Updates on Caries Management in the Primary and Permanent Dentition

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Guest Editor

Julian Schmoeckel

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Guest Editor
Julian Schmoeckel
Pediatric Dentistry
University Medicine of
Greifswald
Greifswald
Germany

Editorial Office
MDPI AG
Grosspeteranlage 5
4052 Basel, Switzerland

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Editorial

Updates on Caries Management in the Primary and Permanent Dentition

Julian Schmoeckel

Department of Pediatric Dentistry, University Medicine Greifswald, 17489 Greifswald, Germany; julian.schmoeckel@uni-greifswald.de

Caries is still one of the most prevalent diseases affecting children and adults worldwide [1]. Reducing its prevalence and improving the quality of dental care, along with the oral-health-related quality of life, should, therefore, be a major goal.

The aim of this Special Issue was to present innovative approaches, high-quality clinical, epidemiological, and dental public health research, or translational research on several aspects of the management of dental caries (preventive/non-invasive, minimally invasive, operative approaches) in children and adults.

First of all, I would like to emphasise that this Special Issue contains a variety of study types, reflecting the different options in research methodology: meta-analysis, systematic reviews, epidemiological research, laboratory studies, retrospective and prospective clinical studies, RCTs, and innovative case series. Furthermore, the Special Issue includes articles on the management of caries in primary teeth and permanent teeth, as well as root caries. This demonstrates the different approaches and perspectives in cariology.

I am delighted that this completed Special Issue contains interesting innovations relating to this topic. In the following, I would like to summarise and highlight specific aspects of the contents of this Special Issue and give my personal outlook for the future.

An epidemiological study on oral health in children in Burundi showed a significant level of caries experience and a very low treatment index, highlighting that caries treatment does not reach the children [2]. This underlines the importance of improvements in prevention and easily assessable and inexpensive management options.

The number of papers in this Special Issue dealing with silver fluoride (SDF) products shows that this is a hot topic and should not be seen as an unsatisfying compromise for so-called "third-world countries" but as a viable alternative or synergistic option for caries management at any stage and on any tooth surface in any patient worldwide.

To my knowledge, two of the published papers [3,4] are related to award-winning presentations at the ORCA Congress 2023 [3] and 2024 [5]. Interestingly, both deal with the use of silver fluoride: (1) in primary teeth, which may eventually dramatically reduce the need for dental general anaesthesia [6], and (2) for young permanent teeth, providing the first pilot data of a reported innovative approach to managing non-cavitated proximal caries [5]. This provides new insights into the potential of silver diamine fluoride (SDF) for treatment of early childhood caries (ECC) [7], as well as options for the management of proximal caries that go beyond the findings from a recent systematic review and meta-analysis [8]. In addition, a double cohort study comparing SDF and 5% fluoride varnish showed that both materials reduced hypersensitivity in children with ECC, but that the potential for caries arrest was much higher with SDF [9].

A laboratory study has shown that an individual's diet may influence the colour stability and microhardness of composite restorations, which are probably one of the most common treatment approaches for caries worldwide [10].

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A long-term split-mouth clinical study from Lithuania compared the survival rate of resin-based and GIC-based fissure sealants and showed that their effectiveness in preventing fissure caries in permanent second molars did not differ significantly over a 10-year follow-up period [11].

A meta-analysis of RCTs on the selective caries removal technique in permanent teeth also confirms, in line with another earlier consensus from ORCA [12,13], that selective caries removal is a less invasive approach to pulp tissue perseveration compared with conventional "complete caries removal" techniques [14].

A fairly wide-ranging systematic review on the cost-effectiveness of ECC treatment shows that socio-economic, cultural, and ethnic differences need to be taken into account [15]. This is particularly important in populations with a high prevalence of ECC and with a highly polarised distribution of ECC, in order to implement the most cost-effective approaches.

The direction of minimally invasive dentistry is also favoured by the authors of a study on root caries [16], which shows that the progression of initial active root carious lesions using GICs may be an interesting and promising approach.

Last but not least, a study on decision making for caries management in children shows that this part is much more complex than a tooth-level decision. Consequently, there is a need for simple and effective treatments, while unfortunately, there is still a tendency for too invasive or unrecommended treatment suggestions. The main challenge is to always make the correct diagnosis based on appropriate examinations (clinical, radiographic, etc.). Perhaps future innovations in artificial intelligence will assist dentists in facilitating diagnosis, and robots will be able to perform the necessary restorations or procedures.

I am confident that in the future, with continued research and development of novel treatment strategies, further reductions in the caries prevalence in all age groups worldwide will be achieved. Personalised medicine, multimodal and interdisciplinary management, and digital innovations can further transform the way in which we approach the field of cariology, both clinically and scientifically. Several aspects in the field of caries management have been addressed in research, but there are still relevant gaps, mainly in the areas of research on cost-effectiveness and the translation of knowledge into everyday dental practice. These advances will bring us closer to our goal of improving the oral-health-related quality of life of millions of children, adolescents, adults, and seniors.

Conflicts of Interest: The author declares no conflicts of interest.

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Article

Dental Decision-Making in Pediatric Dentistry: A Cross-Sectional Case-Based Questionnaire Among Dentists in Germany

Bakr A. Rashid [1], Ahmad Al Masri [1,2], Christian H. Splieth [1], Mustafa Abdalla [3] and Julian Schmoeckel [1,*]

[1] Department of Pediatric Dentistry, University Medicine Greifswald, Walther-Rathenau Str. 42a, 17475 Greifswald, Germany; bakr.rashid@stud.uni-greifswald.de (B.A.R.); ahmad.almasri@uni-greifswald.de (A.A.M.); splieth@uni-greifswald.de (C.H.S.)
[2] Department of Orthodontics, University Medicine Greifswald, Walther-Rathenau Str. 42a, 17475 Greifswald, Germany
[3] MyPediaClinic, Dubai Healthcare City, Dubai P.O. Box 505206, United Arab Emirates; drmustafaabdalla@hotmail.com
* Correspondence: julian.schmoeckel@uni-greifswald.de; Tel.: +49-383-486-7167

Abstract: *Background and Objectives*: The most recent guidelines and recommendations regarding treatments of dental caries in children are shifting towards evidence-based minimal or non-invasive approaches aiming to preserve the vitality of teeth and potentially reduce the need for dental general anesthesia. This study investigated the treatment recommendations of dentists actively practicing pediatric dentistry in Germany regarding different patient cases with caries in primary teeth. *Materials and Methods*: The questionnaire was distributed on paper or online to pediatric dentists and general dentists practicing pediatric dentistry. Five cases of children with dental treatment needs representing a variety of clinical situations were selected for the questionnaire. Considering four different scenarios regarding pain symptoms (yes/no) and cooperation level (good/low) for each case resulted in 20 questions, where the preferred treatment option could be chosen out of 21 options ranging from observation only to extraction with/without different sedation techniques. The answers were categorized into three categories for each case and scenario according to guidelines, recent scientific evidence, and recommendations (recommended, acceptable, or not recommended/contraindicated). *Results:* In total, 222 participants responded to the survey (161 female; 72.5%). In 55.2% of the total 4440 answers, the participants chose a "recommended" treatment option, in 16.4% "acceptable", but in 28.4%, a "not recommended" treatment, which ranged for the five cases between 18.7 and 36.1%. While pain and low cooperation levels led to more invasive and justified treatment choices (only 26.3% "not recommended"), less severe scenarios resulted more often in "not recommended" options (pain with good cooperation: 31.0%; or low cooperation without pain: 32.6%). The dentist's age, experience, and educational background did not significantly correlate to choosing "not recommended" treatment options. *Conclusions:* A child's pain and cooperation level greatly impact the treatment decisions made by dentists, with a risk of too-invasive treatment options in low-severity cases. Substantial disparities in treatment recommendations for caries in primary teeth persist among dental practitioners regardless of their age, experience, and educational background.

