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Review Derleme

WHITE SPOT LESIONS: DIAGNOSIS AND TREATMENT METHODS

Beyaz Nokta Lezyonları: Tanı ve Tedavi Yöntemleri

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ABSTRACT

White spot lesions are early caries lesions with a milky white opaque appearance, clearly distinguishable from the surrounding intact enamel due to the difference in refractive index between the intact enamel and the demineralized area. Diagnosing these lesions and treating them early prevents the excessive loss of material in the dental tissue that will occur as the caries progresses. This review is mainly focusing on, the development, diagnosis and management of the white spot lesions.

Keywords: *Dental caries, white spot lesion, demineralization, remineralization, resin infiltrant*

ÖZ

Beyaz nokta lezyonları, sağlıklı mine ile demineralize alan arasındaki kırılma indeksi farkı sonucunda çevredeki sağlıklı mineden açıkça ayırt edilebilen, süt beyazı opak görünüme sahip başlangıç çürük lezyonlarıdır. Bu lezyonların tanısının konulup erken tedavi edilmesi, çürüğün ilerlemesiyle oluşacak diş dokusundaki aşırı madde kaybını engeller. Bu derlemede, beyaz nokta lezyonlarının oluşumu, tanı ve tedavi yöntemleri incelenmiştir.

Anahtar Kelimeler: *Diş çürüğü, beyaz nokta lezyonu, demineralizasyon, remineralizasyon, rezin infiltrant*

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INTRODUCTION

In today's dentistry, it is a priority to diagnose dental caries in the early stages and reverse this process. For this purpose, preventive applications aim to prevent demineralization before it occurs, to remineralize demineralized areas before cavitation occurs, and to restore tooth-hard tissues to their former health (1). Early diagnosis and treatment of caries lesions allow the physician to perform easy-to-apply treatments in a shorter period of time, easy tolerance of the treatment by the patient, and economic and conservative applications (2).

White Spot Lesions

White spot lesions, which are limited to enamel, are the earliest stage of caries formation. White spot lesions, also called 'initial caries', 'early enamel caries', or 'smooth surface caries', occur as a result of demineralization that starts when the pH in the oral environment falls below the critical value of 5.5 and remains at this value for 30 minutes (3). The opaque white appearance is due to the loss of minerals in the subsurface enamel and the different reflection of light compared to intact enamel. However, these areas should be differentiated from hypocalcified areas. In the differential diagnosis of these lesions, visual and probe examinations after drying the lesion with air spray are important. When the surface is wet, white spot lesions look translucent, but after they are dried with air spray, they appear opaque white. Conversely, hypocalcified defects exhibit opaque white pigmentation on dry surfaces and are unaffected by environmental conditions. The surface of the earliest caries lesions is porous and softer, even though both lesions have a non-cavitated surface. Dental plaque formation is not seen on surfaces with hypocalcified defects, although it is typically apparent on surfaces with early caries lesions (4). White spot lesions are common in orthodontically treated patients, and these lesions may cause aesthetic problems even years after treatment (5). In the literature, the prevalence of white spot lesions varies between 23% and 95% when different evaluation methods are used (5-7).

The white spot lesion consists of 4 layers from the outside to the pulp: the superficial layer, the lesion body, the dark layer, and the translucent layer (2). The superficial layer is the outermost, hardest, and most difficult to dissolve the layer of enamel caries. It is more porous than intact enamel. The pores are wider than the pores in a normal enamel structure. This layer is permeable to ion diffusion. Thus, the migration of calcium and phosphate minerals belonging to the enamel structures dissolved in the lower layer to the surface and the migration of fluoride from the outside to the enamel surface make the superficial layer more resistant to acid attacks. The superficial layer becomes hypermineralized by remineralization from the outer part and the accumulation of the structures destroyed by the deeper caries layers in this layer. The lesion body forms the largest part of the enamel caries below the superficial layer and can be observed on radiographs in advanced lesions. It contains 24% less mineral by volume than intact enamel. The area is highly porous. The pore volume, which is 5% near the superficial layer, increases to 25% towards the center of the body. The dark layer lies beneath the lesion body and appears dark under polarized light microscopy. The large pores in the caries body become micropores in the dark layer. These micropores are formed by the accumulation of material into large pores, that is, by remineralization. Longer remineralization treatment is required for white spot lesions with a large dark layer. The layers where remineralization is observed in white spot lesions are the dark layer and the superficial layer. The translucent layer distinguishes carious enamel structure from normal, intact enamel. Retzius lines and transverse lines of prisms are completely absent or very reduced. Both large pores and micropores were found in the structure of the translucent layer which is ten times more porous than normal enamel (8,9).

