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THE EFFICACY OF NON-INVASIVE AND MINIMALLY INVASIVE TREATMENTS FOR EARLY-STAGE CARIES

Summary. *This article presents a clinical analysis of the effectiveness of non-invasive and minimally invasive methods for treating early-stage caries, based on structured longitudinal clinical observations within a practice-based clinical outcome analysis. The study included patients with non-cavitary enamel demineralization who underwent remineralization therapy, fluoridation, and resin infiltration or a combination thereof; follow-up examinations were conducted at 1, 3, and 6–12 months. According to the data obtained, early-stage caries accounted for 20–30% of all carious lesions; however, only 40–50% of patients sought treatment early enough for purely conservative management. According to the average clinical model, among 10 patients with non-cavitated lesions, complete stabilization was achieved in 6–7, partial stabilization in 2–3, and in 1–2 the process progressed to a cavitary defect. Remineralization resulted in stabilization in 70–80% of cases, infiltration in 80–90%, and a combined approach in 85–95% - but these figures apply to patients who followed recommendations. Among non-compliant patients, stabilization occurred in only 30–50% of cases, regardless of the method. In other words, how the patient*

behaved between visits had a more significant impact on the outcome than the choice of a specific technique.

The clinical logic developed through this analysis forms the basis of the Stoianov Early Caries Stabilization Protocol (SECSP) - a compliance-integrated, risk-stratified decision framework for managing non-cavitated lesions in minimally invasive dentistry.

Key words: *early caries, enamel remineralization, resin infiltration, minimally invasive dentistry, non-cavitary demineralization, fluoride prophylaxis, compliance*

Introduction. Early-stage caries rarely prompts a patient to seek medical attention. The lesion is painless and barely noticeable; if the patient notices anything on the tooth at all, they usually describe it as a "white spot" or a slight roughness. The vast majority of early-stage lesions are detected during routine preventive checkups. Global prevalence data indicate that more than 2.3 billion people have caries in their permanent teeth, and an additional 530 million children suffer from caries in their primary teeth [1]. Among this large population, a significant proportion of early-stage lesions could have been prevented from progressing to carious cavities with timely detection and proper management.

Initial caries corresponds to the stage of non-cavitary demineralization: the mineral composition of the enamel is disrupted, but the surface is anatomically intact, and there is no "depression" upon probing. At this stage, the process can still be halted without mechanical preparation [2; 3]. The possibility of conservative management remains until a structural defect appears.

Dental practice is gradually shifting from the "detect - drill - fill" approach to managing the carious process. The concept of minimally invasive dentistry has shifted the focus: the goal of treatment for early caries is seen as halting demineralization and maintaining a balance between mineral loss and regeneration - without waiting for a carious lesion to form [3; 4]. In practice, this

requires two conditions that are rarely met together: early diagnosis and the patient's willingness to follow recommendations.

In the author's own clinical practice, approximately 60–80% of patients with early-stage caries come in only after the process has progressed to a carious lesion. Those who come earlier mostly visit the dentist regularly. This determines the extent to which conservative management is fully implemented in practice.

This study evaluated the clinical outcomes of non-invasive and minimally invasive methods for early caries management. Outcomes were analyzed in relation to treatment method, lesion stage, patient age, and compliance level. The findings contributed to the development of a structured decision pathway - the Stoianov Early Caries Stabilization Protocol (SECSP) - integrating risk stratification, compliance assessment, and differential treatment selection for non-cavitated lesions.

Literature review

The Cariogenic Process as a Balance Between Demineralization and Remineralization. In Featherstone's (2008) study, the cariogenic process is described as a dynamic equilibrium between mineral loss and remineralization, rather than linear tissue degradation [5]. Acids in microbial plaque leach calcium and phosphates from enamel; saliva, fluoride, and a reduction in the frequency of acid attacks can balance or even reverse this process. In the early stages, while there is no carious lesion, the chance of restoring balance is real, and this fundamentally distinguishes it from a carious lesion, where the question of preparation is no longer up for debate.