Keywords: dentistry; primary teeth; dental treatment; decision-making; nitrous oxide sedation; general anesthesia

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1. Introduction

Decision-making in medicine and dentistry is one of the most critical steps before initiating any clinical treatment. Especially in pediatric dentistry, many factors should be considered in the process of decision-making, far beyond tooth level, such as the cooperation level of the child, the overall oral treatment need, caries risk and activity, the

accuracy of the diagnosis, potential risks of the treatment and sedation options, the financial aspects, and the duration of the treatment [1–3]. In modern dentistry, reaching a treatment decision is not done by the dentist alone (anymore). A change from the traditional, rather so-called "paternalistic" approach to more participative approaches with informed consent has occurred in medicine and dentistry in the past decades [4], which is oriented toward the autonomy of the patients and includes their competencies. Pediatric health care has the challenge of having "immature" patients with limited cooperation and understanding of health issues, as well as difficulties regarding parental preferences. This makes decision-making in pediatric dentistry far more challenging than other specialties in dentistry, which should not be underestimated, as the initial recommendations of the dentist for a certain treatment path lay the basis for later communication and decision-making with informed consent from the parent or the guardian [3].

The challenges in decision-making in pediatric dentistry extend beyond finding the balance between parental preferences and children's capabilities, as the treatment options on the tooth level have witnessed a shift towards minimal or non-invasive approaches. The conventional restoration (CR) of a cavity on a primary tooth using amalgam, glass ionomer cement, resin composite, or polyacrylic acid-modified composites used to be the standard treatment in pediatric dentistry [5]. These types of restorations are still widely used, even though they show weak performance with a high need for retreatment [6] and may be associated with a high risk of restoration failure and pulpal complications [7]. With a correct pulp diagnosis of reversible pulpitis, selective carious tissue removal or caries sealing (e.g., the Hall technique) could be performed, avoiding complete caries removal near the pulp and minimizing the risk of pulp exposure, which can preserve the vitality of the primary molar [8]. Non-restorative cavity control (NRCC) is also a modern concept that aims to arrest the progression of caries through oral hygiene after removing overhanging enamel and dentin, if needed, to make the lesion accessible, which should be followed by repeated and regular biofilm removal as well as fluoride application to stimulate the remineralization of the carious tooth structure and stop the activity of the lesion arresting its progression, which requires the high adherence of patients and/or parents to manage the lesion [2]. The integration of silver diamine fluoride (SDF) and the Hall technique (HT) into modern caries management in pediatric dentistry has expanded the dental treatment spectrum in pediatric dentistry and provided options for children with limited cooperation, offering effective solutions with minimal invasiveness. These evidence-based approaches provide comprehensive care while prioritizing the preservation of tooth structure and patient comfort [9–11]. Moreover, sedation methods such as nitrous oxide or general anesthesia (GA) widen the spectrum of treatment approaches even further, which makes the decision on the best treatment approach in different circumstances in pediatric dentistry even more challenging. In general, no single treatment option is the only possible, and no treatment option can always be considered the best. However, some good treatment options might be considered unsatisfactory in certain circumstances or situations. For instance, a pulpotomy on a symptomless primary tooth with (deep) proximal dentin caries is an evidence-based approach with reported high success rates. Still, in a case of low cooperation, the treatment would probably require sedation or even GA. Considering the risks of GA along with other less invasive evidence-based approaches, such as the HT with a diagnosis of reversible pulpitis, a pulpotomy could be considered disadvantageous as the HT is possible even in the case of limited cooperation, avoiding the need for DGA [12].

With these wide ranges of treatment options and approaches in pediatric dentistry and the shift towards minimal and non-invasive treatments, it remains unclear whether daily clinical practices are following the updates in the literature. Therefore, this study aimed to investigate the treatment recommendations of dentists actively practicing pediatric dentistry in Germany based on different cases of caries in primary dentition, with suggested scenarios considering pain symptoms and cooperation levels.

2. Materials and Methods

This questionnaire-based study includes five cases with clinical and/or radiographical pictures suggesting different dental treatment options with different scenarios.

2.1. Study Population and Data Collection

As the study aimed to investigate the different approaches of dentists in different clinical scenarios and cases in pediatric dentistry, it was necessary to include a large number of participants actively practicing pediatric dentistry, regardless of their qualifications and specialization. The questionnaire was sent via email to all listed pediatric dental clinics from the website of the German Society for Pediatric Dentistry (DGKiZ, N = 360) and to all participants in, as well as graduates of, a postgraduate master's program in Preventive and Pediatric Dentistry at the University of Greifswald in Germany (N = 108). Moreover, the questionnaire was handed out personally to general dentists in Germany (N = 86) who were attending continuing education courses in the field of pediatric dentistry before the start of the course to avoid bias. To calculate the sample size, the population size of dentists practicing pediatric dentistry was anticipated to be around 3500. With a 95% confidence interval and a 10% margin of error, a sample size of 94 was needed. Data collection was done in the period from March 2020 to August 2022.

2.2. The Questionnaire

A questionnaire was designed to include five typical cases of dental caries in primary teeth with clinical and/or radiographical pictures. Participants were asked to choose their recommended treatment option for each case 4 times for different scenarios that reflect real-life scenarios in pediatric dentistry. The four scenarios for each case were as follows:

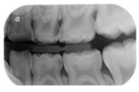
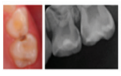
- No reported pain, cooperative child (P−, ↑);
- No reported pain, uncooperative child (P−, ↓);
- Reported pain symptoms, cooperative child (P+, ↑);
- Reported pain symptoms, uncooperative child (P+, ↓).

The predefined treatment options for the cases with the different scenarios in the survey were 20 in total. They ranged from observation to invasive treatment options such as endodontic treatment or extraction of the tooth, considering also the treatment setting, such as nitrous oxide sedation or GA. The participants had an extra space after each question for typing a treatment option other than the listed ones. Traditional treatment options such as complete caries removal and filling and modern, less traditional treatment modalities such as silver diamine fluoride (SDF) and the Hall technique (HT) were all included as options. An overview of the treatment options and the cases can be seen in Table 1.

