


Inconsistent decision making in dental caries diagnosis and treatment: A case-based questionnaire survey

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Abstract

Background and Aims: Delayed implementation of new knowledge into clinical practice poses patient safety risks. This study investigates agreement on use of the dental caries interventions, sealing, and stepwise excavation.

Methods: A cross-sectional questionnaire survey, based on 11 constructed cases with descriptions of patient symptoms, radiographic, and clinical findings. Interrater agreement on dental caries- and pulp diagnoses and interventions were measured with Cohen's and Light's κ . The data collection period was September 28 to November 5, 2021. To explore variations in use and knowledge factors, we examined Danish dentists' attitudes toward continuing education.

Results: Based on 243 responses, moderate interrater agreement for dental caries and pulp diagnoses and weak agreement on interventions were seen. The agreement with the gold standard for caries was moderate. No agreement was found for dental pulp diagnosis, and for interventions the agreement was weak. No pattern in agreement with the gold standard was seen in relation to case difficulty level. The majority reported knowing of and using stepwise excavation, in conflict with findings that less than half chose stepwise excavation in cases, where considered appropriate. One in four (25%) reported to be unfamiliar with sealing, and half (50%) use sealing regularly. Better access to continuing education and for universities to offer continuing education as alternatives to one-sided private market were requested.

Conclusion: Some patients may receive too radical treatment despite available less invasive evidence-based effective treatments. Dentists acknowledge the importance of continuing education. Easier access and perhaps more incentives for seeking out high-quality continuing education from trustworthy sources are needed.

KEYWORDS

continuing education, decision making, dental caries, dental pulp, diagnosis, epidemiology, fissure sealants, public dental health

Sofie Henneberg and Julie Henriksen shared first authorship.

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1 | INTRODUCTION

Medical error is a significant patient safety problem worldwide and causes avoidable patient harm and expenses.^{1,2} In Denmark, a yearly national report³ show that wrong diagnostic decisions and treatments constitute 51% of 1102 sustained patient complaints of 1888 filed complaints, in total.³ A healthcare system devoid of errors is probably not achievable but still actively working to limit the number and seriousness of errors is essential. Hence, clinical decision making is fundamental for optimal oral healthcare. Patients trust and expect healthcare providers to adopt evidence-based interventions that fit their individual needs and perhaps patients do not necessarily realize that clinical decision making is not always straightforward. It is a known problem that dentists will sometimes come to different diagnostic conclusions.^{4–9} Sackett et al. describe how clinical decisions ideally are made by well-balanced weighing of the health professional's clinical experience and judgment, the most recent high-quality evidence and the patients' values and preferences.¹⁰ Hence, in matters with a high level of certainty of (quality) evidence, less variation in clinical decisions should be expected and accepted, within the boundaries of patient preferences. However, with uncertain evidence greater variations in clinical decisions are acceptable as decisions to a higher extent, are to be based on individual dentist's experiences and the patients' preferences.¹¹ Too large a variation in matters with a high level of evidence suggests that some patients receive suboptimal care, whereas too little variation in the absence of robust evidence may indicate too little consideration of the patient's preferences.

When new intervention modalities are introduced, general practitioners seem to take in new knowledge at different pace giving rise to variations in the use of such new intervention modalities.¹²

Growing evidence show that micro invasive plus sealing and resin infiltration of active cavitated occlusal caries lesions, for which filling therapy in decades has been the appropriate treatment, is safe and in selected cases hinders or postpones the need for filling therapy and thereby improves the prognosis of the tooth.¹³

Stepwise excavation also has the potential to improve tooth prognosis. It is another tooth substance preserving treatment modality, with lower risk of traumatic pulp exposure and need for root canal treatment, compared with the complete excavation procedure.^{14,15} According to unpublished Danish health insurance data stepwise excavation is not used very often among Danish dentists. Unpublished Danish public health insurance data from 2015, on 34,963 25-year-old users of private dental care, show the proportion of stepwise excavation compared with all dental filling treatments was 0.3%/year. However, the treatment modality may be more widely used without being registered in public registers. Internationally, there are numerous studies pointing to deep caries lesions not always being treated appropriately.¹⁶

The overall aim of this study is to examine to what extent Danish dentists agree on caries- and pulp-diagnostics and related intervention decisions in regard to sealing and stepwise excavation. Some level of disagreement on when to apply these treatments is expected and may pose a threat to patient safety and receipt of optimal oral health care. A secondary aim is to examine Danish dentists' attitudes toward continuing education and their suggestions for improving these activities.

2 | METHODS

A cross-sectional study was carried out using an online questionnaire survey, based on 11 constructed cases with descriptions of patient symptoms, radiographic and clinical findings (see Supporting Information: [Appendix](#)). Responding dentists were to decide on 5 dental caries diagnoses, 5 dental pulp diagnoses, and 10 types of interventions corresponding to The International Caries Detection and Assessment System (ICDAS)^{17,18} criteria for caries diagnostics combined with the International Caries Classification and Management System criteria (ICCMS),¹⁹ forming the basis for the terminology used at the University of Copenhagen (see [Table 1](#)). Dentists who did not agree with any answering options, could opt for "different terminology."