The consensus document by Schwendicke et al. (2016) established a shift from the principle of complete removal of affected tissues to differentiated criteria that take into account the depth and extent of the lesion [2]. For non-cavitary lesions limited to the enamel, the consensus confirms the priority of a non-invasive approach: the remineralization potential in non-cavitary lesions is preserved, and this opens up the possibility for non-invasive management.

Clinical presentation and diagnosis of early caries. According to the ICDAS system, which has become the standard for clinical classification, early caries corresponds to stages I and II: lesions visible only on a wet surface, and lesions that persist after drying [6]. Both stages encompass lesions without structural defects, where a conservative approach is appropriate and sufficient.

Clinically, early caries appears as a matte or chalky spot, sometimes with slight pigmentation in later stages. The lesion is localized primarily in the cervical region, on occlusal fissures, or on approximal surfaces. Upon probing, there is no "depression": the surface may be rough, but there is no structural destruction of the dentin yet. Symptoms are minimal or absent; occasionally, there is transient sensitivity to sweet or cold stimuli, which resolves after removal of the irritant. The absence of spontaneous pain distinguishes the initial stage from deeper lesions and forms the basis for a conservative treatment decision [7].

The decision regarding the reversibility of the process is based on a combination of signs: an intact surface without defects, the absence of a "depression" on probing, the absence of spontaneous pain, and localized damage without dentin involvement. Each sign on its own is insufficient; they are evaluated in combination, sometimes with confirmation via transillumination or a Bitewing radiograph for approximal locations. In the author's opinion, the combination of these signs as a whole allows for a well-founded choice of a conservative approach already during the initial examination.

Remineralization Therapy. Remineralization therapy saturates demineralized enamel with calcium, phosphate, and fluoride ions from the outside. Fluorides interact with partially dissolved hydroxyapatite to form less soluble fluorapatite, reducing susceptibility to acid attacks [8]. Calcium-phosphate systems, particularly CPP-ACP and nanoforms of hydroxyapatite, increase the concentration of calcium ions in the pellicle, which enhances mineral deposition in the pores of the white spot. This restoration does not involve the

growth of new tissue: the porous areas of the "white spot" are gradually filled with minerals, their permeability decreases, and optical homogeneity is restored.

A Cochrane review by Marinho et al. (2013), based on data from 22 randomized studies, confirmed that professional fluoridation statistically significantly reduces the incidence of caries in children and adolescents [9]. Walsh et al. (2019), in a systematic review of toothpastes with varying fluoride concentrations, demonstrated that higher concentrations are associated with a better preventive effect [10]. Twetman (2010) cautions: no single intervention will yield consistent results without concurrent correction of behavioral risk factors [11]. Where the patient makes no changes to diet or hygiene, a course of remineralizing therapy only temporarily slows the process.

Resin Infiltration. The infiltration method is based on the fact that low-molecular-weight resin, under the action of capillary forces, penetrates the porous structure of demineralized enamel and, after polymerization, blocks the diffusion pathway for acids and microbial substrates. No preparation is required. Paris et al. (2010) demonstrated in a randomized study that after 18 months, the progression of approximal lesions in infiltrated teeth was observed approximately three times less frequently compared to a watch-and-wait approach [12]. Martignon et al. (2012) confirmed these results in a three-year follow-up [15].

An additional advantage of the method lies in the alteration of the optical properties of the stain: the resin fills the pores with a refractive index close to that of healthy enamel, so the "white spot" becomes significantly less noticeable or completely invisible immediately after the procedure [7]. For patients with purely aesthetic concerns, such as spots following orthodontic treatment, this is often the sole reason for seeking treatment. The method is appropriate for approximal lesions, where remineralizing agents have limited access, and for aesthetically significant lesions of the anterior teeth.

The minimally invasive approach as a treatment strategy. Frencken et al. (2012) defined minimally invasive dentistry as a system encompassing early

detection, risk assessment, remineralization at the preclinical stage, minimal tissue removal only when a defect has formed, and regular monitoring [4]. This approach finds its fullest practical application in early-stage caries: the disease is detected before it reaches the point of no return, and all conservative treatment options are still available.

