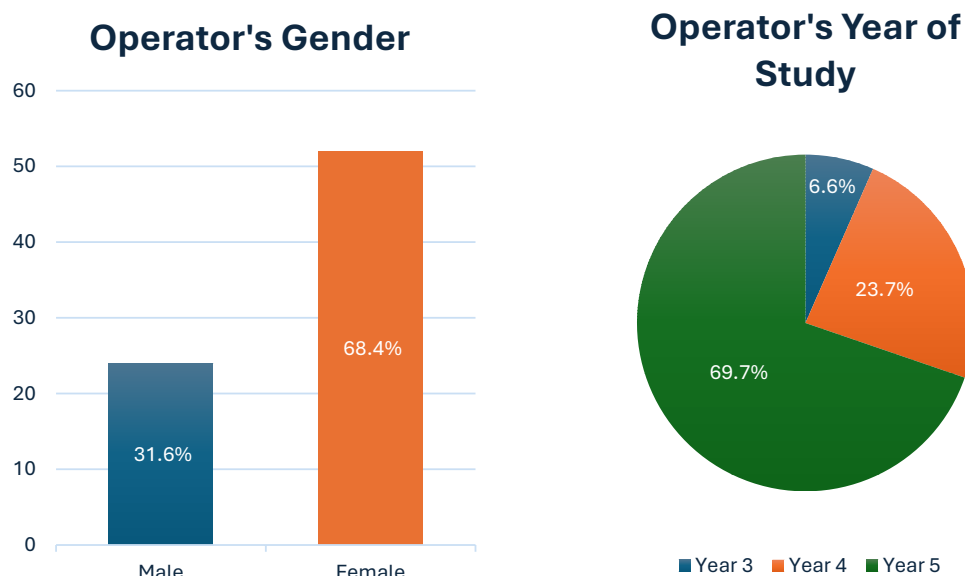


matrix bands for proximal restorations. Restorations placed with a matrix band may have been lower rated than necessary as "no matrix band usage" was considered when the type of matrix band used was not specified or when matrix band usage was not mentioned in the patient records. This highlights the importance of complete patient records, which is a very important factor that should be emphasized during clinical training.

Our results on the sociodemographic variables of the operator in Fig. 3 show that there were 68% female operators and 31% male operators. This is probably due to the higher number of female students in the dental undergraduate program. Better documentation of the procedure by female students than by male students could also be a contributing factor, as restorations with complete documentation of isolation and restoration techniques were included in the study. Year Three students are starting their clinical training, therefore predominantly handle preventive procedural cases such as plaque debridement treatments and fissure sealants. This difference also shows that there were relatively fewer restorations performed by Year Three students, compared to students in Years Four and Five, who are already in clinical training for more than a year.

The Chi square test was used to assess the relationship between independent variables and quality of composite resin restorations. Upon investigating the relationship between the quality of restorations and a list of variables, the operator's year of study exhibited statistically significant correlations ($p = 0.039$) with the outcome. Generally, identical studies where dentists performed the procedures had substantially lower failure rates than those of undergraduates, ranging from 1.6% to 1.8% at 5 years (Opdam et al. 2014; Cetin et al. 2013). This may be related to the

operator's experience in providing the best results in clinical procedures. Da Franca et al. (Franca et al. 2011) discovered a significant difference when comparing operators' performance in Class II (proximal) restorations, in which students had a lower rate of success. Likewise, restorations done by Year Five operators exhibited a higher success rate in the present study. This may be related to Year Five students having more clinical experiences as well as better psychomotor skills compared to the younger students. Senior students therefore attain higher maturity in procedural skills contributing to better outcome of restorations (Santos et al. 2022).

Most of the restorations in this study were deemed unsatisfactory due to an unacceptable colour match as successful colour-matching is highly dependent on clinical skills to reproduce natural tooth shades when using resin composites. Colour perception is subjective for individual observers, leading to variations in colour evaluation and matching among clinicians (Bahannan 2014). Moreover, resins exhibit characteristics such as low colour stability, susceptibility to dietary extrinsic staining, natural breakdown of the chemical constituents with time, and colour shifting upon curing. (2018) The colour stability of resin composites depends on the nature of their matrix and filler content. In vitro experiments have revealed microhybrid as the most stable type and nanofill being the least stable as determined by immersing test specimens in tea for a week and a month (Lempel et al. 2017).

