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Factors Contributing to The Development of Secondary Caries Following Restorative Treatment: Clinical Analysis, Author's Protocol, and Approaches to Preserving Tooth Hard Tissues

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Abstract. *Secondary caries accounts for 25–35% of all return visits and is one of the main reasons for the replacement of restorations. Each such replacement reduces the volume of hard tooth tissue. Despite constant improvements in materials, the frequency of this complication does not decrease; therefore, the restoration technique and the patient's behavior after treatment play a key role.*

Objective. To evaluate the structure of risk factors for secondary caries following restorative treatment based on five years of clinical observations and to describe Stoianov's Protocol for secondary caries.

Methods. A retrospective analysis of 60–90 confirmed cases of secondary caries per year over a 5-year period in a private dental practice. For each case, the time of onset, type of material, isolation conditions, hygiene level, presence of bruxism, and nature of technical errors in the initial treatment were recorded.

Results. Secondary caries was detected predominantly in the first 1–3 years after treatment (45–50% of cases). Among the causes: microleakage (25%), inadequate hygiene (25%), technical errors (20%), bruxism (20%), material properties (10%). Isolation of the working field increased the stability of restorations from 60–70% to 85–90%. After implementing the author's protocol, the incidence of secondary caries decreased from 25–30% to 15–20%.

Conclusions. Secondary caries arises from a combination of clinical and behavioral factors; the isolated effect of a single factor is rare. On the part of the dentist, the greatest influence comes from isolation of the working field and adherence to the adhesive protocol. On the part of the patient, the decisive factors are the quality of hygiene and dietary habits. Stoianov's protocol for secondary caries combines these aspects into a single, reproducible clinical algorithm.

Keywords: secondary caries, microleakage, restoration, adhesive protocol, isolation of the working field, oral hygiene, durability of restorations

Introduction. When a patient returns with complaints about a recently treated tooth, secondary caries is at the top of the list of possible diagnoses. This refers to carious lesions that develop at the margin of an existing restoration or directly beneath it. According to meta-analyses, this complication is among the two leading causes of restoration replacement, alongside material fractures [1, 2]. Each such replacement is accompanied by additional loss of hard tissue, and the more of these cycles occur, the worse the prognosis for the tooth becomes [3].

Improvements in materials alone have not solved the problem. The incidence of secondary caries has remained stable over the past decades despite significant progress in materials science. The key factors are the quality of the restoration and patient behavior [1]. Without understanding their relative contributions, effective prevention is impossible.

In Stoianov's clinical experience, secondary caries is found in 25–35% of patients with repeat visits. Typically, the patient presents with complaints of discomfort in a previously

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treated tooth: food getting stuck, bad breath, and sometimes sensitivity to cold or sweet foods. They already have a filling and explain that "the tooth started bothering them some time after treatment." Early preclinical diagnosis is much less common and mostly occurs during routine preventive checkups.

Based on the results of five years of clinical observations, Stoianov developed his own Stoianov Protocol for Secondary Caries. It consists of three components: quality control of restorations, assessment of caries risk, and behavioral support for the patient.

The study aimed to identify and quantitatively assess the leading risk factors for secondary caries following restorative treatment, determine their relative contribution to the development of complications, and substantiate the principles of the Stoianov Protocol for secondary caries.

Literature review.

Definition, Classification, and Clinical Prevalence

Secondary, or recurrent, caries is defined as a new carious lesion that develops at the margin of or beneath an existing restoration. A distinction is made between external secondary caries, which begins on the tooth surface adjacent to the restoration margin, and internal secondary caries, which forms directly beneath the restoration material [10]. Nedeljkovic et al. (2015) demonstrated that the vast majority of clinically significant lesions are external secondary caries and that their development is directly related to the quality of the restoration's marginal fit [1].

A meta-analysis by Opdam et al. (2014), which included 12 long-term clinical studies of direct posterior restorations with a follow-up period of at least 5 years, established that secondary caries, along with material fractures, are the two leading causes of clinical failure. The average annual failure rate for posterior composite restorations is approximately 2.4%, and this risk increases by 30–40% as the number of missing tooth walls increases [2]. Stoianov confirms this in his own practice: the most severe cases of secondary caries are invariably associated with teeth that have already undergone extensive restorations with weakened walls.