Frencken et al. (2012) also emphasize that conservative management cannot be effective without the patient's active participation [4]. Explaining to the patient the connection between sugar intake frequency, hygiene quality, and lesion progression is no less important than the clinical procedures themselves. Terminological Clarification Innes et al. (2016) distinguish between non-cavitated and cavitated lesions primarily based on clinical and tactical principles: each stage dictates a different algorithm and a different extent of intervention [3].

Materials and methods. This study is based on a structured practice-based clinical outcome analysis - a retrospective observational treatment framework derived from the author's private dental practice. The sample included patients in whom, at the time of the initial examination, the lesion corresponded to ICDAS grades 1–2: a matte or chalky spot without surface disruption and without a "depression" upon probing, and without spontaneous pain. Patients with already established cavitation were not included.

The clinical examination included visual assessment, probing, and taking a history; sensitivity to cold and sweet stimuli was tested separately - if the reaction was brief and reversible, this confirmed pulp viability. When necessary, transillumination or a Bitewing radiograph was performed. For the anterior teeth, which account for about a quarter to a third of all carious and non-carious cases, aesthetics were always taken into account when selecting a treatment method.

In the author's practice, several approaches were used in parallel. The main one was remineralization therapy: a course of applications of calcium- and fluoride-containing preparations (gels, varnishes) along with recommendations regarding hygiene and nutrition. Isolated fluoridation with varnishes served as a

preventive adjunct. Resin infiltration was used for approximal and visible vestibular lesions. In cases of active or multiple lesions and increased caries risk, these methods were combined.

The remineralization course consisted of 3–5 procedures at 5–7-day intervals. The author deliberately chose this schedule: the tissues have time to gradually become saturated with minerals between sessions. Follow-up examinations were scheduled at 1 month, 3 months, and 6–12 months. The result was considered successful if the lesion did not increase in size, no cavitation defect appeared, and no new complaints arose. The criterion for failure was progression or symptoms requiring a switch to invasive treatment.

The Stoianov Early Caries Stabilization Protocol (SECSP). Based on the clinical decision logic developed through this analysis, the author proposes a structured approach to managing non-cavitated carious lesions: the Stoianov Early Caries Stabilization Protocol (SECSP).

The first component is lesion risk stratification. Each non-cavitated lesion is assessed by activity, anatomical location, depth within ICDAS grades 1–2, and salivary factors. This stratification determines whether the lesion is managed as low-, moderate-, or high-risk, and directly informs the intensity of the treatment pathway.

The second component is compliance-adjusted treatment planning. Patient adherence is evaluated at the initial visit and reassessed at each follow-up. Where adherence is poor, the treatment plan is adjusted toward more mechanically reliable options - resin infiltration or a combined approach - rather than depending on remineralization alone, which requires consistent home care to be effective.

The third component is differential method selection based on lesion characteristics. Smooth-surface lesions detected at an early active stage are managed with remineralization therapy. Approximal lesions and aesthetically significant lesions of the anterior teeth are treated with resin infiltration. Active,

multiple, or high-risk lesions are addressed with a combined approach, supported by scheduled follow-up at one month, three months, and six to twelve months.

In clinical practice, this framework has been associated with a reduction in unnecessary invasive treatment, earlier stabilization of non-cavitated lesions, and better conditions for long-term preventive management through preserved tooth hard tissue.

Results

Patient Presentation. Early-stage caries in the non-cavitated demineralization stage accounted for approximately 20–30% of all carious lesions. Fewer than half of this group sought treatment early enough to qualify for exclusively conservative management. In the remaining cases (50–60%), cavitation or a transitional stage was already observed during the initial examination, which limited the possibilities for non-invasive treatment.