The outcome of shade matching relies on the method used for determining the correct shade of the tooth. The dentine shade and the enamel translucency have to be assessed. In a study conducted by Bahannan (Bahannan 2014) students displayed a lower ability in shade matching when using the visual method (36.3%) than when using the Easy Shade

## Patient's Gender

## Smoking Habit

## Bruxism Habit

## Coffee/Tea Consumption
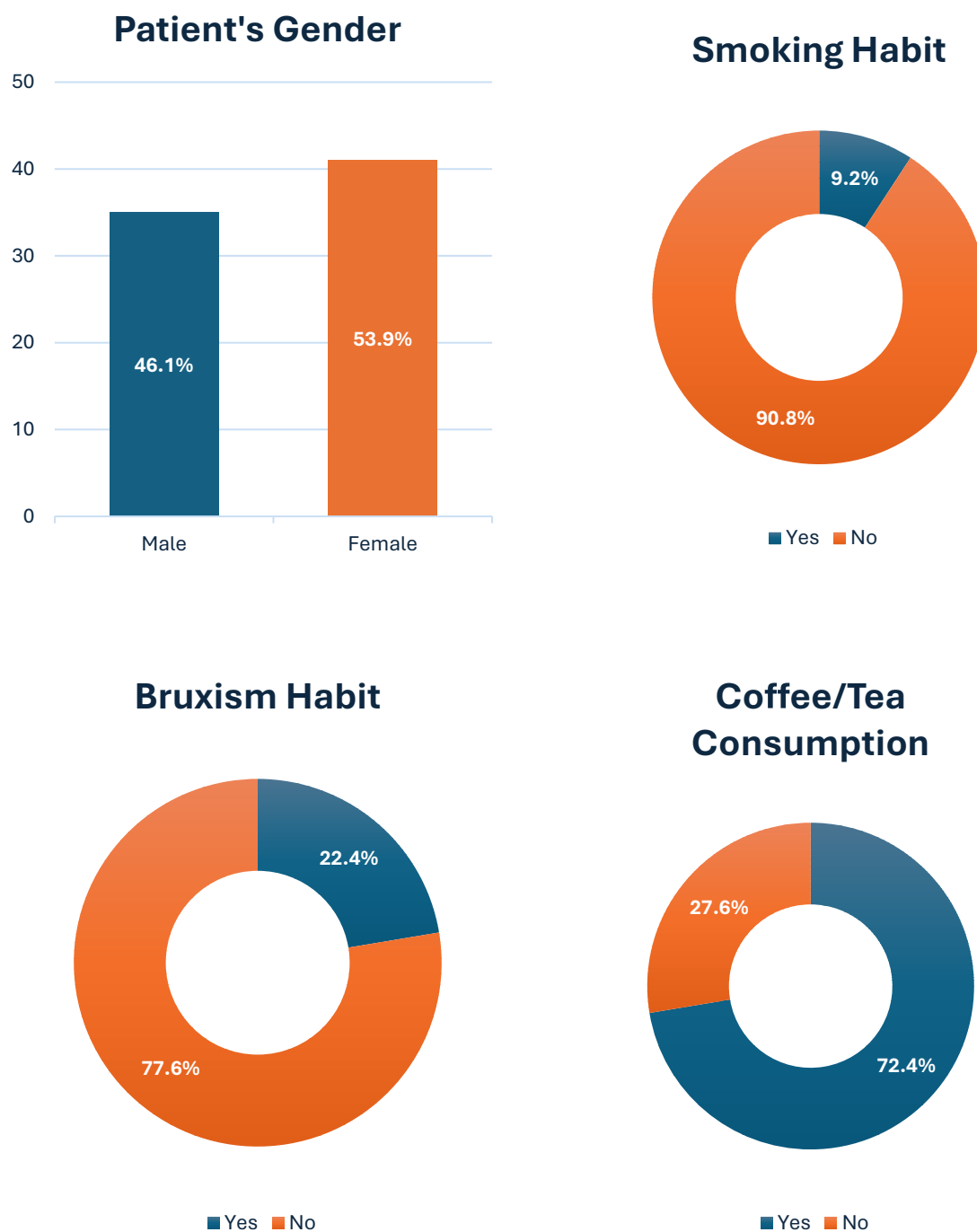


**Fig. 4** Socio-demographic data of patients

Compact machine (80.4%). However, student clinicians may also be lacking in this ability due to limited resources available and the environmental setting of the student clinics.