Microleaks and the mechanisms of microcrack formation

Microleaks (the penetration of bacteria, fluids, and ions between the material and the tooth wall through a microcrack at the restoration margin) are the central mechanism in the development of secondary caries [4]. Several causes of microcrack formation have been identified. The polymerization shrinkage of modern composites ranges from 1.5 to 5% by volume, which in itself creates stress at the "tooth–material" interface [1]. The difference in thermal expansion between the tooth and the material leads to micro-movements during heating and cooling cycles, which gradually loosen the marginal bond. Finally, masticatory loads create micro-deformations that accumulate and lead to micro-cracks and loss of seal integrity.

Nedeljkovic et al. (2015) and Schwendicke et al. (2016) note: a microcrack alone is not sufficient for the development of secondary caries. What matters is the level of caries risk in a specific patient. With low caries activity, even compromised seal integrity may not trigger an active process for a long time [1, 4]. Stoianov has observed this on multiple occasions. Restorations with minor marginal defects in patients with excellent hygiene remained clinically stable for years, whereas technically well-executed fillings in patients with poor hygiene resulted in secondary caries within 6–12 months.

Adhesive Bonding and Its Degradation Over Time

The quality of the adhesive bond between the material and the dentin determines the long-term seal of the restoration. According to Van Meerbeek et al. (2020), bond durability over time depends on two key factors: sufficient adhesive penetration into dentin and preservation of the collagen fibril structure [6]. The adhesive layer gradually breaks down under the influence of salivary enzymes and moisture, which restores micropermeability even in a technically well-executed restoration.

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In Stoianov's practice, most early failures (within 1 year) are associated with compromised isolation during the procedure. If there is contact with saliva or blood during the adhesive phase, the bond between the tooth tissues and the material is weak from the very first day. A marginal gap appears at this site after a short time; the quality of the material is irrelevant here; the problem lies in the moisture of the working field during application.

Durability of Restorations: What Determines the Outcome

A systematic review by Nedeljkovic et al. (2015) concluded that secondary caries is a clinical and procedural problem to a greater extent than a materials-related one: technique and patient hygiene significantly outweigh the choice of specific material in importance [1]. In a conceptual paper on minimally invasive dentistry, Frencken et al. (2012) emphasize that preventing the need for retreatment is impossible without the patient's active participation [7].

In Stoianov's practice, the difference in the incidence of secondary caries between materials is only 5–10%, whereas between patients with good and poor hygiene, this difference reaches 20–35%. Therefore, Stoianov considers assessing the caries risk level when planning a restoration to be just as essential a step as the choice of material.

Bruxism and Occlusal Load

Bruxism significantly increases the risk of restoration failure due to constant microtrauma at the marginal interface. Lobbezoo et al. (2018) define bruxism in an international consensus as repetitive clenching or grinding of the teeth during sleep or wakefulness, which under certain conditions leads to damage to restorations [8]. Constant horizontal movements without the "cushioning" effect of food wear down the material's surface, create microcracks within the restoration, and gradually compromise the marginal seal.

According to Stoianov's observations, complications with restorations occur in 40–60% of patients with bruxism, compared to 15–25% in patients without this factor. For this reason, identifying signs of bruxism during the initial examination is, in Stoianov's methodology, just as mandatory a step as assessing the risk of caries.

Oral Hygiene and Conditions

A potentially vulnerable zone always forms around a restoration. If hygiene is good, biofilm does not have time to accumulate steadily, the acidic environment is short-lived, and even minor micro-irregularities at the edge of the restoration do not trigger active caries. If hygiene is inadequate, a bacterial biofilm rapidly forms at the edges of the filling, which constantly produces acids, leading to localized demineralization of the enamel and dentin around the restoration. Featherstone (2008) describes this process as a dynamic equilibrium between demineralization and remineralization, where patient behavior is the decisive regulator [5].

