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PRACTITIONER KNOWLEDGE OF DENTAL ADHESIVE MANUFACTURER'S INSTRUCTIONS FOR USE: A SURVEY-BASED STUDY

by

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A thesis submitted to the Faculty of the
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DEDICATION

To Jessie

DISCLAIMER

The views presented here are those of the author and are not to be construed as official or reflecting the views of the Uniformed Services University of the Health Sciences, the Department of Defense or the U.S. Government.

ABSTRACT

Practitioner Knowledge of Dental Adhesive Manufacturer's Instructions for Use: A Survey-Based Study.

Michael Carey DeFazio, DDS, 2023

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Introduction: The use of dental adhesives is highly technique sensitive. To achieve the best bonding result, manufacturers provide instructions for use (IFU) specifically written for each product they sell. Since dental adhesives are used by dentists in their daily practice, they should be familiar with the IFU. **Objective**: The purpose of this study was to evaluate dentists' knowledge of the IFU for the dental adhesive they utilize most frequently in their practice. **Methods:** This was a survey-based cross-sectional study in which 975 dentists in military dental treatment facilities were eligible to participate. The survey included commonly used dental adhesives: OptiBond™ FL (Kerr), OptiBond™ Solo Plus (Kerr), CLEARFIL™ SE Bond 2 (Kuraray), Adhese® Universal (Ivoclar Vivadent), and Scotchbond™ Universal (3M). Questions surveyed dental adhesive usage and adherence to manufacturer IFU. Dentists' answers were compared to IFU and evaluated for accuracy. Responses were grouped by adhesive type, postgraduate education level of the dentist, and whether the dentist's military dental treatment facility had conducted an Operative Dentistry Calibration Seminar (ODCS) within the past year. Mean and standard deviations were determined for percent correct per group. Data were analyzed

with a one-way ANOVA followed by pairwise comparisons using Tukey's method. **Results:** Survey response rate was 17 % (n=164). Significant differences in the percent of acceptable responses were identified between OptiBond™ FL vs. both OptiBond™ Solo Plus ($P < .005$) and Scotchbond™ Universal ($P < .003$). Dentists that had attended an ODCS answered a greater proportion of questions correctly compared to those that had not ($P < .05$). There was no difference between dentists with and without postgraduate dental education. **Conclusions:** Dentists, on average, were more likely to answer IFU guidelines correctly for dental adhesives with fewer steps. ODCS attendance significantly improves adherence to IFU.

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LIST OF ABBREVIATONS

ER	Etch-and-Rinse Adhesive System
SE	Self-Etch Adhesive System
10-MDP	10-Methacryloyloxydecyl Dihydrogen Phosphate
IFU	Instructions for Use
DTF	United States Navy Dental Treatment Facility
USN	United States Navy
ODCS	Operative Dentistry Calibration Seminar
WDU	Weekly Dental Update
PGY-1	Postgraduate Year One
AEGD	Advanced Education in General Dentistry
GPR	General Practice Residency
GS	General Scale

CHAPTER 1: Introduction

Composite resin restorations are described as "technique sensitive" due the increased number of steps when compared to dental amalgam, and the necessity to complete each step properly. Since Buonocore introduced acid etching of tooth structure in 1955, the importance of dentin and enamel bonding has increased dramatically. Patients' desires for more esthetic restorations and potential toxicity and environmental concerns of mercury in dental amalgam have driven a change in modern restorative dentistry.[1] Despite the increased longevity, decreased cost, and lower technique sensitivity of posterior dental amalgam restorations, composite resin has progressively become the restorative material of choice for many providers.[2, 3] However, the increased technique sensitivity of composite resin and its associated adhesive bonding agents requires a high level of both knowledge and adherence to protocol when placing restorations.

Dental adhesives serve as means to bond the hydrophilic tooth structure (both enamel and dentin) to the hydrophobic composite resin material. Adhesive systems consist of three components: etchant, primer, and bonding resin.[4] The etchant is an acid that serves to modify the surface of the enamel and dentin. This surface modification increases the permeability of resins and removes the smear layer in etch and rinse systems.[5, 6] Hydrophilic primers penetrate the etched surface of the enamel and dentin, which then allows the hydrophobic adhesive resin to follow the primer. This results in a micromechanical bond in enamel by forming resin tags that interlock with the enamel prisms.[7] The micromechanical bond in dentin is formed when the primer and adhesive penetrate the exposed type I collagen and dentinal tubules to form the hybrid layer and

resin tags respectively.[8, 9] Once the adhesive is integrated into the tooth structure and polymerized, the exposed carbon-carbon double bonds of the adhesive resin monomers and composite resin monomers can polymerize to form a covalent bond, thus, holding the restoration in place.[4]