Figure 5 also illustrates that the composite resin restorations that were placed without matrix band usage show a higher number of failed restorations, as compared to those that had some form of proximal matrix band placed. Looking at the quality of composite resin restorations included in this study, Fig. 6 shows 42.1% were satisfactory and 57.9% were unsatisfactory. This could be due to several factors previously discussed, such as bruxism, tea and coffee consumption, as well as a higher number of smokers.

Marginal discolouration (21%) was noted to be the second most common cause of failure in the present study, after

## Indication of Restoration



## Number of Restoration Surfaces



## Matrix Band Usage
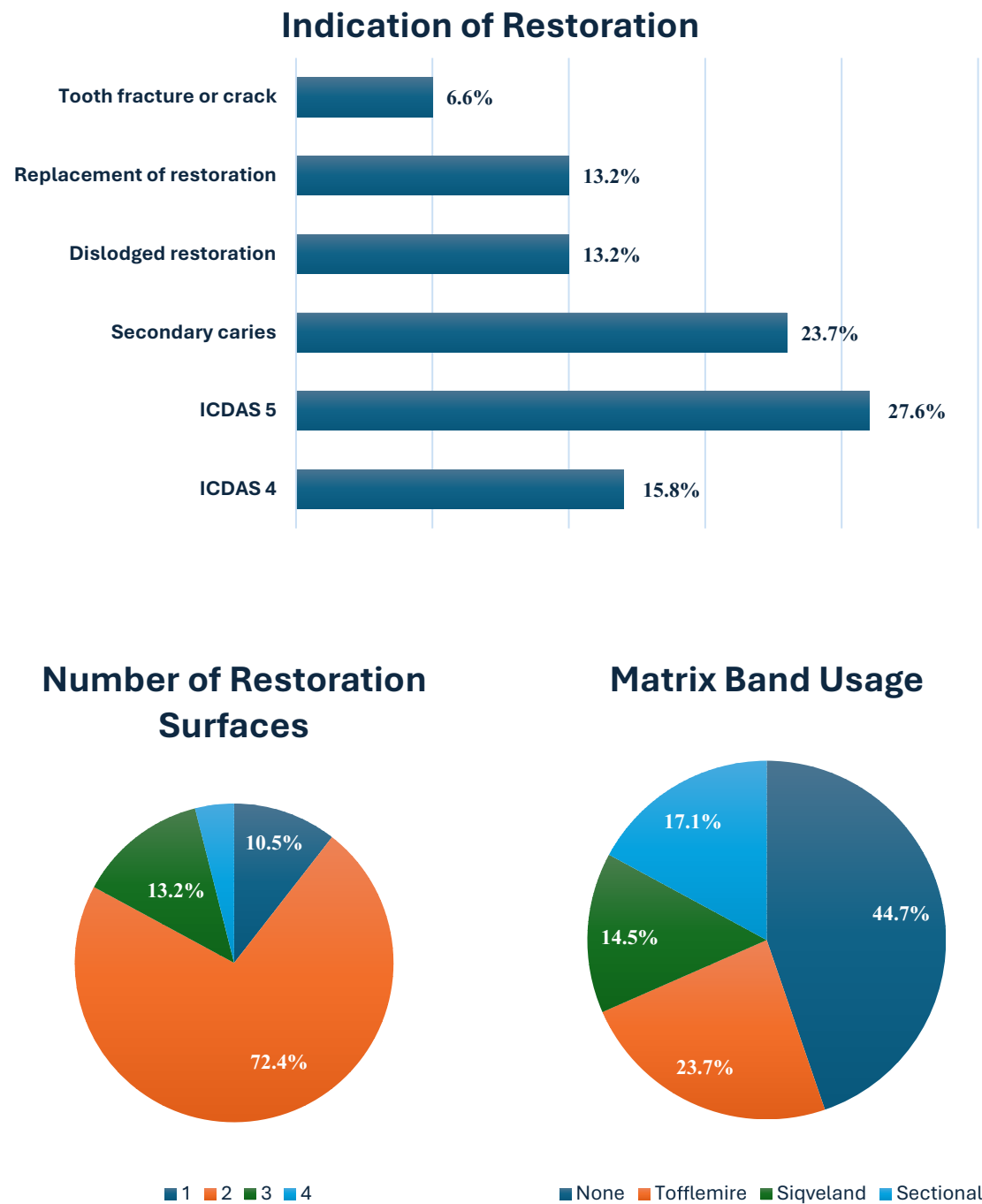


**Fig. 5** Data of tooth/restoration-related variables

colour mismatch (39.4%). Marginal adaptation was deficient in 9.1% of restorations. Secondary caries may result from micro-infiltration due to the presence of defective margins. (Santos et al. 2023) The primary reasons for poor marginal adaptation in composite resin restorations are polymerization shrinkage, degradation of adhesive bonding over time, and fatigue under constant occlusal forces. According

to Alauddin et al. (Alauddin et al. 2021) and Sidhu et al. (Sidhu et al. 2021), most teaching in Malaysian dental schools incorporates bevelling on the occlusal and proximal box margin in posterior restorations despite authorities like the British Association of Teachers of Conservative Dentistry (BATCD) making recommendations (Lynch et al. 2007) that occlusal bevelling be avoided. Bevelling in these

## Quality of Restorations
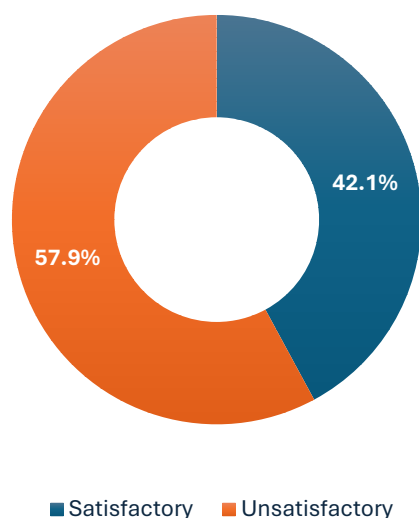


