

## Variability in Caries Management Decision-Making In a Dental School Setting

Evan T Booth<sup>1</sup>, DDS; George J Eckert<sup>2</sup>, MS; Margherita Fontana<sup>3</sup>, DDS, PhD

<sup>1</sup> Dentist, class of 2021 from University of Michigan School of Dentistry, Ann Arbor, MI

<sup>2</sup> Biostatistician Supervisor, Department of Biostatistics and Health Data Science, Indiana University School of Medicine and Richard M. Fairbanks School of Public Health, Indianapolis, IN

<sup>3</sup> Clifford Nelson Endowed Professor of Dentistry, Department of Cariology, Restorative Sciences & Endodontics, University of Michigan School of Dentistry, Ann Arbor, MI

Running title: Caries management decision-making

Corresponding Author:

Margherita Fontana

1011 North Michigan Ave

Ann Arbor, MI 48109

[mfontan@umich.edu](mailto:mfontan@umich.edu)

734-647-1225

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the [Version of Record](#). Please cite this article as [doi: 10.1002/jdd.12762](https://doi.org/10.1002/jdd.12762).

This article is protected by copyright. All rights reserved.

## ABSTRACT

**Objective:** To assess variability in caries management decision-making by faculty and dental students. Understanding sources of variability during training can aid in implementing evidence-based clinical decision-making in caries management. **Methods:** A voluntary, anonymous survey including clinical scenarios was distributed online to dental students in their first (D1) and third-year (D3) of training, and to faculty in the Department of Cariology, Restorative Sciences and Endodontics. **Results:** The response rate was=100% (108/108) for D1-students, 56% (73/130) for D3-students, and 39% (34/88; 12 full-time and 22 part-time) for faculty. D1-students, who were completing a cariology course, were in general more conservative in restorative thresholds for less severe caries lesions than D3-students and sometimes clinical faculty [e.g., for lesions at the DEJ, a significantly ( $p<0.05$ ) higher percentage of D3-students would restore these (53%) compared to D1-students and faculty (19% and 18%, respectively;  $p>0.05$ )]. For all groups, the threshold for doing restorative intervention was shifted towards less severe caries lesions as the caries risk increased [e.g., very few respondents would restore an occlusal lesion confined to enamel, with significantly ( $p<0.05$ ) less percentage of D1-students (lower risk scenario-LR=4%; higher risk scenario-HR=22%) compared to D3-students and faculty (LR=15% and 18%; HR=66% and 62%, respectively;  $p>0.05$ )]. Class lectures/pre-clinical instructors were the most important factor influencing decision-making for D1-students, vs. clinical experiences/instructors for D3-students. **Conclusion:** Although the majority of respondents used best-evidence deciding caries management, there was variability in how to manage less severe lesions, with caries risk influencing clinical thresholds, and clinical experiences influencing students' decision-making over time.

**Key Words:** Caries management; decision making; carious lesions; occlusal lesions; interproximal lesions; restorative treatment threshold; dental students; dental faculty.

## INTRODUCTION

Despite current evidence strongly supporting use of minimally invasive (MI) procedures for caries management within a comprehensive, evidence-based disease management strategy at the tooth/individual level,<sup>1,2</sup> studies suggest there is a large gap between evidence-based recommendations and application in practice.<sup>3,4,5</sup> Minimal intervention dentistry is a holistic caries management philosophy with the main objective of tissue preservation and maintenance of pulpal health, including prevention of new lesions, detection and monitoring of early stages of lesion formation to arrest disease progression, non-restorative intervention of non-cavitated lesions, and minimally-invasive restorative procedures, when necessary, for more advanced lesions.<sup>6,7</sup>

In order to assess whether evidence supporting a modern caries management philosophy has led to changes in restorative treatment decisions by practicing dentists, questionnaires including clinical-case scenarios have been used. Data from these studies demonstrate a wide variation among dentists, including within and between countries, and have identified factors that influence decision-making.<sup>8</sup> Findings from some of these studies suggest that male practitioners and practitioners from solo or small group practices tend to intervene at an earlier stage of caries progression, and that overall, dentists are more willing to intervene at earlier stages of interproximal caries progression than they are at similar stages of occlusal caries progression.<sup>3,4,9</sup>

Dental education can play an influential role in accelerating implementation of evidence-based caries management strategies into dental practice. The process of critical thinking and clinical decision-making inculcated in dental school, and particularly what is modeled during clinical training experiences, has a great potential to impact a graduating dentist's decision-making process, especially whether to be more or less invasive in the management of caries lesions.<sup>2</sup> Cariology curriculum frameworks have been developed, including in the U.S., to help guide teaching and implementation of evidence-based information, yet many challenges remain.<sup>10</sup> Effective

communication, and training and calibration of all faculty and departments with responsibilities for the educational competencies associated with caries management, both restorative and non-restorative, is integral to successful implementation of evidence, and translation of evidence into clinical experiences. Didactic and pre-clinical courses, where evidence for caries management is initially discussed in most curricula, occur early in a dentist's training, while most clinical experiences are concentrated in the later years of training. One of the biggest challenges in implementing a cariology curriculum in many schools is the disconnect between clinical and preclinical expectations and competencies.<sup>10,11</sup> Little is known regarding how decision-making in cariology differs between students and faculty, or how it changes over time during dental students' training. Thus, the aim of this study was to assess and compare decision-making associated with managing caries lesions of different severity in patients with varying risk by dental students and faculty at the University of Michigan School of Dentistry.

## MATERIALS AND METHODS

This descriptive study was deemed exempt by the Health Sciences and Behavioral Sciences Institutional Review Board (IRB) at the University of Michigan, Ann Arbor, MI (HUM00162309).

**Procedure:** Data were collected through use of a voluntary, anonymous survey that was completed electronically using Qualtrics. Dental students were invited to participate at the end of their first year of dental school (D1=first quarter of 2017; n=108), while completing two consecutive cariology courses, and during their third year (D3=second quarter of 2019; n=130). The increase in student size in the D3 is because international trained dentists seeking a DDS in the U.S. join the DDS class in the middle of their D2 year and were also invited as part of the D3 class. Faculty (n=88, including full and part-time) in the Department of Cariology, Restorative Sciences and Endodontics were also invited to participate in this study in 2019. The D1 and D3 years of training were chosen to

This article is protected by copyright. All rights reserved.

represent students after completing their cariology didactic and preclinical training (at the end of their D1 year), and while they are completing most of their clinical experiences (in their D3 year). The cariology curriculum consists of 2 semester long courses, Cariology I (fall of D1 year; Appendix 1) and Cariology II (winter of D1 year; Appendix 1). These courses are integrated with D1 clinical foundation and restorative preclinical courses, all taught by faculty in the Department of Cariology, Restorative Sciences and Endodontics. During the D2-D4 years students begin clinical experiences, and a caries risk assessment and management plan must be developed and re-evaluated overtime for every patient. Cariology is assessed in these years through clinical test cases, and an Objective Structured Clinical Examination (OSCE) in the D4 year.