The earliest example of bonding to tooth structure was demonstrated by Buonocore in 1955 when he utilized 85% phosphoric acid to etch the surface of enamel in order in increase adhesion of resin composites, however, no bonding agents were utilized.[1] Since Buonocore's initial success with bonding, dental adhesives have evolved in both technique and components. Prior to the 1990's, selective acid etching of the enamel only was the common method of tooth preparation in the United States.[10] In 1979, Fusayama first introduced the total-etch technique in which both enamel and dentin are acid etched, and Kanca later popularized the technique in the US.[11, 12] Additionally, Kanca introduced the concept of "wet-bonding" in which the dentin is left moist prior to the application of the primer. Wet-bonding contrasted the previous methodology of dry-bonding in which both enamel and dentin were desiccated prior to application of the primer. The total-etch combined with wet-bonding techniques demonstrated markedly improved dentin bond strengths, and decreased post-operative sensitivity.[5, 11, 13]

Modern adhesive systems are categorized based on generation (first through eighth), and the generations currently used are primarily fourth, fifth, sixth, seventh, and eighth. Fourth generation adhesives are three step etch and rinse systems, where the etchant, primer, and adhesive are all separate components. Due to their history of excellent clinical performance and over twenty-five years of clinical use, fourth generation adhesives are widely considered the gold standard of bonding agents.[14-17] Sano

et al 1998 demonstrated that increased number of steps of adhesive systems may increase the amount of error by the practitioner, especially in less experienced practitioners.[18] Additionally, three individual steps for bonding systems results in a time-consuming protocol. Thus, the trend moving forward from fourth generation adhesives has been toward simplification to decrease technique sensitivity as well as time required for bonding. Fifth generation condenses the bonding sequence into two steps by combining the hydrophilic primer and the hydrophobic adhesive into a single solution. Just as in fourth generation adhesives, the etchant remains a separate component in the fifth generation, so they can be both categorized as etch-and-rinse (ER) adhesive systems.[5] Sixth generation adhesives also consist of two steps, but instead combine the etchant and primer into a single solution by utilizing an acidic monomer that functions as a self-etching primer, and it is followed by a separate adhesive resin.[19] Since there is no rinsing step to sixth generation adhesives, they fall under the self-etch (SE) category of adhesives instead of ER. It should be noted, however, that many sixth generation adhesive systems include an option to selectively etch the enamel with phosphoric acid, combining ER and SE protocols. Also considered a SE, seventh generation adhesive systems continued the trend of simplification by creating an all-in-one system, with the etchant, primer, and adhesive in one bottle. However, due to decreased bond durability, seventh generation adhesive systems have been mostly replaced by the more modern eighth generation "Universal" adhesives.[20, 21] Universal adhesives, also an all-in-one system, are referred as such due to their ability to be used in either ER or SE modes, as well as their adhesion to ceramics and zirconia via silane and 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) respectively.[17] The variation in number of steps and techniques amongst the

different generations of adhesives can be confusing for practitioners and potentially lead to incorrect use of the product.

To decrease the variability amongst dental providers, manufacturers provide Instructions for Use (IFU) for their dental adhesives based on what they have determined to provide the best results with their products. It is the role of the dental provider to utilize the information provided by the manufacturer's IFU to obtain a more predictable, longer lasting restoration. Although the steps vary based on specific products and generation of adhesive, the steps included in the IFU typically include conditioning of tooth structure (acid etch), application of primer, application of adhesive, and polymerization.

ER adhesive systems and SE adhesive systems that have selective etch and total etch options give exact amounts of time for phosphoric acid contact time. This is to ensure adequate etching of the enamel and dentin surfaces to achieve ideal surface roughness of enamel, expose proper amount of collagen in dentin, and remove the smear layer so that the adhesive can achieve micromechanical retention with the tooth structure. Since enamel is 96% inorganic hydroxyapatite crystals, it must be etched for at least 15 seconds with 30-40% phosphoric acid to achieve adequate surface roughness.[22] However, etching for up to 60 seconds has not shown to affect the bond strength positively or negatively.[23, 24] On the contrary, dentin is only comprised of 45-50% inorganic hydroxyapatite crystals, and within 15 seconds of 30-40% phosphoric acid etch a 5-8 μm depth of the inorganic crystals is removed.[5] The exposed collagen is penetrated by the adhesive to form the hybrid layer, but etching for too long will create a depth of collagen that the adhesive cannot fully penetrate.[8, 24] The exposed collagen is more susceptible to

nanoleakage and hydrolysis leading to bond degradation.[16, 17, 25] After 15 seconds of contact, the acid etch must be thoroughly rinsed from to the tooth to remove both the etchant and the dissolved calcium phosphates.[26] Once the etchant is removed with air and water, the tooth structure must be gently dried to achieve the proper level of moisture to allow for adhesive infiltration. Enamel may be desiccated to confirm adequate etching via visualizing a frosty surface.[17] Dentin, however, is more technique sensitive. Over-drying of dentin will lead to collapse of the collagen scaffold and prevent penetration of the adhesive to form the hybrid layer.[27] Conversely, pooling of water will lead to dilution of the primer and decrease its efficacy.[24] Thus, the IFU will typically recommend lightly air-drying dentin, but not desiccating.