TABLE 1 ICDAS/ICCMS codes and related terminology.

ICDAS	ICCMS	Caries diagnosis	Pulp diagnosis	Treatment
0	-	Healthy surface	Healthy pulp	No treatment needed, risk-based intervention/prevention (motivational interviewing, hygiene instructions)
1–2	CPS	White/brown spot lesions, non-cavitated	Healthy pulp	Risk-based intervention/prevention (Local flouride application, sealing/infiltration, motivational interviewing, hygiene instructions)
3–4	CPM	Radiographic radiolucencies, clinical shadows, enamel cavities.	Reversible pulpitis	Selective excavation to firm dentine, fillings
5–6	CPP/CP1,2,3	Dentine cavities	Reversible pulpitis, irreversible pulpitis, necrotic pulp	Stepwise excavation (including selective caries removal to soft dentine centrally), pulp capping, root canal treatment, extraction

Note: Real clinical cases may not always correspond entirely to the categorical schematic presentation in this table, but this forms the basis for the Gold Standard answers in the present study.

The online platform SurveyXact™ hosted the questionnaire and lives up to the required local data safety regulations. The questionnaire was distributed to Danish dentists through membership registers from the two major dental unions: The Danish Dental Association (3833 actively working dentist members) and ATO (The Union for Employed Dentists) with 1350 members. The questionnaire was also distributed via the Facebook group “Tandlæger [Dentists],” which per 28/9-21 had around 4000 dentist members. The data collection period elapsed from September 28 to November 5, 2021.

According to the most recent survey, 4889 dentists constituted the Danish workforce in 2019. The survey is available online at <https://www.esundhed.dk/Registre/Bevaegelsesregisteret>.

No permission from The Danish Data Protection Agency was needed as no personal information about invitees and responders were disclosed for the researchers and no personal data were collected and handled during the study.

According to the guidelines from The National Committee on Health Research Ethics, research projects handling anonymous data only does not need permission or notification of the Committee on Health Research Ethics.

Written informed consent was obtained from all participants at the point of inclusion.

The oral health conditions in question were all dental carious lesions at different stages and each case provided information about patient symptoms, clinical and radiographic findings. Gold standard (GS) answers for dental caries- and pulp diagnoses and related interventions for each case were set, based on evidence-based clinical guidelines from the Department of Odontology, University of Copenhagen, and on consensus, reached via a thorough discussion, within the author-group. Five cases were characterized by clear information and considered to have low level of difficulty, three to have a medium level of difficulty with somewhat ambiguous information and finally, three were considered difficult, as cases included ambiguous information. Thus, high, moderate, and low inter-rater agreement, respectively, were expected.

As we specifically wanted to investigate the use of sealing and stepwise excavation, six of the cases addressed these topics: three of each.

The cases on root canal interventions and dental fillings were included to avoid respondents being able to guess that we had particular interest in their opinion on the use of sealing and stepwise excavation and hence avoid any bias relating to this and to get an idea of their general agreement across different dental caries diagnoses and related interventions.

The dentists were instructed to give one dental caries and one pulp diagnosis and a corresponding choice of intervention for each case. Subsequently, they were asked about their knowledge and use of sealing and stepwise excavation and finally their attitude toward and use of continuing education. Main themes were extracted by identifying all mutually exclusive themes emerging from the respondents' free text answers.

2.1 | Statistics

Only pre-planned statistical tests were carried out. Two-tailed tests were used, a statistical significance level of $p = 0,05$ was applied and R® version 4.0.1 (2020-06-06) was used.

Cohen's κ was used to measure agreement between two raters. Light's κ , which is the average of each rater pair's Cohen's κ value, or the average of each rater's responses compared with the GS, was used when dealing with more than two raters.^{20,21}

The interrater agreement is initially affected by the response option “Different terminology” which causes many answers to appear in agreement while they equally likely may represent disagreement. “Different terminology” answers ($n = 12$) were excluded from the analysis to avoid bias. Only the Light's κ for interrater agreement, was affected, with 12 respondents excluded. The agreement between the GS and each rater, the response “Different terminology” was seen as in disagreement with the GS.

For analysis of agreement of the use of the sealing interventions a binomial model was used. The p value was calculated using the asymptotic normal distribution of the underlying probability parameter in the binomial distribution for two groups, that is, public dentists and private employed dentists.²²

Regarding the three cases on sealing interventions and the three cases on stepwise excavation, it is not reasonable to assume independence between the cases under a single dentist. To mitigate interdependency problems each dentist only contributed with the average amount of correct sealing/stepwise excavation recommendations when the p -value was calculated. We assume independence between each dentist, and hence, this lies within the framework of the binomial model.

Raw data is published and can be accessed via ERDA platform (<https://erda.dk/wsgi-bin/fileman.py>) and pending its unique Digital Object Identifier.