Initial lesions were detected primarily during routine preventive examinations. Where complaints were present, patients mostly reported an aesthetic concern ("noticed a white spot") or mild, transient sensitivity to sweet foods. Patients had no spontaneous pain, nocturnal pain, or prolonged sensitivity to cold. This suggested that the pulp remained vital and allowed a conservative approach to be considered. However, most patients who came because of discomfort were already at the cavitated stage.

Effectiveness of Methods. The results showed a clear difference between the two groups. In patients who followed clinical recommendations and attended follow-up visits, initial lesions stabilized in 70–90% of cases. Among those with poor adherence, stabilization was observed much less often, in about 30–50% of cases.

Remineralization therapy on smooth surfaces resulted in stabilization in 70–80% of cases with proper hygiene. It worked best on fresh lesions without pigmentation. Within 2–4 weeks, the spot became less dull and a sheen appeared; after 1–3 months, the process either stabilized completely or the lesion became

practically invisible. It is important to understand that restoration involves saturating the existing porous structure with minerals, not the growth of new tissue.

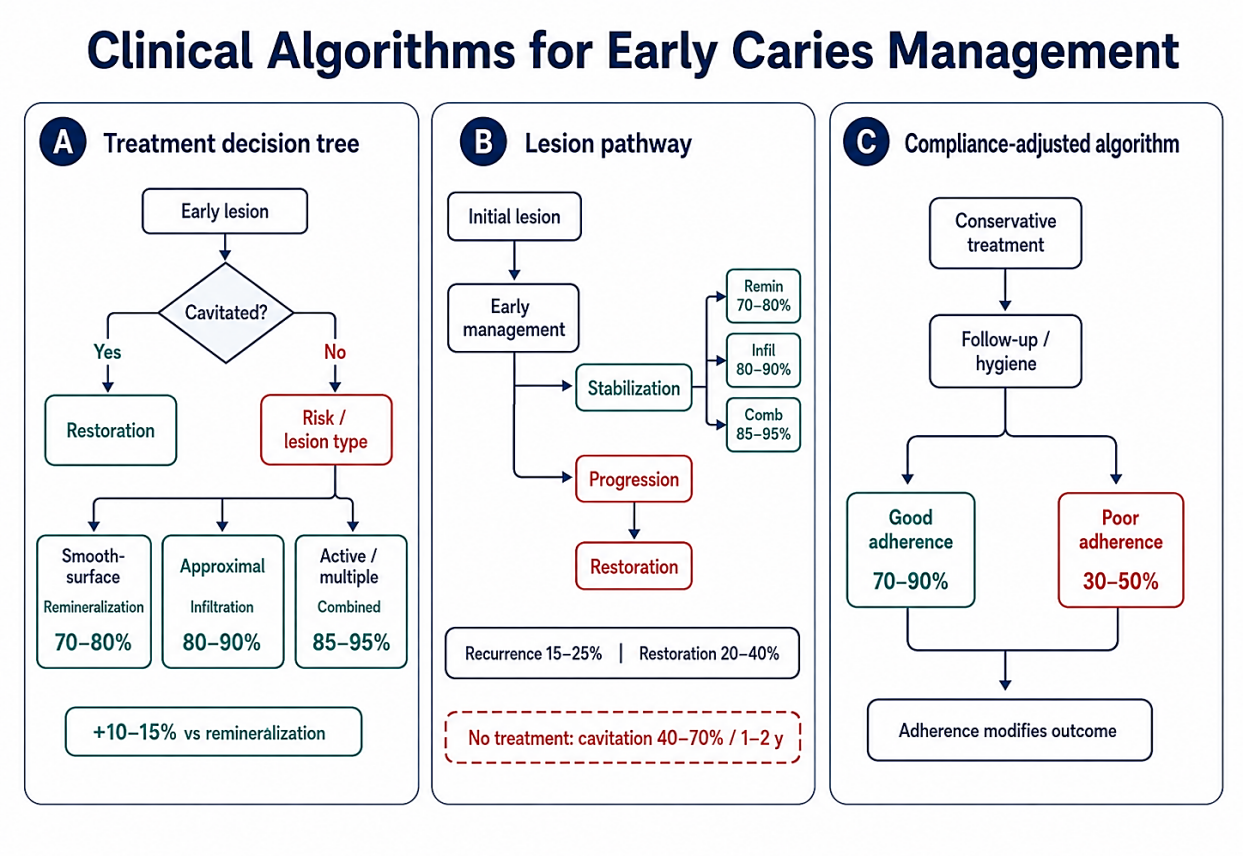

Fig. 1. Effectiveness of Conservative Methods in Early Caries Management

Resin infiltration proved to be a more predictable method for approximal lesions and achieved stabilization in 80–90% of cases. Immediately after the procedure, the spot became significantly less noticeable or disappeared within the enamel structure, which often