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German dentists' management of non-cavitated proximal caries lesions: A qualitative interview study

Understanding German dentists' management of proximal caries

Background:
For managing non-cavitated proximal caries lesions, non- or micro-invasive strategies (NI/MI) are currently recommended over invasive (restorative) approaches. However, survey data indicate that dentists may not have adopted these strategies. This qualitative study aimed to identify barriers and facilitators for using NI/MI in Germany.

Methods:
A diverse sample of 12 dentists was recruited. Semi-structured interviews were conducted by telephone, using an interview schedule based on the Theoretical Domains Framework.

Results:
Limited financial reimbursement and an organizational framework centering around placing restorations, patients' lacking adherence to advice and oral hygiene (and associated high caries risk) as well as the fear of lesion progression (anticipated regret) were identified as relevant barriers for NI/MI. Facilitators were found to be working in a team where NI/MI is promoted, having knowledge of the disadvantages of restorations and the evidence supporting NI/MI, regularly attending ongoing professional development courses and professional satisfaction when doing "the right thing" for the patient.

Conclusions:
A number of aspects at individual, practice and healthcare level could be targeted to enhance dentists' uptake of NI/MI for managing non-cavitated proximal caries lesions.

Keywords:
attitudes; dental; decision-making; enamel caries; evidence-based practice; qualitative studies; theoretical domains framework

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Background

Dental caries is the most prevalent disease worldwide, burdening billions of people and generating substantial direct and indirect costs [16, 17]. In Germany, the caries experience in children has been decreasing, but remains high for adults and seniors [15]. The traditional approach towards managing caries lesions has been the removal of all this tissue and the placement of a restoration. This was grounded on an understanding of caries as an infectious disease. This understanding has been superseded by caries being seen as a bacterially-mediated, behavioral disease: Only when sufficient dietary carbohydrates are supplied, the physiologic dental biofilm is altered, with selection of cariogenic species, and eventually becomes highly cariogenic [18]. Thus, caries and also caries lesions can be controlled without removing hard tissue, especially for early caries lesions, where the surface is non-cavitated [29].

Such control can be performed using different strategies. Non-invasive strategies do not breach the surface of the tooth and include, for example, reducing the intake of cariogenic sugars (dietary control), avoiding biofilm maturation (oral hygiene control) and providing remineralizing agents like fluoride (remineralization control) [23, 32]. Micro-invasive strategies remove a few micrometers of tooth tissue during an acid-conditioning step; they involve, for example, sealing or infiltrating lesions using resins. The installed diffusion barrier (on or within the lesion) impedes acid diffusion into the tooth tissues and mineral loss from it, thereby arresting the lesion [29]. Both non- and micro-invasive techniques (NI/MI) are successful in controlling caries lesions [8, 32] and are currently recommended over invasive (restorative) treatments when managing early, non-cavitated lesions [29]. This recommendation is based on the understanding that (1) during invasive (restorative) treatments, significant amounts of sound or remineralizable tissues are lost during preparation; this is the more true for proximal surfaces, where the marginal ridge will usually be intact if an early non-cavitated lesion is present proximally, and (2) the fact that restorations have limited lifespans and need to be replaced at some point, leading to more tooth tissue loss, repeated treatment costs and, in some instances, tooth loss [1, 31, 33].

International data indicate that not all dentists have adopted NI/MI [14]. To change the underlying attitude and the resulting behavior of dentists, it is necessary to understand factors driving these attitudes and behaviors; that is, the underlying barriers and enablers. To gain such understanding, qualitative studies are needed; these should, if possible, employ a theoretical framework to understand the behavior processes that could be tackled later on by interventions [29]. In the present study, we used the Theoretical Domains Framework (TDF), which is a common framework in implementation research [12, 20, 35], but has only sparsely been used in dentistry so far [10, 12, 30]. The aim of this study was to identify barriers and enablers for dentists managing non-cavitated proximal caries lesions using NI/MI. Interviews were conducted in 3 countries; the US, New Zealand and Germany. Results of this cross-country analysis have been published elsewhere [28]. Here, we report in-depth on the findings from Germany.

Method

This study used semi-structured interviews (see appendix for the interview schedule, p. 41-42). The TDF was utilized to develop the interview schedule and analyze the data. The reporting of this study follows the COREQ (Consolidated criteria for Reporting Qualitative research) checklist [36]. Ethical approval was obtained (Charité – Universitätsmedizin Berlin EA2/137/14).

