

Preclinical assessment of Class IV proximal contacts following different teaching strategies

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Abstract

Introduction: Class IV composite restorations are one of the biggest challenges in dentistry. Furthermore, replacing adequate proximal contours on Class IV restorations is crucial for the function and aesthetics. The objective of this study is to assess four different teaching strategies used to improve first-year dental students' Class IV restoration proximal contact performance over a period of 4 years.

Materials and Methods: We assessed four cohorts of first-year dental students who were exposed to four different teaching strategies during the first-year preclinical training over two consecutive academic terms. The four different teaching strategies used were: (a) two waxing exercises (control cohort, strategy 1); (b) digital dentistry and four waxing exercises (strategy 2); (c) four waxing exercises (strategy 3); and (d) four waxing exercises and live demonstrations (strategy 4). All cohorts were exposed to the same didactic lecture of Class IV restorations.

Results: Our results showed that all teaching strategies resulted in better student's performance and content retention compared to the control cohort. However, the teaching strategy that resulted in the best pass/fail ratio was the association of waxing exercises with live demonstrations (strategy 4).

Discussion: Increasing the number of waxing exercises may improve students' performance either alone or associated with different teaching strategies. However, when associated with live demonstrations, waxing exercises have significantly reduced critical errors.

Conclusions: Our study demonstrated for the first time the benefits of the affordable and traditional waxing exercises associated with instructor demonstrations as a teaching strategy for first-year dental students.

KEYWORDS

Class IV, preclinical dental education

1 | INTRODUCTION

Composite resin restorations have the potential to reproduce the natural tooth's appearance and constitute an excellent aesthetic and conservative alternative to laboratory-fabricated restorations such as crowns and ceramic veneers. However, composite resin restorations require the knowledge of the materials involved and attention to detail whilst selecting the hue and shade of the resin composite material used. Furthermore, artistic and fine motor skills are crucial to reproduce the natural tooth's shape and proximal contour.¹⁻⁴

Achieving clinically acceptable proximal contact contours in composite restorations constitutes a challenge even for experienced clinicians. Therefore, teaching the manipulation and the placement of composite restoration is essential in preclinical dental education. More specifically, teaching dental students how to properly reproduce the restorations' proximal contact areas has become crucial for clinical dental educators.^{5,6}

Dental education and training are composed of many factors such as adequate preclinical training, which should be assessed by its outcomes for different competencies.^{5,6} Therefore, finding adequate strategies to teach preclinical dental students is necessary for the development of students' manual dexterity and comprehension of procedures needed to succeed in the clinic,⁷ which includes the understanding and practising the reproduction of ideal interproximal contours. Given the importance of preclinical training to ensure students have the necessary knowledge and skills to enter the clinic, it is surprising that there has not been more research on the effectiveness of preclinical teaching strategies to improve performance in Class IV restorations.⁸

Additionally, failing to reproduce adequate proximal contact areas in anterior restorations is considered a critical error in dentistry for the Commission on Dental Competency Assessment (CDCA). The CDCA administers clinical examinations that are accepted in 49 different jurisdictions, including the United States, Puerto Rico, the US Virgin Islands and the Commonwealth of Jamaica.⁹ Therefore, in order to prepare dental students to successfully complete their preclinical requirements and subsequent clinical training and obtain a practitioner licence, finding feasible teaching strategies to improve proximal contact replacement in composite resin Class IV restorations is paramount.¹⁰⁻¹⁵

To develop mastery in composite resin Class IV restorations, instructors must guide students to acquire knowledge of the restorative concepts and to achieve the dexterity to place the restorations and to reproduce interproximal contacts.^{14,15} Faculty instructions regarding the Class IV restoration techniques can be offered using different strategies to improve students' performance.^{10,13,16,17} Consequently, our study proposes to evaluate four different preclinical teaching strategies used in first-year dental students to improve the students' performance in placement of the proximal contact areas in Class IV mesio-facial-incisal-lingual (MFIL) composite restorations.