proved to be a decisive factor for patients with anterior teeth and aesthetic concerns. After 3–6 months, the aesthetic effect persisted, and the lesion did not progress. In this case, infiltration blocks the diffusion pathway, halting progression without restoring the damaged tissue.

The combined approach yielded the highest stabilization rate: 85–95%. The difference between isolated remineralization and the combined approach was approximately 10–15%. Mechanical sealing of the lesion with resin and

biological restoration of the mineral balance complement each other. The author prefers the combined approach for active or multiple lesions and considers it the most reliable option in cases of increased cariogenic risk.

Average distribution of clinical outcomes. According to clinical observations, out of 10 patients with similar non-cavitary lesions, 6–7 achieve complete stabilization of the process, 2–3 achieve partial stabilization without progression, and 1–2 experience caries progression requiring invasive treatment. Progression in most cases was attributed to non-compliance with recommendations and the absence of follow-up examinations, or to the fact that the depth of the lesion was underestimated during the initial examination.

Recurrence and Transition to Invasive Treatment. Recurrence or progression of caries was observed in 15–25% of patients, primarily within 6–12 months after completion of the active treatment course. Approximately 20–40% of patients eventually required a transition to restorative treatment: either due to the formation of a cavity or because the depth of the lesion at the outset was greater than clinically apparent.