The research team involved an experienced psychologist and qualitative researcher (SB), who focused on the design of the interview schedule and the analysis, as well as clinicians, cariologists and epidemiologists (FS, LAS, LFP, MF, WMT). The interviews were conducted by one independent interviewer in 2016. Pilot interviews were conducted prior to full data collection in order to train the interviewer, and to adapt the interview schedule where necessary. A dental researcher with previous experience in qualitative research (LAS) coded the interviews; 10 % were additionally and independently coded by SB to check if different coders would lead to relevant differences in findings; this was not the case. The interviewees did not have any relationship to the interviewers.

A sample size calculation, as required for quantitative studies, is usually not performed in qualitative research [9]. However, we aimed to collect sufficiently broad data to allow some generalization as to the identified barriers and facilitators. Hence, dentists of different gender, age, and practice location and type were sampled from registration lists or by convenience, as detailed in the results. Non-responders were not separately analyzed and reasons for non-response not followed up.

As described, the interview schedule was designed based on the TDF, with some modifications to allow ease of administration. A mix of open- and closed interview questions were used. The interviews were conducted by telephone and audio-recorded and lasted between approximately 20 minutes and one hour.

The data were analyzed by LS by grouping the responses under the TDF domains and constructs, this was double-checked by SB. A simple count of the excerpts grouped under the different constructs was taken to provide an overall picture of the pervasiveness of a domain (these are shown and explained in Table 1).

Results

The 12 dentists (7 female, 5 male) had an average of 17.8 years of clinical practice (ranging from 10 months to 41 years). Eight participants worked in urban practices; 4 in rural practices, with diversity as to the practice model (single-practitioner or group practice). All worked predominantly within the statutory health insurance, as would be expected in Germany.

When analyzing the interview data, some domains were more common than others with regards to the number of excerpts grouped within them (Figure 1).

Domain	Construct	Definition
Knowledge	Knowledge	Knowledge of a condition or scientific rationale
	Procedural knowledge	Knowing how to do something
	Knowledge of task environment	Knowledge of the social and material context in which a task is undertaken
Skills	Skills	An ability or proficiency acquired through practice
	Skills development	The gradual acquisition or advancement through progressive stages of an ability or proficiency acquired through training and practice
	Competence	One's repertoire of skills, and ability especially as it is applied to a task or set of tasks
	Ability	Competence or capacity to perform a physical or mental act. Ability may be either learned or unlearned
	Interpersonal skills	An aptitude enabling a person to carry on effective relationships with others, such as ability to cooperate, to assume appropriate relationships with others or to exhibit adequate flexibility
	Practice	Repetition of an act, behaviour or series of activities, often to improve performance or acquire a skill
Social influences	Social pressure	The exertion of influence on a person or person or group by another person or group
	Social norms	Socially determined consensual standards that indicate what behaviours are considered typical in a given context and what behaviours are considered proper in the context
	Group conformity	The act of consciously maintaining a certain degree of similarity to those in your general social circle
	Social comparisons	The process by which people evaluate their attitudes, abilities, or performance relative to others
	Group norms	Any behaviour, belief, attitude or emotion reaction held to be correct by any given group in society
	Social support	The apperception or provision of assistance or comfort to others, typically in order to help them to cope with a variety of biological, psychological or social stressors. Support may arise from interpersonal relationships in an individual's social network, involving friends, neighbours, religious institutions, colleagues, caregivers or support groups
	Power	The capacity to influence others, even when they try to resist this influence
	Intergroup conflict	Disagreement or confrontation between two or more groups and their members. This may involve physical violence, interpersonal discord, or psychological tension
	Alienation	Estrangement from one's social group; a deep seated sense of dissatisfaction with one's personal experiences that can be a source of lack of trust in one's social or physical environment or in oneself; the feeling of separation between one's thoughts and feelings