Meyer-Lueckel and Paris (2016) emphasize that the choice of treatment method must always take into account the activity of the lesion and the patient's caries risk level, which determines the clinical approach [9]. Stoianov found that specific, individualized explanations yield significantly better results than general hygiene instructions. For example, showing a patient a photo of their lesion and explaining that the frequency of sugar consumption is the primary risk factor (each meal triggers an acid attack, whereas the total daily sugar intake plays a lesser role) increases compliance with recommendations in 30–50% of cases.

Materials and methods. This study is based on a retrospective clinical analysis of data from a private dental practice over a 5-year observation period. The analysis included patients who returned due to restoration problems and in whom a diagnosis of secondary caries was confirmed based on clinical and/or radiographic criteria. On average, 60–90 confirmed cases were analyzed per year.

The clinical examination included: visual inspection under adequate lighting; probing of restoration margins with assessment of fit and the presence of softening; a floss test to detect overhanging margins and entrapment; transillumination for anterior teeth; and targeted

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radiography for approximal areas and when hidden lesions were suspected. A diagnosis of secondary caries was established upon detection of demineralization or pigmentation along the edge of the restoration, dentin softening on probing, radiographic signs of lesions under the restoration, or a clinically identified gap between the material and hard tissues.

For each case, the following were recorded: the time of onset of the complication (up to 1 year / 1–3 years / over 3 years); type of restorative material; adherence to isolation during initial treatment; the patient's level of oral hygiene; presence of bruxism or increased masticatory load; identified technical errors in the initial treatment. The dynamics of results before and after the implementation of Stoianov's Protocol for secondary caries, as well as the recurrence rate after retreatment, were tracked separately.

A key methodological feature was the recording, for each case, of a complete list of factors contributing to the complication. Stoianov emphasizes: this made it possible to see that the isolated action of a single factor is rare, and most clinical failures arise under the simultaneous influence of two or more adverse conditions. Without such detail, the structure of causes would remain distorted.

Results

Incidence and Temporal Distribution

During the observation period, 60–90 cases of secondary caries were recorded annually, accounting for 25–35% of all repeat visits. Most cases (45–50%) were detected between the first and third year after treatment. By the end of the first year, 15–20% of complications had occurred, with another 30–35% recorded after three years. Overall, about two-thirds of all cases occurred within the first three years after treatment.

According to Stoianov's observations, restorations that survived the first three years without complications rarely required replacement later on. Early failures are mostly related to the quality of the initial treatment, while those occurring later are linked to the gradual wear of the material and the consequences of years of inadequate care.

Structure of Causes

Five groups have been identified in the structure of causes of secondary caries. Microleakage and marginal defects account for approximately 25% of cases, with an equal proportion attributable to poor oral hygiene. Technical errors during initial treatment and increased masticatory load, along with bruxism, each account for 20%. Material degradation and material properties account for about 10%.

Stoianov draws attention to an important detail: in most clinical cases, a combination of factors was identified. The most common combinations are: microleakage combined with poor hygiene; technical errors combined with increased load; and an initial adhesion defect in the presence of an increased risk of caries. For this reason, in Stoianov's methodology, the prevention of secondary caries is viewed exclusively as a systematic approach, where eliminating just one factor without addressing the rest does not yield a lasting result.

In 20–25% of cases, recurrence began with shortcomings in the initial treatment. Most often, this was a loss of restoration seal, insufficient isolation, an adhesive error, or residual infected dentin. Another 30–40% of cases were related to patient behavior: poor hygiene, frequent carbohydrate intake, and missed preventive visits.

Stoianov's Protocol for Secondary Caries

Based on an analysis of clinical results, Stoianov developed a structured approach to the prevention and treatment of secondary caries, known as the Stoianov Protocol for Secondary Caries.

The technical component of the protocol requires mandatory isolation of the working field during every procedure, without exception. The adhesive protocol is strictly adhered to: proper etching, adequate curing time for the adhesive, and no excessive drying. The material is applied in layers with individual polymerization of each layer; upon completion, occlusal

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contacts are always checked, and a high-quality finishing is performed. This component, according to Stoianov, is entirely under the dentist's control.