The five selected cases included a range of clinical situations concerning children with dental treatment needs, which covered most of the problems and challenges in caries management in primary teeth (Table 1):

- **Case 1:** arrested deep carious lesions (ICDAS 6) on first primary molars (74, 84) in a preschool child;
- **Case 2:** active deep proximal carious lesion (ICDAS 5) on a second primary molar (85) in a preschool child with high caries experience;
- **Case 3:** proximal carious lesion on a first primary molar (74, likely ICDAS 4, detected in bitewing radiograph as D2 lesion) in an elementary schoolchild;
- **Case 4:** clinical and periapical X-ray showing a proximal ICDAS 5 lesion and an occlusal ICDAS 4 lesion on a second primary molar with a dentine bridge between the lesion and the pulp in a preschool child;
- **Case 5:** clinical picture of semi-active dentine carious lesions on anterior primary teeth (Early Childhood Caries; 3-year-old child).

Table 1. The cases and scenarios along with the percentage-wise assignment of each treatment option to the categories of level of recommendation (colors), and the results of the participants in percentages (n = 222).

Cases	Case 1 Arrested ICDAS 6 on #74 and #84				Case 2 Active ICDAS 5 #85				Case 3 ICDAS 4 Proximal #74				Case 4 ICDAS 4 Okklusal and ICDAS 5 Proximal #65				Case 5 ECC #52–62			
Clinical/radiographical pictures																				
Treatment options/different scenarios *	P− ↑	P− ↓	P+ ↑	P+ ↓	P− ↑	P− ↓	P+ ↑	P+ ↓	P− ↑	P− ↓	P+ ↑	P+ ↓	P− ↑	P− ↓	P+ ↑	P+ ↓	P− ↑	P− ↓	P+ ↑	P+ ↓
No treatment/observation only	2.7	6.3	-	1.4	-	3.2	-	1.8	0.9	4.5	0.5	2.7	0.9	1.8	0.5	2.7	0.9	4.5	2.7	3.6
Non-restorative caries control: fluoride varnish and brushing instructions	10.8	30.6	-	0.5	1.8	8.6	-	2.7	2.7	18.0	0.9	6.3	2.7	10.4	0.5	1.8	15.3	24.8	1.4	3.2
Silver diamine fluoride application	2.3	19.4	0.5	5.0	1.4	24.8	0.5	4.1	1.4	14.0	0.9	8.6	0.9	20.7	1.4	4.1	17.1	34.2	6.3	7.2
Atraumatic restorative treatment with glass ionomer filling (ART)	3.6	4.5	2.7	3.6	1.8	9.0	2.3	6.8	1.8	3.6	2.3	2.7	2.3	9.5	2.3	2.7	3.2	4.1	1.8	0.9
GIC filling (with complete caries removal)	2.7	1.4	1.8	1.4	5.9	2.7	4.1	2.3	4.5	3.2	3.2	1.8	3.6	3.2	1.8	2.3	0.5	0.5	-	0.9
Compomer filling (selective caries removal)	15.3	2.7	6.8	1.4	19.4	2.3	4.5	1.4	23.0	5.9	14.0	2.7	15.8	3.6	6.8	0.5	11.7	1.8	7.2	0.5
Compomer filling (complete caries removal)	8.1	-	4.5	-	17.1	0.9	8.6	0.5	33.8	8.1	19.8	5.4	25.2	3.6	6.3	0.5	3.3	0.5	2.3	-
Zirconia pediatric crown	0.5	-	0.9	-	-	-	-	-	-	-	-	-	-	-	-	0.5	9.9	5.4	5.9	3.6
Strip crown composite restoration	-	-	-	-	-	-	-	-	0.5	-	0.5	-	-	-	-	-	28.8	6.3	10.4	2.3
Stainless steel crown (SSC) in Hall technique (no caries removal, no preparation)	24.8	13.5	1.4	1.8	13.5	15.3	2.7	3.6	12.2	19.8	6.8	11.7	16.2	14.0	1.4	0.5	0.5	0.5	0.5	0.9
SSC in conventional technique (complete caries removal, preparation)	8.6	0.9	1.8	0.5	10.8	1.8	6.8	0.9	7.7	1.4	5.9	0.9	6.8	1.8	5.9	0.9	--	-	0.5	-
Pulpotomy and SSC	11.7	1.4	37.4	1.4	18.9	0.9	36.9	-	7.7	-	26.1	2.3	19.4	0.9	39.6	2.3	-	-	1.8	-
Pulpotomy and SSC with nitrous oxide sedation	4.5	3.6	6.8	15.8	4.5	7.7	8.6	19.4	1.4	9.5	8.1	16.7	3.2	11.3	9.0	21.2	0.5	-	0.9	-
Pulpotomy and SSC under general anesthesia	0.5	8.1	3.6	19.4	2.7	17.6	2.7	25.2	0.5	8.1	1.8	20.3	0.9	14.9	1.8	23.9	0.5	0.9	1.8	2.7
Calcium hydroxide/iodoform paste, pulpectomy, and SSC	1.4	-	8.6	-	1.4	0.5	10.4	0.5	0.9	0.5	3.6	-	1.4	0.5	9.5	0.9	-	0.5	4.5	-
Calcium hydroxide/iodoform paste, pulpectomy, and SSC with nitrous oxide sedation	-	0.9	4.1	5.0	-	0.5	2.7	6.3	-	0.5	0.9	4.1	0.5	1.4	4.5	7.7	-	0.5	0.9	4.5
Calcium hydroxide/iodoform paste, pulpectomy, and SSC under general anesthesia	0.5	0.9	0.5	7.7	0.5	2.3	1.8	7.7	1.4	3.2	1.4	4.5	-	1.8	1.4	9.5	0.9	1.4	3.6	7.2
Local anesthesia extraction	1.8	-	12.2	0.5	-	0.5	3.6	0.9	-	-	1.8	-	-	-	5.4	0.9	2.3	0.9	16.7	2.3
Local anesthesia extraction with nitrous oxide sedation	0.5	1.4	5.9	9.5	0.5	0.5	3.2	5.0	-	-	1.4	5.0	-	-	2.3	6.8	-	2.3	14.0	7.7
Extraction under general anesthesia	-	4.5	0.9	25.7	-	1.4	0.9	11.3	-	-	0.5	4.5	0.5	0.9	-	10.8	5.5	11.3	17.1	52.7
Percentage of chosen recommended treatment options	71.6	74.3	74.8	52.7	59.5	57.7	65.3	49.1	76.6	19.8	34.2	11.7	58.1	45.0	70.3	50.9	83.8	63.5	30.6	52.7
Percentage of chosen possible and acceptable treatment options	13.1	3.6	5.0	30.2	1.8	25.2	7.7	36.0	13.1	41.4	48.2	33.8	-	-	-	31.1	3.2	6.3	8.1	19.8
Percentage of chosen not recommended or contraindicated treatment options	15.3	22.1	20.3	17.1	38.7	17.1	27.0	14.9	10.4	38.7	17.6	54.5	41.9	55	29.7	18	13.1	30.2	61.3	27.5

Green colored: Recommended treatment. Yellow colored: Acceptable treatment. Red colored: Not recommended/contraindicated treatment. * Abbreviations and symbols: ↑: cooperative child, ↓: uncooperative Child, P+: pain symptoms, P−: no pain symptoms, ART: atraumatic restorative treatment, ECC: Early Childhood Caries, GIC: glass ionomer cement, ICDAS: International Caries Detection and Assessment System, SSC: stainless steel crown.