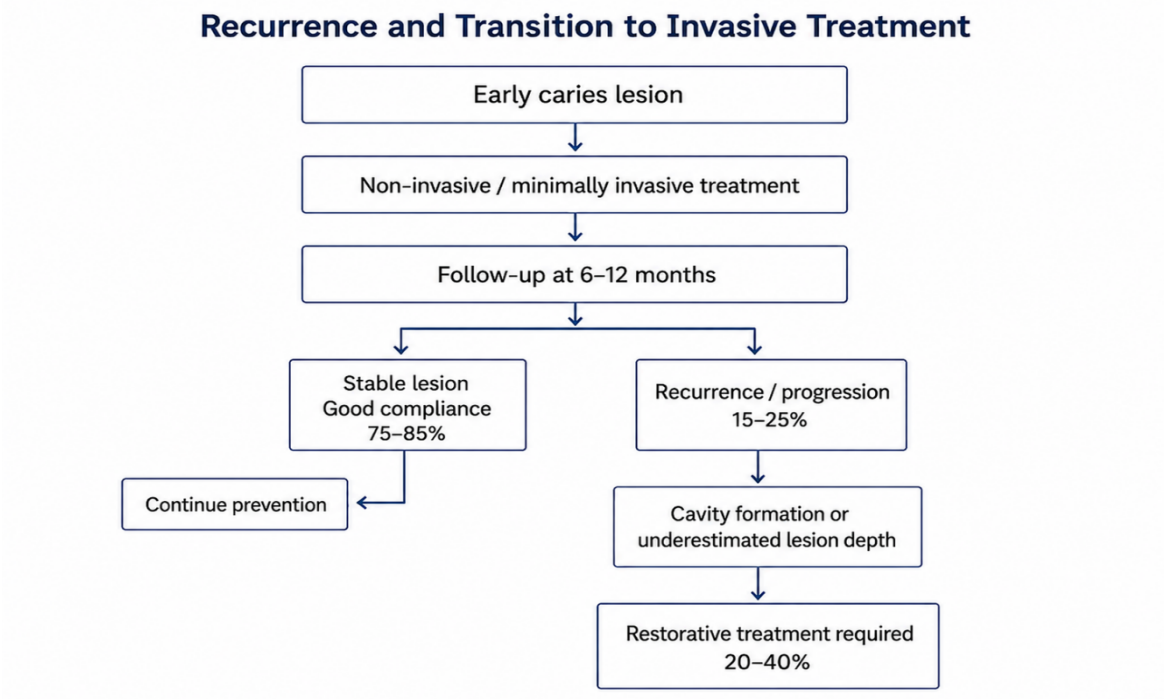

Fig. 2. Compliance-adjusted pathway of recurrence and transition to restorative treatment

In patients without conservative treatment and without control of risk factors, progression to carious cavities was observed in 40–70% of cases within 1–2 years. Some lesions remained stable or progressed very slowly, especially with a low overall cariogenic load. However, it was not always possible to predict in advance which lesion belonged to which group based solely on clinical data.

Results in children and adults. Children usually showed a faster response to conservative treatment. Initial lesions stabilized in 80–90% of cases, while recurrence was relatively uncommon. The first changes were often visible after 2–4 weeks, and stabilization was usually reached within 2–3 months. Parental support was important here: when parents monitored daily hygiene and helped maintain the routine, adherence was comparatively high.

In adults, the results were more modest: stabilization in 60–75% of cases, recurrence in 20–30%, and a compliance was noticeably lower. Tissues responded more slowly - the first changes appeared after 3–4 weeks, and complete stabilization took 3 to 6 months. A combined approach was more often required. The difference between the groups is easily explained: children have higher enamel mineral activity and better buffering capacity of saliva; in adults, these mechanisms are weaker, so the outcome depends even more on behavior between visits.

The Impact of Timely Treatment. When patients sought treatment at the non-cavitary stage, stabilization was achieved in 80–90% of cases, and in a significant portion of these, remineralization therapy and hygiene correction were sufficient. In cases of late presentation, when a carious lesion had already formed or the process was approaching the dentin, the effectiveness of the conservative approach decreased to 40–60%, and in 50–70% of cases, preparation was already required.

Discussion

Clinical results compared to study data. Stabilization rates of 70–90% in compliant patients and 30–50% in non-compliant patients correspond to the

range described in randomized trials, although direct comparison is complicated by differences in inclusion criteria. Paris et al. (2010) reported a reduction in the progression of proximal lesions by approximately threefold 18 months after infiltration [12]; Martignon et al. (2012) confirmed these results in a three-year follow-up [15]. The stabilization rate with infiltration in the author's own practice (80–90%) corresponds to the upper limit of these data, which likely reflects the selection of patients with regular follow-up.

The fact that 50–60% of patients with initial caries present after cavitation has already occurred implies that the actual potential for conservative management is significantly higher than what is currently achieved in practice. A significant portion of the lesions that required preparation and filling could have been stabilized earlier. Preventive examinations, in this context, allow for the detection of non-cavitated lesions before they progress to a carious form, which defines their clinical role.