	Group identity	The set of behaviour or personal characteristics by which an individual is recognizable (and portrays) as a member of a group
	Modelling	In developmental psychology, the process by which one or more individuals or other entities serve as examples (models) that a child will copy
Social/ professional role and identity	Professional identity	The characteristics by which an individual is recognised relating to, or connected with, or benefitting, a particular profession
	Professional role	The behaviour considered appropriate for a particular kind of work or social position
	Social identity	The set of behaviours or personal characteristics by which an individual is recognizable [and portrays] as a member of a social group, relating to, or connected with or benefitting a particular profession
	Identity	An individual's sense of self defined by a) a set of physical and psychological characteristics that is not wholly shared with any other person and b) a range of social and interpersonal affiliations (e.g. social roles)
	Professional boundaries	The bounds or limits relating to, or connected with, a particular profession or calling
	Professional confidence	An individual's beliefs in his or her repertoire of skills, and ability as it is applied to tasks or set of tasks
	Group identity	The set of behaviours or personal characteristics by which an individual is recognisable [and portrays] as a member of a group
	Leadership	The process involved in leading others, including organising directing, coordinating and motivating their efforts toward achievement of certain group or organisational goals
Beliefs about consequences	Beliefs	The thing believed, the proposition or set of propositions held true
	Outcome expectancies	Cognitive, emotional, behavioural, and affective outcomes that are assumed to be associated with future or intended behaviours. These assumed outcomes can either promote or inhibit future behaviour
	Characteristics of outcome expectancies	Characteristics of the cognitive, emotional, behavioural outcomes that individuals believe are associated with future or intended behaviours and that are either believed to promote or inhibit these behaviours. These include whether they are sanctions/rewards, proximal/distal, valued/not valued, probable/improbable, salient/not salient, perceived risks or threats
Reinforcement	Anticipated regret	A sense of the negative consequences of a decision that influences the choice made; for example an individual may decide not to make an investment because of the feelings associated with an imagined loss
	Consequence	An outcome of behaviour in a given situation
	Rewards	Return or recompense, made to or received by a person contingent on some purpose
	Incentives	An external stimulus, such as a condition or object that enhances or serves as a motive for behaviour

	Punishment	The process in which a relationship between a response and some stimulus or circumstance results in the response becoming less probable; a painful, unwanted or undesired event or circumstance imposed on a wrong doer
	Consequents	An outcome of behaviour in a given situation
	Reinforcement	A process in which the frequency of a response is increased by a dependent relationship or contingency with a stimulus
	Contingencies	A conditional probabilistic relation between two events. Contingencies may be arranged via dependencies or they emerge by accident
	Sanctions	A punishment or other coercive measure, usually administered by a recognised authority, that is used to penalise and deter inappropriate or unauthorised actions
Intentions	Stability of intentions	Ability of one's resolve to remain in spite of disturbing influences
	Stages of change model	A model that proposes that behaviour change is accomplished through five specific stages: pre-contemplation, contemplation, preparation, action and maintenance
	Trans-theoretical model and stages of change	A five-stage theory to explain changes in people's health behaviour. It suggests that change takes time, that different interventions are effective at different stages, and that there are multiple outcomes occurring across different stages
Goals	Goals (distal/proximal)	Desired state of affairs of a person or system; these may be closer (proximal) or further away (distal)
	Goal priority	Order of importance or urgency of end states toward which one is striving
	Goal/target setting	A process that establishes specific time based behaviour targets that are measurable, achievable and realistic
	Goals (autonomous/ controlled)	The end state towards which one is striving: the purpose of an activity or endeavour. It can be observed by observing that a person ceases or changes its behaviour upon attaining this state; proficiency in a task to be achieved within a set period of time
	Action planning	The action or process of forming a plan regarding a thing to be done or a deed
	Implementation intention	The plan that creates in advance of when, where and how one will enact a behaviour
Environmental context and resources	Environmental stressors	External factors in the environment that cause stress
	Resources material resources	Commodities and human resources used in enacting behaviour
	Organisational culture/ climate	A distinctive pattern of thought and behaviour shared by members of the same organisation and reflected in their language, values, attitudes, beliefs and customs
	Salient events/critical incidents	Occurrences that one judges to be distinctive, prominent or otherwise significant

	Person – environment interaction	Interplay between an individual and their surroundings
	Barriers and facilitators	In psychological contexts barriers/facilitators are mental, emotional or behavioural limitations/strengths in individuals or groups
Behaviour regulation	Self-monitoring	A method used in behaviour management in which individuals keep a record of their behaviour, especially in connection with efforts to change or regulate the self; a personality trait reflecting an ability to modify one's behaviour in response to a situation
	Breaking habit	To discontinue a behaviour or sequence of behaviours that is automatically activated by relevant situational cues
	Action planning	The action or forming of a plan regarding a thing to be done or a deed