SE adhesives systems decrease the technique sensitivity of conditioning the tooth structure by eliminating the rinsing and drying steps, but this increases the importance of proper application of the self-etching primer. SE systems utilize acidic functional monomers such as 10-MDP to simultaneously demineralize tooth structure and prime the tooth structure for the hydrophobic adhesive.[28] In the case of both ER and SE systems, following the time recommended in the IFU for application of the primer ensures adequate displacement of remaining moisture in the collagen scaffold, followed by gentle air drying allows for evaporation of the solvent.[17] If residual solvent is present after polymerization, water will diffuse into this space and likely have negative effects on the bond.[29]

Adequate application of the adhesive is vital to obtaining a predictable bond to tooth structure. Rubbing the adhesive into the microporosities of the enamel and exposed collagen scaffold of the dentin assists in infiltration of the resin.[30] Vigorously rubbing the

adhesive into tooth structure has been demonstrated to increase the resin-dentin bond strength, decrease the bond degradation rate, and improve the clinical performance of the adhesive.[31] Similarly, one-step SE systems will traditionally recommend multiple applications to refresh the acidic monomer and obtain a deeper hybrid layer and allow for better penetration of the adhesive.[32] Once applied, air thinning is recommended to obtain a uniform thickness of adhesive. The proper thickness may allow the bonding agent to absorb tensile stresses from polymerization shrinkage of the restorative composite resin while inadequate thickness of adhesive may decrease the fracture toughness of the restorative material.[33, 34]

The final step of adhesive systems is polymerization. Poorly polymerized adhesive resin results in increased resin permeability and water sorption, leading to decreased bond durability.[35] Thus, following the IFU for minimum polymerization time will improve longevity of the bond.

Adherence to the manufacturer's IFU has shown improvement in bond strength, decreases post-operative sensitivity, and increased longevity of the restoration.[36-38] Due to the increase in composite resin restorations, a thorough knowledge and understanding of adhesive systems is critical to restoration longevity. Within the United States Navy (USN) Dental Corps, adherence to IFU could result in improved dental readiness and decreased time spent in a dental chair for the warfighters. Operative Dentistry Calibration Seminars (ODCS) are sometimes held throughout United States Navy Dental Treatment Facilities (DTFs) to ensure that providers understand proper diagnosis and treatment planning for dental caries. Some DTFs will use this as an opportunity to discuss other topics in operative dentistry and provide Continuing Dental Education.

The objective of this study was to evaluate dental providers' knowledge of the IFU for the adhesive bonding agent they utilize most frequently in their practice. An additional objective was to determine the influence of ODCS on adherence to IFU.

CHAPTER 2: Materials and Methods

STUDY DESIGN

This was a survey-based study administered on a secured web-based survey platform. The survey was designed as a decision tree format with skip logic. Questions were primarily multiple choice, drop down, and sliding scale for numerical responses. Six questions allowed narrative comment for the respondent to explain the answer choice "other."

The first section of the survey allowed the respondent to select the adhesive system they utilize most frequently, which, utilizing the skip logic, directed them to the second section in which they were asked between eight to twelve questions based on the product's IFU. The number of questions in the second section depended on the number of steps and the various options in the specific product's IFU. The final section of the survey consisted of seven demographic questions including time in practice, postgraduate dental education, and recent continuing dental education courses. The total number of questions in the survey ranged from 17 to 21 depending on the dental adhesive product selected by the respondent.

The adhesive systems included in the study are shown in **Figure 1**. Respondents could choose between the fourth generation Optibond™ FL (Kerr), fifth generation Optibond™ Solo Plus (Kerr), sixth generation Clearfil™ SE Bond 2 (Kuraray), eighth generation Scotchbond™ Universal and Scotchbond™ Universal Plus (3M), eighth generation Adhese® Universal (Ivoclar), or "other adhesive." These products were selected because they are commonly available adhesive systems in US Navy dental clinics.