All the cases and questions focused on a specific tooth, and not on all carious teeth in the pictures because patient-level decisions are much more complicated and require a thorough explanation for many related factors, which would lengthen the questionnaire and the time required to fill it out and thus reduce the response rate. However, patient-related aspects were still considered in the scenarios mentioned above, mainly regarding pain symptoms and the cooperation level of the child. Other relevant information on the patient level is obtainable from the given pictures/radiographs, such as caries experience/risk/activity and phase of dentition.

Moreover, to investigate the factors influencing dental decision-making, the demographic data of the participants were collected, as well as answers to further questions regarding the number of children treated per week, years of experience as a dentist, years of experience with nitrous oxide sedation and GA, and years of practice as a specialist in pediatric dentistry.

2.3. Ethical Considerations

This study was conducted in full conformance with the principles of the "Declaration of Helsinki" and Good Clinical Practice (GCP) and within the laws and regulations of Greifswald University. Whether on the paper form or online, informed consent was obtained from all participants before filling out the questionnaire. Ethical approval was obtained from the Ethical Committee of the University of Greifswald (BB 052/20). The clinical intra-oral pictures of the patients were presented anonymously to study participants, as consent was taken from the parents/guardians of the children to use the intra-oral photos and/or X-rays in anonymous form for research purposes.

2.4. Treatment Recommendations

Three specialists in pediatric dentistry from the University of Greifswald met to develop an outline for rating the treatment options for the different cases with consideration of the scenarios; two of the three were specialist pediatric dentists and members of the university teaching staff with clinical experience, while the third was a last year postgraduate student in a master program in Preventive and Pediatric Dentistry. A fourth specialist pediatric dentist, who was the head of the Department of Preventive and Pediatric Dentistry at the university and of the mentioned master's program, with a leading role in many worldwide recognized organizations in the field of cariology and pediatric dentistry, was consulted for his opinion in the treatment recommendations. The decision on categorizing the treatment options was thus based on the actual international recommendations and guidelines, yet with consideration of clinical real-life experience. The treatment options were divided according to the case and the suggested scenario into the following categories:

- **Recommended treatment options:** treatment options that follow the up-to-date evidence-based recommendations and guidelines for the management of the mentioned tooth/teeth, considering the suggested scenario regarding pain symptoms and the cooperation level of the child;
- **Possible and acceptable treatment options:** treatment options that do not follow the up-to-date evidence-based recommendations and guidelines for the management of the mentioned tooth/teeth, considering the suggested scenario regarding pain symptoms and the cooperation level of the child. However, although these treatment options are not up-to-date, they are still not contraindicated and could be performed;
- **Not recommended and contraindicated treatment options:** treatment options that do not follow the up-to-date evidence-based recommendations and guidelines for managing the mentioned tooth/teeth, considering the suggested scenario regarding pain symptoms and the cooperation level of the child, which are disadvantageous or even contraindicated.

2.5. Statistical Analysis

The questionnaire responses were exported to an Excel sheet (Microsoft Office 2021), anonymously coded, assigned to the categories of recommendation level as in Table 1, and exported into IBM SPSS for Windows (Version 23.0) for analysis. Frequencies and percentages were calculated for all qualitative variables, while means and standard deviations (SDs) were computed for quantitative variables. To investigate the factors influencing dental decision-making, the number of chosen "not recommended and contraindicated" treatment options was analyzed as the dependent variable. The independent variables considered were age, years of experience as a dentist, experience with nitrous oxide (in years), experience with general anesthesia (in years), years of practicing as a specialist, and the number of children treated per week.

A negative binomial regression model was used to investigate the factors that might lead to choosing an increased number of contraindicated treatment options. A further analysis was performed for each of the independent variables separately to investigate if any of these variables would show an effect on the total numbers of selected "not recommended/contraindicated" treatment options, where a Mann–Whitney test was performed

for the categorial variables and Pearson correlation was used for the continuous variables. Moreover, a chi-square analysis was performed to analyze the differences in the distribution of the answers to the three categories of recommendation level between the cases and the scenarios. Statistical significance was set at a *p*-value of <0.05.

3. Results

In total, 222 participants responded to the survey. A total of 54 responses were in paper form (24.3%), while the majority of responses were collected through the online version (75.7%, $n = 168$). The total number of participants consisted of participants who are still attending or have completed a postgraduate master's program in Pediatric and Preventive Dentistry in Germany, general dental practitioners in Germany, and members of the German Society for Pediatric Dentistry (DGKiZ e.V.). As efforts were made to invite as many practitioners as possible to participate in the survey, participants were asked to forward the online version of the questionnaire to colleagues in the same field. Thus, the precise number of participants who received the invitation and the exact response rate could not be calculated.

Table 1 shows the five cases of the questionnaire with the suggested scenarios and all the treatment options that were available in the questionnaire, as well as the percentages of the answers of the participants for each scenario (↑: cooperative child, ↓: uncooperative Child, P+: pain symptoms, P−: no pain symptoms) categorized into the three above-mentioned groups.

Table 2 provides the demographic and biographic characteristics of the respondents, along with the results of the negative binomial regression to investigate the variables' relation to the total number of not recommended/contraindicated treatment options for each participant.

The Pearson correlation and Mann–Whitney tests revealed no significant association between choosing the "not recommended/contraindicated" treatment options with any of the study variables, such as years of experience, the educational background of the dentist in pediatric dentistry, the number of patients per week, etc. (Table 2).

The total of answers in the not recommended category in the five cases ranged from 18.7 to 36.1% according to the cases, regardless of the specific scenarios, as illustrated in Figure 1. Case 4 (cavitated D2 approximal lesion) showed the highest percentage of chosen not recommended treatment options (36.1%), while case 1 (inactive lesions) had the lowest percentage with 18.7%. The differences between the cases in the distribution of answers to the assigned categories were statistically significant, as shown by the chi-square independent test ($p < 0.01$).

When considering the specific scenarios, regardless of the cases, there were statistically significant differences between the scenarios in the distribution of the answers, as depicted in Figure 2 (chi-square test $p < 0.01$). The percentages of the chosen not recommended treatment options for the scenarios "no pain and uncooperative patient" and "pain and cooperative patient" (32.6% and 31.0%, respectively) were higher than for the scenarios "no pain and cooperative patient" and "pain and uncooperative patient" (23.9% and 26.3% respectively).