3 | RESULTS

3.1 | Survey responses

A total of 442 dentists responded to the survey. However, 198 questionnaires were incomplete and were excluded, leaving 243 fully completed questionnaires (Sample ≈ 4889). This equals a response rate of $\approx 5\%$. The composition of respondents is described in Table 2.

The overall interrater agreement is shown in Figure 1A and agreement with the GS is shown in Figure 1B.

Being unfamiliar with the terminology used at the University of Copenhagen was reported by 7% (SD 2.6) of the dentists regarding caries diagnoses, by 1.8% (SD 1.1) for pulp diagnoses, and 0.3% (0.6) for intervention decisions.

Considering the dentists' case-level answers compared with the GS some main patterns were seen (Table 3).

The dentists tended to choose “healthy pulp” over the GS “reversible pulpitis” (cases 5,7,8,11), and nonselective excavation over

selective excavation to firm dentine. In case 5 most of the dentists agreed with the GS caries diagnosis, and the pulp condition in this case is of less importance. Ten percent of the dentists chose "non-selective peripheral caries removal" and "selective caries removal to soft dentine

centrally" in accordance with the GS, while 84% chose "non-selective excavation" (case 5, Supporting Information: [Appendix](#)).

Furthermore, the dentists tended to choose caries "caries progressiva superficialis" (CPS) over GS "caries progressive media" (CPM) in cases addressing sealing (cases 6,8,11). All three cases 6,8,11 show a great variety of intervention choices ranging from: no intervention, fluoride intervention, fissure sealing, sealing, and different types of excavation and filling.

In all three cases 6,8,11, the dentists tended to choose a less serious caries and pulp diagnosis. Yet, in case 6, 66% of the dentists chose excavation and filling over the GS sealing intervention, hence in this case they chose a less serious caries and pulp diagnosis, but a more invasive intervention compared with the GS.

In relation to the stepwise excavation cases (cases 3,7,9) most of the dentists agreed with the GS caries and pulp diagnoses, but disagreed with the GS intervention stepwise excavation, and tended to choose a more invasive intervention. Stepwise excavation (cases 3,7,9) was the intervention of choice for 42%, 20%, and 41%, respectively. The majority chose interventions such as nonselective excavation.

No obvious pattern in agreement with the GS based on the case categorization into easy, medium, or difficult was found.

Regarding self-reported knowledge of the two interventions in question (sealing and stepwise excavation) 75% reported to know of the indications for when to apply and how to apply sealing, but only 48% considered it an important and integrated part of their intervention options.

Regarding stepwise excavation, 99% reported knowing of the indications for and how to apply the intervention, and 80% considered it an integrated part of their intervention options.

Knowledge of indications for and on how to carry out sealing was reported by 58% of private dentists and by 96% of public dentists

TABLE 2 Distribution of background variables in the study population.

N = 243 (100%)	
Graduation year	
2015–2020	57 (24%)
2010–2014	32 (13%)
2005–2009	24 (10%)
2000–2004	24 (10%)
1995–1999	19 (8%)
1990–1994	17 (7%)
1985–1989	34 (14%)
1980–1984	30 (12%)
1955–1979	6 (2%)
Graduation place	
University of Copenhagen	145 (60%)
University of Aarhus	85 (35%)
Other	14 (5%)
Employment ^a	
Private dentist	142 (58%)
Public dentist	115 (47%)

^aThe surplus 6% is due to some dentists ($n = 14$) working both in the private and public sector.