**Materials:** Data were collected through use of a modified questionnaire, originally developed by Sundberg et al.<sup>12</sup> There were twenty questions, including two demographic questions, three clinical-based scenarios with photos and three to four associated questions each, and an additional seven questions about decision-making in caries management (Appendix 2). The questionnaire is used in the curriculum to engage with students on discussions around decision-making and for faculty training. For this study, the focus were the questions related to the three clinical scenarios, and the last question on the most important factor influencing the decision-making process.

The first clinical scenario asked about a series of six illustrations representing radiographic appearance of interproximal lesions on the distal surface of the maxillary second premolar (Figure 1). Lesion severity ranged from the outer half of enamel to the inner half of dentin. The second clinical scenario involved five images of occlusal caries (Figure 2) in a lower second molar. The lesions in these images ranged from slightly discolored fissures to a lesion with considerable loss of tooth structure and caries in the inner third of dentin. The last clinical scenario included an image of an occlusal lesion with an accompanying radiograph (Figure 3).

For each of the clinical scenarios, respondents were told that the patient was twenty years old, sees the dentist once a year, has adequate oral hygiene, uses fluoride toothpaste twice daily, and the patient's medical history is negative for any abnormalities. However, for the second scenario, the question was also repeated with a higher caries risk scenario: the twenty year old patient had bad oral hygiene, inadequate fluoride intake, and frequent sugary/cooked starch snacks between meals. Following the clinical photographs and/or radiographs, respondents were asked three questions about (1) the stage of lesion progression that restorative treatment is indicated; (2) the type or preparation they would use; and (3) the choice of restorative material indicated for the smallest lesion requiring immediate restorative intervention.

**Statistical analyses:** D1-students, D3-students, and faculty groups were compared for differences in survey responses using chi-square tests. A 5% significance level was used for all tests. All analyses were performed using SAS version 9.4.

## RESULTS

Analyses were limited to respondents who completed the entire survey. The response rate was 100% (108/108) for first-year students, 56% (73/130) for third-year students, and 39% (34/88) for Cariology, Restorative Sciences and Endodontics faculty. Of the thirty-four faculty respondents, twelve were full-time and twenty-two were part-time faculty.

Regarding the management of interproximal lesions (Figure 1), the majority of respondents in the three groups did not choose to restore lesions radiographically into the outer or inner half of enamel (groups were not significantly different,  $p>0.05$ ). For lesions at the DEJ, a significantly ( $p<0.05$ ) higher percentage of D3-students would restore these (53%) compared to D1-students and faculty (19% and 18%, respectively; not different,  $p>0.05$ ). For lesions radiographically into the outer third of dentin, D1-students were significantly less likely to restore these (60%) compared to D3-

This article is protected by copyright. All rights reserved.

students (79%). Faculty were not significantly different than both groups of students (74%,  $p>0.05$ ). The majority of respondents in all three groups chose to restore lesions radiographically into the middle and inner third of dentin. When asked how they would restore the smallest lesion they had decided to restore, the preferred preparation type for D1-students (71%), D3- students (75%), and faculty (62%) was the box or slot preparation (groups were not significantly different,  $p>0.05$ ; Table 1). The most common restorative material chosen amongst all groups was composite resin (D1-students<D3-students,  $p<0.05$ ; Table 1).

For questions regarding the restorative management of occlusal lesions (Figure 2), answers varied depending on the caries risk scenario of the patient. There was a shift for all three groups towards higher percentage of respondents deciding to restore less severe occlusal caries lesions in the higher caries risk patient scenario compared to the lower risk scenario. In the lower risk scenario (Figure 2, top), very few respondents would restore a lesion confined to enamel with minor loss of tooth substance and no radiographic signs of dental caries. A significantly ( $p<0.05$ ) lower percentage of D1-students (4%) compared to D3-students and faculty (15% and 18%, respectively; not different,  $p>0.05$ ) selected to restore lesions confined to enamel. In the higher risk scenario (Figure 2, bottom), the percentage of participants who responded they would restore this lesion was higher for all three groups compared to the lower risk scenario. D1-students were still significantly less likely to restore this lesion (22%) compared to D3-students and faculty (66% and 62%, respectively; not different,  $p>0.05$ ).

For the higher risk scenario (Figure 2, bottom), once a lesion was clearly cavitated, with considerable amount of loss of tooth structure, and/or with radiographic signs of dental caries into dentin, more than 79% of respondents in all groups would decide to restore these lesions. In the lower caries risk scenario (Figure 2, top), this was only true for clearly cavitated lesions, radiographically into the middle or inner third of dentin. For a lesion with no clinically obvious cavitation, but described to have moderate loss of tooth structure, and a caries lesion in the outer

third of dentin radiographically, D1-students were significantly less likely to restore this lesion (41%) compared to D3-students (71%). Faculty were not significantly different than any of the two student groups (59%;  $p>0.05$ ).

For the smallest occlusal lesion that needed restorative intervention, in a lower caries risk scenario, 90% of D1-students, 63% of D2-students, and 74% of faculty stated their preferred preparation would be the removal of carious tissue only. However, 8% of D1-students, 37% of D3-students, and 24% of faculty stated they would remove carious tissue and open the whole fissure system (significantly less D1-students than D3-students,  $p<0.05$ , no significant difference between faculty and the two student groups,  $p>0.05$ ; Table 1). The majority of respondents in each group selected composite resin as their preferred restorative material restoring the occlusal lesion. 4% of D1-students, 21% of D3-students, and 18% of faculty chose a preventive resin restoration (significantly less D1-students than D3-students and faculty,  $P<0,05$ ; Table 1).