2 | MATERIALS AND METHODS

The University of Michigan Institutional Review Board reviewed and approved this study based on the following methods (HUM00147576). In this study, we followed 4 cohorts of first-year dental students along two subsequent foundation courses that take place in the fall semester and winter semester. In the fall course (October), students learn and practise waxing techniques. In the winter course, students learn and practise the fundamental tooth preparations and restorations, starting with Class IV composite restoration in the winter month of January.

From 2016 to 2020, from fall (October) to winter (January) preclinical foundation courses, first-year dental students of four cohorts (2017 N = 107 control cohort; 2018 N = 107; 2019 N = 108; and 2020 N = 109 experimental cohorts) were trained and assessed for their competency to place a Class IV MFIL composite restoration on the right maxillary central incisor (tooth 11). All four cohorts had the same Class IV lecture content delivered by the same lecturer during the winter course in January. The duration of the lectures was approximately one hour. All four cohorts of students received the same Columbia typodont pre-cut test teeth (Figure 1A). For each cohort, a different teaching strategy was implemented as described in Table 1. For the cohort class of 2017 (strategy 1), students performed 2 waxing exercises (tooth 11 and 35) during the fall semester of 2016. The cohort class of 2018 performed 4 waxing exercises Class IV MFIL (4 exercises on tooth 11) and had two digital (virtual) dentistry waxing exercises of tooth 11 during the fall semester of 2017 (strategy 2). The cohort class of 2019 also performed 4 waxing exercises Class IV MFIL (4 exercises on tooth 11) during the fall semester of 2018 (strategy 3). However, the cohort class of 2019 did not have digital (virtual) dentistry waxing exercises. Finally, cohort 2020 performed 4 waxing exercises Class IV MFIL (4 exercises on tooth 11) during the fall semester of 2019 and had live demonstrations (DEMOS) in January during the winter of 2020 (strategy 4). For proximal contacts in the waxing exercises, students were encouraged to assess the presence of adequate proximal contact areas by visual inspection only through lifting the waxed cast at different angulations. The rubrics for physical and virtual proximal contact in waxing exercises can be seen in Table 2 and Table 3, respectively.

The Class IV MFIL composite restorations practical competency assessments on tooth 11 were done during the winter term course (January) that followed the fall course (October) when students performed the waxing exercises. The practical competency assessments were ninety-minute long. During the allocated time, students had to place the Class IV MFIL composite restoration on tooth 11 under rubber dam isolation. The rubrics for proximal contact in Class IV composite restorations can be seen in Table 4.

The class of 2017 was used as the control cohort as there were only 2 waxing exercises with faculty feedback. All cohorts, control (cohort, class of 2017) and experimental cohorts (cohort classes of 2018, 2019 and 2020), had the Class IV lecture and Class IV restoration assessment during the winter term in the month of January (Table 1).

FIGURE 1 Representation of the possible student's outcomes (E, S, N and C system) for Class IV assessment of the contact area. A, Tooth provided to students for the class IV assessment. Proximal contact area is open. B, Class IV restoration proximal contact area that scored as E. The anatomical features are restored correctly and there is adequate contact between tooth 11 and tooth 21. C, Class IV restoration that scored as S due to the presence of excess of restorative material and mild roughness in the proximal contact area. D, Class IV restoration that scored as N due to the presence of excess of restorative material and roughness in the contact area. E, Class IV restoration that scored as C due to an open proximal contact