Table 2. The demographic characteristics of the study population and the correlation of these variables with the number of not recommended/contraindicated answers.

	Mean Value ± SD	*p*-Value (Negative Binomial Regression as Continuous Variable)	Groups	Total Number	*p*-Value (Negative Binomial Regression as Categorial Variable)
Age	37.1 ± 9.8	0.582	-	-	-
Sex	-	-	Male	61 (27.5%)	0.704
			Female	161 (72.5%)	
Children treated per week	45.7 ± 78.2	0.402	-	-	-
Experience as a dentist (years)	11.7 ± 9.1	0.972	-	-	-
Experience with nitrous oxide sedation (years)	2.4 ± 4.9	0.403	Yes	104 (46.8%)	0.999
			No	118 (53.2%)	
Experience with GA (years)	4.89 ± 7.1	0.768	Yes	147 (66.2%)	0.534
			No	75 (33.8%)	
Experience as specialist pediatric dentist (years)	3.03 ± 5.3	0.649	Yes	120 (54.1%)	0.341
			No	102 (45.9%)	

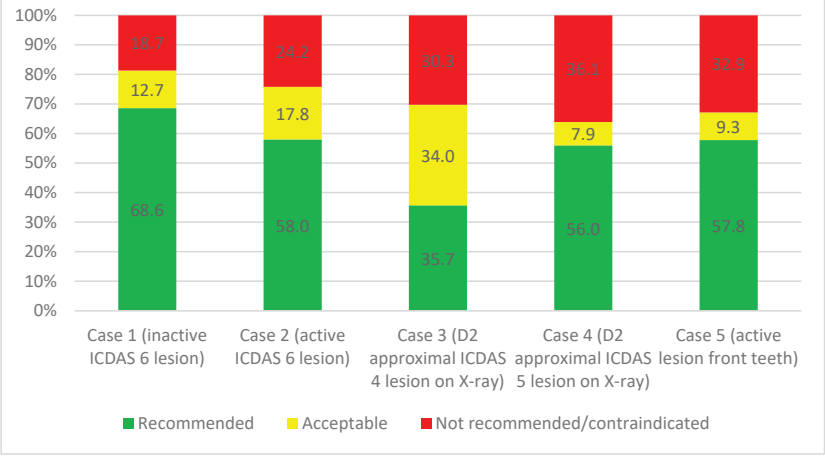


Figure 1. The percentages of the treatment options in the different cases were categorized according to the level of recommendation (n = 888 answers for each case in the four different scenarios from the 222 participants), differentiated by recommended, acceptable, and not recommended/contraindicated.

The percentage of the chosen not recommended/contraindicated treatment options did not differ when considering only the cooperation level of the child regardless of the pain symptoms. In contrast, the percentage of the chosen recommended treatment options was much less in scenarios with limited cooperation (Figure 3). These differences were statistically significant, as shown by the chi-square independent test ($p < 0.01$). The same pattern was also observed when considering pain symptoms regardless of the cooperation level, where pain symptoms lead to fewer chosen recommended treatment options (Figure 4). The differences between the scenarios "pain" and "no pain" in the distribution of answers to the assigned categories were statistically significant, as shown by the chi-square independent test ($p < 0.01$).

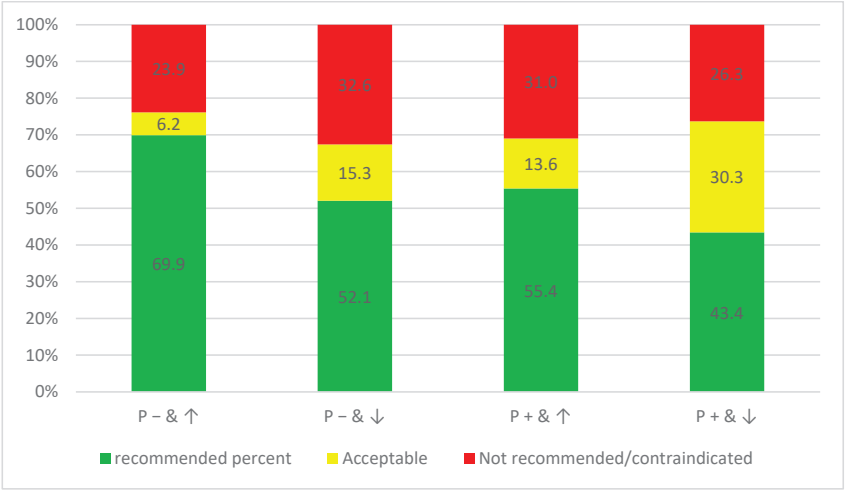


Figure 2. The categorization of the chosen treatment options regarding the suggested scenarios from the cases pooled together and shown as percentages (n = 888 answers for each scenario from all cases for the 222 participants). Differentiated by recommended, acceptable, and not recommended/contraindicated for ↑: cooperative child, ↓: uncooperative Child, P+: pain symptoms, and P−: no pain symptoms.

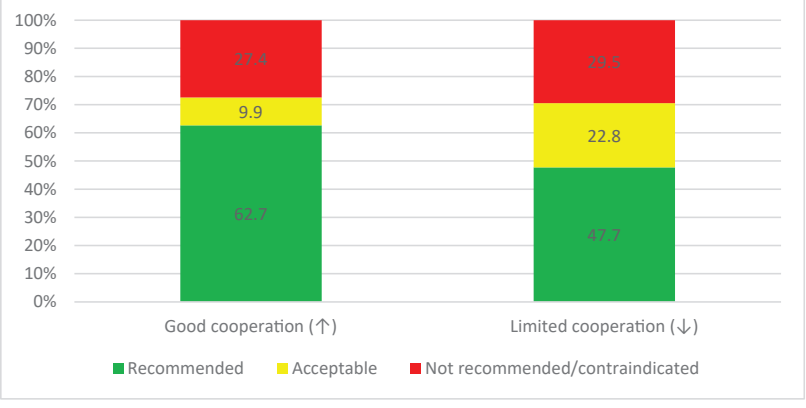


Figure 3. The categorization of the chosen treatment options regarding the cooperation of the patient from the cases pooled together, shown in percentages (n = 888 answers for each scenario from all cases for the 222 participants). ↑: cooperative child, ↓: uncooperative child.

Among the treatment options as seen in Table 1 that were classified in the category "not recommended and contraindicated" for specific scenarios, there were eight treatment options that were selected by more than 30% of the participants in these specific scenarios, which are further summarized and explained in Table 3.