Today, dentists aim is to treat these lesions with non-invasive methods and to take precautions by identifying all risk factors and preventive treatments in order not to lose the aesthetics and functions of the teeth.

Methods Used in the Diagnosis of White Spot Lesions

1. Visual and Radiographic Evaluation

In the light of standardized examination, visual inspection, probing, and radiography have been used for diagnostic purposes for many years. By spreading caries-causing bacteria from the affected location to other areas or by stimulating the formation of occlusal caries in its early stages, probe inspection may result in iatrogenic damage (10). Today, probe examination is not preferred because it may damage non-cavitating surfaces. A blunt-tipped periodontal probe can be used to check the surface structure of the lesion. Quantitative grading of the severity, progression, or regression of lesions detected by visual examination is important for determining the correct treatment strategy (11). It is possible to minimize the examiner's interpretation and increase reproducibility by using detailed visual indices. The addition of conventional radiographs to the visual examination is helpful for making the diagnosis. However, occlusal lesions where the outermost enamel layer is intact and there is no macroscopic distortion are difficult to diagnose, and radiation is the most obvious disadvantage (12). Additionally, in order to interpret radiographs and differentiate between intact, demineralized and carious teeth, a software can be used. This software in the Logicon system (Logicon Caries Detector™; Carestream Dental, Atlanta, USA) analyzes

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and correlates radiographs with clinical pictures and generates a graphical chart (13).

2. Laser Fluorescence

The laser fluorescence method is based on the measurement of the difference in fluorescence between intact and carious enamel surfaces after the application of light to dental tissue. One of the most widely used device is DIAGNOdent (KaVo Dental, Biberach, Germany) (11). Afterward, some features of DIAGNOdent were developed, and a DIAGNOdent Pen (KaVo Dental, Biberach, Germany) device working with the same mechanism was produced. Its lightweight, practical usage, and ability to rotate the tips around its axis are important advantages compared to DIAGNOdent (11,14).

3. Quantitative Light-activated Fluorescence (QLF)

It's a type of laser fluorescence that works by using light rather than a laser. Green fluorescence from hard tissues is stimulated by blue light that is applied to the teeth during QLF. Demineralized areas seem darker and have a reduction in this natural glow (15). This method gives successful results, especially on flat surfaces (16).

4. Fluorescence Camera

A fluorescence camera is an intraoral camera that records the reflected light as a digital image by applying a violet-colored light (λ=405 nm) to the tooth (16). VistaCam iX (Dürr Dental, Bietigheim-Bissingen, Germany) is a camera system launched in 2007. The head of the system, which is used for caries detection is called VistaProof (Dürr Dental, Bietigheim-Bissingen, Germany) (17).

5. Electronic Caries Monitor (ECM)

Due to the porosity of demineralized enamel, these areas are filled with saliva, and electrical conduction is increased. Intact enamel surfaces have a limited conductivity. These days, the electronic caries monitor (ECM; Lode Diagnostic, Groningen, The Netherlands) is the most significant tool employed for this aim. While ECM performs better on smooth surfaces, it is less effective on occlusal surfaces (18).

6. Alternating Current Impedance Spectroscopy

Another technique based on measuring electrical conductivity is the spectrophotometer with alternating current impedance (CarieScan Pro; CarieScan Ltd., Dundee, Scotland). This technique detects soft-surface and occlusal caries using a variety of electrical frequencies. This approach is more dependable than ECM since it is not impacted by dyes or discoloration (19).