Table 1 Domains of the Theoretical Domains Framework (TDF) (mod. to [10])

Environmental context and resources

(TDF definition: Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behavior)

The overwhelming majority of participants mentioned that the lack of financial reimbursement for NI/MI under the statutory health insurance was a barrier for implementing NI/MI in their practice. Moreover, 3 participants stated that they were pressured by their bosses to make money from providing restorations instead of NI/MI. Some explained that other dentists performed restorations because they wanted their practice to be profitable, while they themselves did not do that. Consequently, an organizational culture where restorations were favored over NI/MI, due to more favorable reimbursement rates, was a barrier. These comments are typified by the following:

G2: Well most colleagues think that invasive measures generate more income than non-invasive measures. That's why most (colleagues) wouldn't consider non-invasive treatments.

G3: In short, our boss wants to make money (laughs). Non-invasive procedures are desirable for the patient and of course are very good, but in reality [one] has to place some fillings.

G4: [NI and MI methods] ... requires more work that is not paid. Hence it isn't really worth it for me, maybe for the patient but sadly not for me. It just isn't paid well.

G7: Well it's a bit iffy financially. It is dependent on the area one is in.

At the same time, G10 said being her/his own boss meant that s/he could choose to implement NI/MI:

G10: Well firstly of course, that I am under no pressure or obligation from my employer to practice a certain way. Yes. And that I have access to all the resources and I can pretty much use the treatment approach/concept I want.

Another identified barrier was a lack of patients' oral hygiene. For instance, when G4 asked whether there had been instances when s/he had chosen to place restorations rather than using NI/MI, she answered:

G4: That has probably happened to a patient with lots of decay and poor oral hygiene. And maybe [also had] a certain pain sensibility.

Social influences

(TDF definition: Those interpersonal processes that can cause individuals to change their thoughts, feelings and behaviors)

Practicing or socializing with colleagues who shared similar philosophies was another identified enabler for the implementation of NI/MI. For instance, G1 explained:

G1: When I do see [colleagues] then I do notice an amazing knowledge in that area. There are a lot of colleagues that are pretty careful.

On the other hand, comparison with colleagues but also fear of being judged negatively were factors determining behavior:

G2: I see colleagues that have got themselves financially into a difficult situation and seal everything that is possible and change fillings that don't even need to be changed. Black sheep are here and there and everywhere. But generally I believe the greater part of my colleagues think like I.

G7: When the patient goes to a different practice, because this one is closed, then the colleague says: "Oh what is this, look, there is more decay and what not." And that is wrong and terrible. One would have to be able to understand that dentistry isn't all about a burr and filling materials, but also how you would act in respect to the patient. And one does not drill a hole into everything. However, this understanding is still lacking.

Patients who had a good oral hygiene and were judged as being likely to cooperate were more likely to be selected for NI/MI. Consequently, patient factors such as the ability to comply was an enabler:

G2: I think [treatment] would be depending on the overall oral hygiene of the patient. If the patient has great oral hygiene, apart from, for example, 1–2 interproximal lesions that extend up to the inner enamel part ... if he has otherwise a great oral hygiene, then I would not consider invasive treatments. We would observe it. However, the patient will need to cooperate.

Knowledge

(TDF definition: An awareness of the existence of something)

An extensive knowledge of NI/MI methods and how to perform them was an enabler. For instance, G7 explained:

G7: Well I would take a holistic approach. That's what we normally do here. The patient comes in for an appointment, visual report, what needs doing, followed by periodontal screening index, [and] then we talk about his/her oral hygiene. I ask him/her what he/she uses to maintain his/her oral hygiene. Most of the time the answer is, just the toothbrush. Then I would draw his/her attention to dental floss and the interdental brushes. Then there is of course the diagnostic analysis based on the X-rays and from all this I come up with a diagnostic analysis and, sadly I, as a practitioner, have to say that only very few are able to optimize their [dental] situation to largely avoid the use of a drill ... However, then the requirement also is to regularly have the teeth professionally cleaned and have regular checkups. If I then notice that it is working I lengthen the appointment intervals to a year, under the condition that the patient has his teeth professionally cleaned twice a year.