**Fig. 6** Quality of composite resin restorations

cavo-surface margins can lead to negative consequences, including poor adaptation of the restoration at the tooth-restoration-matrix system area, and unnecessary removal of enamel essential for proper bonding. Intrinsic polymerization shrinkage may also lead to poor marginal adaptation. In addition, the thin residue of composite resin at a bevelled margin may fracture or chip under normal chewing forces. That can then lead to marginal staining and loss of marginal integrity, so compromising the longevity of the restoration concerned (Alauddin et al. 2021). Appropriate finishing and polishing procedures are crucial to prevent plaque retention on the resin surface, thus aiding in preserving marginal adaptation, controlling discolouration, and decreasing the likelihood of recurrent caries.

### 4.2 Patient-related factors

In the present study, the limitation of the sample size emphasizes the need for cautious analysis of the results and interpretation. The lack of patient motivation to seek optimal oral health care may have led to a low response rate, as the appointments offered in order to recruit participants for the study only included patient evaluation and not procedural treatments (Rodolpho et al. 2022).

Figure 5 shows the reasons for placement of these composite resin restorations. The most common reason for restoration was carious exposure of the tooth. A total of 67.1% restorations were placed for the management of ICDAS Codes 4 and 5 carious lesions together with secondary caries associated with previous restorations. Reasons for failure in the present study include various factors such as

discolouration of the restoration, colour mismatch, marginal discolouration and deterioration, and secondary caries.

### 4.3 Discoloration and marginal deterioration

The sociodemographic variables of the patients shown in Fig. 4 indicate that 90% of the total sample were smokers, and 72% were consumers of tea and coffee possibly leading to staining. Of the included patients, 77% were showing signs of bruxation. These features could produce high rates of failure of composite resin restorations over time.