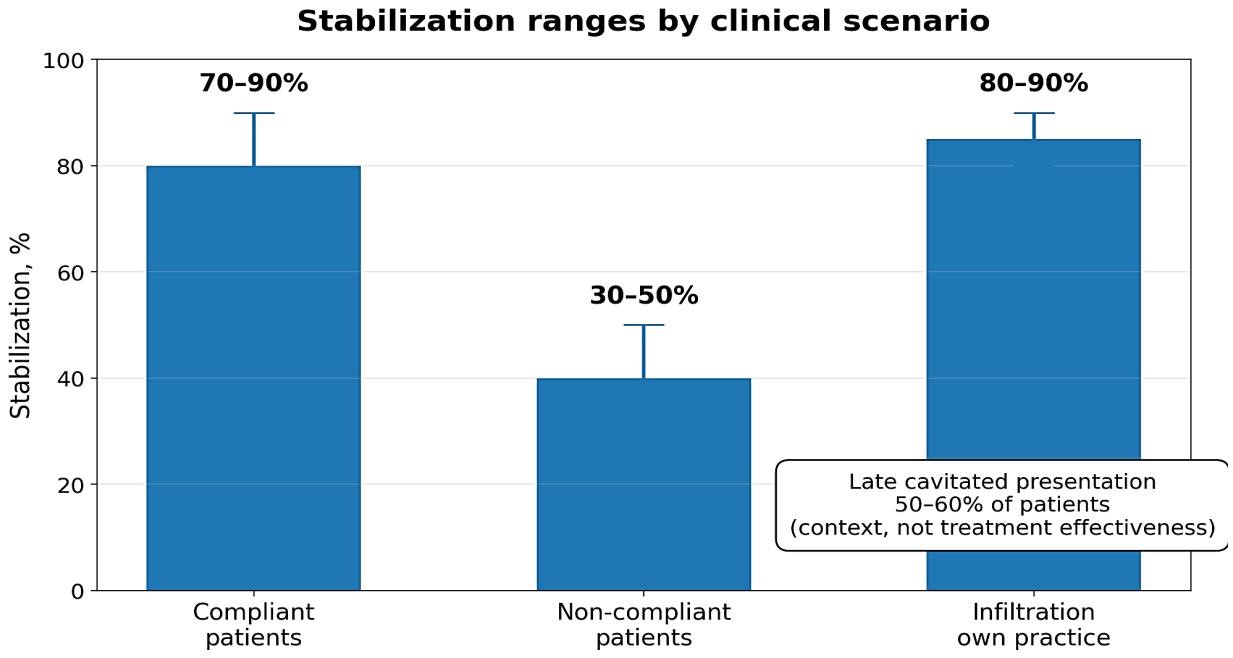

Fig. 3. Stabilization Ranges and Preventive Potential in Early Caries

Patient Compliance and Behavior. After treatment, daily patient behavior often determined whether the lesion remained stable. Adherence explained approximately 50–60% of the differences in outcomes. This finding positions compliance not merely as a confounding variable, but as a primary prognostic factor within a behavior-integrated preventive dentistry model - a compliance-based prognostic system embedded in the SECSP framework. The most common problems were frequent sweet snacks, missed evening brushing, lack of interdental cleaning, and unfinished fluoride courses. When there was no pain, patients often assumed that the lesion was no longer a problem. Without follow-up, early progression could remain unnoticed for several months.

Frencken et al. (2012) emphasize that a minimally invasive approach requires active patient participation [4]. In the author's clinical practice: approximately 30–50% of patients significantly improve their oral hygiene after the cause-and-effect relationships are explained; another 20–30% consistently follow the recommendations; the rest revert to their previous habits. About half of the patients willingly choose "treatment without drilling," but are not always ready to fulfill the part of the agreement regarding dietary habits and regular checkups.

Specifics and visual aids worked better than any general advice: showing a photo of the lesion, explaining that the problem isn't the amount of sugar, but how often it comes into contact with the enamel. The author often told patients directly: "If you don't change your habits, this spot will turn into a cavity in a few months." Those who understood this and returned for follow-up visits had significantly better results.

Biological and Clinical Factors. Even with good hygiene, some lesions stabilize more slowly. This may be related to low salivary buffering capacity, reduced remineralizing potential, xerostomia, or systemic disorders of mineral metabolism. In these situations, the clinician may choose resin infiltration or schedule follow-up visits at shorter intervals.

Anatomy and access also matter. Orthodontic appliances, deep fissures, and approximal surfaces can prevent remineralizing agents from reaching the lesion properly. Because of this, standard remineralization is not always enough, and the treatment approach may need to be adjusted.

A separate source of failure: underestimation of lesion depth during the initial examination. In approximately 30% of unfavorable cases, the lesion was found to be closer to the dentin than expected based on clinical data. Where the clinical picture is ambiguous, a bitewing radiograph or transillumination reduces the risk of error.