7. Canary System

Canary is a laser system for the visualization of tooth structure and caries by using a combination of heat and light. The basis of both frequency domain laser-induced infrared photothermal radiometry and modulated luminescence technologies is the measurement of the tooth's absorption of infrared laser light in proportion to the temperature change that results. Compared to visual methods, the thermal energy conversion of optical energy offers a more accurate evaluation of tissue density and lesion depth (20).

8. Fiber Optic Transillumination (FOTI), Digital Fiber Optic Transillumination (DIFOTI)

The early identification of caries is starting to benefit from the fast advancement of imaging technologies. Using light transmission, these techniques include digital fiber optic transillumination (DIFOTI; Electro-Optical Sciences, Irvington, NY, USA) and fiber optic transillumination (FOTI; Electro-Optical Sciences, Irvington, NY, USA). Small, superficial white lesions can be observed when fiber optic light is used; a strong light beam enters the tooth and experiences optical refraction (21). The DIFOTI technique can identify demineralization as early as two weeks, but it is unable to gauge the extent of the lesion (22). DIAGNOcam (KaVo Dental, Lake Zurich, IL, USA), in which the fiber optic transillumination system is combined with a camera, is a newly developed system that works on the principle of simple transillumination and uses stimulating light at a wavelength of 780 nm near infrared (23).

9. Ultrasound

When using ultrasonography, high-frequency sound waves that the probe applies are reflected back from the tissues and transformed into electrical pulses, which are then measured. Research has demonstrated that ultrasonography is an effective technique for treating deep dentin lesions, but its use in assessing remineralization is even greater (24,25). The sensitivity and specificity of the method were reported to be 88% and 86%, respectively, in a study comparing ultrasonography, histology, and ultrasound to detect white spot lesions in mandibular molars. The study concluded that ultrasound is a useful tool in the detection of these lesions (26).

10. Optical Coherence Tomography (OCT)

Optical coherence tomography (OCT) combines low-coherence interferometry with confocal microscopy to produce high-resolution pictures of around 10-20 µm using infrared light. With OCT, precision is quite good. After being exposed to acid for 24 hours, it might exhibit early mineral alterations in vivo (27).

Classifications Used in the Diagnosis of White Spot Lesions

1. Nyvad System

The Nyvad system is a reliable method for the visual and tactile evaluation of caries lesions with and without cavitation. According to this system, the carious lesion is classified as active or inactive by evaluating only the clinical features of the surface (opacity, presence of cavitation) (Table 1) (28).

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Table 1: Nyvad criteria for caries lesion

0	Sound
1	Active caries (intact surface)
2	Active caries (surface discontinuity)
3	Active caries (cavity)
4	Inactive caries (intact surface)
5	Inactive caries (surface discontinuity)
6	Inactive caries (cavity)

2. Universal Visual Scoring System (UniViSS)

This system was developed to overcome the deficiencies of previous systems and to meet new requirements. In this system, evaluation was made in three steps (29).

Step 1: Lesion detection and caries severity assessment: Six scores are used to assess the severity of caries.

Score F is the first visual sign of a caries lesion.

Score E, established caries lesion;

Score M, microcavity and/or localized enamel breakdown;

Score D, dentin exposure;

Score L, large cavities;

Score P is recorded as pulp exposure.

Step 2: Assessment of coloration: Four scores are used.

Score 1, white;

Score 2, white-brown;

Score 3, dark brown;

Score 4 recorded as greyish translucent.

Step 3: Activity assessment:

Lesion activity is recorded as yes or no.

Assessment for occlusal pits and fissures:

Active;

- If detected several years after the eruption of the tooth,
- If there's a vinyl record,
- An enamel surface that appears dull and rough after air drying,
- Microcavities,
- White or white-brown coloration,
- Soft, wet, and colored dentin.

Inactive;

- A permanent image for years,
- No vinyl,
- Smooth and shiny appearance after drying with roasting,
- No pathological progression,
- Brown discoloration of the enamel,
- Sound, dry, and uncolored dentin.

3. The International Caries Detection Assessment System (ICDAS)

In 2002, the International Caries Diagnosis and Assessment System (ICDAS) was developed as a guide for caries diagnosis. In 2005, it was observed that the current findings of the ICDAS criteria were insufficient for evaluating lesion activity, and ICDAS II was created by modifying them. The ICDAS system categorizes caries into 3 groups: coronal caries (pit-fissure, buccal-lingual, mesial-distal), restoration and sealant-related caries, and root caries. The ICDAS II criteria determined for the flat surfaces of the teeth explained the stages of caries from the first stages of demineralization until cavitation occurs in six stages, as seen in Table 2 (30).