The survey link was made available via the Weekly Dental Update (WDU), a newsletter disseminated to dentists affiliated with the United States Navy. Additionally, the survey link was emailed by the United States Navy Specialty Leaders to their respective communities. The communities that received the emailed link were Operative Dentistry, Prosthodontics, Postgraduate Year One (PGY-1) which includes one-year Advanced Education in General Dentistry (AEGD) and General Practice Residency (GPR), and Comprehensive Dentistry (two-year AEGD).

DATA ANALYSIS

Responses were compared to the steps in the IFU for their accuracy, as demonstrated by percent correct. Additionally, the percentage of clinically acceptable responses were calculated. Categorical data was represented by counts with percentages and Chi-square analysis was utilized for differences. Continuous Data was represented by means with standard deviations and analyzed with ANOVA for two or greater groups with Tukey's method.

CHAPTER 3: Results

The profile of survey respondents is shown in **Table 1.** There were a total of 164 responses to the survey which equaled a 17 percent response rate. Primarily Active Duty United States Navy dentists that responded to the survey, with some civilian dentists (i.e., General Scale (GS) and contractors). Nearly two-thirds of the respondents reported completing some form of postgraduate dental education. 37 percent of respondents reported that they had attended an ODCS within the past year.

Table 2 outlines the preferred adhesives of the respondents. More than half of the respondents reported primarily using Scotchbond™ Universal, making it by far the most commonly used adhesive system. Optibond™ Solo Plus was the second most common with 26.5 percent of respondents, followed by Optibond™ FL, Clearfil™ SE Bond 2, and Adhese® Universal with 9, 5.8, and 1.9 percent respectively. Out of 164 total survey responses, nine respondents reported primarily using "other adhesive." The data from these "other adhesive" responses were not included in the analysis.

Percent of correct responses when compared to the IFU were lower for the two-component Optibond™ FL (52.3%) and Clearfil™ SE Bond 2 (58.3%) versus the single-component Optibond™ Solo Plus (71.7%), Scotchbond™ Universal Plus (73.5%), and Adhese® Universal (75%). The percent of clinically acceptable responses were higher for all adhesive systems, but they were significantly lower for Optibond™ FL (67.9%), than both Optibond™ Solo Plus (83.9%; $P < 0.005$) and Scotchbond™ Universal Plus (83.6%; $P < 0.003$). The percent of correct responses by adhesive system are shown in **Figure 2.**

Additionally, ODCS attendance resulted in higher percent of acceptable responses ($P < 0.05$). Those who attended an ODCS within the past year answered 85.1 percent of

acceptable responses, while those who did not attend answered 77.8 percent acceptable. Percent of correct responses by ODCS attendance are shown in **Figure 3.** Postgraduate Dental Education showed no statistically significant difference for both percent of correct or acceptable responses.

CHAPTER 4: Discussion

In order to mitigate complexity of the multiple steps in applying dental adhesives, manufacturers of dental adhesives provide Instructions for Use for their products. Correctly following the steps in the IFU has demonstrated improved bond strength, decreased post-operative sensitivity, and increased longevity of the restoration.[36-38] The primary objective of this study was to evaluate provider adherence to IFU for dental adhesives. When comparing the percent of correct survey responses between the various adhesive systems, this study found that providers had higher adherence to IFU with single component adhesive systems. Additionally, we found that those who attended Operative Dentistry Calibration Seminars (ODCS) had a higher percentage of correct responses.

A similar survey was conducted by Peutzfeldt et al in 1998[39] and concluded that adherence to IFU decreased as the number of steps for the adhesive system increased. Sano et al 1998[18] demonstrated that increased number of steps for adhesives led to weaker bond strengths with inexperienced dental providers. Similarly, this study found that single component adhesives with fewer steps led to higher provider adherence. The single component Scotchbond™ Universal Plus is both the most used adhesive and had the highest IFU adherence amongst USN dental providers. Due to the multiple etching techniques available for Scotchbond™ Universal Plus, there are more correct options available. This inherent flexibility of the adhesive system increases the likelihood that a provider would answer the IFU step correctly. Similarly, the single component Optibond™ Solo Plus was the second most used adhesive, and it also showed a higher level of adherence to IFU than the two component Optibond™ FL. While both Optibond™ Solo Plus and Optibond™ FL only allow for the ER workflow, the separate

primer in Optibond™ FL adds two steps: applying and air drying the primer. These two additional steps increase the complexity of the adhesive, which may have contributed to the observed lower IFU adherence. However, despite lower adherence to IFU for Optibond™ FL, multiple studies have demonstrated that it has better clinical performance than simplified single component systems.[20, 39, 40] Thus, the questions remains as to whether simplified adhesive systems should be recommended due to improved IFU adherence, despite decreased clinical performance.

