INSTITUTO UNIVERSITÁRIO EGAS MONIZ

MESTRADO INTEGRADO EM MEDICINA DENTÁRIA

MANAGEMENT OF POST ORTHODONTIC WHITE SPOT LESIONS

Trabalho submetido por

AZMI BEN DHIAB

para a obtenção do grau de Mestre em Medicina Dentária

Outubro de 2021

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DEDICATION

I would like to express my gratitude to my parents Mohamed&Najet, my wife Meriem, my brothers Marouane, Amir, Elyess, Wala and Kenza.

I would to think my cousins Ahmed, Mejdi, Walid, Imen, Adib, Acil and Dan. Without their tremendous understanding and encouragement in the past few years, it would be impossible for me to complete my study.

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ABSTRACT

White Spot Lesions (WSLs) are a common iatrogenic finding along brackets used in orthodontic treatment. WSLs are frequently noticed as small opaque lesions with lessened radiolucency which might have a lasting unaesthetic effect. These lesions might range from small lines along bracket peripheries and less frequently might be observed as larger demineralized areas with or without cavitation.

The development of WSLs is principally enhanced by the accumulated plaque around brackets due to a compromised oral hygiene that might be aggravated by the presence of dental crowding. Furthermore, The presence of fixed orthodontic apparatus leads to alteration in the oral microflora causing reduction in the PH level and increased bacterial adherence to the metal facade through electrostatic effect.

There are several preferences for treatment of WSL, ranging from conservative approaches relying on remineralization to invasive techniques. The severity of lesions is a determinant of which option is most appropriate. The management of WSLs is based on remineralization strategies or in other situations on a minimal-invasive camouflage of the lesions. Although orthodontic WSLs are one of the most frequent and most visible adverse effects of comprehensive fixed appliance treatment, the efficacy of their intervention continues to be assessed in the literature and up to date there is no consensus on the best evidence-based approach to manage such lesions.

Therefore, the aim of the present thesis is to review and critically appraise the contemporary evidence related to causes, diagnosis, prevention, risk evaluation and management of WSL associated with orthodontic appliances. Furthermore, clinical recommendations that might be useful for both the general dentist as well as the orthodontist.

This literature review will be undertaken by searching the database engines, Pubmed, Medline, Google Scholar, B-on and Science Direct. The search will include the literature published inbetween 2005-2021.

Key word: Orthodontics, white spot lesion, enamel demineralization, resin infiltration, fluoride

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LIST OF ABBREVIATIONS

ACP: Amorphous Calcium Phosphate

Al: Abbreviation for et alia: and others

CPP: Casein phosphopeptide phosphate

DEJ: Dentin enamel junction

DMFT: Decayed, missing, or filled teeth

DIFOTI: Digital Imaging Fiber-Optic TransIllumination

CPP: Casein phosphopeptide phosphate

DMG: Dental Milestones Guaranteed

FOTI: Fibre-Optic Transillumination

ICDAS: International caries detection and assessment system

JADA: The Journal of the American Dental Association

LED: Light-emitting diode

NaFl: Fluorescein sodium

Ppm: Partie par million

QLF: Quantitative light-induced fluorescence

RMGICs: Resin Modified Glass Ionomer

TEGMA: Triethylene glycol dimethacrylate

WSLs: White spot lesions

µm: Micrometer

£: Pound

I. Introduction

The most frequent iatrogenic complication of orthodontic treatment is the unwanted development of white spot lesions (WSLs) which can compromise the final results of a successfully treated case [1, 2]. WSLs are formed by demineralization of the subsurface layer of the enamel clinically observed as opaque, white areas mildly softer than the peripheral enamel surface. The uneven surface of orthodontic brackets, tubes and elastomeric chains create areas on the tooth surfaces favor the increase of plaque accumulation due to the restrictive access for self-cleaning and difficulty in performing oral hygiene measures effectively. [3] Furthermore, WSLs are commonly noticed in orthodontic cases treated with aligners and bonded expanders that cover the teeth. [9]WSLs are considered an incipient caries lesions and they can be seen as soon as one month of bracket bonding. In a study, undertaken on 338 orthodontically treated patients Shungin et al. observed that 36% of the examined subject had a minimum of one WSL on a maxillary incisor tooth at the completion of treatment in spite of the undertaken preventive efforts. WSLs are usually detected on the cervical third of the crown. [3] The spots range in size and appearance from a minor white opaque lesion to brown discoloration and roughness of the enamel surface. Depending on the level of the oral hygiene, the developed lesions might remeniralize, continue to be stable or form a caries cavity that requires restoration. The most common cause of this phenomenon is inappropriate and poor oral hygiene before and during treatment as well as when the treatment begins at a young age. [4]