Table 2: ICDAS II criteria (ICDAS= The International Caries Diagnosis and Assessment System)

ICDAS- II Criteria	
0	No change in enamel translucency after air drying for 5 seconds
1	Visual changes after prolonged air drying
2	Significant visual change in enamel
3	Disruption of the surface integrity of opaque or coloured enamel
4	Dark shadow reflected from dentin
5	Visually detectable cavitation reaching the dentin
6	Cavitation involving more than half of the dentin

Treatment of White Spot Lesions

There are two strategies in the treatment of white spot lesions. The first one is based on the protection and remineralization of the lesions. The second is interventional treatments such as tooth whitening, microabrasion, and resin infiltration.

1. Oral Hygiene

The main goal of contemporary dentistry is to stop the course of disease by noninvasively managing early caries lesions through remineralization. Maintaining excellent dental hygiene is crucial for shielding teeth against white spot lesions. Patients' education and motivation will be the main means of achieving this. As long as the surface of the initial enamel caries is intact, it is suggested as the most effective control method to ensure oral hygiene and mechanical removal of plaque with a toothbrush and dental floss (31). Although it has been shown that regular tooth brushing and flossing habits are effective methods for reducing the amount of plaque on the tooth surface and preventing caries formation, the use of fluoride and other chemoprophylactic agents, together with mechanical applications, is also of great importance for complete caries control (32).

2. Regulation of Diet

Dietary fermentable carbohydrates are metabolized anaerobically, and the organic acids produced demineralize enamel and dentin, creating a local risk factor for dental caries. Proteins such as cheese, milk, and unrefined cereals are known to contain polyphenols, organic phosphates, minerals, and chemical building

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blocks of foodstuffs such as cocoa and tea show a bacteriostatic effect by inhibiting the metabolism of pathogenic microorganisms (33).

3. Nano Hydroxyapatite

Hydroxyapatite is one of the few materials that can support bone development and osseointegration without degradation or dissolution. In a study by Swarup and Rao, it was reported that hydroxyapatite dissolves under acidic conditions, calcium and phosphorus ions are released, and thus remineralization occurs (34).

4. Casein Phosphopeptide - Amorphous Calcium Phosphate (CPP-ACP)

The CPP-ACP nanocomplex is incorporated into the dental plaque structure and inhibits demineralization by increasing plaque calcium and phosphate ion levels. CPP-ACP-containing products are used in caries prophylaxis, as a preventive treatment in individuals with high caries risk, and in the treatment of white enamel lesions in orthodontic patients (35).

5. Tricalcium Phosphate

Tricalcium phosphate is obtained by modifying sodium lauryl sulfate with calcium. Since the beta form of tricalcium phosphate is less soluble, the alpha form is often preferred. Alpha-calcium phosphate is thought to provide remineralization by increasing free calcium and phosphorus levels (36). In an *in vitro* study on remineralization of initial enamel lesions, tricalcium phosphate was reported to provide more effective remineralization than fluoride toothpastes (37).

6. Bioactive Glass

When the calcium sodium phosphosilicate (NovaMin®; NovaMin Technology Inc., FL, USA), which is in the class of bioactive glasses that have been used in dentistry in recent years, comes into contact with saliva, sodium, calcium, and phosphorus ions that can be used for remineralization is released, and hydrocarbon apatite similar to hydroxyapatite is formed (36).

7. Fluoride Applications

The caries-preventive effect of fluoride is explained by three basic mechanisms that can be listed as preventing demineralization, increasing remineralization, and inhibiting bacterial enzymes (38). As a result of the replacement of fluoride with hydroxyl ions in hydroxyapatite crystals, fluoroapatite or fluorohydroxyapatite crystals are formed. With in the incorporation of fluoride into the tooth structure, the resistance of the tissue against acid attacks increases, and demineralization is prevented. The remineralization capacity of fluoride depends on the amount of bioavailable calcium and phosphate ions in saliva. Fluoride shows a high tendency to bind to calcium. Therefore, it attracts the calcium ions in the saliva to itself, by interacting with the crystals on the tooth surface and phosphate ions follow the calcium ions. The calcium and phosphate ions lost as a result of demineralization are restored to the tooth structure, and remineralization is achieved (39).