Some participants also reported that they knew particular NI/MI methods worked because this is what they were taught during their training. Nevertheless, when the participants were asked if they based their practice on scientific research, 4 participants stated that they had not participated in any on-going professional or knowledge development since they graduated from dental school. Not practicing with up-to-date knowledge was a barrier to the implementation of NI/MI:

G1: I really can't tell you. I haven't looked at any studies for 20 years.

G2: I believe so because this is what I was told at university.

G10: I can't think of the name of the study, but this is what I had learnt back in the day.

G12: Can I answer that with I do think it is scientifically proven ... during my studies [is where I learned it and] everything you learn there you apply in your practice.

Having knowledge of specific patient (risk) factors, such as age, impacted on decision-making:

G11: Well to be honest. I am a bit hesitant with elderly patients, [but] with younger ones I tend to check their general oral hygiene first and then I would check the papillary bleeding, well the papillary bleeding index. And if they have heaps of plaque everywhere, then ... I will ask the patient to have a prophylaxis appointment. And I would decide afterwards and again will ask for them to come more frequently to see whether or not the situation has improved and then I would be more conservative and wouldn't drill ... [I am a bit hesitant with elderly people] because it takes longer ... I speak from experience.

Beliefs about consequences

(TDF definition: Acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use)

Almost all of the participants stated that restorations served to weaken the tooth structure, and began a cycle of continually needing to replace the restoration. Consequently, a belief that restorations might cause damage to healthy tooth structure served as an enabler:

G2: The advantage is the preservation of the tooth structure. We will preserve the tooth without a filling because even the best filling isn't the greatest compared to an untouched enamel layer.

G6: I would say it is always possible for people who look after their teeth well. One can definitely remineralize these things.

G9: It's encouraging when you notice that there hasn't been any change to the worse after 1, 2, 3 years.

At the same time, some participants were hesitant to implement NI/MI with some patients who were unlikely to return for regular follow-up appointments, fearing lesion progression. The sense of anticipated regret about not restoring earlier and protecting patients from cavitation, pain, or the need for an extraction was a barrier:

G9: If I know that I can't motivate the patient to have better oral hygiene, then I know that interproximal decay in its early stages can progress to quite deep decay within a quarter of a year. Often that is too late. And often the patients don't come back. That's why I rather treat an early decay in the dentine right away. Those patients tend to only come when they are in pain. I am less invasive with people that come regularly to the recalls.

G1: The disadvantage is that if one cannot see the patient for a follow up then it can turn to custard, rather quickly and 2 years down the track the next dentist would say: "This dentist had used micro-invasive treatments and now the tooth needs to be taken out, because no one removed the decay". That is why I would be careful.

G3: Well the disadvantages are that one would risk the decay to go deeper and that the patient, the decay would advance further resulting in the inflammation of the pulp and in extreme cases the need for a root canal.

Reinforcement

(TDF definition: Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus)

The personal and/or professional rewards that participants experienced as a result of the implementation of NI/MI methods was an enabler:

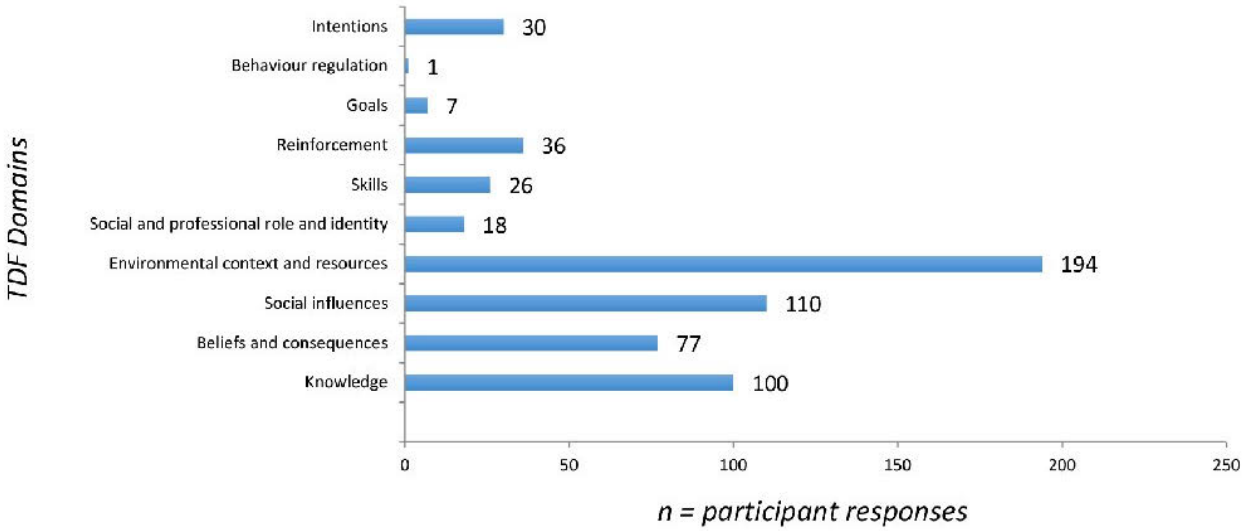
G1: Certainly for the patient, preserving tooth enamel. I tend to have a better feeling with it and sleep better at night.