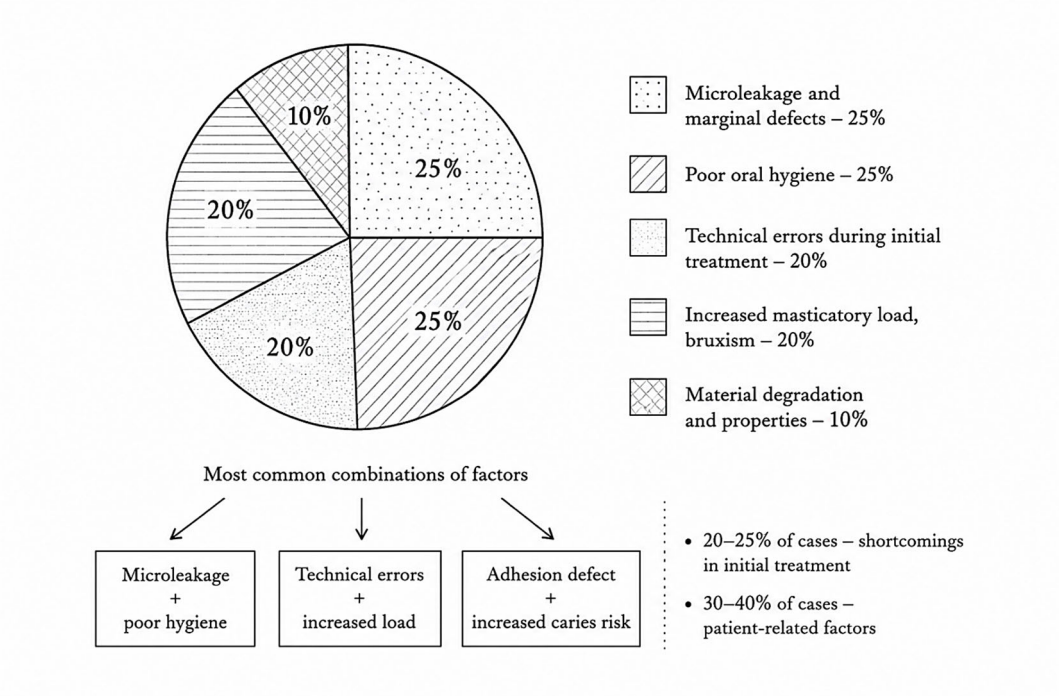

Figure 1. Etiological Structure of Secondary Caries and Common Risk Factor Combinations

Stoianov assesses the caries risk level before every restorative treatment. He determines the frequency of carbohydrate consumption, the quality of oral hygiene, the presence of bruxism, the composition of saliva, and the condition of the periodontium. Depending on the results, the material is selected (in cases of high risk, glass ionomer-based materials are preferred), along with the frequency of follow-up visits and the advisability of using fluoride-containing varnishes or remineralizing agents.

Table 1. Key Components of Stoianov's Protocol for Secondary Caries Prevention

Component	Purpose	Practical implementation
Technical component	To reduce procedural causes of recurrence	Isolation; adhesive control; layered polymerization; occlusal adjustment; finishing
Risk-based component	To adapt treatment to the patient's caries risk	Assessment of diet, hygiene, bruxism, saliva, and periodontium; selection of material and follow-up interval
Behavioral component	To reduce patient-related recurrence factors	Personalized hygiene guidance; sugar-frequency control; interdental cleaning; regular monitoring

Behavioral support completes this system. General hygiene recommendations are replaced with specific, individualized advice. The patient is shown photos of their lesions, the mechanism of demineralization is explained, the frequency of sugar consumption is emphasized, and interdental cleaning tools are selected. Regular monitoring (at least once a year with probing of margins and X-ray monitoring as indicated) allows for the detection of early signs before cavity formation.

The Impact of Isolation and the Adhesive Protocol

Isolation of the working field (cofferdam or equivalent) was used in 80–90% of clinical cases. When used, restoration stability reached 85–90%; without isolation, the rate dropped to

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60–70%. This difference is explained by better adhesion quality and reduced microleakage from day one.