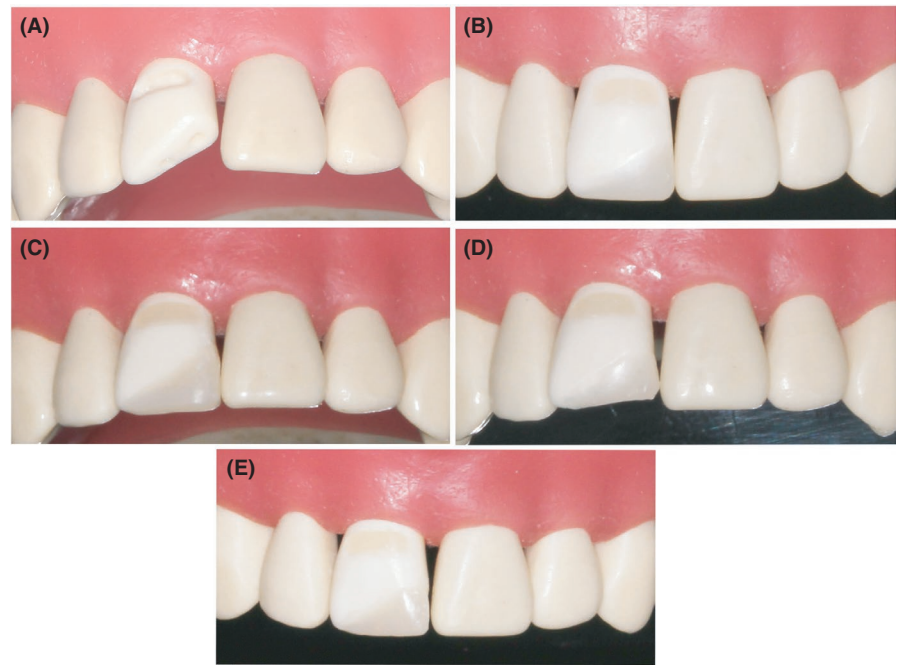


TABLE 1 Teaching strategy according to the years and terms

| Cohort Class Strategy | Cohort size | Teaching strategy Fall (October)/Year | Teaching strategy Assessment Winter (January)/Year |
|-------------------------------|-------------|--|---|
| Control Class 2017 Strategy 1 | 107 | 2 Waxing exercises Fall (October)/2016 | Lecture Assessment Class IV (MFIL) Winter (January)/2017 |
| Class 2018 Strategy 2 | 107 | Digital Dentistry 4 Class IV MIFL waxing exercises Fall (October)/2017 | Lecture Assessment Class IV (MFIL) Winter (January)/2018 |
| Class 2019 Strategy 3 | 108 | 4 Class IV MIFL waxing exercises Fall (October)/2018 | Lecture Assessment Class IV (MFIL) Winter (January)/2019 |
| Class 2020 Strategy 4 | 109 | 4 Class IV MIFL waxing exercises Fall (October)/2019 | Lecture Live DEMOS Assessment Class IV (MFIL) Winter (January)/2020 |

For the waxing exercises of Class IV MFIL, students completed either two (Class of 2017) or four waxing exercises (Class of 2018, 2019 and 2020). The waxing exercises were done with casts mounted in a Hanau articulator using pre-cut tooth 11 (Viade Products, Inc.). All teaching strategies were done in the same simulation laboratory under the student-instructor ratio of 8:1 for feedback. The same criterion for proximal contact was used to evaluate students' work (waxing and restorations) in all four strategies used in this study (Tables 2, 3 and 4).

The digital dentistry activity held in the fall term of 2017 consisted of two sessions when students designed anterior restorations. More specifically, first-year dental students had three-dimensional (3D) virtual design exercises of Class IV MFIL in the CEREC OminiCam (Dentsply Sirona, software version 4.4.2) in design mode. For the digital dentistry exercises, the pre-cut tooth 11 was scanned

and made available for the students to virtually design a Class IV restoration (Figure 1A). To work on the software, students had 1 h of lecture about CEREC CAD software and 2 h hands on training to familiarise with the software applications, design and use.

For the teaching strategy 4, second-year graduate restorative dentistry residents at the University of Michigan School of Dentistry (UMSOD) performed the live Class IV composite restoration live (DEMOS) during the winter term subsequent course (Table 1). The 2020 cohort of dental students was divided into small groups of eight, and each group was assigned to a graduate resident. The rationale of having small groups was to allow the dental students to properly see the DEMOS while graduate residents were performing the Class IV restoration step by step. All residents follow the same steps while placing the restoration during the DEMOS. To further make sure all dental students would