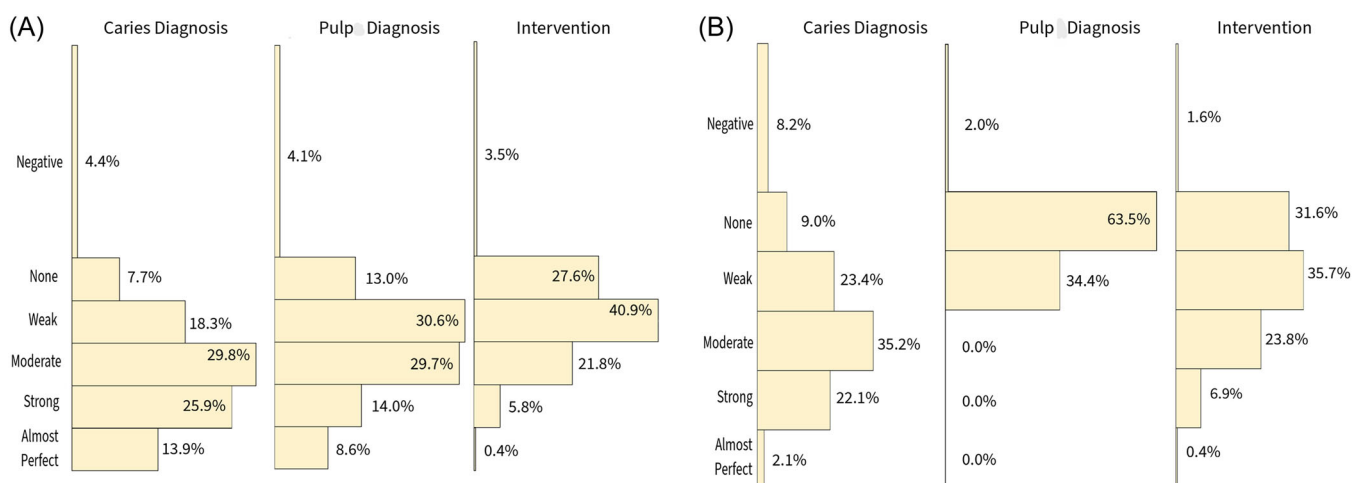


FIGURE 1 (A) and (B) Overall interrater agreement and agreement with the Gold Standard. (A) Histograms showing the dentist's interrater agreement. Caries diagnosis Light's $\kappa = 0.52$ (moderate agreement). Pulp diagnosis Light's $\kappa = 0.43$ (moderate agreement). Light's κ for intervention = 0.30 (weak agreement). (B) Histograms showing the dentists' agreement with the GS. Caries diagnosis Light's $\kappa = 0.42$ (moderate agreement), Pulp diagnosis Light's $\kappa = 0.17$ (none), Intervention Light's $\kappa = 0.31$ (weak). Percentages represent the proportion of the total number of observations (ratings of individual cases).

TABLE 3 Case-level agreement with the Gold Standard.

Cases (Presumed level of difficulty)	Gold standard caries diagnosis (ICDAS) Level of agreement (%)	Gold standard pulp diagnosis Level of agreement (%)	Gold standard intervention Level of agreement (%)
1 (easy)	Caries progressiva profunda (6) 39%	Irreversible pulpitis 39%	Root canal treatment 62%
2 (easy)	Caries progressiva profunda (6) 74%	Necrotic pulp 86%	Root canal treatment 98%
3 (medium)	Caries progressiva profunda (5) 79%	Reversible pulpitis 60%	Stepwise excavation 42%
4 (medium)	Caries progressiva profunda (5) 75%	Irreversible pulpitis 46%	Root canal treatment 42%
5 (easy)	Caries progressiva media (4) 82%	Reversible pulpitis 36%	Selective excavation to firm dentine 10%
6 (difficult)	Caries progressiva media (4) 35%	Reversible pulpitis 3%	Sealing 23%
7 (easy)	Caries progressiva profunda (5) 71%	Reversible pulpitis 37%	Stepwise excavation 20%
8 (medium)	Caries progressiva media (4) 13%	Reversible pulpitis 0%	Sealing 43%
9 (difficult)	Caries progressiva profunda (5) 80%	Reversible pulpitis 74%	Stepwise excavation 41%
10 (difficult)	Caries progressiva profunda (5) 75%	Irreversible pulpitis 55%	Root canal treatment 51%
11 (easy)	Caries progressiva media (4) 2%	Reversible pulpitis 0%	Sealing 18%

Note: Schematic overview of the respondents' answers to each case: percentage of agreement with the GS. Cases considering SEALING are marked yellow. Cases considering stepwise excavation are marked blue.

(Figure 2). Regarding the three sealing cases, 18% of private dentists and 42% of public dentists agreed that sealing was the most appropriate intervention. The difference being statistically significant.

Knowledge of indications for stepwise excavation and of how to carry it out were reported by 99% of private dentists and by 100% of public dentists (Figure 2). Regarding the three stepwise excavation cases, 28% of private dentists and 44% of public dentists agreed with the GS. The difference between public and private dentists is statistically significant.

Figure 2 Agreement with GS and self-reported knowledge of indications for, and knowledge of how to carry out, sealings and stepwise excavations, for private and public dentists.

The most reported way for the dentists to participate in continuing educational activities was annual courses, reported by 87%. Second, 61% reported to attend online activities, for example through professional groups via social media. Further, 36%–46% reported to seek information through scientific literature. Participation

in regular meetings with colleagues to discuss quality of care was reported by 33%. Finally, 11% reported to participate in “Knowledge generation activities” such as scientific research. No one answered that they did not feel the need to keep up to date.

Furthermore, multiple dentists gave additional comments about how they use colleague sparring and/or are a part of professional groups, exchanging experiences regularly.

Many dentists expressed wishes for better access to webinars and to websites with guidelines and podcasts, allowing better time management. A mentioned downside for online educational activities is the lack of social gathering and networking. Furthermore, some dentists suggested that the public health authorities should take upon them more responsibility for continuing education, quote: “Better presentations from public institutions rather than private companies” and quote: “Would be great if the dental school would reintroduce summarizing courses with the newest knowledge from the different areas of expertise.” Some dentists wished for new inspiration from