Before beginning orthodontic treatment and for avoiding the development WSLs it is very important to educate each patient to maintain an excellent oral hygiene. Besides, orthodontist must use appropriate measures to prevent the formation WSLs. Furthermore, orthodontists must detect and manage WSLs when present as early as possible. Nowadays, several methods and treatment modalities are available in order to successfully prevent and treat WSLs. Therefore, the aims of the present work were to summarize the related updates in the literature and to provide a contemporary guidance to relevant prevention, detection and treatment WSLs.

II. White spot lesions in orthodontic treatment

2.1. Definition and histopathology

WSLs are a result of acid dissolution of the enamel surface in the initial stage of carious development . Clinically, WSLs are defined as an opaque area on the enamel surface with a visual appearance ranging from white to brown that may present cavitation or not.[5] From a histological point of view WSLs the lesion is characterized by four successive zones (figure 1 and Figure 2) that have been defined as follow:

1. Surface zone: This zone ranges from 20 µm to 50 µm of thickness and it represents a relatively unaffected sphere by the carious process. The mineral loss in this area is approximately 5 %.

2. Body of the lesion: This zone appears parallel to the surface or adopt a triangular shape, with a top oriented toward the dentinoenamel junction. The mineral loss ranges from 10 % to 25 %.

3. Dark zone: This zone is observed in 85–90 % of the lesions and present a mineral loss of 5 %.

4. Translucent zone: This zone is not always detectable and present a mineral loss of 1%.

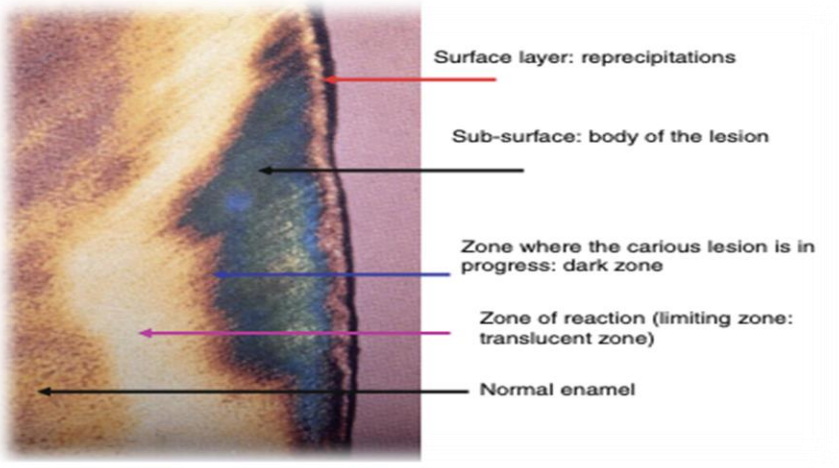


Figure 1: Ground section of an initial carious enamel lesion (with permission of Dr Omar Marouane).*

*The surface layer is due to mineral re-precipitations. In the subsurface, the body of the lesion is triangular in shape, with a summit oriented toward the dentinoenamel junction. The lesion displays two borders: one dark zone that is in progress and a reaction zone (limiting or translucent zone).