In the third scenario involving a clinical photo and radiograph of an occlusal lesion (Figure 3), there were no significant differences ( $p<0.05$ ) amongst groups on the diagnosis of the lesion, with most respondents in each group selecting caries confined to enamel. D1-students (76%) recommended fissure sealants as the preferred treatment for the occlusal surface of this tooth significantly more often than D3-students (27%) and faculty (26%) (Table 2). 63% of D1-students, 29% of D3-students, and 35% of faculty said they would not restore this tooth. D3-students (34%) and faculty (44%) were significantly more likely to recommend a preventive resin restoration than D1-students (5%;  $p<0.05$ ; Table 2).

D1-students were significantly more likely to select class lectures (72%) and pre-clinical instructors (57%) as the most important factor in their decision-making, while D3-students were more likely to cite clinical instructors (93%) and personal experiences in clinic (89%) as their main influences (Table 3).



## DISCUSSION

Effective management of dental caries throughout life depends on an ongoing process that is characterized first by early detection and diagnosis of existing caries lesions, determination of their severity at the tooth level, and then an assessment of caries activity and risk, both at the tooth and patient level. This information, together with an understanding of the patient's needs and desires, available evidence supporting treatment alternatives, and the dentist's clinical expertise can then be used to reach a clinical decision on how to control existing lesions and prevent occurrence of new ones.<sup>13</sup> Current understanding of the caries process supports the use of minimal intervention dentistry whenever possible, conserving tooth structure and preserving pulpal health.<sup>1,2,14</sup> However, for the most part, thresholds on when to restore caries lesions have not changed overtime in practice.<sup>8</sup> Studies assessing clinical decision making by U.S. dental practitioners participating in a National Dental Practice-Based Research Network indicate a large variation in the restorative decision-making process,<sup>3,4,15</sup> with many dentists treating less severe caries lesions restoratively prematurely, especially when working in solo practices compared to large groups practices.<sup>4</sup> A survey of U.S. practitioners suggested that complete caries removal to hard dentin is very common in practice, and that pulp diagnostic tests are not used routinely prior to decisions for treatment of teeth with deep caries lesions.<sup>16</sup> There is a wide range of teaching practices in cariology in U.S. dental schools, resulting in differences regarding caries tissue removal,<sup>17</sup> implementation of individualized evidence-based caries preventive approaches based on risk, and the use of routine caries risk assessment in practice.<sup>5,18</sup> All these findings suggest that an invasive and not individualized approach to caries management is common. This may be related to the fact that competency associated with caries management has been focused, until recently, primarily on assessing restoration of teeth as part of the accreditation standards for dental training in the U.S. It may also be related to the fact that many licensing exams still expect removal of carious tissues to hard dentin, in contrast with current recommendations.<sup>14</sup> The lack of high-level evidence and

remuneration options for non-invasive or MI therapies in U.S. populations may have also compounded the implementation of these concepts.<sup>2</sup>

Findings from this study suggest that for young adult patients that seek routine care, and have good oral hygiene and fluoride exposure, the majority of D1 and D3-students and faculty would not restore early non-cavitated lesions (i.e., interproximal caries lesions radiographically into enamel, or occlusal caries lesions with minimal tissue loss and/or no radiographic signs of dental caries). These decisions are in agreement with existing best-evidence and clinical recommendations for the management of non-cavitated caries lesions.<sup>14,19</sup> However, even in the lower risk scenario described, for occlusal non-cavitated lesions with no radiographic involvement, a meaningful group of respondents (4-18% among the three groups) would restore these lesions. These numbers increased dramatically (41-71%) when the lesion involved radiographically the outer third of dentin, even when visually there was no clear evidence of cavitation. In a recent systematic review and meta-analysis, Innes and Schwendicke<sup>8</sup> found that 12% of dentists/therapists would restore occlusal lesions presenting enamel discoloration/cavitation without clinical/radiographic signs of dentin involvement. The percentage increased to 74% when outer dentin was involved. These non-cavitated lesions could be managed using a range of non-restorative strategies, including use of dental sealants.<sup>20,21</sup> In fact, in the case of the clinical image and radiograph showing a stained occlusal surface with no radiographic evidence of caries in a 20 year old patient with routine care and good oral hygiene and fluoride exposure, D1-students were three times more likely than D3-students and faculty to recommend dental sealants. Although not addressed in the survey, the hesitancy of D3-students and faculty to recommend sealants in this case could be related to a number of internal and external modulators of the decision-making process, such as the possibility that if there was a very early caries lesion it could have been arrested, and/or the fact that most third party payers do not reimburse for the use of sealants for adults in the U.S.

This study also showed that the perceived caries risk strongly influences clinical thresholds for restorative intervention, with a higher risk scenario leading to intervening restoratively at earlier stages of the caries process, including early non-cavitated lesions. A 2017 systematic review and meta-analysis reported that the likelihood of restorative intervention almost doubled (risk ratio=1.98; 95% Confidence Interval-CI=1.68-2.33) in high caries risk patients.<sup>8</sup> This could be related to a perceived lack of trust of the patient engaging in at home strategies to reduce their risk, and the belief that restorative intervention would be a better solution, even when a higher caries risk is also associated with higher restoration failure rates.<sup>22</sup>

Innes and Schwendicke reported that for proximal lesions extending up to the DEJ, 48% (95% CI= 40-56%) of dentists/therapists would intervene restoratively. These levels were not reached in our study except for D3-students, while D1-students and faculty were significantly more conservative. It is possible the restorative decision-making behavior of students during their clinical years as it relates to lesions radiographically to the DEJ or outer third of dentin could be influenced by another external modulator: clinical requirements, perceived or real, of regional licensing boards. There is a misalignment between what is required in some regional board live patient exams and what is taught in the curriculum of many schools. This has been identified as a barrier for implementation of a MI, evidence-based approach to caries lesion management.<sup>2,10</sup> It is worth mentioning that although lesions radiographically into the outer third of dentin could be non-cavitated,<sup>23</sup> and thus multiple effective non-restorative treatment options are available for their management,<sup>21</sup> the majority of students and faculty chose to restore them in a lower risk scenario, albeit with D1-students at a significantly lower percentage than D3-students and faculty. The survey did not provide options for consideration of the effect of lesion activity in the decision-making process, or other factors that would influence the decision-making process in real life. The difference between students at different stages of their training could also be impacted by the fact that class

lectures/pre-clinical instructors were the most important factor influencing decision-making for D1-students vs. clinical experiences/instructors for D3-students.