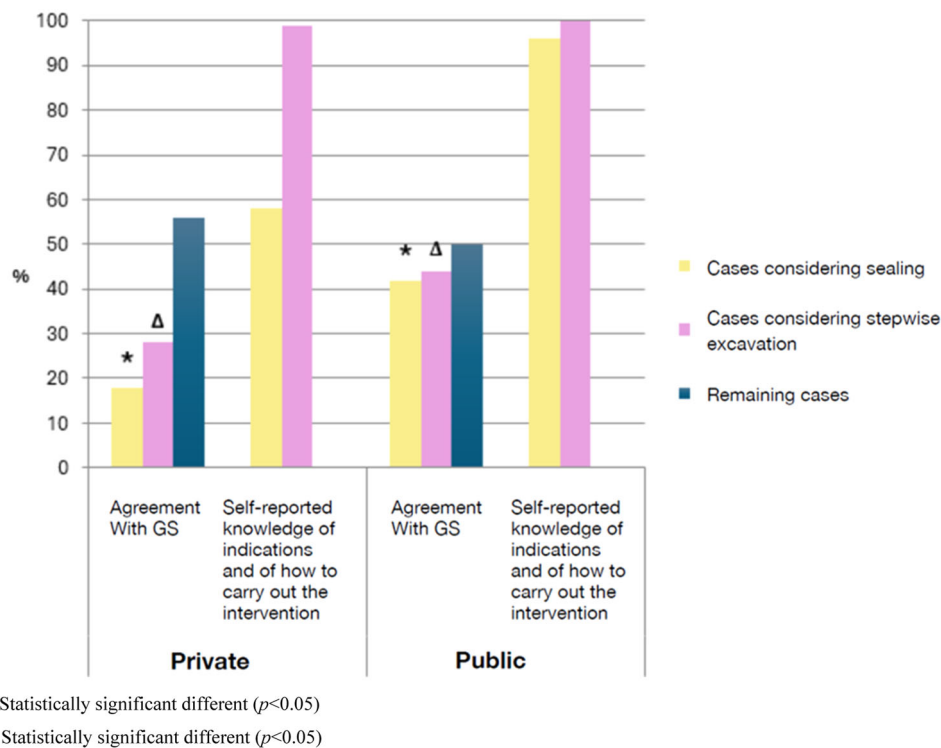


FIGURE 2 Agreement with GS and self-reported knowledge of indications for, and knowledge of how to carry out, sealings and stepwise excavations, for private and public dentists. *Statistically significant different ($p < 0.05$). ^ΔStatistically significant different ($p < 0.05$).

other course providers and felt that existing course providers often come from too closed a circle.

4 | DISCUSSION

Variations in caries and pulp diagnostic decisions and related treatments were found in a sample of Danish dentists. In general, dentists do not agree with each other and do not always agree with the evidence-based relevant guidelines.

The dentists attained the highest level of agreement in relation to caries diagnosis, yet the agreement was lower than expected. Considering dental pulp diagnosis, the dentists had moderate interrater agreement, however, agreement toward the GS was much lower than expected. Concerning decisions on interventions, the interrater agreement and agreement with the GS were lower than we had expected as well.

The discrepancies in caries diagnostic decisions, may partly be due to descriptions of the radiographs in the relevant cases (cases 6,8,11), as the radiolucency are described as limited to the outer $\frac{1}{3}$ of the dentin, which, in the absence of other more important findings, is consistent with superficial caries. Yet the clinical description includes a grayish shadow and when in combination with a radiographic finding, often underestimating the depth of the cavity, it should point the dentist in the direction of a deeper media lesion rather than superficial caries.¹⁸ In practice, a grayish shadow indicative of caries can be hard to differentiate from normal tooth substance, and

radiolucency in radiographs is associated with some uncertainty as this can depend on the eyes that see and can even differ from the same dentist over time.^{5,23} Hence, we expect the agreement to be even smaller in real life, as the dentists in our cases were given limited and uniform information of findings and did not have to collect and evaluate clinical findings themselves.

Some of the observed moderate interrater agreement for dental pulp diagnoses, may be due to choices of “healthy pulp” over “reversible pulpitis” even when most dentists agreed on caries being present, thereby neglecting or not being aware of how caries affects the pulp in different caries stages. It is debatable whether this is a “grave” error since the pulp condition has little influence on intervention choices in these cases. Yet, the pulp condition still ought to be considered by dentists to be able to inform patients on tooth- and intervention prognosis and on whether pain or discomfort may be expected.

It is mainly sealing (cases 6,8,11) and stepwise excavation (cases 3,7,9) cases that lower the overall agreement, confirming the expectations of less agreement on the use of these specific treatment modalities.

Case 5 is a good example of this, with 84% of the dentists opting for nonselective excavation over selective excavation to firm dentine. Decades ago, nonselective excavation (complete excavation) was considered the most appropriate excavation method, but today it is acknowledged that soft dentin can be left centrally, making nonselective excavation a too risky and radical intervention.²⁴ With 57% of the study sample having graduated after the year 2000 one

would expect that their knowledge of less invasive excavation methods would be up to date. Whether dentists who opted for “complete excavation” do so in practice—would be a reasonable next step to explore; either some dentists overtreat or use the outdated terms for excavation while having adapted their clinical practice. Terminology can be misleading, and the low agreement may to some extent be due to a lack of consensus on terms.