Regardless of the adhesive system of choice, it is important to adhere to the IFU. ODCS attendees, on average, answered approximately one more question correctly than those who did not attend an ODCS. While primarily designed to calibrate providers on diagnosis of caries and the USN Dental Classification System, the additional Continuing Dental Education provided at ODCS may have resulted in this difference. Only 37 percent of respondents reported having attended the seminar in the last year, which demonstrates the opportunity to improve the adherence to IFU if more people attend, and if there is training focused on the IFUs of the adhesive systems utilized within the DTF.

For all adhesive systems, two of the commonly incorrect answers were regarding time for application of the primer and adhesive. Inadequate application of primer and adhesive can lead to poor hybrid layer formation[25] and result in inferior bond strength and durability.[16] There is no evidence at this time to demonstrate that prolonged application time of primer and adhesive can result in decreased bond strength. Thus, the time requirement for primer and adhesive application in the IFU can be considered a minimum time. When allowing for “acceptable” responses, we allowed for prolonged application time over the IFU recommendation, however anything under the time recommendation

was considered unacceptable. Similarly, increased phosphoric etch contact time with enamel up to 60 seconds has demonstrated no difference in bond strength versus the recommended 15 seconds.[23] Any response between 15 and 60 seconds was considered acceptable for enamel etch time.

The 133 responses account for approximately 18 percent of all Active Duty USN restorative dentists. While convenience bias is a potential limitation, this was an adequate sample size to achieve statistically significant data. Additionally, since this survey was not conducted in a controlled environment, there was the risk of participants searching for the correct responses using personal electronic devices. Although, based on the limited number of people that responded 100% correctly, there is minimal to no evidence that this occurred frequently. The survey was anonymous, and thus, did not track data on the respondents. It is possible that respondents could have taken the survey multiple times to improve their score. To decrease the time required to complete the survey and improve response rate, it was created in a multiple choice, dropdown, and slider scale format. Upon reading a question, the respondent may have been prompted to answer a question for a step that they otherwise skip in practice. Ideally, the respondents would have been required to list the steps from memory. Finally, while previous studies have demonstrated IFU adherence impacts restoration longevity, this study did not evaluate clinical outcomes. Confirmatory research on IFU compliance and associate clinical outcomes is needed.

Practicing dentists will benefit from future research including a follow-up survey after implementing adhesive IFU training to compare IFU adherence and evaluate

efficacy of the training. Additionally, clinical outcomes of different adhesive systems, regardless of IFU compliance could lead to specific product recommendations for DTFs.

CHAPTER 5: Conclusions

This study found that IFU adherence was significantly higher for the single component Optibond™ Solo Plus and Scotchbond™ Universal Plus when compared to the two component Optibond™ FL. IFU adherence was also affected by ODCS attendance, with attendees answering approximately one more question correctly than those who did not attend. Future ODCS attendance should be highly encouraged and should incorporate continuing dental education that discusses the IFU for dental adhesives used throughout the DTF. After implementation of the IFU training, a follow-up survey should be conducted to determine efficacy.

APPENDIX A

Table 1. *Profile of Survey Respondents*

	Overall (N=164)
Affiliation	
US Navy Active Duty	133 (81.1%)
GS	15 (9.1%)
Contractor	3 (1.8%)
Other	2 (1.2%)
Postgraduate Dental Education (PDE)	
Yes	107 (65.2%)
No	46 (28.0%)
Program Type	
Comprehensive Dentistry (2-year AEGD)	18 (11.0%)
AEGD	28 (17.1%)
GPR	24 (14.6%)
Prosthodontics	22 (13.4%)
Operative Dentistry	10 (6.1%)
Endodontics	2 (1.2%)
Other	4 (2.4%)
ODCS Attendance in Past Year	
No	70 (42.7%)
Unsure	22 (13.4%)
Yes	61 (37.2%)

Table 2. *Adhesive System of Choice*

	# of survey questions	% of respondents (N=155[a])
Adhese® Universal	8	1.9
Clearfil™ SE Bond 2	8	5.8
Optibond™ Solo Plus	10	26.5
Optibond™ FL	12	9.0
Scotchbond™ Universal (Plus)	8	56.8

[a]Data from nine respondents who selected “other adhesive” were not included in analysis

Figure 1. Adhesive systems included in the study. Clockwise from upper left: fourth generation Optibond™ FL (Kerr), sixth generation Clearfil™ SE Bond 2 (Kuraray), eighth generationScotchbond™ Universal Plus (3M), eighth generation Adhese® Universal (Ivoclar), and fifth generation Optibond™ Solo Plus (Kerr).