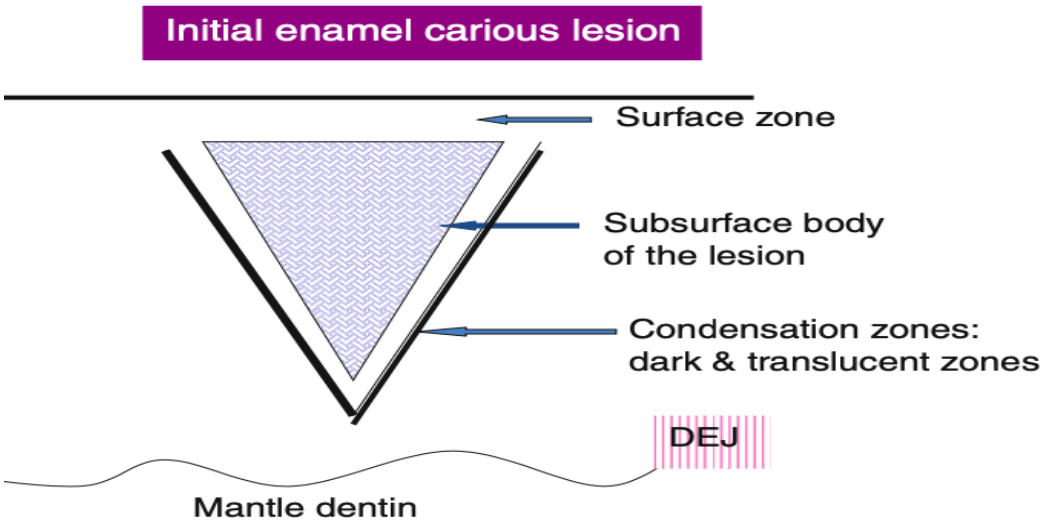


Figure 2: Schematic drawing of the initial carious lesion including a surface zone, the subsurface lesion (or body of the lesion), the condensation zones (dark zone and translucent zone), and the normal enamel above the mantle dentin

Figure 3: Post-treatment intraoral frontal (C), right (A) and left (B) side views of a patient treated with full fixed orthodontic appliances for 24 months. Note that WSLs (white and brown spot) can be observed in the cervical areas of maxillary and mandibular (with permission of Dr Omar Marouane).

2.2. Incidence and prevalence

The reported prevalence of WSLs varies among different publications that develop during orthodontic treatment. The reported occurrence of post orthodontic treatment WSLs varied from 4% to 96%.[6]

This wide discrepancy might be explained by the heterogeneous methods used to detect the WSLs. Using standardized clinical images under reflected light condition Richter et al. [7] found that 72.9 % of 350 orthodontic patients treated with fixed orthodontics appliances had developed new WSLs. In contrast, using the quantitative light-induced fluorescence method to detect WSLs, Boersma et al.[8] found that 97% of their examined patients had developed new WSLs after performing fixed orthodontics treatment.

After post-orthodontic bracket removal,[9] and due to natural remineralisation it has been shown the number of WSLs decrease over the years. A study utilizing the quantitative light-induced fluorescence for the detection of WSLs revealed that 33% of WSLs had regressed after six months, 10 % had worsened whereas the majority of the WSLs remained stable.

2.3. Risk factors in the formation of WSLs

2.3.1. Gender

Despite the fact that the carious process is not related to gender, several studies had reported that male patients are more affected by WSLs during orthodontic treatment than females. This gender difference may be due to the commonly reported better oral hygiene standards in females than in males.[10,11]

2.3.2. Age

Several studies have shown that the incidence of WSLs correlate positively with the patient age. The age at the start of treatment is an important predicting factor in WSLs development. Indeed, it has been shown that adolescent patients are more prone to WSLs than adult patients. This can be attributed to better oral hygiene maintenance by adult

patients than adolescents which is considered a relevant clinical parameter for orthodontists who decide at what age a treatment is initiated.[10, 11]

2.3.3. Location of WSLs

Several studies have evaluated the location of WSLs during orthodontic treatment. While, it has been shown that no significant differences were observed in WSL development between right and left sides of the maxillary and mandiblular teeth, significant disparity was observed in the location of WSLs between both jaws, maxillary teeth being more affected than mandibular teeth. Furthermore, it has been noticed that the most affected maxillary teeth were in this order; lateral incisors, canines, premolars, followed by central incisor. While in the mandible, premolars followed by canines were the most affected. .[11] Regardless of the teeth affected, the cervical third of the vestibular tooth surface is always the most affected.