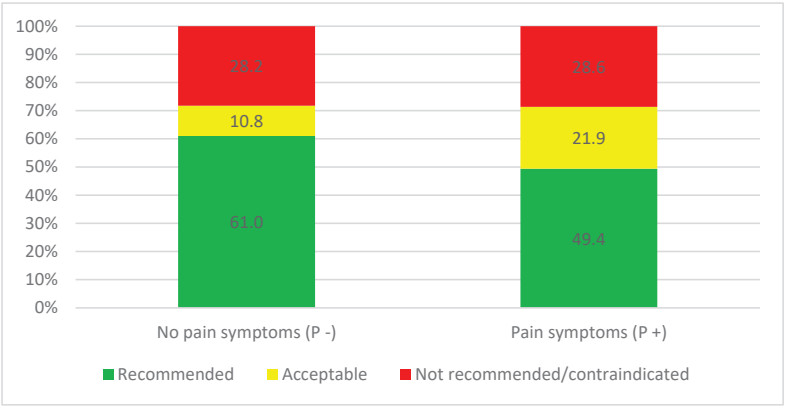


Figure 4. The categorization of the chosen treatment options regarding the symptoms of the patient from the cases pooled together, shown in percentages (n = 888 answers for each scenario from all cases for the 222 participants). P+: pain symptoms, P−: no pain symptoms.

Table 3. The treatment options, contraindicated or not recommended in specific scenarios, were chosen in ≥10% of these specific scenarios by participants, with the explanation for grouping them as contraindicated.

Treatment Option and Scenario	"Not Recommended/Contraindicated" Answers in %	Reason of Contraindication
Case 2 (Scenario: P− and ↑) Compomer filling (complete caries removal) in deep cavity	17.1%	Although symptomless, complete caries excavation in deep carious lesions is not recommended due to the risk of pulp exposure [13–15].
Case 2 (Scenario: P− and ↑) SSC in conventional technique (complete caries removal, preparation) in deep cavity	10.8%	Although symptomless, complete caries excavation in deep carious lesions is not recommended due to the risk of pulp exposure [13–15].
Case 3 (Scenario: P+ and ↓) Pulpotomy and SSC (caries media) under general anesthesia	20.3%	In this case, the pain was described as sensitivity on trigger, which indicates reversible pulpitis. GA carries risks of major and minor complications and should be avoided if possible [16,17]. There is no indication for GA as the carious lesion is not deep and, despite low cooperation, can be treated with minimal invasive options that do not require cooperation, such as the Hall technique [9,18].
Case 4 (Scenario: P− and ↑) Treatment of active caries approximal and occlusal ICDAS 4 with compomer filling (complete caries removal)	25.2%	Although symptomless, complete caries excavation in deep proximal carious lesions is not recommended due to the risk of pulp exposure [13–15].
Case 4 (Scenario: P− and ↓) Treatment of active caries approximal and occlusal ICDAS 4 with pulpotomy and SSC under general anesthesia	14.9%	GA carries risks of major and minor complications and should be avoided if possible [16,17]. There is no indication for GA as the carious lesion is not deep and, despite low cooperation, can be treated with minimal invasive options that do not require cooperation, such as the HT [9,18].

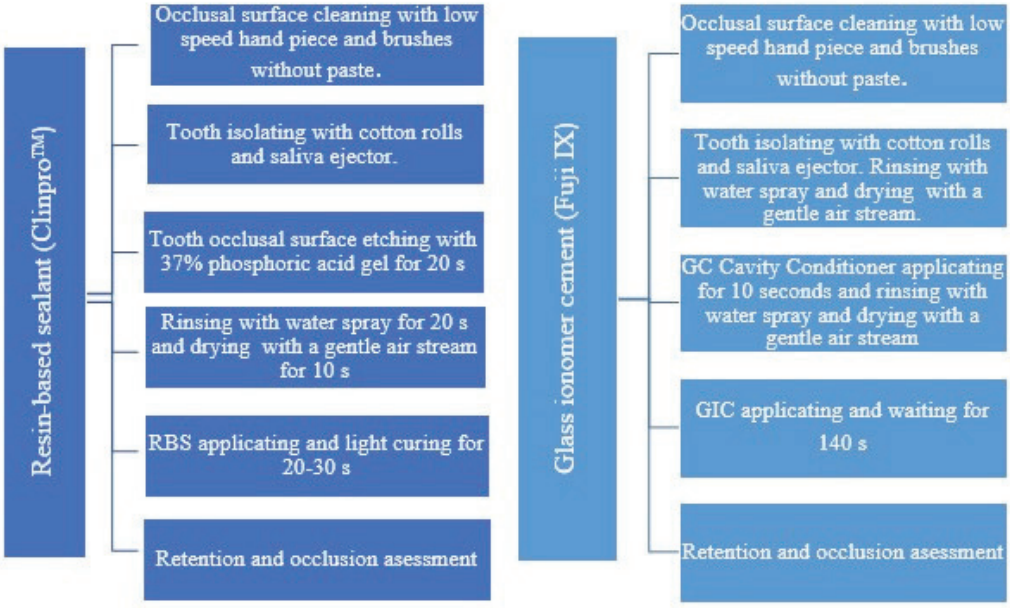


Figure 2. The step-by-step sealant application procedures for both materials (RBSs and GIC).

Professional oral hygiene was performed, and regular oral hygiene instructions were given to all participants at the beginning and during follow-up appointments.

2.4. Outcome Measurement

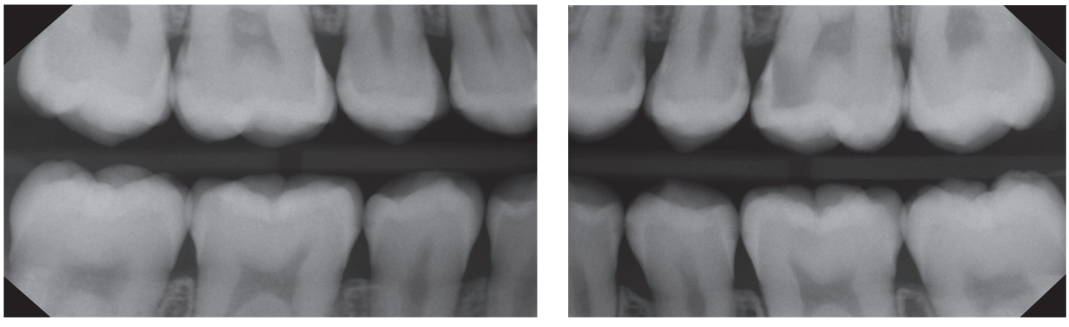
The integrity of the sealant was assessed clinically during the follow-up appointments after 1 year, 3 years, and 10 years of placement. The retention of the sealant material on each sealed tooth was determined according to the Kilpatrick criteria [40] as follows: 0 indicates complete retention, 1 indicates the loss of 1/3 of the sealant, 2 indicates the loss of 2/3 of the sealant, and 3 indicates the complete loss of the sealant (more than 2/3 of the material). The later scores of sealant retention were regrouped as complete retention (score 0), partial loss (scores 1 and 2), and total loss (score 3). In addition, all the surfaces of the teeth sealed with sealants were evaluated in terms of caries development during follow-up visits. The criteria for evaluation were the following: 0 indicates no caries, and 1 indicates caries (filling) present [41]. Later, "failure" was defined as a partial loss of the sealant or a complete loss of the sealed material and filling.