G9: In the end it is also good for the dentist-patient-relationship when the patient knows that one is doing everything they can to preserve their teeth with the least invasive approach.

G8: Respectively this would delay or eliminate the point at which one would really need ... to use invasive measures, which ultimately results in the delay of losing that tooth.

Intentions

(TDF definition: A conscious decision to perform a behavior or a resolve to act in a particular way)



(Fig. 1: F. Schwendicke)

Figure 1 Total number of participant responses grouped per the domains of the TDF (mod. to [10])

The desire to implement NI/MI, whenever possible now and in the future was a further facilitator:

G2: I always try to, when one does have a filling then it will need to be renewed at some point, and if one is somehow able to keep the surface area intact and to allow it to remineralize, then it is better in the long term.

G10: I would take the same approach [if the decay is extending into the enamel-dentine-junction] ... In general, we can say that I would be conservative, even when it is already extending up to the enamel-dentine-junction. We do have a very good prophylaxis program at the practice. Firstly, I would inform the patients about it all and would try to find out whether they are interested in maintaining the situation or improving it. I tend to be conservative.

G11: I would take non-invasive approaches in the same way, whether the compliance is good or not.

Skills

(TDF definition: An ability or proficiency acquired though practice)

Greater clinical competence in and knowledge of NI/MI, as a result of years of practice experience or education, was another enabler. Moreover, specific knowledge of tooth morphology and how this changes over time was mentioned by G3. This comment was grouped under the skills domain because it highlights his/her diagnostic skills and the ability to cater treatment methods to patients' needs.

G5: Well I have been working as a dentist for ages and am increasingly treating my patient using that concept. Well not in the beginning, seen as I had learnt about this in a very different way, however, due to the regular courses I attend and due to my personal experience I have learnt [a lot] and observe my patients and it was worth it ... I am doing the same with my patients and over the years my assumption had been proven correct, that ... if one uses fluoridation treatment and if one has a good compliance and regularly attends prophylaxis appointments, then one can prevent micro-lesions from demineralization any further.

G3: Yes, there are definitely differences. Regarding the youth, for example, it's very possible to educate them. One would probably be able to manage the oral hygiene habits. However, if the patient is 70 years of age, then if you tell him to use floss, after 50 years of never doing so then he would most likely not do it. There are definitely differences. One would also have to think about the technical aspect, for youth the pulp is bigger, meaning it can become hypersensi[tive] if one drills too extensively.

Social and professional role and identity

(TDF definition: A coherent set of behaviors and displayed personal qualities of an individual in a social or work setting)

The comments grouped under social and professional role and identity generally centered on the participants' role as dentists in offering patients advice on their oral health care and treatment. Consequently, the participants' role as a dental expert in helping to shape patients' oral hygiene practices was a facilitator. One participant also mentioned his/her role as a practice leader to implement NI/MI.

Goals and behavior regulation

(TDF definition "goals": Anything aimed at managing or changing objectively observed or measured actions; TDF definition "behavior regulation": Anything aimed at managing or changing objectively observed or measured actions)

Few comments were grouped here, and most had already been categorized under other domains. The goal of implementing NI/MI was a facilitator:

G2: Well the biggest benefit is to the patient directly to avoid having restorative work done on their teeth and preserving the natural tooth structure ... maintaining ... existing tooth structure should be of paramount priority.