The highest incidence of WSLs in maxillary lateral incisors can be explained by the small tooth surface area between the gingiva and bracket leading to increase in plaque accumulation. Furthermore, the fact that maxillary teeth are more affected than their mandibular counterpart may be explained by the increased exposure of the lower teeth to saliva compared to the upeer ones.[10]

2.3.4. Treatment duration

Numerous researchers noticed that prolonged orthodontic treatment is an important risk factor for developing WSLs. Patients with longer treatment duration presented with significantly more WSLs in comparison with patients whose treatment time was short . This is because the longer the appliance remains on the teeth, the longer the teeth are exposed to plaque accumulation. [10]

2.3.5. Appliance type

Over the last decades, the spectrum of orthodontic appliances has widened with the addition of more versatile modalities including self ligating technique and Invisalign. Numerous investigations compared the association between the type of orthodontic appliances used and the level of biofilm formation. Polat et al., concluded that the development of WSLs depends mostly on the the patient oral hygiene status. There is low evidence that stainless steel wire and self ligation apparatus are better than

elastomeric ligation in terms of plaque accumulation. However, this evidence is not strong enough to favor self ligation method over conventional fixed appliance therapy to minimize plaque accumulation. .[12]

Forsberg et al. [13] conducted a split mouth prospective study to evaluate and compare the association between the type of ligature used in fixed orthodontic appliances being a steel or elastomeric ligature. and the number of microorganisms embedded into steel and elastomeric ligation. A split mouth design was planned; elastomeric rings were used for ligation on one side of the arch, whereas steel wires on the opposite side. The result of this study showed that the number cariogenic bacteria are significantly higher with elastomeric ligation in comparison with steel ligation. The authors concluded that for patients with poor oral hygiene the use of elastomeric rings for ligation cannot be recommended due to higher risk microbial accumula-tion adjacent to the brackets, leading to development of WSLs.

2.3.6. Risk assessment

Prior to starting an orthodontic treatment, a risk assessment could be undertaken. Patients are categorized in one of two groups according to their potential of developing WSLs: a low risk group and a high risk group. The orthodontist has to allocate the patient according to a multifactorial approach (Table 1). A patient is categorized in the high risk group if he has more than one high risk factor. Furthermore, when a patient develops a WSL during treatment, he automatically be categorized as a high risk [8].

Table 1: Risk assessment for development of white spot lesio

Low risk	**High risk**
No previous WSL	Existing WSL
Good oral hygiène	Poor oral hygiène
Low dietary sugar exposure	High dietary sugar exposure
Short treatment time	Long treatment time
Controlled etching	Excessive etching
Lingual appliances	Labial appliances
No/minimal DMFT	High DMFT score
No intratreatment lesion(s)	Itratreatment lesion(s)

III. Diagnosis

3.1.Preparing teeth for a clinical examination.

Preparing teeth for a clinical detection of WSLs is a mandatory step. Prior to clinical examination tooth surface should be clean and dry. As a matter of fact, the earliest optical changes of WSLs are very subtle. For a better detection of WSLs pellicle, plaque and food debris that may hide WSLs must be eliminated. Ideally cleaning teeth should be carried out using a rotating brush with a paste or an air-polisher. Enamel should be dried prior to WSLs detection in order to improve their visibility. This is because the difference between the refractive index on a wet enamel surface is 1.3 and the refractive index of sound enamel is 1.6. This difference is due to the filling of wet enamel pores with water leading to a reduction of their refractive index. The drying process is undertaken by air (refractive index 1.0). Therefore this large difference i between dry and wet enamel lead to a better detection of WSLs.[14]

3.2. Visual

Classically detection of WSLs is performed in adequate lighting under reflected light conditions. WSLs recognition involves perception of signals such as a change in enamel color that may range from white to brown zone or translucency modifiying the enamel surface.[15] During orthodontic treatment, and for a better visualisation, it is important to remove arch wires, ligatures, elastomeric chains, or other orthodontic auxiliaries for a better visibility. Also, the presence of gingival inflammation may reduce the amount of visible enamel between the bracket and gingival margin. Performing the clinical examination in healthy periodontal conditions is important. Otherwise some WSLs may be overlooked or underestimated.