2.5. Statistical Analysis

A statistical analysis was performed using the Statistical Package for Social Sciences (SPSS version 29). A chi-square test served to measure the differences between the assessed sealant groups. The Mann–Whitney U test was used to compare the mean scores of the PI at different time periods. A comparison of different time periods with respect to the mean scores of the DMF-T index and its components (D-T, M-T, and F-T) was performed using the Wilcoxon test. A survival analysis of the different sealant materials was performed with the Kaplan–Meier method and the Cox proportional hazard model. The significance level was set at $p < 0.05$.

3. Results

Table 1 shows the demographic characteristics of the study participants, as follows: seven boys (46.7%) and eight girls (53.3%), with a mean age of 12.3 ± 0.9 years at the baseline.



(**a**) (**b**)

Figure 2. Case 1—After more than 2 years, the bitewings on the right (**a**) and left side (**b**) in 02/2022 show caries progression with a solely non-invasive caries management approach, like instructions to floss and apply fluoride varnish, before the COVID-19 pandemic. The patient is now 15 years old, and the bitewings depict the status before the decision to apply SF on the initial/non-cavitated lesions alongside the restorative treatment (composite restorations in moderate lesions, and for the deep lesion in tooth 26, selective caries removal with the application of biodentine (Septodont) prior to the restoration); see Figure 3; for a lesion assessment, see Table 1.

(**a**) (**b**)

Figure 3. Clinical photos after placement of orthodontic separators proximally but prior to SF application (04/2022, patient's age: 15 years) in the upper (**a**) and lower jaw (**b**). Tooth 26 was already treated restoratively occluso-mesially with selective caries removal and indirect pulp capping with biodentine. The black staining in 26 occurred due to SF application on the distal lesion of 25 after tooth preparation and biodentine application but before composite filling in 26, as the D1 lesion in 25 was distally clinically non-cavitated (similar to 24).

3. **Tooth separation with orthodontic rubbers:** This revealed the absence of cavitation (Figure 3a,b).

These methods were used together as it was found that a combination of all three methods could improve the number of carious lesions detected [17].

In total, 15 initial (non-cavitated) lesions were detected radiographically (02/2022): 9 enamel lesions (E1, E2) and 6 (D1) dentine lesions (Figure 2). Moreover, the high plaque and gingival bleeding index of the patient indicated that the proximal lesions were very likely active [16,18].

Therapeutic intervention

1. **Prophylaxis program**

(**a**) (**b**)

Figure 4. Clinical photos in 04/2022 directly after application of SF (riva star, SDI) in upper (**a**) and lower jaw (**b**); same day as application of separators for 2 h; patient's age: 15 years. Partial irritation and black staining of the gums can be seen interproximally, which usually disappears within a few days and does not cause long-term effects as the follow-up photos (see Figure 5) demonstrate.

(**a**) (**b**)

Figure 5. One-year follow-up after SF in 06/2023; patient's age: 17 years. Clinical photos after staining the plaque and self-brushing of the patient. Composite restorations on 24 and 26 unfortunately still show the discolorations due to SF application on neighboring teeth during the same treatment session (**a**). The staining of the other initial proximal lesions is not or is barely visible and does not cause aesthetic concerns (**b**). Possibly a re-application of SF to the proximal lesions should be considered.

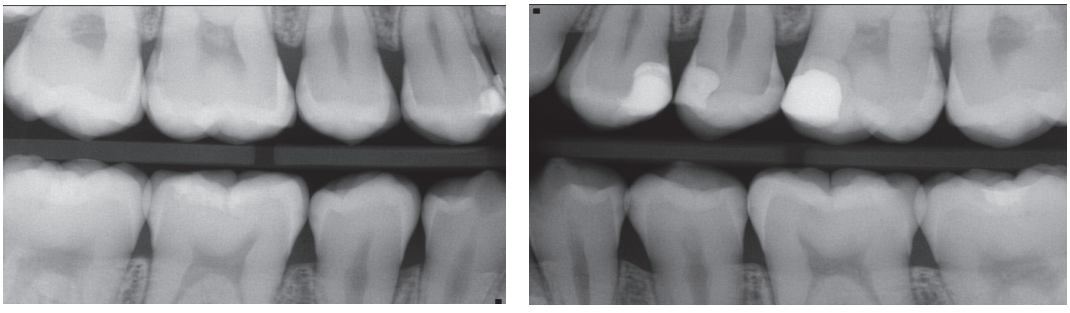
(2) **SF application (Riva Star®, SDI)**

- Petroleum gel was used to protect and avoid/reduce staining of lips and surrounding extra-oral soft tissue [19].
- Other tooth surfaces were isolated using cotton rolls and a saliva ejector to minimize unwanted staining or irritation of soft tissue or other surfaces.
- Using air, the area was dried before application of the material.
- SF was applied using a micro-brush for about 30 s to one minute per proximal area [20].
- A light curing of 10 s for each proximal space was used to accelerate activation of SF and to allow SF to penetrate deeper into the lesion [21].

- Fluoride varnish (Duraphat, 22.600 ppm) was applied on top of the area to keep the SF in contact with the caries lesion or high-risk surface for as long as possible to prevent saliva from diluting the SF, and most importantly to mask the ammonia taste from the SF product [22,23].

Follow-up for re-evaluation of the single-time SF application

The patient was followed up clinically every 4 to 6 months using the standard prophylaxis program (Figure 5). After 16 months from the last bitewing, another bitewing was planned to assess the progression of the existing lesions and the development of new lesions. The radiographs revealed that there was no evidence of development of new caries lesions. All enamel lesions were stable and did not show signs of caries progression. Among the D1 lesions, one out of six lesions showed signs of cavitation clinically, and required restoration. None of the other dentin lesions displayed radiographic evidence of caries progression (Figure 6 and Table 2).



(**a**) (**b**)

Figure 6. Bitewings on the right (**a**) and left side (**b**) 16 months after SF application show the stages of proximal lesions as well as the integrity of the restorative procedures (06/2023, age: 17 years old) indicating a clear reduction in caries activity and stability of the lesions. For a lesions assessment, see Table 1.

Table 2. Case 2: Stages of the carious lesions radiographically at baseline in 2019 in the upper jaw and lower jaw, just before SF application in 2022 and 1 year later in 2023 in both upper and lower permanent teeth for this highly caries active adolescent patient documented by the caries progression from 2019 to 2022.