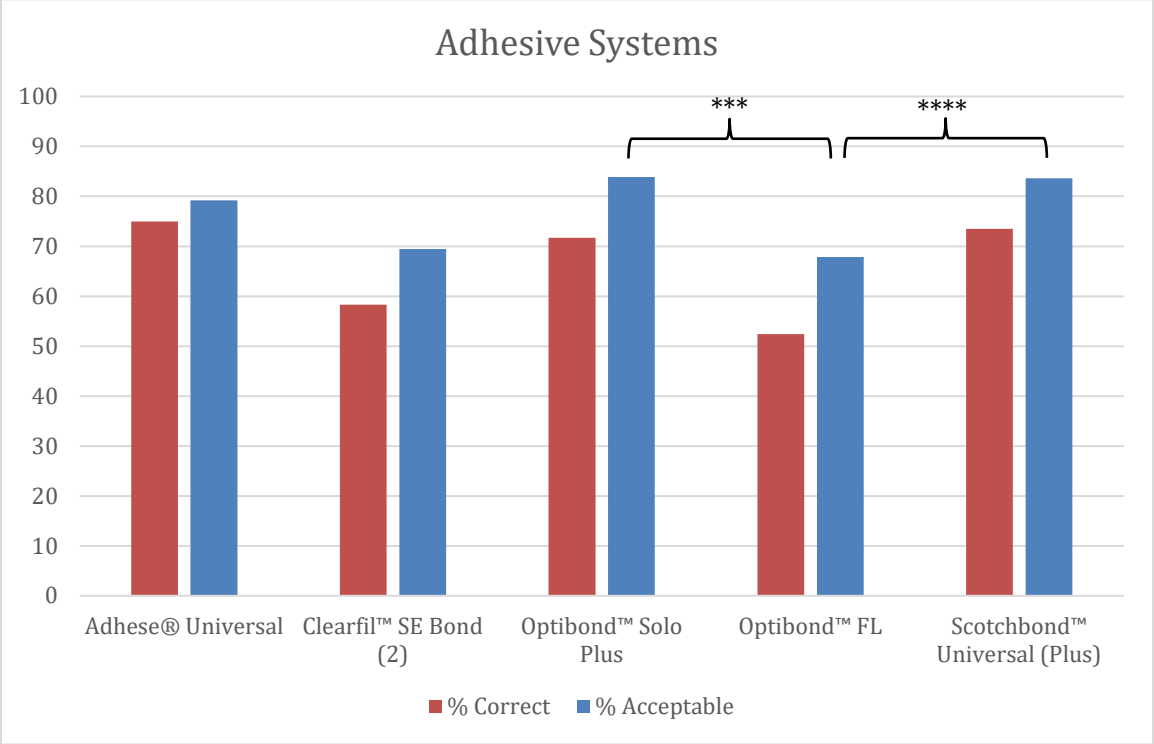

Figure 2. Number of survey questions (in percent) participants answered correct and acceptable among five adhesive systems. Five adhesive systems were included in the survey for the respondent to select as their primary adhesive system. The responses were compared to the IFU of each adhesive system for their accuracy, demonstrated by percent correct. Additionally, the percentage of clinically acceptable responses were calculated. The percent of clinically acceptable responses for Optibond™ FL were significantly lower than both Optibond™ Solo Plus and Scotchbond™ Universal Plus. *** $p < 0.005$. **** $p < 0.003$.