8. Microabrasion

Microabrasion helps to improve the appearance of white spot lesions by removing material from the outer layer of the enamel, but the amount of material that needs to be removed for the improvement of the appearance is high. However, in the resin infiltration technique, only the hypermineralized surface layer is removed, and the low-viscosity resin can penetrate deep into the lesion (40). When the effect of resin infiltration and microabrasion on the aesthetic appearance of whitehead lesions was analyzed, resin infiltration seemed to be more effective than microabrasion for the aesthetic improvement of whitehead lesions after 12 months of follow-up (41).

9. Tooth Whitening Treatment

Whitening treatment is used to camouflage the undesirable aesthetic appearance of white spot lesions and developmental enamel opacities. This treatment has limited aesthetic effects and has side effects such as tooth sensitivity after treatment. The disadvantages of this procedure include such results like; a decrease in the microhardness of the enamel surface as in demineralized enamel surfaces, a decrease in abrasion resistance, a decrease in dentin microhardness, and a decrease in dentin bond strength if restoration is performed immediately or less than one week after whitening (42). It has been shown that the decrease in the microhardness of the enamel in bleached teeth can be restored by the post-treatment remineralization process (43). Whitening treatment is recommended for the removal of discoloration after orthodontic treatment (44). Demineralized areas formed during orthodontic treatment can appear as white spot lesions adjacent to the brackets and the free gingival margin. White spot lesions can often be concealed by whitening the intact enamel adjacent to the demineralized areas with whitening treatment performed under the supervision of a dentist.

10. Laser Application

When the laser is applied to the enamel surface, a microgap is formed that allows important ions to remain fixed instead of leaving the enamel during acid attacks to which the enamel is exposed, and the surface properties of the enamel are affected (45). Ca^{+2}, PO4, and F ions in saliva precipitate into these microgaps and increase the resistance of enamel against demineralization. In addition, they also increase mineral uptake from saliva (46). Topical fluoride laser usage has been demonstrated to have a synergistic impact, including enhanced fluoride absorption and reduced enamel disintegration rate (47). The hydroxyapatite in the tooth structure absorbs a significant amount of

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energy from the Er,Cr:YSGG laser, preventing surface ablation. It only modifies the enamel's chemical composition (48). It has been demonstrated that low intensity Nd:YAG laser irradiation is beneficial in preventing occlusal caries in the pits and fractures of deciduous teeth (49). Given the difficulty of utilizing fluoride, CO_2 lasers are equally useful in the control of demineralization, with advantages such as rapid, convenient, and simple application, particularly in children (50). Further research is required to determine how long-lasting laser treatments are in preventing dental caries and how they affect white spot lesions by remineralizing them.

11. Ozone Application

Ozone's potent oxidizing activity and consistent microbiocidal impact make it a viable alternative therapy option. It destroys the acid-producing bacteria that cause caries and breaks down the cell membranes of bacteria, viruses, and fungus. Nevertheless, this course of therapy is limited to eliminating germs from the external surface of the enamel lesions and halting the demineralization process (51).

12. "Etch-Bleach-Seal" Technique

Another conservative treatment option for developmental enamel opacities is the "etch-bleach-seal" technique. In this technique, it is aimed at penetrating the fissure sealer into the enamel surface, similar to resin infiltrant, and improving the aesthetic appearance by changing the light refractive index of the enamel. In this technique, the enamel surface is first roughened with 37% orthophosphoric acid for 60 seconds, then 5% sodium hypochlorite is applied to the roughened enamel surface for 5-10 minutes to whiten it. The enamel surface is roughened again with 37% orthophosphoric acid for 60 seconds, and the treatment is completed by covering the porous surface with fissure sealant (52).