Only one comment was grouped under behavior regulation. This comment highlighted how patient consultation and decisions by the patient determined the course of action:

G4: I would definitely prefer a minimal invasive filling, however, in individual cases I may leave the decision up to the patient, yes ... if the patient is willing to wait then I would also wait.

Discussion

For decades, dental caries has been seen as an infectious disease, and dentists had been trained accordingly to remove all carious tissue from a tooth to "cure" the disease. Numerous studies have shown that a large part, in some countries even the majority, of dentists continue to follow that path, which involves significant overtreatment and induces unnecessary tooth tissue loss and costs [14]. The present study aimed to understand barriers and facilitators determining dentists' behavior towards non-cavitated proximal lesions. Based on such understanding, we will develop interventions to change this behavior and increase the uptake of evidence-based management of early lesions. We found a number of factors that acted as barriers or facilitators. These can be structured according to the level to which potential interventions can be directed; that is, the individual, practice and healthcare levels.

On an individual level, the dentists' knowledge, their professional role, but also the individual patient and his/her adherence and risk profile have been found to significantly impact on the management of non-cavitated proximal lesions. Dentists basing their decision on outdated knowledge as to the pathogenesis of caries – and those not attending continuous professional development in the field of cariology – seem to adhere to "traditional" management options more frequently. There are a number of ways for tackling this. First, undergraduate education should follow current standards in cariology, as outlined for example in the European Core Curriculum for Cariology [26]. This might not be the case for all universities at present [27]. Second, continuous professional development should not be only mandatory in fields like first aid and radiology, as is currently the case, but also in cariology (with caries being the most frequently found disease in dentistry).

Dentists also decide their interventions based on patients' characteristics, like caries risk. High-risk patients are managed more invasively, as has been found in numerous other studies [14]. We showed that such behavior is grounded in anticipated regret, assuming that the efficacy of NI/MI, for example, is lower in such high-risk individuals and the risk of needing to place a (then larger) restoration soon after. However, as demonstrated by abundant evidence, the lifetime of restorations is lower in high-risk patients [5–7, 22], and risk-group adjusted analyses showed that especially in these patients, efforts should be undertaken to holistically manage them (and not restoratively mask their symptoms) [34]. Thus, especially high-risk patients should be provided with the needed non-invasive care to modify their risk (patient-level interventions such as dietary control or biofilm control can be used, for example). In addition, and given that these patients usually also come with a less favourable utilization pattern [25], adherence-independent therapies should be used as well (dentists seem to perceive restorations as such therapy). Sealing and infiltration may be such therapies.

On the practice level, having a team focused on a holistic and multiprofessional management of oral health seems beneficial. It is likely that being able to interact with other oral health care professionals with differing undergraduate and continuous professional education, regulation, culture etc. may provide new perspectives on and confidence in NI/MI, as well as on the changing dentists professional role and view of themselves. The current trend to practices with more than one practitioner, relying on a team of care providers, may be beneficial in that sense [2, 11].

Finally, on a system's level, the remuneration model for dental care should be re-thought. While there is an ongoing debate over the mode of dental remuneration (fee-per-item versus capitation) [24], it is clear that regulators should incentivize preventing disease and avoiding invasive re-interventions and tooth loss. The current focus on restorative and/or prosthetic dentistry is unlikely to be suitable to facilitate NI/MI [3, 4, 37].

In conclusion, and within the limitations of this qualitative study, a range of factors on individual, practice and healthcare level were identified as barriers and facilitators. These could be targeted to enhance dentists' uptake of NI/MI for managing non-cavitated proximal caries lesions [19, 21].

Conflicts of Interest:

The authors declare that there is no conflict of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

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Appendix 1: Interview Guide

Welcome and establishment of ground rules

Participants will be thanked for agreeing to take part in the study and sparing time for the interview. They will be reassured there are no right or wrong answers. It will be explained that the use of a tape recorder by the researcher is to help them remember what is said without them having to take notes. Participants will be assured that the researcher will treat the information given as confidential.

The interviewer will then inform the participant about the focus of the study which is on gaining more information about the barriers and enablers for dentists in using non- or micro-invasive measures for managing proximal lesions confined to the outer half of enamel and at the enamel-dentine junction. Non- or micro-invasive measures include applying remineralizing agents (fluoride varnish, CPP-ACP etc.), proximal sealing or caries infiltration, flossing and/or demonstrating oral hygiene maintenance.