Our results show that there is variability in decision-making in cariology between students at different stages of their dental education. Although changes are expected as more information is learned expanding from didactic and preclinical courses to clinical experiences, and there are increased experiences with other variables (healthcare system, provider-related factors, patient-related factors, etc.)<sup>24</sup> that influence clinical-decision-making, unintended variation in implementation of evidence-based approaches should be further evaluated. As has been described in the literature, there are numerous factors that can modulate or impact implementation of best evidence in cariology into education and practice.<sup>2,10,25</sup> Examples of these factors associated with dental education include having: 1) a well-defined cariology curriculum, effectively integrating didactic, preclinical and clinical teaching components (existing in our school's curriculum); 2) a dental health record that supports charting and monitoring of caries lesion severity and activity, and use of a caries risk assessment protocols with individualized risk-based re-assessments (existing in our clinics); 3) ongoing and regular faculty training and calibration programs, including effective communication between departments and those involved in preclinical and clinical education (although we have a single Department in charge of cariology and restorative sciences, which facilitates communication, faculty training and calibration, particularly involving the part-time important clinical faculty workforce, can always be improved, and could explain part of the variability seen in the clinical years); 4) outcomes assessments that reward and value implementation of best-evidence and appropriate decision-making (whether restorative or non-restorative) (this is an expectation of all care provided in our clinics, yet there is no doubt that restorative experiences to gain technical expertise are highly valued, thus possibly de-emphasizing the perceived educational "value" of non-restorative options); and 5) diagnostic and risk-based codes that are used routinely to facilitate tracking and assessment of interventions and resulting

health outcomes (the current electronic health record allows tracking of procedures or diagnostic codes used; however, use of appropriate diagnostic codes can be improved). External factors that could challenge implementation include perceived or existing standards of care, the health care system, public expectations of treatments and outcomes, patient preferences, provider preferences and training, etc. Out of these, many consider lack of economic incentives for non-invasive procedures as one of the largest barriers to implementing MI cariology approaches, as revenue is dependent on the type of procedures performed, and not the successful chronic management of the disease process.<sup>2,26</sup>

This study presents with several limitations in that it uses self-reported questions, some with limited validation, on a limited convenient sample. Yet this questionnaire has been used in multiple formats by many others, and it was chosen for comparison purposes. Unfortunately, it did not address specifically factors associated with lesion activity, and caries lesion classification terminology reflected the time period when the survey was originally developed. Many factors not included in the questionnaire could have affected the decision-making process and the interpretation of the data. There was also discrepancy in response rate between the three groups surveyed. First-year students had a 100% response rate because they completed the survey during their cariology course at the conclusion of their first year. In their third year, the same students were asked to participate in the study outside the context of a specific course and the response rate dropped. A 39% response rate for dental school faculty is slightly lower than similar French studies.<sup>27</sup> The decision to use the same cohort of students in their first and third year was made to assess changes in restorative decision-making as students make their way from didactic courses and preclinical exercises to treating patients in a clinical setting. This decision was complicated by the addition of twenty-two international students to the original cohort as part of the Internationally Trained Dentist Program, and their addition may have impacted the D3-student results. The survey also did not include a choice about how much evidence influenced decisions, and respondents were not allowed to

expand on reasons behind choices made. All of these limitations affect the generalizability of the findings. To better understand these data, future studies relying on qualitative methods could provide important additional details on these decisions.

**CONCLUSION**

The majority of students and faculty used best-evidence to make MI treatment decisions for caries management, with caries risk influencing clinical thresholds, and clinical experiences influencing students' decision-making over time. These findings indicate that restorative decision-making changes throughout dental school as students progress to the clinical environment and are exposed to multiple factors that modulate the decision-making process beyond evidence. Variability is expected, but understanding undesirable variability during training can aid in improving implementation of evidence-based clinical decision-making in caries lesion management during clinical care. Repeated exposure to evidence-based caries management strategies later in the curriculum, more faculty calibration and training, as well as reorganizing the educational incentive structure for a variety of clinical procedures to focus on management of chronic diseases and their outcomes could help close the gap between evidence-based practices and dental student and faculty restorative decision-making.

**ACKNOWLEDGEMENT**

Funding for this study was partially provided by the University of Michigan School of Dentistry Pathways Program. We thank all faculty and students who participated in the survey.

## REFERENCES

1. Innes NP, Chu CH, Fontana M, Lo EC, Thomson WM, Uribe S, Heiland M, Jepsen S, Schwendicke F. A century of change towards prevention and minimal intervention in cariology. *J Dent Res* 2019;98(6):611-7.
2. Fernández CE, González-Cabezas C, Fontana M. Minimum intervention dentistry in the US: an update from a cariology perspective. *Brit Dent J* 2020;229(7):483-6.
3. Gordan VV, Garvan CW, Heft MW, Fellows JL, Qvist V, Rindal DB, Gilbert GH, DPBRN Collaborative Group. Restorative treatment thresholds for interproximal primary caries based on radiographic images: findings from The Dental PBRN. *Gen Den* 2009;57(6):654.
4. Gordan VV, Bader JD, Garvan CW, Richman JS, Qvist V, Fellows JL, Rindal DB, Gilbert GH, Dental Practice-Based Research Network Collaborative Group. Restorative treatment thresholds for occlusal primary caries among dentists in the dental practice-based research network. *J Am Dent Assoc* 2010;141(2):171-84.
5. Riley III JL, Gordan VV, Ajmo CT, Bockman H, Jackson MB, Gilbert GH, Dental PBRN Collaborative Group. Dentists' use of caries risk assessment and individualized caries prevention for their adult patients: findings from The Dental Practice-Based Research Network. *Comm Dent Oral Epidemiol* 2011;39(6):564-73.
6. Machiulskiene V, Campus G, Carvalho JC, Dige I, Ekstrand KR, Jablonski-Momeni A, Maltz M, Manton DJ, Martignon S, Martinez-Mier EA, Pitts NB. Terminology of dental caries and dental caries management: consensus report of a workshop organized by ORCA and cariology research group of IADR. *Caries Res* 2020;54(1):7-14.