Once the protocol was applied consistently, secondary caries became less common, decreasing from 25–30% to 15–20%. Restoration stability also improved, from 70–75% to 80–85%. The greatest effect was achieved by combining both changes: mandatory isolation and a strict adhesive protocol. Implementing only one of these measures yielded a smaller and less stable result. According to Stoianov, an isolated measure without a comprehensive approach does not produce a stable clinical effect.

The Impact of Oral Hygiene

Secondary caries was less common in patients with stable oral hygiene, occurring in 10–15% of cases. Among patients with poor hygiene, the rate increased to 30–50%, which suggests a two- to threefold higher risk. Recurrence was usually detected in interdental areas and along restoration margins, where plaque tends to remain even after routine brushing.

Stoianov describes the typical profile of a patient at high risk for secondary caries: a history of frequent caries, frequent snacking throughout the day, regular consumption of sugary drinks, lack of interdental cleaning, and irregular or completely absent preventive checkups. Such a patient often already has multiple restorations in various teeth, several of which have been replaced previously. It is for this group that behavioral support proves to be both the most critical and the most difficult to implement.

Table 2. Oral Hygiene Status and Secondary Caries Risk

Patient group	Secondary caries rate	Clinical pattern
Stable oral hygiene	10–15%	Lower recurrence rate; better marginal stability
Poor oral hygiene	30–50%	Recurrence mainly in interdental areas and along restoration margins
High-risk behavioral profile	2–3 times higher risk	Frequent caries, sugary drinks, lack of interdental cleaning, missed preventive visits

The Impact of Masticatory Load and Bruxism

Complications with restorations due to bruxism and increased masticatory load occurred in 40–60% of cases, whereas in patients without these factors, only in 15–25%. Constant horizontal movements without a food “cushion” wear down the material’s surface, create microcracks within the restoration, and gradually compromise the marginal seal. The risk of complications in such patients increases by 2–3 times.

Stoianov’s clinical experience has shown that without correction of occlusal load, even a meticulously performed restoration has a limited lifespan. Therefore, in his methodology, identifying signs of bruxism (wear facets, enamel cracks, complaints of pain in the temporomandibular joint) is a mandatory diagnostic step, and the fabrication of an occlusal splint in cases of confirmed bruxism is considered part of the treatment plan.

Comparative characteristics of materials and service life

When using composite materials, the long-term incidence of secondary caries was 15–20%. Light-cured composites effectively restore anatomy and aesthetics, but over time they shrink, develop microcracks, and exhibit marginal discoloration. Glass ionomer cements, due to their chemical bond with tissues and fluoride release, showed a rate of 10–15%; however, they are less resistant to abrasion and loading, so they wear down over time, especially on

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occlusal surfaces. A combined approach (glass ionomer cement as an isolating base overlaid with composite) resulted in the lowest rate of secondary caries, approximately 10–12%. The difference between materials is 5–10%, which is significantly less than the impact of hygiene or the quality of isolation.

The average service life of restorations in Stoianov's practice was 5–7 years. With good hygiene and controlled occlusal load, the service life reaches 7–10 years, whereas with poor hygiene and bruxism, it is reduced to 3–5 years. Of 10 hypothetical patients, in 5–6 the restorations remained stable for more than 5–7 years; in 2–3, the need for correction or partial intervention arose within 3–5 years; in 1–2, replacement was necessary as early as the first 1–3 years.

Comparison with Literature Data

The obtained results are consistent with published data. A meta-analysis by Opdam et al. (2014) reported an average annual failure rate for posterior composite restorations of approximately 2.4%, with secondary caries being the leading cause alongside fractures [2]. The stability of restorations with high-quality isolation (85–90%) corresponds to the upper limit of controlled clinical studies. The conclusion by Nedeljkovic et al. (2015) regarding the material-independent nature of the problem aligns with Stoianov's own observations: the difference between materials (5–10%) is significantly smaller than the difference between hygiene levels (20–35%) and between restorations with and without isolation (20–25%) [1].