Figure 7 and Table 4 show the quality of composite resin restorations and the reasons for failure; colour mismatch and marginal discolouration are the major factors resulting in unsatisfactory restorations. Fracture of restorations and marginal deterioration is also suggestive of a similar pattern of failed composite resin restorations, which could be due to bruxing and clenching, as suggested by demographic variables of the included patients.

Furthermore, there was a statistically significant association between the number of restoration surfaces and the outcome ($p = 0.039$). A study conducted by Opdam et al. (Opdam et al. 2014) also found a significantly elevated risk of failure for restorations with a greater number of restored surfaces. It was noted that each additional surface incorporated into a restoration increases this risk by 30%−40%. Van de Sande et al. (Dijken and Lindberg 2015) also mentioned in their clinical study that an increased number of restoration surfaces may be predisposing the restorations concerned to greater probability of failure. This could be attributed to the diminished structural integrity of the remaining tooth structure exerting a significant impact on the overall longevity of those particular restorations.
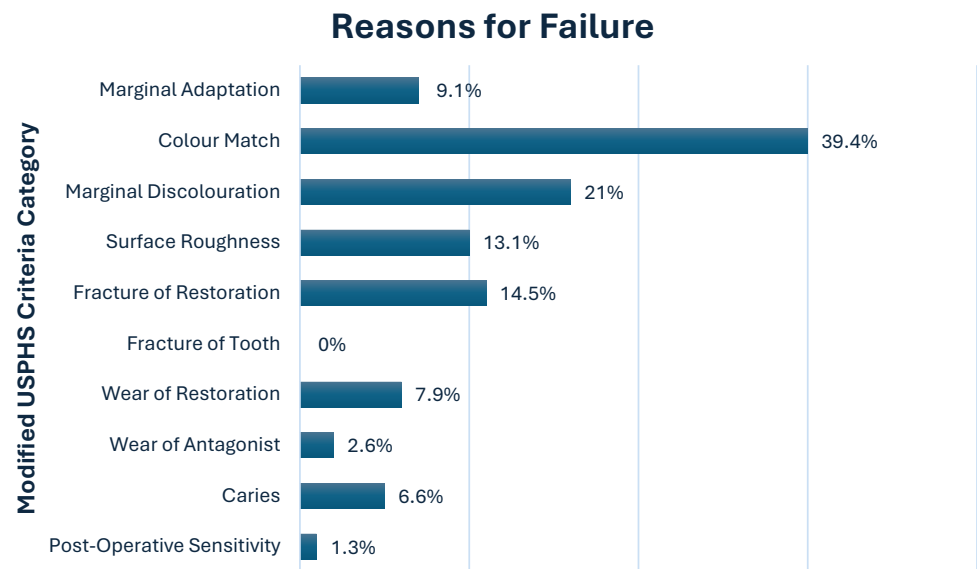
The present study reported an exceptionally high failure rate of 58% when compared to similar studies conducted to evaluate the success of composite resin restorations placed by undergraduate students. Jacinta et. al. (Santos et al. 2023) found a 24.2% five-year failure rate, Moura et. al. (Moura et al. 2011) reported 15% failure within three years, while Qamaruzzaman et. al. (Qamaruzzaman et al. 2009) reported a failure rate of 22% after four years. In the present study, colour mismatch was found to be the most prevalent reason for failure. This contrasts with other studies where restoration failure was mainly due to fracture of the restoration, debonding of the restoration, and secondary caries. This could also be attributed to a large sample of patients in the present study who were smokers (90%) and tea/coffee drinkers (72.4%).

The importance of quality assurance of clinical procedures by retrospective audits cannot be overemphasized. Retrospective clinical audits are an important component of clinical practice for improving service delivery (Hook 2020). It is also necessary in order to ensure the highest quality standards being applied in undergraduate clinical training.