7. Urquhart O, Tampi MP, Pilcher L, Slayton RL, Araujo MW, Fontana M, Guzmán-Armstrong S, Nascimento MM, Nový BB, Tinanoff N, Weyant RJ. Nonrestorative treatments for caries: systematic review and network meta-analysis. *J Dent Res* 2019;98(1):14-26.
8. Innes NPT, Schwendicke F. Restorative Thresholds for Carious Lesions: Systematic Review and Meta-analysis. *J Dent Res*. 2017 May;96(5):501-508.
9. Heaven TJ, Gordan VV, Litaker MS, Fellows JL, Rindal DB, Firestone AR, Gilbert GH, National Dental PBRN Collaborative Group. Agreement among dentists' restorative treatment planning thresholds for primary occlusal caries, primary proximal caries, and existing restorations: findings from The National Dental Practice-Based Research Network. *J Dent* 2013;41(8):718-25.
10. Fontana M, Guzmán-Armstrong S, Schenkel AB, Allen KL, Featherstone J, Goolsby S, Kanjirath P, Kolker J, Martignon S, Pitts N, Schulte A. Development of a core curriculum framework in cariology for US dental schools. *J Dent Educ* 2016;80(6):705-20.
11. McComas MJ, Hurlbutt M, Fontana M. A survey of cariology education in US dental hygiene programs: The need for a core curriculum framework. *J Dent Educ* 2020;84:1348-1358.
12. Sundberg H, Mejåre I, Espelid I, Tveit AB. Swedish dentists' decisions on preparation techniques and restorative materials. *Acta Odontol Scand* 2000;58(3):135-41.
13. Fontana M, Huysmans MC. Clinical Decision-Making in Caries Management: Role of Caries Detection and Diagnosis. In: *Detection and Assessment of Dental Caries – A Clinical Guide*; Zandona A, Longbottom C, Eds. Springer (2019). Chapter 23; p. 227-234.
14. Schwendicke F, Frenchen J, Bjørndal L, Maltz M, Manton DJ, Ricketts D, Van Landuyt K, Banerjee A, Campus G, Doméjean S, Fontana M, Leal S, Lo E, Machiulskiene V, Schulte A,



- Splieth C, Zandona A, Innes N. Managing carious lesions: Consensus recommendations on carious tissue removal, *Adv Dent Res*;2016;28:58-67.
15. Rechmann P, Doméjean S, Rechmann BM, Kinsel R, & Featherstone JD. Approximal and occlusal carious lesions: restorative treatment decisions by California dentists. *J Am Dent Assoc* 2016;147(5):328-338.
  16. Koopaei MM, Inglehart MR, McDonald N, Fontana M (2017) General dentists', pediatric dentists', and endodontists' diagnostic assessment and treatment strategies for deep carious lesions: A comparative analysis. *J Am Dent Assoc* 148, 64-74.
  17. Nascimento MM, Behar-Horenstein LS, Feng X, Guzman-Armstrong S, Fontana M (2017) Exploring How U.S. Dental Schools Teach Removal of Carious Tissues During Cavity Preparations. *J Dent Educ* 81, 5-13.
  18. Norton WE, Funkhouser E, Makhija SK, Gordan VV, Bader JD, Rindal DB et al. (2014) Concordance between clinical practice and published evidence: findings from The National Dental Practice-Based Research Network. *J Am Dent Assoc* 145, 22-31.
  19. Schwendicke, F., Splieth, C.H., Bottenberg, P. et al. How to intervene in the caries process in adults: proximal and secondary caries? An EFCD-ORCA-DGZ expert Delphi consensus statement. *Clin Oral Invest* 24, 3315–3321 (2020).
  20. Griffin SO, Oong E, Kohn W, Vidakovic B, Gooch BF, Bader J, Clarkson J, Fontana MR, Meyer D, Rozier RG, Weintraub JA, Zero DT.. The effectiveness of sealants in managing caries lesions. *J Dent Res* 2008;87(2):169-174.
  21. Slayton RL, Urquhart O, Araujo MWB, Fontana M, Guzman-Armstrong S, Nascimento MM et al. (2018) Evidence-based clinical practice guideline on nonrestorative treatments for carious lesions: A report from the American Dental Association. *J Am Dent Assoc* 149, 837-849 e819.

22. Opdam NJ, van de Sande FH, Bronkhorst E, Cenci MS, Bottenberg P, Pallesen U, Gaengler P, Lindberg A, Huysmans MC, van Dijken JW. Longevity of posterior composite restorations: a systematic review and meta-analysis. *J Dent Res*. 2014 Oct;93(10):943-9.
23. Holmgren C, Gaucher C, Decerle N, & Doméjean S. Minimal intervention dentistry II: part 3. Management of non-cavitated (initial) occlusal caries lesions—non-invasive approaches through remineralisation and therapeutic sealants. *Br Dent J* 2014;216(5): 237-243.
24. Sayre JW, Toklu HZ, Ye F, Mazza J, Yale S. Case Reports, Case Series - From Clinical Practice to Evidence-Based Medicine in Graduate Medical Education. *Cureus*. 2017 Aug 7;9(8):e1546. doi: 10.7759/cureus.1546. PMID: 29018643; PMCID: PMC5630458.
25. Fontana M, Wolff M (2011) Translating the caries management paradigm into practice: challenges and opportunities. *J Calif Dent Assoc* 39, 702-708.
26. Fontana M, Carrasco-Labra A, Spallek H, Eckert G, Katz B. Improving Caries Risk Prediction Modeling: A Call for Action. *Journal of Dental Research*. 2020;99(11):1215-1220.
27. Tubert-Jeannin S, Doméjean-Orliaguet S, Riordan PJ, Espelid I, & Tveit AB. Restorative treatment strategies reported by French university teachers. *J Dent Educ* 2004;68(10):1096-1103.