Further, the results do not support the hypothesis that the degree of complexity of cases would affect the level of agreement, as we found no clear patterns in the interrater agreement and agreement with GS based on case categories: easy, medium, or difficult. This may be interpreted as a lack of common understanding between researchers and practitioners of what are considered important findings to base decisions on.

Researchers involved in enunciation of terminologies within their field of specialty, should pay attention to the need for terminologies that also make sense to clinicians and are not too comprehensive and complex for everyday use.

Categorizing the dentists into public or private dentists the public dentists showed the greatest knowledge and use of sealing and stepwise excavation (Figure 2). The greatest difference concern sealing. For both private and public dentists less than half chose sealing and stepwise excavation when considered the GS intervention.

The greater knowledge and use of sealing and stepwise excavation for the public dentists over the private dentists may be due to several factors: both interventions demand more frequent follow-up, which can be easier to achieve in a public sector, where the patient does not need to pay for follow-up examinations and radiographs. Furthermore, the patients in the public sector may be more prone to receive dental care in the same clinic, whereas some patients in the private sector might move around more and receive dental care from different oral health professionals, making follow-up more difficult which again may influence the initial clinical decisions. Further, private dentists may feel that cost-benefit considerations for patients are better addressed when the tooth is fully treated with a filling or endodontic intervention, in one step, over sealing or stepwise excavation, where the true outcome of the intervention is “revealed” several months after the initial intervention. Dentists may want to ensure a clearer prognosis and avoid unclear long-term feedback loops and won't risk losing credibility toward the patient if the intervention is unsuccessful and needs reevaluation. This underlines the importance of involving patients in decision-making processes and of educating patients to appreciate and understand uncertainty and concepts of probabilities.

Some dentists may feel reluctance toward sealing and stepwise excavation as the interventions leave behind infected tissue, as it may be in sharp contrast to previous perceptions of what is *lege artis*. Hence, the value of unlearning outdated intervention modalities must be appreciated as much as learning new ones.²⁵ Furthermore, current financial incentives built into the system, may incentivize use of interventions with higher public reimbursements before other less reimbursed interventions. A recent study²⁶ found that changes in policies and reimbursements may stimulate dentists to change behavior

and the way they manage dental caries, due to extrinsic motivational factors, until knowledge have diffused out into all layers of the dental society and dentists become intrinsically motivated to carry out the most appropriate intervention²⁶ and until patients become more well-informed on new less invasive intervention options and demand builds.

Notably, the majority of dentists reported to know of and use stepwise excavation, but the results revealed discrepancies between stated knowledge and use with their actual treatment choices, as less than half of the dentists chose stepwise excavation when deemed appropriate as the GS (Figure 2).

Barriers to realizing and valuing needed changes to one's existing “intervention habits,” may be experiences of success and confidence with specific interventions. This perhaps exacerbated by cognitive bias giving more weight to clinical experiences and judgments over evidence. It probably makes it even harder to change behavior and integrate new interventions if one only has theoretical knowledge of an intervention but no “hands-on experience.” This corresponds to the findings of the difference between the dentists' reported knowledge of sealing and stepwise excavation and their reported actual use in practice.^{27,28}

The dentists value and request more support for continuing education, which may benefit from more evidence-based approaches. It is up for discussion whether a “for-profit” market-based system is sufficient to deliver effective multimethod and multiphase continuing education or whether continuing education should be regulated, managed, and provided more thoroughly by the responsible health authorities.²⁹

Naturally, the constructed cases in our study are far from perfect true pictures of real clinical conditions. However, the cases made it possible to test agreement between dentists on uniform and definite information, keeping out many other factors that might have influenced agreement between dentists, as for instance interpretation of dental radiographs. A recent study³⁰ supports that probably even more disagreement would have been seen, had the dentists not been given the results of the radiographic examination but were to interpret radiographs themselves.³⁰ One could argue that the results give a clearer picture of agreement compared with a similar study conducted in a clinical setting with real patients. A follow-up study in a clinical setting would be interesting, however, even larger variations in diagnostic and intervention decisions would be expected. No restrictions were set for how many times a dentist could answer the questionnaire, hence there is a risk that some dentists may have contributed more than once, however, this is not very likely as dentists are difficult to get to answer just once. Though we reached out to the Danish dentists through the only two dental associations and Facebook, we received answers corresponding to an approximately 5% response rate. The low response rate may be due to a lack of interest or time from the dentists, or maybe some dentists are reluctant to feel exposed professionally. If the latter is the case, we need to foster a culture for discussion of disagreement. There is a risk for nonresponse- and drop-out bias, and the answers given by the respondents are probably not representative for all Danish dentists as we have an overweight of younger and public employed dentists.

In clinical practice, it is not always possible to unambiguously decide when diagnostic and intervention choice variation is too large or too little because every patient encounter and clinical problem are unique and influenced by individual characteristics and multiple external factors. However, the differences in diagnostic and intervention choices in our study, are concerning in relation to whether some patients may receive too radical or invasive caries interventions, as the relatively well-defined cases build upon clinical problems with robust evidence informed interventions available.