**Table 4** Quality of composite restorations based on modified USPHS criteria.[10]

| Criteria | Number of Restorations | |
|---|---|---|
| | n | (%) |
| **Marginal Adaptation** | | |
| 0 Smooth margin | 35 | (46.1) |
| 1 All margins closed or poses minor voids, defects (enamel exposed) | 34 | (44.7) |
| 2 Obvious crevice at margin, dentin or base exposed | 3 | (3.9) |
| 3 De-bonded from one end | 2 | (2.6) |
| 4 De-bonded from both ends | 2 | (2.6) |
| **Color Match** | | |
| 0 Very good color match | 14 | (18.4) |
| 1 Good color match | 32 | (42.1) |
| 2 Slight mismatch in color or shade | 20 | (26.3) |
| 3 Obvious mismatch, outside the normal range | 8 | (10.5) |
| 4 Gross mismatch | 2 | (2.6) |
| **Marginal Discoloration** | | |
| 0 No discoloration evident | 29 | (38.2) |
| 1 Slight staining, can be polished away | 31 | (40.8) |
| 2 Obvious staining, cannot be polished away | 15 | (19.7) |
| 3 Gross staining | 1 | (1.3) |
| **Surface Roughness** | | |
| 0 Smooth surface | 36 | (47.4) |
| 1 Slightly rough or pitted | 30 | (39.5) |
| 2 Rough, cannot be refinished | 8 | (10.5) |
| 3 Surface deeply pitted, irregular grooves | 2 | (2.6) |
| **Fracture of Restoration** | | |
| 0 No fracture | 65 | (85.5) |
| 1 Minor crack lines or tiny chipping (< 1/4 of restoration) | 4 | (5.3) |
| 2 Partial fracture of restoration (> 1/4 of restoration) | 5 | (6.6) |
| 3 Debonding of restoration | 2 | (2.6) |
| **Fracture of Tooth** | | |
| 0 No fracture of tooth | 75 | (98.7) |
| 1 Minor crack lines in tooth | 1 | (1.3) |
| 2 Partial fracture of tooth (> 1/4 of crown) | 0 | (0.0) |
| 3 Crown-root fracture (extraction) | 0 | (0.0) |
| **Wear of Restoration** | | |
| 0 No wear | 70 | (92.1) |
| 1 Wear of restoration | 6 | (7.9) |
| **Wear of Antagonist** | | |
| 0 No wear | 74 | (97.4) |
| 1 Wear of antagonist | 2 | (2.6) |
| **Caries** | | |
| 0 No evidence of caries along the margin of the restoration | 71 | (93.4) |
| 1 Caries evident continuous with the margin of the restoration | 5 | (6.6) |
| **Post-Operative Sensitivity** | | |
| 0 No symptoms | 66 | (86.8) |
| 1 Slight sensitivity | 9 | (11.8) |
| 2 Moderate sensitivity | 1 | (1.3) |
| 3 Severe pain | 0 | (0.0) |

**Fig. 7** The cumulative total of unsatisfactory restorations for each category in the modified USPHS criteria

## Reasons for Failure

| Modified USPHS Criteria Category | Value |
|---|---|
| Marginal Adaptation | 9.1% |
| Colour Match | 39.4% |
| Marginal Discolouration | 21% |
| Surface Roughness | 13.1% |
| Fracture of Restoration | 14.5% |
| Fracture of Tooth | 0% |
| Wear of Restoration | 7.9% |
| Wear of Antagonist | 2.6% |
| Caries | 6.6% |
| Post-Operative Sensitivity | 1.3% |