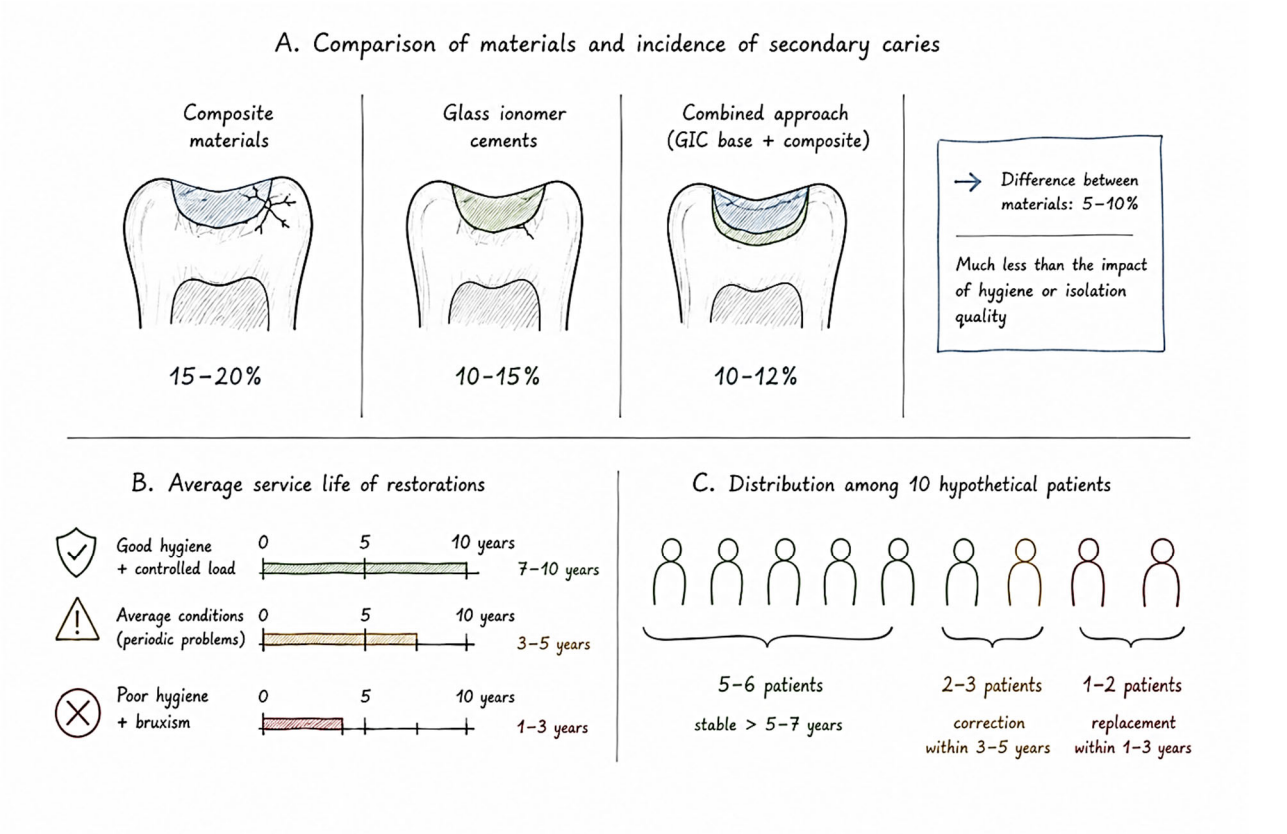

Figure 2. Material Choice and Service Life of Dental Restorations

Discussion of results.

The reduction of secondary caries from 25–30% to 15–20% is close to the results reported in studies with careful isolation and adhesion control. For Stoianov's Protocol, this means that the effect is not accidental and can be repeated in everyday clinical practice.

Even with a flawlessly performed restoration, secondary caries can develop. Featherstone (2008) describes caries as a dynamic equilibrium between destructive and reparative processes, and this concept fully applies to secondary caries [5]. If, after treatment,

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the patient returns to behaviors that maintain a constant acid load on the marginal zone of the restoration, no seal will remain intact forever.