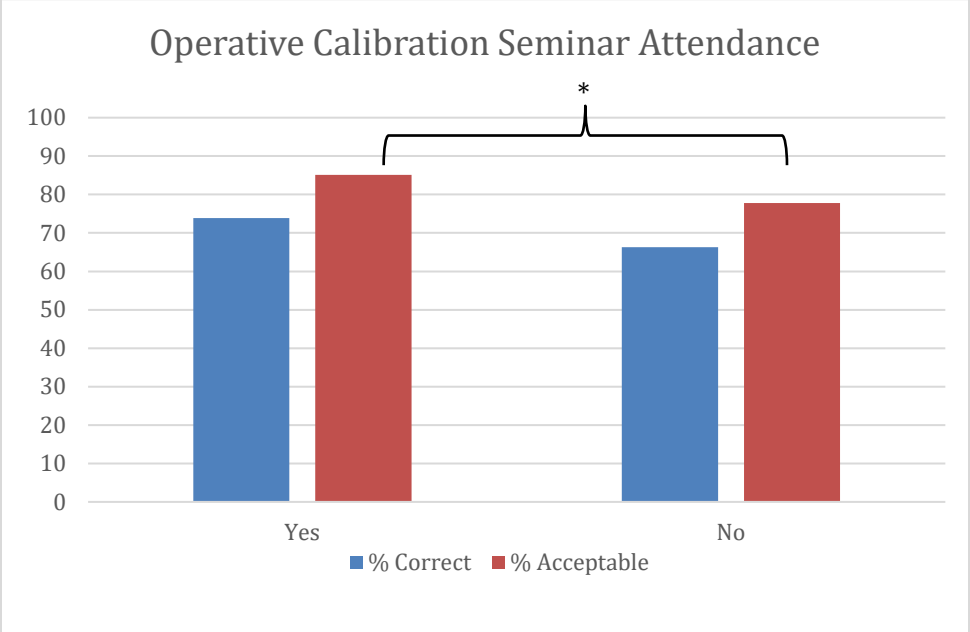

Figure 3. Number of survey questions (in percent) participants answered correct and acceptable between attendees and non-attendees of Operative Dentistry Calibration Seminars (ODCS). ODCS are sometimes held at United States Navy Dental Treatment Facilities (DTFs). Some DTFs will use this as an opportunity to provide Continuing Dental Education. The percentage of correct responses and the percentage of clinically acceptable responses were compared between attendees and non-attendees of ODCS. ODCS attendees answered a higher percent of acceptable responses (85.1%) compared to those who did not attend an ODCS (77%). *$p < 0.05$.

REFERENCES

1. Buonocore M. A Simple Method of Increasing Adhesion of Acrylic Filling Materials to Enamel Surfaces. J Dent Res 1955;34:849-53.
2. Worthington HV, Khangura S, Seal K, et al. Direct composite resin fillings versus amalgam fillings for permanent posterior teeth. Cochrane Database Syst Rev 2021;8:CD005620.
3. Broadbent JM, Murray CM, Schwass DR, et al. The Dental Amalgam Phasedown in New Zealand: A 20-year Trend. Oper Dent 2020;45(3):255-64.
4. Lorenzo Breschi, Jack L. Ferracane, Milena Cadenaro, Annalisa Mazzoni, Hilton TJ. Adhesion to Enamel and Dentin. Summitt's Fundamentals of Operative Dentistry : A Contemporary Approach. Fourth ed; 2013. p. 207-48.
5. Pashley DH, Tay FR, Breschi L, et al. State of the art etch-and-rinse adhesives. Dent Mater 2011;27(1):1-16.
6. Van Meerbeek B, Inokoshi S, Braem M, Lambrechts P, Vanherle G. Morphological Aspects of the Resin-Dentin Interdiffusion Zone with Different Dentin Adhesive Systems. J Dent Res 1992;71(8):1530-40.
7. Gwinnett A, Matsui A. A study of enamel adhesives: The physical relationship between enamel and adhesive. Arch Oral Biol 1967;12(12):1615-20.
8. Nakabayashi N, Kojima K, Masuhara E. The promotion of adhesion by the infiltration of monomers into tooth substrates. J Biomed Mater Res 1982;16:265-73.
9. Carrilho MR, Tay FR, Sword J, et al. Dentin sealing provided by smear layer/smear plugs vs. adhesive resins/resin tags. Eur J Oral Sci 2007;115:321-29.
10. Perdigao J, Swift EJ, Jr., Walter R. Fundamental Concepts of Enamel and Dentin Adhesion. In: Elsevier, editor. Sturdevant's Art and Science of Operative Dentistry. 6th ed: Mosby; 2013.
11. Fusayama T, Nakamura M, Norimasa K, Iwaku M. Non-Pressure Adhesion of a New Adhesive Restartive Resin. J Dent Res 1979;58(4):1364-70.
12. Kanca J. Bonding to Tooth Structure A Rational Rationale for a Clinical Protocol. J Esthet Restor Dent 1989;1(4):135-38.
13. Kanca J. Resin bonding to wet subsrate. I. Bonding to dentin. Quintessence Int 1992;23(1).
14. Wilder AD, Jr., Swift EJ, Jr., Heymann HO, et al. A 12-year clinical evaluation of a three-step dentin adhesive in noncarious cervical lesions. J Am Dent Assoc 2009;140(5):526-35.
15. Peumans M, De Munck J, Van Landuyt KL, et al. A 13-year clinical evaluation of two three-step etch-and-rinse adhesives in non-carious class-V lesions. Clinical Oral Investigations 2012;16(1):129-37.
16. De Munck J, Van Landuyt KL, Peumans M, et al. A Critical Review of the Durability of Adhesion to Tooth Tissue: Methods and Results. J Dent Res 2005;84(2):118-32.
17. Van Meerbeek B, Yoshihara K, Van Landuyt K, Yoshida Y, Peumans M. From Buonocore's Pioneering Acid-Etch Technique to Self-Adhering Restoratives. A