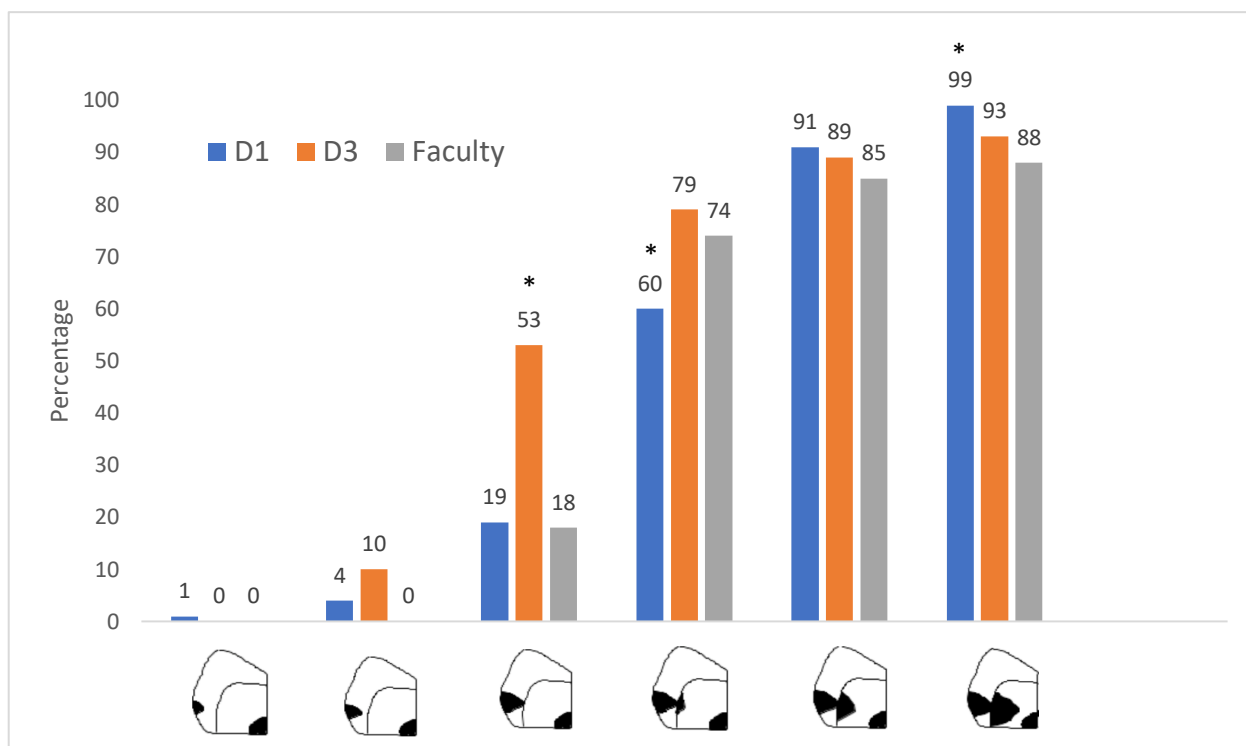


FIGURE 1: Restorative Decision-Making For An Interproximal Caries Lesion

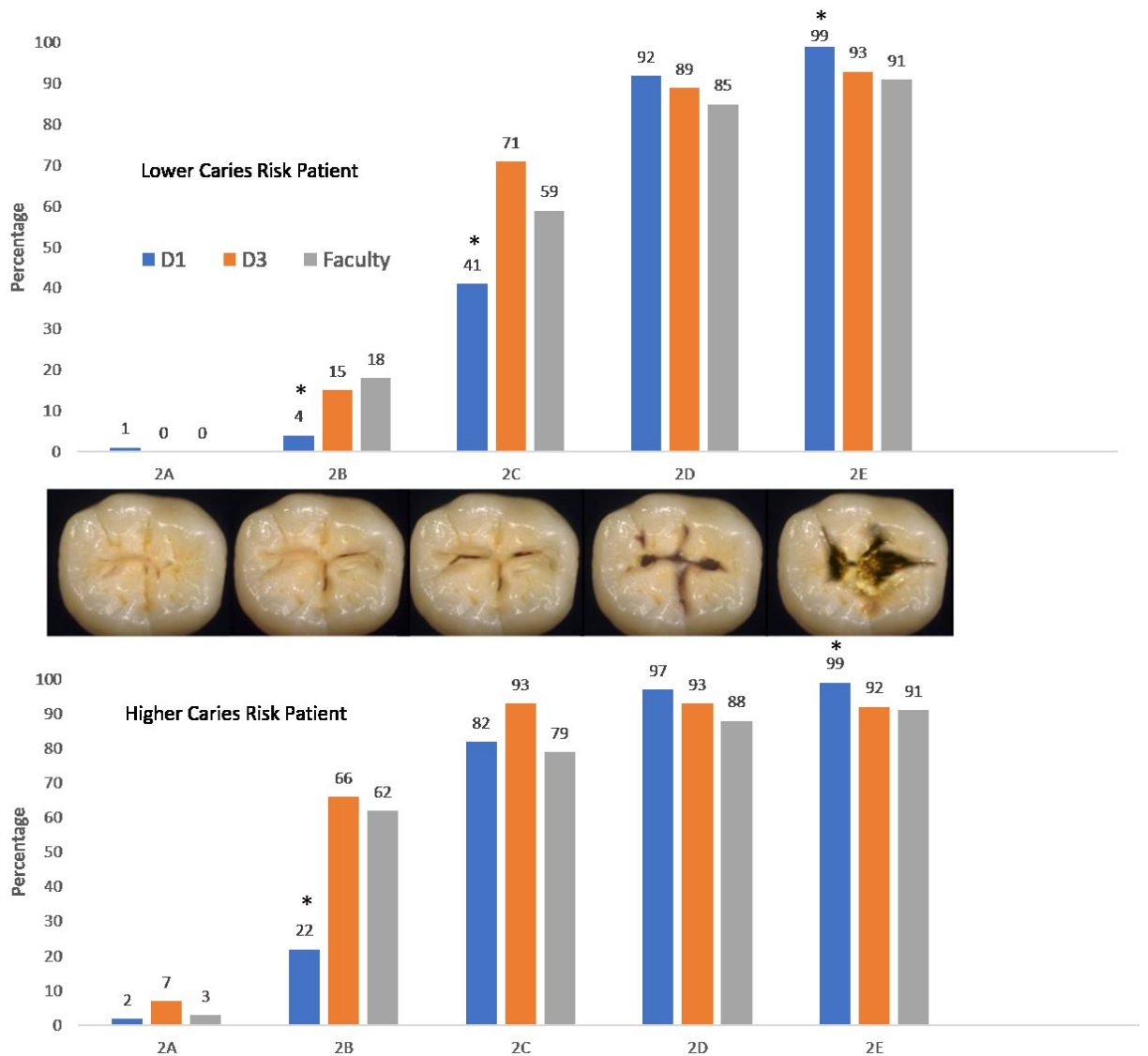
In this clinical scenario, respondents were given images of different radiographic stages of interproximal caries progression on the distal of the maxillary second premolar in an otherwise lower caries risk patient (“The patient is 20 years old, sees the dentist once a year, has adequate oral hygiene, and uses fluoride toothpaste twice daily. The patient’s medical history is negative for any abnormalities”). Respondents were asked to mark all lesions that apply for the following question: “Which lesion(s) do you think require(s) immediate restorative (operative) treatment? That is, the lesion(s) that you would not postpone restorative treatment under any circumstances.”

D1-students are in blue, D3-students in orange and faculty in grey.

Groups with \* were significantly different (p<0.05)

This article is protected by copyright. All rights reserved.