**Cumulative Total of Unsatisfactory Restorations**

**Table 5** Relationship of independent variables and quality of composite restorations

| Independent Variables | Number of restorations- n (%) | Number of Satisfactory restorations – n (%) | Number of Unsatisfactory restorations – n (%) | $P$-value* |
|---|---|---|---|---|
| Operator's Year of Study | | | | |
| Year 3 | 5 (6.6) | 2 (40.0) | 3 (60.0) | 0.039* |
| Year 4 | 18 (23.7) | 3 (16.7) | 15 (83.3) | |
| Year 5 | 53 (69.7) | 27 (50.9) | 26 (49.1) | |
| Patient's Gender | | | | |
| Male | 35 (46.1) | 11 (31.4) | 24 (68.6) | 0.082 |
| Female | 41 (53.9) | 21 (51.2) | 20 (48.8) | |
| Patient's Bruxism Habit | | | | |
| Yes | 17 (22.4) | 6 (35.3) | 11 (64.7) | 0.519 |
| No | 59 (77.6) | 26 (44.1) | 33 (55.9) | |
| Patient's Coffee/Tea Consumption | | | | |
| Yes | 55 (72.4) | 20 (36.4) | 35 (63.6) | 0.101 |
| No | 21 (27.6) | 12 (57.1) | 9 (42.9) | |
| Follow Up Period | | | | |
| < 3 years | 68 (89.5) | 29 (42.6) | 39 (57.4) | 0.780 |
| ≥ 3 years | 8 (10.5) | 3 (37.5) | 5 (62.5) | |
| Number of Restoration Surfaces | | | | |
| 1 surface | 8 (10.5) | 5 (62.5) | 3 (37.5) | 0.039* |
| 2 surfaces | 55 (72.4) | 26 (47.3) | 29 (52.7) | |
| 3 surfaces | 10 (13.2) | 1 (10.0) | 9 (90.0) | |
| 4 surfaces | 3 (3.9) | 0 (0.0) | 3 (100.0) | |
| Usage of Matrix Band | | | | |
| None | 34 (44.7) | 12 (35.3) | 22 (64.7) | 0.316 |
| Tofflemire | 18 (23.7) | 11 (61.1) | 7 (38.9) | |
| Siqveland | 11 (14.5) | 4 (36.4) | 7 (63.6) | |
| Sectional | 13 (17.5) | 5 (38.5) | 8 (61.5) | |

*Pearson's Chi-square test, p < 0.05 statistically significant

Such measures would not only increase the quality of care delivered in the undergraduate programme but also instil a habit of critical thinking and continuous improvement in the clinical practice of all those involved. With such a paradigm shift in dental training the teaching methods and curricula will need to be improved and updated. Teaching clinical audit within the undergraduate curriculum is one of the key areas that should be explored, (Thornley and Quinn 2017).

# 5 Conclusion

In summary, composite resin restorations performed by dental undergraduates exhibited a high failure rate, primarily attributed to colour mismatches, marginal discoloration, and fractures of the restoration. A standardized procedural protocol for placement and review of direct composite resin restorations should be implemented for students. The importance of complete documentation of clinical procedures is of utmost importance. Furthermore, there is a need to emphasize shade matching in the dental curriculum. Patient education about the maintenance and review of composite restorations should be included as part of the treatment.

## 5.1 Limitations and future recommendations

### 5.1.1 Patient selection and recruitment

Patients should be educated more intensively regarding the importance of follow-ups in order to review and ensure proper maintenance of their restored dentition. Furthermore, it is recommended that dental undergraduates are required to carry out frequent and stringent clinical documentation.

### 5.1.2 Sample size

Including only a five-year sample of restorations was one of the limiting factors in this study, as there was no Open Dental Software data time-stamped earlier than that. Including patients from a larger pool with restorations of a longer duration would generate data from restorations over a longer period.

## 5.2 Clinical and radiographic evaluation

Incorporating radiographic evaluations into future studies would provide more accurate assessments of marginal adaptation and of secondary caries in the cavity floor. Also information regarding proximal contours and endodontic outcomes could provide more comprehensive insights into the effect of these factors on the success of restorations. More generally, a review of the criteria used here together with the creation of an updated set of guidelines for assessing restored dentitions with resin composites would be of value before conducting another study of this type.

**Data availability** All data generated or analysed during this study are included in this published article summarised in the form of tables and figures. The datasets generated during the current study are not publicly available due to confidentiality but are available from the authors on reasonable request.

## Declarations

**Ethics approval and consent to participate** Ethical approval was obtained from the IMU Joint Committee on Research and Ethics (IMU-JC 4.9/JCM-264/2023) as well as IMU Healthcare. Informed consent was obtained from all the participants included in the study.

**Consent for publication** Not Applicable.

**Competing interests** All authors (KRN, OME, NKY and AWS) declare that they have no conflicts of interest.

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