Status Perspective of Rapidly Advancing Dental Adhesive Technology. J Adhes Dent 2020;22(1):7-34.
18. Sano H, Kanemura N, Burrow MF, et al. Effect of operator variability on dentin adhesion: students vs. dentists. Dent Mater J 1998;17(1):51-8.
19. Van Meerbeek B, Yoshihara K, Yoshida Y, et al. State of the art of self-etch adhesives. Dent Mater 2011;27(1):17-28.
20. Peumans M, De Munck J, Mine A, Van Meerbeek B. Clinical effectiveness of contemporary adhesives for the restoration of non-carious cervical lesions. A systematic review. Dent Mater 2014;30(10):1089-103.
21. Mahn E, Rousson V, Heintze S. Meta-Analysis of the Influence of Bonding Parameters on the Clinical Outcome of Tooth-colored Cervical Restorations. J Adhes Dent 2015;17(5):391-403.
22. Fruits TJ, Khajotia SS, Nicholson JW. Biologic Considerations. Summitt's Fundamentals of Operative Dentistry : A Contemporary Approach. Fourth ed; 2013. p. 1-36.
23. Barkmeier W, Shaffer S, Gwinnett A. Effects of 15 vs 60 second enamel acid conditioning on adhesion and morphology. Oper Dent 1986 Summer;11:111-16.
24. Swift EJ, Jr., Perdigao J, Heymann HO. Bonding to enamel and dentin: A brief history and state of the art, 1995. Quintessence Int 1995;26(2):95-110.
25. Sano H, Takatsu T, Ciucchi B, et al. Nanoleakage: leakage within the hybrid layer. Oper Dent 1995;20(1):18-25.
26. Tagami J, Hosoda H, Fusayama T. Optimal technique of etching enamel. Oper Dent 1988;13(4):181-84.
27. Pashley DH, Ciucchi B, Sano H, Horner JA. Permeability of dentin to adhesive agents. Quintessence Int 1993;24:618-31.
28. Yoshihara K, Hayakawa S, Nagaoka N, et al. Etching Efficacy of Self-Etching Functional Monomers. J Dent Res 2018;97(9):1010-16.
29. Malacarne-Zanon J, Pashley DH, Agee KA, et al. Effects of ethanol addition on the water sorption/solubility and percent conversion of comonomers in model dental adhesives. Dental Materials 2009;25(10):1275-84.
30. Reis A, Pellizzaro A, Dal-Bianco K, et al. Impact of Adhesive Application to Wet and Dry Dentin on Long-term Resin-dentin Bond Strengths. Operative Dentistry 2007;32(4):380-87.
31. Reis A, Carrilho M, Breschi L, Loguercio AD. Overview of clinical alternatives to minimize the degradation of the resin-dentin bonds. Oper Dent 2013;38(4):E1-E25.
32. Amaral RC, Stanislawczuk R, Zander-Grande C, et al. Bond Strength and Quality of the Hybrid Layer of One-step Self-etch Adhesives Applied with Agitation on Dentin. Operative Dentistry 2010;35(2):211-19.
33. Van Meerbeek B, Willems G, Celis JP, et al. Assessment by Nano-ndentation of the Hardness and Elasticity of the Resin-Dentin Bonding Area. J Dent Res 1993;72:1434-42.
34. Ai H, Nagai M. Effect of the Adhesive Layer Thickness on the Fracture Toughness of Dental Adhesive Resins. Dental Materials Journal 2000;19(2):153-63.

35. Cadenaro M, Antoniolli F, Sauro S, et al. Degree of conversion and permeability of dental adhesives. Eur J Oral Sci 2005;113:525-30.
36. Demarco FF, Correa MB, Cenci MS, Moraes RR, Opdam NJ. Longevity of posterior composite restorations: not only a matter of materials. Dent Mater 2012;28(1):87-101.
37. Peutzfeldt A, Asmussen E. Adhesive Systems: Effect on Bond Strength of Incorrect Use. J Adhesive Dent 2002;4(3):233-42.
38. Finger WJ, Balkenhol M. Practitioner Variability Effects on Dentin Bonding with an Acetone-Based One-Bottle Adhesive. J Adhesive Dent 1999;1:311-14.
39. De Munck J, Mine A, Poitevin A, et al. Meta-analytical Review of Parameters Involved in Dentin Bonding. Journal of Dental Research 2012;91(4):351-57.
40. Peumans M, Kanumilli P, De Munck J, et al. Clinical effectiveness of contemporary adhesives: a systematic review of current clinical trials. Dent Mater 2005;21(9):864-81.