The observed lack of knowledge of established evidence-based treatment modalities is not a criticism of dentists' professional integrity. Several studies have emphasized that keeping up to date is a difficult task to fit into busy clinical daily routines due to the sheer amount of new evidence pouring out from the scientific community and problems with access to relevant guidelines that may help clinicians navigate the evidence landscape. However, this should be seen as a sign that clinicians need more assistance and easier access to high-quality guidelines and continuing education activities.^{31–33} Furthermore, variation in attitudes toward and knowledge of best practices of dental caries treatments is not solely a Danish issue. A Norwegian study showed similar variations in decisions on caries lesion treatments,³⁴ and compared with an American study, Danish dentists seem less radical and more tooth preserving in their treatment choices regarding deep caries lesions.³⁵

With the two main topics, sealing and stepwise excavation, being very clinically relatable, maybe academic detailing activities in professional groups of dentists would be effective.³⁶

In addition to education of dentists and patients on new intervention modalities, reallocation or increased public reimbursements specifically for the interventions in question and the subsequent follow-up examinations will probably help the needed change underway and raise awareness and motivation for the use of sealing and stepwise excavation.²⁶

5 | CONCLUSION

Variations in dentists' decisions on diagnoses and related interventions found in the present study point to the need for multiple approaches to reduce such variation. Some level of variation is warranted, especially in clinical settings with due attendance to patient preference, but the use of radical and invasive intervention modalities with more effective, evidence-based less invasive alternatives at hand should be avoided as much as possible. The findings are indicative of a research-to-practice knowledge gap. Participating dentists themselves call for better access to continuing education activities provided by trustworthy partners. An efficient dental care system should take upon its shoulders to see that implementation of new knowledge is done faster and more systematically into practice, maybe by a combination of formal post-graduate continuing education for instance by means of academic detailing or hands-on courses for practitioners and by education of the public to make patients value less invasive care more. Initially, until awareness and knowledge levels have

been raised, public reimbursement schemes may be useful to speed up the desired provision of care changes.

AUTHOR CONTRIBUTIONS

Sofie Henneberg (DDS) and Julie S. Henriksen (DDS) equally contributed to conception and design of the study, data collection, analysis and interpretation, drafted and critically revised the manuscript. Lasse Christensen (Cand. Act.) contributed to analysis and interpretation of data, drafted and critically revised the manuscript. Merete Markvart (DDS, PhD, Associate Professor) and Kasper Rosing (DDS, PhD, Postdoc) contributed to conception and design of the study, data analysis and interpretation, and critically revised the manuscript. All authors have read and approved the final version of the manuscript.

ACKNOWLEDGMENTS

Many thanks to the Danish Dental Association and to the Danish Association of Publicly and Privately Employed Dentists for their help sending out invitations.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in ERDA at <https://erda.dk/wsgi-bin/fileman.py>, reference number DOI pending.

TRANSPARENCY STATEMENT

The lead author Kasper Rosing affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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REFERENCES

1. World Health Organization. *Patient safety*. 2024. <https://www.who.int/news-room/fact-sheets/detail/patient-safety>
2. Committee on Diagnostic Error in Health Care; Board on Health Care Services; Institute of Medicine; The National Academies of Sciences, Engineering, and Medicine. *Improving Diagnosis in Health Care*. National Academies Press; 2015.
3. The Danish Dental Association. *The Danish Dental Association's Dental Injury Compensation*. 2022.
4. Elmore J. A bibliography of publications on observer variability (final installment). *J Clin Epidemiol*. 1992;45(6):567-580.
5. Bader JD, Shugars DA. Variation in dentists' clinical decisions. *J Public Health Dent*. 1995;55(3):181-188.
6. Reit C, Kvist T. Endodontic retreatment behaviour: the influence of disease concepts and personal values. *Int Endontic J*. 1998;31(5):358-363.
7. Altarakemah Y, Al-Sane M, Lim S, Kingman A, Ismail AI. A new approach to reliability assessment of dental caries examinations. *Community Dent Oral Epidemiol*. 2013;41(4):309-316.