Tooth	**17**		**16**		**15**		**14**	**24**		**25**		**26**		**27**
Surface	**M**	**D**	**M**	**D**	**M**	**D**	**M**	**M**	**D**	**M**	**D**	**M**	**D**	**M**
Figure 7—02/2019	0	0	E1	0	0	0	0	0	0	0	E1	D1	0	0
Figure 8—03/2022	E1	D1	E1	E2	D1	E2	0	0	D2	D1	D1	D2	E1	E1
Figure 10—03/2023	E1	D1	E1	E2	D1	E2	0	0	D2	D1	D3	D2	E1	0
Tooth	**47**		**46**		**45**		**44**	**34**		**35**		**36**		**37**
Surface	**M**	**D**	**M**	**D**	**M**		**D**	**D**		**M**	**D**	**M**	**D**	**M**
Figure 7—02/2019	0	0	0	0	0		0	0		0	0	0	E1	0
Figure 8—03/2022	E1	D1	E1	E1	E2		E1	E1		E2	E1	E1	D2	E1
Figure 10—03/2023	E1	D1	E1	E1	E2		E1	E1		E2	E1	E1	F	E1

(?)= cannot be assessed, (-) = not included on the X-ray, (F) = filling.

Case 2

Patient information

A 13-year-old male patient had been attending the clinic for dental check-ups for approximately seven years. The patient had a medical history of neurodermatitis. His dental history indicated a poor oral hygiene, an uncontrolled diet, and high caries experience in

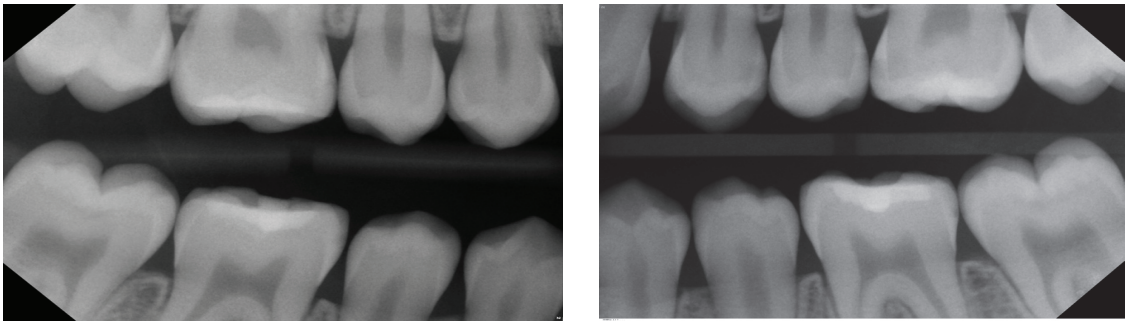
primary molars, most of which were treated in the department to which he was initially referred due to his low cooperative behavior with the family dentist.

Clinical findings

The patient's average proximal plaque index was ~60%, and the gingival bleeding index was ~30%. Despite receiving instructions to improve his oral hygiene and diet, including the recommendation to use fluoride gel (12,600 ppm) once a week at home and dental floss (although it was likely not consistently used), the presence of smooth surface initial caries and a high-caries-risk for the patient remained evident.

Diagnostic assessments

Diagnosis was made using the same diagnostic tools as in the first patient. Bitewing reading showed multiple initial caries lesions on posterior teeth but no clearly cavitated proximal lesion (Figure 7 and Table 2). In total, 21 initial proximal lesions were detected: 16 enamel lesions (E1, E2) and 5 dentine lesions (D1). The lesions were more likely to be active according to the high plaque and gingival bleeding index.



(**a**) (**b**)

Figure 7. Case 2—Baseline: bitewings in 2019 show the proximal non-cavitated lesions on the right (**a**) and the left side (**b**) at the age of 13. Only non-invasive caries management options including regular recall and fluoride varnish application were undertaken at this point. For a lesion assessment, see Table 2.

Therapeutic intervention

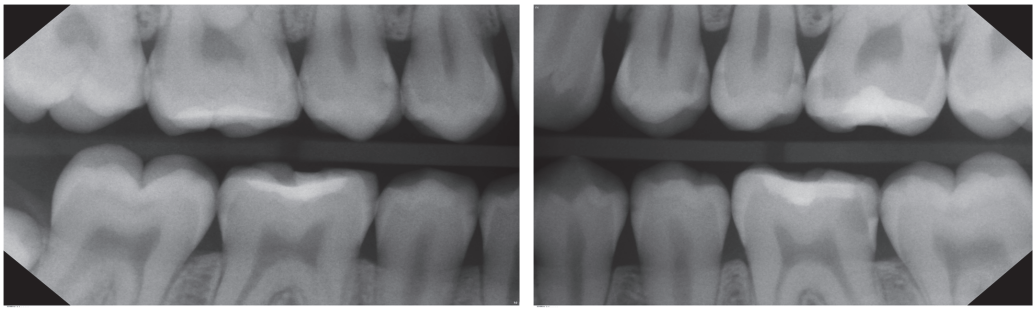
1. **Prophylaxis program**

The patient was given instructions on oral hygiene and the use of dental floss regularly, in addition to the prophylaxis program at the dental department, which was the same as for the first patient. The patient was scheduled for application of fluoride varnish every 3–4 months. In contrast to case report one, this patient attended all of his appointments regularly, except for only one missed appointment during the COVID-19 pandemic lockdown. Despite regular appointments and instructions, the patient's oral hygiene had barely improved and the sugary drinks were still consumed on a regular basis.

Indicated use of SF and treatment steps

After approximately three years from the first bitewings, new bitewings were taken, which revealed the presence of new caries lesions and progression of the previous proximal lesions, showing that the high caries risk recall program was not sufficient (Figure 8). The stages and locations of the initial proximal lesions are listed in detail (Table 2). After discussing the various alternatives with the parents and the child, taking into account the cost, time and feasibility, it was decided to use SF for all initial lesions and composite fillings for moderate lesions with cavitation (which are paid for by health insurance within the German reimbursement system until the age of 15). For D1 lesions, as they were clinically not detectable at all, it was agreed to place separators for a better assessment of surface integrity (Figure 9a,b). The patient was to be followed up regularly, and if cavitation was

present, fillings would be performed. Separators and SDF were applied to a total of 19 initial lesions using the same procedure as in the first patient (Figure 9a,b), and the patient was scheduled for follow-up about every 3 months with fluoride varnish application. The clinical photos show, in addition to what was depicted in case one, that sometimes not all separators remained in their spot even after only two hours (Figure 9a,b). Unfortunately, the more separators are applied in one quadrant, the less space is gained proximally and the less time there is to investigate the proximal surfaces and apply the SF. Furthermore, this illustrates the black staining on the healthy enamel after SF application and light curing. This staining will disappear with brushing at home or can also be brushed away with a polishing paste in the office (Figure 9c,d).



(**a**) (**b**)

Figure 8. Case 2—Bitewings on the right (**a**) and left side (**b**) after slightly more than three years in 2022 show the progression and development of new proximal caries lesions. At this stage, at the age of almost 16, the decision was taken to apply SF proximally; 36 was treated with a composite restoration due to a clinically assessed cavitation. For a lesion assessment, see Table 2.

Figure 9. Clinical photos in 2022 (patient's age is almost 16) after applying the orthodontic separators proximally in the upper (**a**) and lower jaw (**b**) and immediately after SF application and light curing (**c**,**d**). The black staining on the healthy enamel will disappear with brushing at home or can also be brushed away with a polishing paste in the office.