TABLE 2 Criteria for physical wax-up proximal contact area

| Criteria | E—Excellent (25) | S—Satisfactory (20) | N—Needs improvement (15) | C—Critical error (0) |
|--|---|--|---|--|
| Duplication of proximal contacts and embrasure spaces in class IV physical wax-ups | Proximal contact in wax model presents nearly ideal location, size. Proximal contact areas show visible closure of contacts. | Slight variation from normal contact location, size. Contacts is slightly broad/narrow | Moderately variation from normal contact size Contacts is moderately broad/narrow Moderately open/narrow/ | Severe variation from normal contact size and tightness Contacts is severely broad/narrow |
| | Proximal contact is continuous with existing tooth structure creating proper embrasure spaces (aesthetics, function, gingival health) | Slightly open/narrow/ asymmetrical embrasure spaces Slightly bulky/deficient marginal ridges | asymmetrical embrasure spaces Moderately bulky/deficient marginal ridges | Severely open/narrow/ asymmetrical embrasure spaces Severely bulky/ deficient marginal ridges |

TABLE 3 Criteria for digital/virtual wax-up proximal contact area

| Criteria | E—Excellent (25) | S—Satisfactory (20) | N—Needs improvement (15) | C—Critical error (0) |
|--|---|--|---|---|
| Duplication of proximal contacts and embrasure spaces in class IV digital/virtual wax-up | Proximal contact in digital model presents nearly ideal location, size and tightness Proximal contact areas shows visible closure of contacts Proximal contact is continuous with existing tooth structure creating proper embrasure spaces (aesthetics, function, gingival health) Proximal contact ideal colour should be green with appropriate size in digital restorations. | Slight variation from normal contact location, size and tightness Contacts is slightly broad/narrow Slightly open/narrow/ asymmetrical embrasure spaces Slightly bulky/deficient marginal ridges Acceptable colour should be Teal/ green in digital restorations with slightly less than ideal size | Moderately variation from normal contact size and tightness Contacts is moderately broad/narrow Moderately open/narrow/ asymmetrical embrasure spaces Moderately bulky/deficient marginal ridges Proximal contact colour in blue with large amount of teal/ light green or Specks of red/yellow. Proximal size is pin-point contact | Severe variation from normal contact size and tightness Contacts is severely broad/narrow Severely open/narrow/ asymmetrical embrasure spaces Severely bulky/ deficient marginal ridges Proximal contact colour in Red/ no colour/too much of yellow. Proximal size open or no contact |

TABLE 4 Criteria for class IV restorations proximal contact area

| Criteria | E—Excellent (25) | S—Satisfactory (20) | N—Needs improvement (15) | C—Critical Error (0) |
|--|--|--|---|--|
| Proximal contacts, contour and embrasure spaces in class IV restorations | <p>Proximal contact is restored to proper location, size and tightness</p> <p>Proximal contact is smooth with no shredding or breakage of floss</p> <p>Proximal contour is continuous with existing tooth structure creating embrasures that are consistent with aesthetics, function and gingival health</p> <p>No damage to adjacent tooth</p> <p>No damage to the typodont gingiva/Rubber Dam</p> | <p>Slight variation from normal contact location, size or tightness</p> <p>Contact is slightly rough with slight shredding of floss</p> <p>Proximal contour is slightly under or over contoured and embrasures are slightly deviated from the anatomy</p> <p>Slight damage to adjacent tooth</p> <p>Slight damage to the typodont gingiva/Rubber Dam</p> | <p>Moderate variation from normal contact location, size or tightness</p> <p>Contact is moderately rough with moderate shredding of floss</p> <p>Proximal contour is moderately under or over contoured with moderate deviation from normal embrasure contours</p> <p>Moderate damage to adjacent tooth</p> <p>Moderate damage to the typodont gingiva/Rubber Dam</p> | <p>Severe variation from normal contact location, size or tightness (open contact)</p> <p>Contact is severely rough with breakage of floss or inability to pass floss</p> <p>Proximal contour is severely under contoured (OPEN CONTACT) or over contoured with severe deviation from normal embrasure contours</p> <p>Severe damage to adjacent tooth</p> <p>Severe damage to the typodont gingiva/Rubber dam</p> |

have access to the same content, residents had a class IV MFIL restoration guide with pictures and reminders of important points to discuss such as contacts, line angles, margin, anterior guidance, surface finishing and polishing.