Tooth images reprinted with permission of Taylor & Francis Ltd (2021), from Sundberg H, Mejàre I, Espelid I, Tveit AB. Swedish dentists' decisions on preparation techniques and restorative materials. Acta Odontol Scand 2000;58(3):135-41; copyright © Acta Odontologica Scandinavica Society.



**FIGURE 2: Restorative Decision-Making For An Occlusal Caries Lesion**

In the clinical scenario respondents were asked about clinical images of the occlusal tooth surface of a lower second molar. The following descriptions were given for each photograph: 2A-Whitish

brownish discoloration in the enamel, no cavitation, no radiographic caries; 2B-Minor loss of tooth substance with a break in the enamel surface or discolored surface or discolored fissures with gray/opaque enamel and/or caries confined to the enamel. No radiographic caries; 2C-Moderate loss of tooth substance and/or caries in the outer 1/3 of the dentin according to the radiograph; 2D-Considerate loss of tooth substance and/or caries in the middle 1/3 of dentin according to the radiograph; 2E-Considerate loss of tooth substance and/or caries in the inner 1/3 of the dentin according to the radiograph.

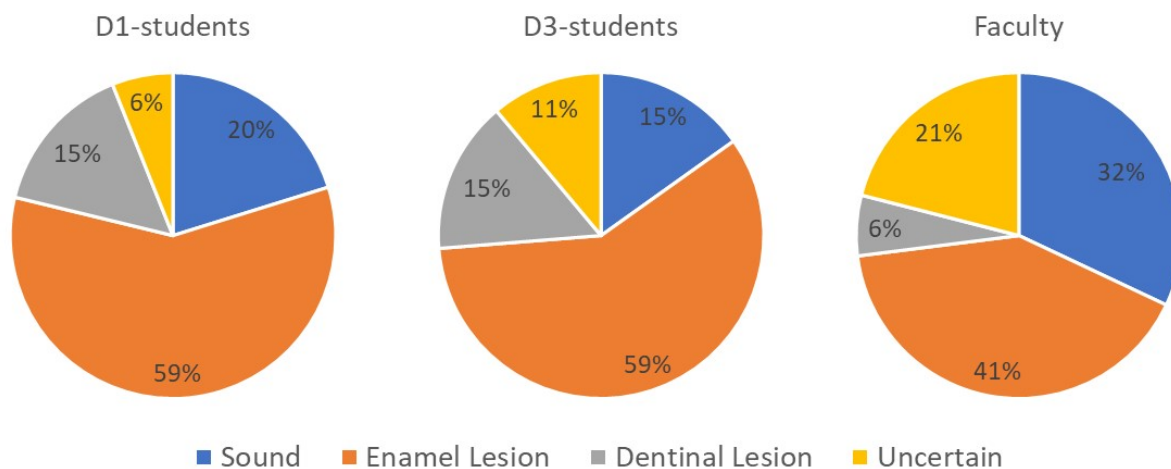
The graphs with responses in the top of the images in the figure represent responses to a lower caries risk scenario ("The patient is 20 years old, sees the dentist once a year, has adequate oral hygiene, and uses fluoride toothpaste twice daily. The patient's medical history is negative for any abnormalities."), while responses in the bottom of the images in the figure represent responses to a higher caries risk scenario ("The patient is 20 years old, has bad oral hygiene, inadequate fluoride intake, and frequent sugary/cooked starch snacks between meals.").

D1-students are in blue, D3-students in orange and Faculty in grey.

Groups with \* were significantly different ( $p < 0.05$ )

Tooth images reprinted with permission of Taylor & Francis Ltd (2021), from Sundberg H, Mejàre I, Espelid I, Tveit AB. Swedish dentists' decisions on preparation techniques and restorative materials. *Acta Odontol Scand* 2000;58(3):135-41; copyright © Acta Odontologica Scandinavica Society.

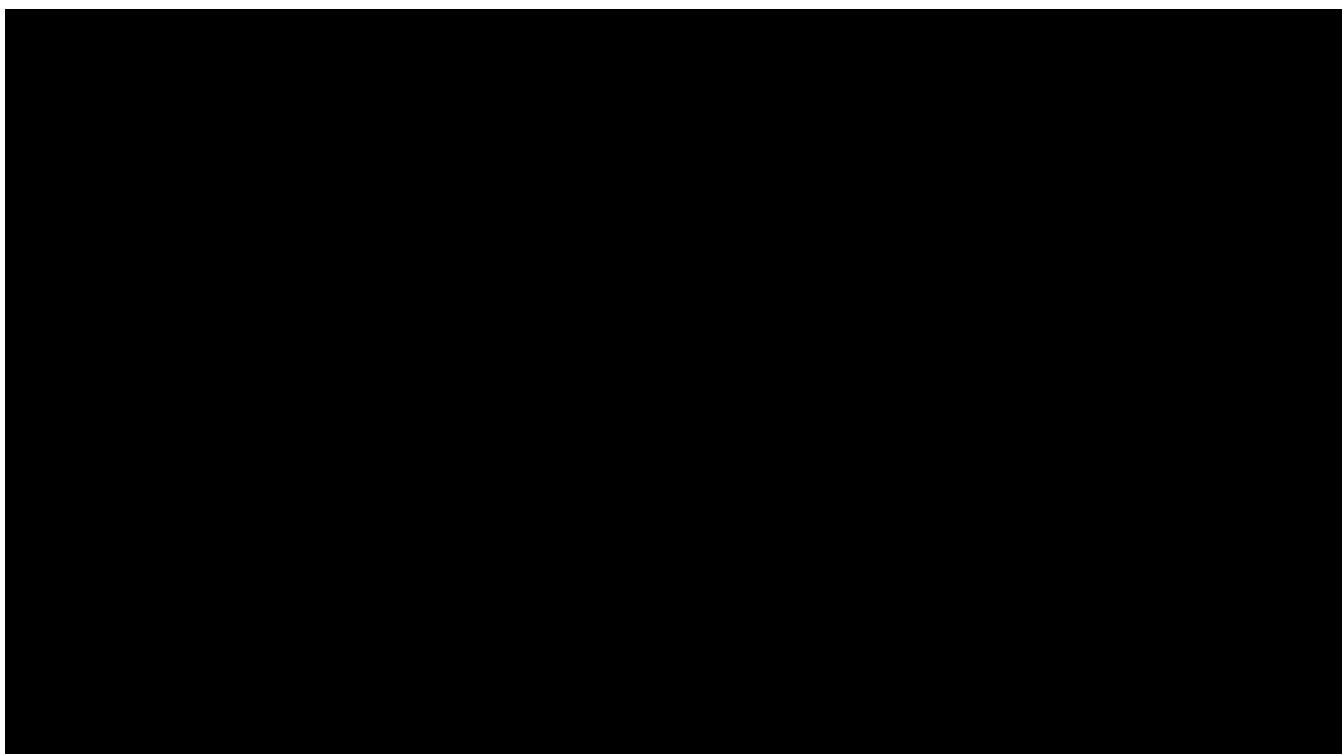
**FIGURE 3: Diagnostic Decision-Making For An Occlusal Tooth Surface**