13. Restorative Procedures

Direct and indirect composite resin restorations and porcelain veneers can be used in the treatment of white spot lesions and developmental enamel opacities where minimally invasive treatments are not successful and material loss is observed. Composite restorations and porcelain veneers, which are the last option for an aesthetic appearance, cause the loss of some intact tooth structure and are more costly. However, in very severe cases, they provide the most aesthetically pleasing result (53).

14. Resin Infiltration Treatment

In the early period, it is possible to penetrate low-viscosity resins into the highly porous structure of the caries lesion, occlude this area, and stop the caries. In order to increase the penetration depth of the resin, it is necessary to use a resin with a high penetration coefficient as well as remove or perforate the superficial layer with a low porous structure. In the studies, it has been found that materials with a higher penetration coefficient provide better penetration with longer application times, and it has been reported that the resin with these properties is TEGDMA (54,55). Resin infiltration treatment can be used in the white spot lesions that occur on flat surfaces after orthodontic treatment, large opaque band-shaped lesions on the tooth surface, molar-incisor hypomineralization, hypoplasia caused by trauma, mild and moderate fluorosis cases, and opaque band-shaped lesions observed due to fluorosis. The resin infiltration technique neither generates pulpal inflammation or tenderness after application, nor causes gingivitis or periodontitis, is easily tolerated by patients, does not require local anesthesia during the procedure, and since the refractive index of the resin (RI: 1.52) is similar to that of healthy enamel (RI: 1.62), it can mask white spot lesions by changing the light reflection characteristics of enamel (52).

Icon (DMG, Hamburg, Germany) is a product developed for the microinvasive treatment of initial carious lesions. It is sold on the market in two separate sets, one for aproximal surfaces and one for flat surfaces. Each set contains acid (Icon-Etch), ethanol (Icon-Dry), resin infiltrant (Icon-Infiltrant), and special application tips. Chemically, Icon-Etch contains 15-20% hydrochloric acid, pyrogenic silicic acid, and a surface-active substrate. Icon-Dry contains 99-100% ethanol. Icon-Infiltran contains a methacrylate-based resin matrix, initiators, and additives. The first stage of Icon application is the application of 15% HCl acid (Icon-Etch) to the surface of the initial enamel lesion for 2 minutes to remove the superficial layer of the lesion. In the second stage, 99% ethanol (Icon-Dry) is applied for 30 seconds to ensure that the lesion is sufficiently dehydrated. In the last stage, TEGDMA (Icon-Infiltrant), a resin with high penetration capacity, is applied for 3 minutes and then polymerized for 40 seconds with a light source with a wavelength of at least 450 nm. Hydrochloric acid (15% HCl) and orthophosphoric acid were used to remove the hypermineralized superficial layer, and it was found that the application of HCl acid for 120 seconds was superior to the application of 37% orthophosphoric acid gel to remove the superficial layer of enamel lesions (56). In contrast to microabrasion of enamel, this technique only abrades 30-40 μm. With this technique, the abrasion of intact and demineralized enamel is at the same rate because no pressure is applied. Studies have shown that resin infiltration reduces surface roughness, improves microhardness, and masks the color of demineralized lesions at the initial stage (57,58). It was found that enamel infiltrated with Icon showed a significant color change after staining compared to intact enamel in a

study by Araujo et al. on bovine teeth to evaluate the color stability of white spot lesions and the whitening effect of resin infiltration after staining on infiltrated and stained surfaces. Therefore, in order to extend the life of resin infiltration in cosmetically significant places, patients should refrain from consuming colored food and beverages. However, whitening treatment can be applied successfully if the infiltrant becomes discolored (59).

CONCLUSION

Early diagnosis and treatment of demineralization of the enamel surface is significantly important for the preservation of the natural structure of the tooth. Initial caries lesions can be controlled by educating and motivating the patient in terms of oral hygiene. Remineralizing agents such as topical fluoride applications, CPP-ACP, antiseptics, lasers, and ozone applications can be used for treatment. In cases where the white, opaque appearance of the lesions can not be treated aesthetically, there are a couple of applications that can be used for treatment such as, tooth whitening, microabrasion, or restorative. The resin infiltration technique is a very effective method to correct and maintain the appearance of white spot lesions in appropriate cases.

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