For the Class IV proximal mesial contact assessment, the criterion described on Table 2 was used. All critical errors are described in the Critical Errors Column (C). Open proximal contact was considered a critical error that results in zero point for that category. In this study, all scores C were due to open proximal contact. Two calibrated faculty assessed all Class IV composite restorations. For calibration procedures, 2 faculty assessed mesial proximal contact areas of different MFIL Class IV composite restorations by visual inspection and by inserting a 0.10-mm thick paper square of 10 by 10 mm and passing dental floss (Oral B—Satin Floss). The introduction of the paper is to confirm the visual open aspect of the proximal contact area, while the passage of the floss through the proximal contact area is to assess roughness. In case of disagreement, faculty revisited the gold standard Class IV MFIL composite restoration and reinserted the 0.10-mm thick square paper for confirmation. The percentage of agreement between the two faculty was 99% and Kappa 0.90.

For statistical analysis, Pearson's chi-squared test was used with $p < .05$, IBM-SPSS software version 25.

3 | RESULTS

From fall 2016 to winter 2020, we evaluated four cohorts of students' ability to reproduce proximal contact areas after using different teaching strategies. For assessment, E is considered excellent, S is satisfactory, N needs improvement and C is considered a critical error. An open proximal contact area is considered a critical error equivalent of a score C and zero point in the category. The total number of students evaluated during the winter terms was consistently similar though the years: 107 (Winter 2017), 107 (Winter 2018), 108 (Winter 2019) and 109 (Winter 2020).

While all critical errors, including open proximal contact areas, are equivalent to a C score, N scores relate to procedure errors that affect the clinical acceptability levels of the outcomes, for example moderate deviation of normal anatomy. More specifically, in this study, the N scores were mostly due to roughness of the proximal contact area and failure to re-establish ideal contours in proximal contact and embrasures. Figure 1BE depicts restorations that received scores E, S, N and C, respectively.

The student's performance for the proximal contact category improved in all 3 experimental cohorts when compared to the control. The total number of students that obtained a passing score (E and S scores) went from 63 in 2017 to 100 in 2020, while the failing scores (N and C scores) consistently decreased from 44 in 2017 to 9 in 2020. All teaching strategies tested improved student's performance when compared to the control cohort. Passing score results were equal in the winter of 2018 and 2019 (88 students passed). These results are depicted in Table 5.

TABLE 5 Teaching strategy and absolute number of students that received passing and failing scores per year

| Class–Teaching strategy | Number of students with passing scores (E +S scores) | Number of students with failing scores (N +C scores) | Number of students with a critical error (C score due to open proximal contact) |
|-------------------------|--|--|---|
| Class 2017–Strategy 1 | 63 | 44 | 34 |
| Class 2018–Strategy 2 | 88 | 19 | 3 |
| Class 2019–Strategy 3 | 88 | 20 | 6 |
| Class 2020–Strategy 4 | 100 | 9 | 0 |

Clearly, the Class IV teaching strategy used on first-year dental students that resulted in the best pass/fail ratio was the association of live DEMOS with four waxing exercises (strategy 4). This teaching strategy improved the ratio pass/fail scores and significantly reduced the number of students who committed critical errors in the proximal contact category (Table 3).

The association of waxing exercises (fall term) and live DEMOS (winter term) teaching strategy (strategy 4) significantly improved students' performance ($p < .0001$) when compared to the control cohort. When strategy 1 (two waxing exercises) is compared to strategy 2 (four waxing exercises and digital dentistry), our results show that students who were exposed to the combination of CAD/CAM and waxing exercises had a significant reduction in the percentages of critical errors and a significant improvement in the pass scores in the same category ($p < .0001$). When strategy 2 (CAD/CAM and four waxing exercises) is compared to strategy 3 (four waxing exercises only), there is no statistical difference ($p = .8850$). However, when strategy 2 (CAD/CAM and four waxing exercises) and strategy 3 (four waxing exercises only) are compared to strategy 4 (live DEMOS associated with waxing exercises), our results show that teaching strategy 4 is significantly better than the other 2 strategies used in the classes of 2018 and 2019 ($p = .0382$ and $p = .0267$, respectively).