The third clinical scenario asked respondents about this clinical photograph and radiograph. The patient scenario provided was as following: “You have not treated this patient before, and two years have elapsed since the patient's last dental examination. The patient is 20 years old, has adequate oral hygiene, and uses fluoride toothpaste twice daily. The patient's medical history is negative for any abnormalities.” The results shown are from the question: “From the clinical and radiographic appearance, does the tooth shown have occlusal (enamel or dentin) caries?”

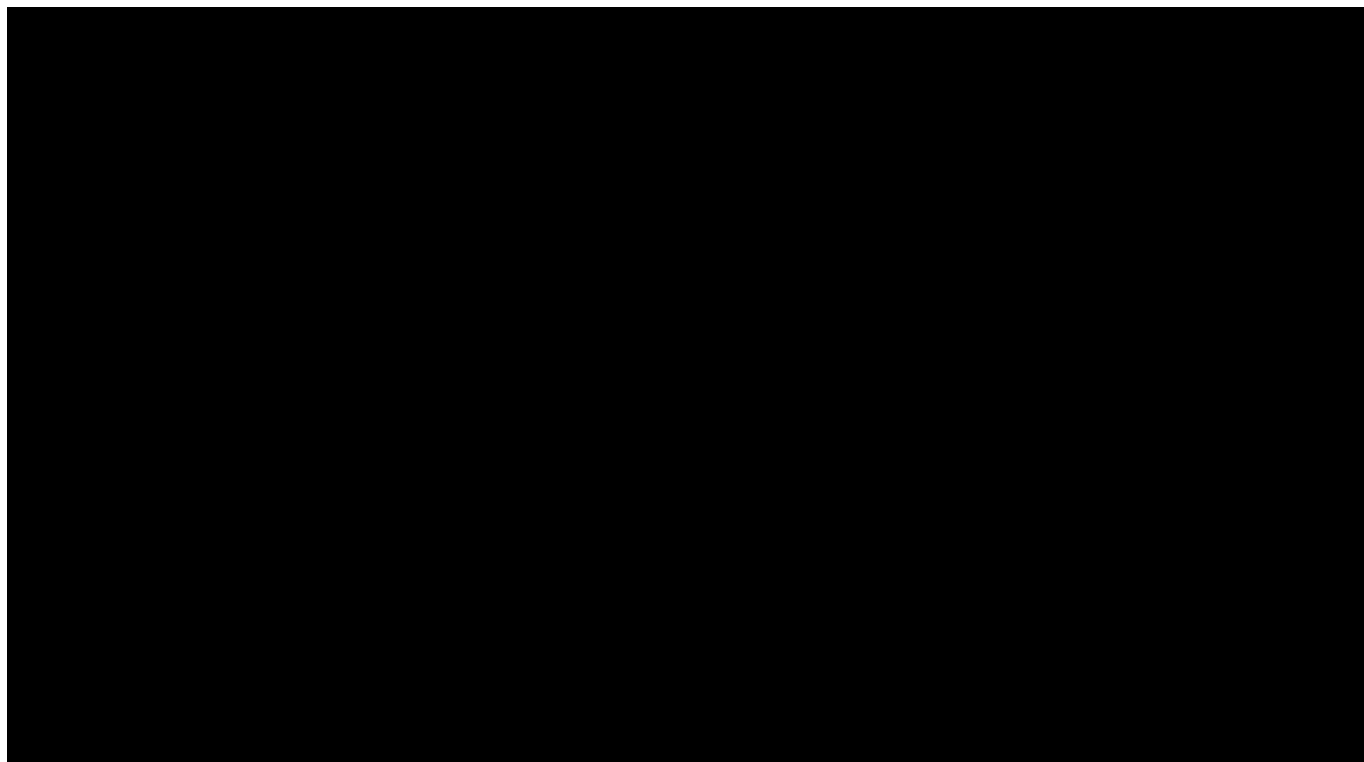
Tooth and Xray image reprinted with permission of Taylor & Francis Ltd (2021), from Sundberg H, Mejåre I, Espelid I, Tveit AB. Swedish dentists' decisions on preparation techniques and restorative materials. *Acta Odontol Scand* 2000;58(3):135-41; copyright © Acta Odontologica Scandinavica Society.

**TABLE 1: Restorative Material and Preparation Type for Occlusal and Proximal Lesion Cases in Figures 1 and 2**



Respondent answers to the question: Which type of preparation technique and restorative material would you prefer for the smallest occlusal or proximal lesion that you decided to restore?

**TABLE 2: Restorative Material and Treatment type for Occlusal Lesion Case in Figure 3**



Respondent answers to the questions: “How would you treat the occlusal surface of the tooth shown in Figure 3?” and “If you would restore the tooth in Figure 3, what material would you use?”



**TABLE 3: Factors Influencing Student Restorative Decision-Making**

	Response	D1 N=108	D3 N=73	Faculty N=34	p-value Overall	D1 vs D3
Lectures	N	30 (28%)	42 (58%)			<b>&lt;.001</b>
	Y	78 (72%)	31 (42%)			
Pre-clinical instructors	N	46 (43%)	57 (78%)			<b>&lt;.001</b>
	Y	62 (57%)	16 (22%)			
Clinical instructors	N	22 (20%)	5 (7%)			<b>0.012</b>
	Y	86 (80%)	68 (93%)			
Personal experiences in clinic	N	39 (36%)	8 (11%)			<b>&lt;.001</b>
	Y	69 (64%)	65 (89%)			
Classmates	N	91 (84%)	54 (74%)			0.089
	Y	17 (16%)	19 (26%)			
Upperclassmen	N	73 (68%)	54 (74%)			0.357
	Y	35 (32%)	19 (26%)			
Other	N	91 (84%)	66 (90%)			0.231
	Y	17 (16%)	7 (10%)			

Student answers to the question: “In terms of restorative dentistry, what/who is the most important factor in your decision-making process?”