Dynamics of Results. Comparing his own practice over time, the author notes an increase in the stabilization rate from approximately 65–70% to 80–85%, while the frequency of progression to preparation decreased from 25–30% to 15–20%. Several changes in approach explain this result. The transition to the principles of selective caries removal has allowed for the preservation of dense dentin over the pulp even in cases of deeper lesions. Infiltration has begun to be used more widely for approximal and aesthetically sensitive lesions, which has affected the number of teeth preserved without preparation. Finally, follow-up examinations have become more systematic - progress is now recorded in a timely manner, and treatment strategies are adjusted before the situation worsens.

Among those who returned for follow-up (about 50–60%), stable results were recorded in 80–90% of cases; among those who did not return, only in 50–60%. There are two explanations for this: timely detection of deterioration allows for adjustments to treatment strategy before complications arise, and regular contact with the doctor prevents the patient from "forgetting" about treatment between visits.

Study Limitations. The retrospective nature of the analysis and the single-center sample limit the external validity of the conclusions. These indicators should be interpreted as clinical observations, not as results of a randomized study. The enamel condition was not verified histologically, and the assessment

did not include microbiological monitoring or standardized saliva testing. Although these data are less controlled, they are based on real clinical practice. Patients differed in adherence: some followed the recommendations, some did so only partly, and some did not return for follow-up. For this reason, the observations show not only the potential of conservative treatment, but also its limits in everyday work.

Conclusions. Conservative management of early-stage caries is effective when the lesion is detected before cavitation occurs and the patient returns regularly for follow-up. Under these conditions, stabilization becomes the typical clinical outcome rather than the exception. Of 10 patients with non-cavitated lesions, in 6–7 the process stabilizes completely, in 2–3 partially, and in 1–2 progresses to the cavitation stage and requires preparation.

The choice of method depends on the location, activity, and clinical characteristics of the lesion. Remineralization therapy is appropriate for smooth surfaces and fresh lesions; resin infiltration provides better predictability for approximal and aesthetically significant lesions; a combined approach yields the highest stabilization rate (85–95%) and is indicated for active or multiple lesions. The author prefers the combined approach in cases of increased caries risk and gives it priority in such cases.

Patient adherence explained approximately 50–60% of the differences in treatment outcomes. In practice, the main risk was often the patient's attitude to early lesions. If there was no pain, follow-up visits and fluoride treatment were easily postponed or ignored. Therefore, the final result depended not only on the chosen method, but also on whether the patient understood the risk and continued daily hygiene control.

Early detection changed the prognosis considerably. When non-cavitated lesions were diagnosed in time, stabilization without invasive treatment was achieved in 80–90% of cases. With delayed diagnosis, this rate decreased to 40–60%. Preventive examinations were therefore important because they allowed

clinicians to detect lesions before cavitation, while conservative management was still likely to work.

The use of selective caries removal, resin infiltration, and systematic recall was associated with a reduction in progression to invasive treatment from 25–30% to 15–20%, demonstrating the practical impact of a structured minimally invasive approach on preservation of tooth hard tissue and reduction of unnecessary drilling. These outcomes informed the Stoianov Early Caries Stabilization Protocol (SECSP): a compliance-integrated minimally invasive treatment framework combining risk stratification, differential lesion management, and a behavior-integrated preventive dentistry model.

The stepwise structure of the SECSP makes it reproducible across different clinical settings, clinically transferable to general and preventive dentistry practice, and directly applicable within standard preventive dentistry workflows. As these findings remain observational, prospective randomized validation with standardized adherence assessment is indicated.

Author's contribution. This study introduces:

– a structured prognostic approach for early-stage caries management based on longitudinal practice-based clinical outcome analysis;

– the Stoianov Early Caries Stabilization Protocol (SECSP): a compliance-integrated minimally invasive treatment framework;

– a differential decision pathway for non-cavitated lesions incorporating risk stratification, compliance-adjusted planning, and method selection;

– a behavior-integrated preventive dentistry model identifying patient adherence as the primary prognostic determinant in conservative caries management.

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