4 | DISCUSSION

Our results show that the association of live DEMOS with waxing exercises resulted in the best pass/fail ratio for Class IV MFIL restoration proximal contact assessment. Importantly, all teaching strategies improved the amount of E and S (passing scores) and decreased the amount of N and C (failing scores), which may indicate that knowledge is better retained when the teaching strategies are carried on consistently from one term to the next, in this study from Fall to Winter. However, it is important to consider that our study did not consider previous years as additional control cohorts to demonstrate stable pass rates before the introduction of our teaching strategies. In our study, we only considered the cohort class of 2017 that only had 2 waxing exercises as our sole control.

Importantly, although we see a failure rating moving down from 34, to 3, to 6 and finally to 0 over the studied years, this does not imply that the overall performance in Class IV practical assessment followed the trend. We observed a significant improvement in the proximal contact area category, which is one of the major reasons dental students often fail the clinical examinations. Additionally,

there was no other significant change in the courses followed in this study. However, there was an emphasis on improving the students' ability to rebuild the proximal contact areas using different teaching strategies. Therefore, our results only allow us to conclude that the students committed fewer critical errors in the proximal contact area category as compared to the control cohort.

The students learn the importance of re-establishing an adequate proximal contact area during lectures but usually do not know how to physically achieve it while doing a restoration. A key aspect when establishing a good proximal contact area is the correct use of the matrix band. Thus, a live demonstration on how to correctly position the matrix band and secure it with a wedge before inserting the restorative material was pivotal for students to make the connection between what they learn in class and how to reproduce it clinically. Additionally, the live DEMOS were also an opportunity for a small-group discussion, which is a well-established strategy in dental education.¹⁸ With the use of visual teaching tools and small groups, students were able to conceptualise the criteria necessary for self-reflection and successful assessment.¹⁹

The increase from two to four waxing exercises showed improvement in passing scores in all conditions that it was used (alone or in combination to digital dentistry) but when the live DEMOS were added, there was a 10% improvement when compared to waxing exercises only. The art of waxing teaches students how to carve amalgam or shape composite restorations to accurately restore the form and function of posterior teeth damaged by caries or tooth fracture.^{19–22} If practitioners are unable to shape or carve direct restorative materials accurately, the resultant restorations will have poor longevity and recurrent caries.¹⁹

Our results did not show significant differences when digital dentistry and four waxing exercises were used together (strategy 2) and four waxing exercises only (strategy 3). However, when these strategies were compared to 2 waxing exercises (strategy 1), a significant performance improvement was observed in re-establishing proximal contact areas during the winter competency assessment. This implies that as a teaching tool for placement of proximal contact with composite resin, the use of digital dentistry is not as effective as waxing exercises. Moreover, digital dentistry is a costly technique, which requires training for instructors and additional equipment.

Interestingly, the students perceived experience with waxing exercises was superior to their experience with digital dentistry. Importantly, the majority of the students reported that re-establishing the proximal contacts using digital dentistry did not provide them with realistic training for the actual procedure of placing

a composite restoration. This perception that digital dentistry does not fully help novice learners was also previously described in the literature.²³ Preclinical dental students positively perceived digital dentistry as a learning tool, but they still preferred the interaction with instructors due to aspects such as feedback and tips and tricks about different aspects involved during the teaching interactions.²³

Digital dentistry is becoming broadly used and students have to be exposed to this technology during their training. However, there is no consensus in the literature on how and when to integrate digital technology into dental education. Some authors believe that the incorporation of teaching digital dentistry should be broad and progressive as in business such as aviation.²⁴ While others analysing different areas not restricted to dentistry believe that a radical change from conventional teaching strategies to incorporate modern technologies can be misleading.²⁵ UMSOD students start to learn and use digital dentistry in their first preclinical course in the first year of dental school. Our study shows that the use of digital dentistry to improve proximal contacts in Class IV composite restorations in preclinic is not as effective as the use of waxing exercises associated with live DEMOS. This study was the first study at the UMSOD to compare the use of CAD/CAM with waxing exercises and live demonstrations as educational tools to first-year dental students in preclinical settings.

5 | CONCLUSION

Increasing the number of waxing exercises associated with live faculty demonstrations improved the pass/fail rates in Class IV competency assessments and promoted learning retention over two consecutive academic terms.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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