8. Conrad J, Retelsdorf J, Attia S, Dörfer C, Mekhemar M. German dentists' preferences for the treatment of apical periodontitis: a cross-sectional survey. *Int J Environ Res Public Health*. 2020;17(20):7447.
9. Rønneberg A, Skaare AB, Hofmann B, Espelid I. Variation in caries treatment proposals among dentists in Norway: the best interest of the child. *Eur Arch Paediatr Dent*. 2017;18(5):345-353.
10. Sackett DL, Rosenberg WMC, Gray JAM, Haynes RB, Richardson WS. Evidence based medicine: what it is and what it isn't. *BMJ*. 1996;312(7023):71-72.
11. Djulbegovic B, Guyatt GH. Progress in evidence-based medicine: a quarter century on. *Lancet*. 2017;390(10092):415-423.
12. Green LW, Ottoson JM, Garcia C, Hiatt RA. Diffusion theory and knowledge dissemination, utilization, and integration in public health. *Annu Rev Public Health*. 2009;30:151-174.
13. Qvist V, Borum MK, Møller KD, Andersen TR, Blanche P, Bakhshandeh A. Sealing occlusal dentin caries in permanent molars: 7-year results of a randomized controlled trial. *JDR Clin Transl Res*. 2017;2(1):73-86.
14. Bjørndal L, Fransson H, Bruun G, et al. Randomized clinical trials on deep carious lesions: 5-year follow-up. *J Dent Res*. 2017;96(7):747-753.
15. Recchi AF, Azambuja RS, Alves LS, Maltz M, Jardim JJ. Restorations performance after selective caries removal to soft dentine: 18-month follow-up of a controlled clinical trial. *J Dent*. 2024;147:105099.
16. Schwendicke F, Göstemeyer G. Understanding dentists' management of deep carious lesions in permanent teeth: a systematic review and meta-analysis. *Implement Sci*. 2016;11(1):142.
17. Ekstrand KR, Luna LE, Promisiero L, et al. The reliability and accuracy of two methods for proximal caries detection and depth on directly visible proximal surfaces: an in vitro study. *Caries Res*. 2011;45(2):93-99.
18. Gugnani N, Pandit I. International caries detection and assessment system (ICDAS): a new concept. *Int J Clin Pediatr Dent*. 2011;4(2):93-100.
19. Ismail AI, Pitts NB, Tellez M. The International Caries Classification and Management System (ICCMS™) an example of a caries management pathway. *BMC Oral Health*. 2015;15(suppl 1):S9.
20. Cohen J. A coefficient of agreement for nominal scales. *Educ Psychol Meas*. 1960;20(1):37-46.
21. Conger AJ. Integration and generalization of kappas for multiple raters. *Psychol Bull*. 1980;88(2):322-328.
22. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33:159-174.
23. Bader JD, Shugars DA, Bonito AJ. A systematic review of the performance of methods for identifying carious lesions. *J Public Health Dent*. 2002;62(4):201-213.
24. Schwendicke F, Walsh T, Lamont T, et al. Interventions for treating cavitated or dentine carious lesions. *Cochrane database Syst Rev*. 2021;7(7):013039.
25. Carthy P, Harvey I, Brawn R, Watkins C. A study of factors associated with cost and variation in prescribing among GPs. *Fam Pract*. 2000;17(1):36-41.
26. Gabel F, Kalmus O, Rosing K, Trescher AL, Listl S. Implementation of altered provider incentives for a more individual-risk-based assignment of dental recall intervals: evidence from a health systems reform in Denmark. *Health Econ*. 2020;29(4):475-488.
27. Greenhalgh T, Snow R, Ryan S, Rees S, Salisbury H. Six 'biases' against patients and carers in evidence-based medicine. *BMC Med*. 2015;13:200.
28. Wieringa S, Engebretsen E, Heggen K, Greenhalgh T. Rethinking bias and truth in evidence-based health care. *J Eval Clin Pract*. 2018;24(5):930-938.
29. Firmstone VR, Elley KM, Skrybant MT, Fry-Smith A, Bayliss S, Torgerson CJ. Systematic review of the effectiveness of continuing dental professional development on learning, behavior, or patient outcomes. *AADS Proc*. 2013;77(3):300-315.
30. Feigin K, Snyder C, Tai J, Stepaniuk K, Hetzel S. Intraoral radiographic interpretation agreement between veterinary students, veterinary dental residents and veterinary dental specialists. *J Vet Dent*. 2024;41(4):301-311.
31. Andermann A, Pang T, Newton JN, Davis A, Panisset U. Evidence for Health II: overcoming barriers to using evidence in policy and practice. *Health Res Policy Syst*. 2016;14:17.
32. Landhuis E. Scientific literature: information overload. *Nature*. 2016;535(7612):457-458.
33. Science Fiction Books. *Science Fiction*. 2020: Penguin Random House.
34. Stangvaltaite L, Kundzina R, Eriksen HM, Kerosuo E. Treatment preferences of deep carious lesions in mature teeth: questionnaire study among dentists in Northern Norway. *Acta Odontol Scand*. 2013;71(6):1532-1537.
35. Oen KT, Thompson VP, Vena D, et al. Attitudes and expectations of treating deep caries: a PEARL Network survey. *Gen Dent*. 2007;55(3):197-203.
36. Baådoudi F, Duijster D, Maskrey N, Ali FM, Rosing K, van der Heijden GJMG. Academic detailing in oral healthcare - results of the ADVOCATE Field Studies. *Acta Odontol Scand*. 2020;78(7):481-493.

SUPPORTING INFORMATION

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

How to cite this article: Henneberg S, Henriksen J, Christensen L, Markvart M, Rosing K. Inconsistent decision making in dental caries diagnosis and treatment: a case-based questionnaire survey. *Health Sci Rep*. 2024;0:e2278. doi:10.1002/hsr2.2278