Thinking generally in relation to these recommendations, please explore the following. There are no right or wrong answers!

The interviewer will be open to the participants' narratives and flexible in switching between the interview topics. The following is therefore a guide based on the domains from the revised theoretical domains framework. Although all domains need to be covered, the interview can be flexible in their approach to the interview structure.

Background: To begin, participants will be asked:
- Job title, years of experience since qualification
- Brief synopsis of place of work (solo/group practice; private-insurance/public mix; rural/urban; number of patients registered; number of dentists/hygienists in practice; remuneration system e.g. fee-for-service, capitation)

Current Practice/Skills:
- Ask the participant to describe the routine care they'd provide to manage proximal lesions confined to the (1) outer half of enamel and (2) at the enamel-dentine junction in the permanent teeth of an adolescent or adult.

Prompt: What were the circumstances? Why was the decision made? Is this situation common?

1. Knowledge and Skills
Are you aware of any guidelines in relation to non- or micro-invasive measures for the management of proximal lesions confined to the outer half of enamel (or at the enamel-dentine junction)?
- If yes, what is your understanding of the recommendation for management of permanent teeth?
- How strong do you think the evidence is for the recommendations? Is there anything that would give you more confidence in the guidance?
- Does the guidance help you give non- or micro-invasive management to patients? Why or why not?

2. Intentions/ Social/Professional Role and Identity
Do you view it as your responsibility to ensure non- or micro-invasive management is carried out in every situation possible? Is it a priority for you in your professional role?

Is management with non- or micro-invasive measures rather than restoration something that you intend to do wherever possible in the future? If yes, explore whether this maps to current practice. If no, explore why their intentions aren't in line with guidelines.

3. Goals/Behavioural Regulation
Are non- or micro-invasive measures part of a routine you have for managing all patients with proximal lesions confined to the outer half of enamel (or at the enamel-dentine junction)?

Are there procedures or ways of working that would make it easier using non- or micro-invasive measures as a 'first step' rather than restoring proximal lesions confined to the outer half of enamel (or at the enamel-dentine junction) (prompts: training needs, courses; guidelines)?

4. Beliefs about Consequences/Reinforcement
What are the benefits/advantages of using non- or micro-invasive measures as a 'first step' instead of restoring lesions at the (1) outer half of enamel and (2) enamel-dentine junction lesions? (prompt: To you? Your patients? Time? Staff resources? Financial incentives/disincentives? Prevent caries?)

Are there any disadvantages/downsides of using non- or micro-invasive measures instead of restoring proximal lesions confined to the outer half of enamel (or at the enamel-dentine junction)?

Do you think the benefits of non- or micro-invasive measures outweigh the costs?

5. Environmental Context and Resources
To what extent do factors within your practice influence your ability to use non- or micro-invasive measures?
- physical resources (e.g. access to equipment; more staff/space)
- finances (e.g. time available; remuneration)
- colleague's expectations, beliefs, attitudes etc.

(prompt: which factors act as barriers and which as facilitators?)

What factors related to your patients may influence your decision?
- co-operation, expectations, beliefs, attendance record, oral hygiene etc.

(prompt: which factors act as barriers and which as facilitators?)

What about factors outside your practice influence your decision whether you use non- or micro-invasive measures? (e.g. dental association, health policy, performance targets)
(prompt: which factors act as barriers and which as facilitators?)

6. Social Influences
Is non- or micro-invasive management something that your patients want?
Is managing proximal lesions confined to the (1) outer half of enamel and (2) enamel-dentine junction by non- or micro-invasive actively supported by colleagues in your practice?
In what way does the wider dental profession influence your decision about preventive management?

7. Other
Is there anything else about the non- or micro-invasive management of caries that you would like to mention that we haven't already covered?
Is there anything that you have found the most helpful in assisting you in adopting non- or micro-invasive caries management? (if haven't adopted – what would be the most helpful in assisting you?)
Who would you trust/consider to be an expert/leader in the non- or micro-invasive management of caries?

Closing
Participants will be asked if they would like to add any further information and thanked for the discussion. Participants will be de-briefed on the next steps of the research process. To include giving participants product voucher and recommendations on non-invasive management of lesions.