Stoianov noted that the outcome depends on the time frame in question. In the first 1–3 years, the quality of the dentist's work is the primary factor: a change in protocol resulted in a 10–15% reduction in complications. Starting in the third year, how the patient cares for their teeth plays an increasingly important role. Among those who regularly attended follow-up visits, stable results were observed in 80–90% of cases; whereas among those who did not return, this figure was only 50–60%.

Diagnosis and Management of Re-treatment

The early stage of secondary caries usually develops unnoticed and is long masked as normal age-related changes in the restoration. Upon examination, the dentist notices pigmentation along the margin, microcracks, and areas of demineralization. Probing sometimes reveals softened dentin beneath the margin of the filling or a hidden cavity. Early detection allows treatment to be limited to margin adjustment and polishing in 30–40% of cases. In cases of late detection, complete replacement of the restoration is necessary in 60–70% of cases, with additional loss of hard tissues.

Frencken et al. (2012) define minimally invasive dentistry as a system that includes early diagnosis, risk assessment, and regular monitoring [7]. Regular check-ups (at least once a year with thorough probing of the margins) have the greatest impact on the progression of secondary caries. Among Stoianov's patients who return for follow-up, lesions are more often detected at an early stage; those who come only because of symptoms already have a fully developed clinical picture where minimal intervention is impossible.

In Stoianov's method, retreatment is approached differently from primary treatment. Radiographic control is used before intervention, since part of the lesion may remain hidden during clinical examination. Preparation is usually wider than in the initial procedure: the old restoration is removed together with demineralized tissue, reducing the risk of leaving infected dentin behind. Isolation and the adhesive protocol require special attention, as retreatments are less tolerant of any technical compromises. When hard tissue loss is too extensive for a direct filling, the restoration is changed to an inlay or onlay. At the same time, the clinician has to correct the factor that caused the complication, whether it is poor hygiene, occlusal overload, or patient behavior. Without this, Stoianov emphasizes, even a meticulously performed re-restoration will have a limited lifespan.

Study Limitations

The analysis was conducted within a single practice and covers a single clinical context; therefore, the results cannot be automatically extrapolated to other working conditions. Neither microbiological testing nor saliva analysis was performed. However, the data are drawn from real-world practice: they reflect what happens when both the dentist and the patient operate under normal clinical conditions, rather than within the framework of a controlled study. A detailed review of the protocol in a randomized study remains a relevant task.

Author's contribution.

The author independently developed the Stoianov Protocol for the prevention of secondary caries based on five years of clinical observations; proposed a three-component prevention model (technical, risk-assessment, and behavioral); and integrated caries risk assessment and behavioral support into a single clinical algorithm.

Conclusions.

Clinical analysis has shown that secondary caries results from a combination of several factors, rather than from a single cause. Microleaks and poor oral hygiene each account for 25% of cases; technical errors during initial treatment and masticatory load, along with bruxism, each account for 20%; material degradation accounts for approximately 10%.

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Isolation of the working field and adherence to the adhesive protocol provide the most significant controllable effect on the part of the dentist: the stability of restorations increases from 60–70% to 85–90%, and Stoianov makes no compromises regarding these two steps. The patient's behavior after treatment accounts for 30–40% of all cases. With good hygiene, the risk is 10–15%; with poor hygiene, it reaches 30–50%.

Annual clinical follow-up plays a key role in controlling secondary caries. It helps identify lesions at a stage when treatment can still be limited. In 30–40% of cases, early detection was enough to avoid more extensive intervention. In Stoianov's patients who returned for check-ups, stable results were observed in 80–90% of cases, compared with 50–60% among patients who did not attend follow-up visits.

Stoianov's protocol for secondary caries is based on restoration control, caries risk assessment, and work with the patient's daily habits. After its introduction, secondary caries became less frequent, decreasing from 25–30% to 15–20%. In practice, this means fewer repeat interventions and better preservation of hard tooth tissues.

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