According to the visual appearance of the WSLs many classifications and scoring systems have been developped in order to describe and to assess accurately WSLs. Among all this classifications International caries detection and assessment system ICDAS [16] (Table 2) and Gorelick[17] scoring system (figure 4) are the most widely used classifications. Despite intensive effort to describe WSLs, (figure 5) detection of early stage of carious lesions have some limitations. Enamel opacity detection involves perception of subjective signals such as color or translucency. The latter may be

influenced by external light conditions which may make enamel opacities undetectable or overlooked when clinical examination is performed under excessive brightness or in inadequate lighting conditions (table 3,4). [18, 19]

Finally it has been shown that detection of WSLs under reflected light condition remains insensitive. Indeed, it is widely recognised that visual caries detection cannot notice caries lesions until a relatively advanced stage, involving as much as one-third of the thickness of enamel . [15]

Table 2: Classification of caries lesions according to ICDAS by Ekstrand (Caries Res, 1997)

	Clinical criteria	**Histology**
0	Absence of, or slight change in, enamel translucidity after prolonged drying (> 5 s)	No clear-cut demineralization
1	Opacity or scarcely visible discoloring on wet surface but visually distinct after drying/	Demineralization limited to the external half of the enamel
2	Opacity or discoloring clearly visible after drying	Demineralization as far as the median third of the enamel
3	Presence of an enamel cavity in colored opaque enamel and/or greyish discoloring of the underlying dentin	Demineralization as far as the internal third of the enamel. The dentin can also be affected
4	Cavity in opaque or discolored enamel exposing the dentin	The entire thickness of the enamel is involved and the dentin is infected

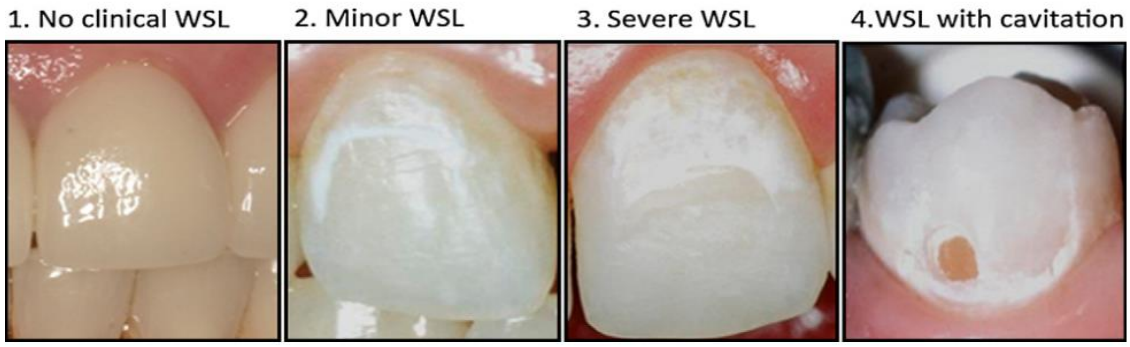


Figure 2: Clinical images showing Gorelick classification system for scoring clinically visible white spot lesions (goerlick et al,1982)

Table 3: Description of codes for scoring activity and severity of enamel, coronal, and root dentin caries lesions Nyvad criter (*Nyvad et al. 1999)l*

Score	**Category**	**Criteria**
0	**Sound**	Normal enamel translucency and texture (slight staining allowed in the fissure)
1	**Active, non-cavitated**	Whitish/yellowish opaque with loss of luster; feels rough when the tip of the explorer is moved across the surface; usually covered with plaque. No clinically detectable loss of substance Smooth surface: lesion typically located close to the gingival margin
	Active, cavitated	
2	**Surface discontinuity**	Same as score 1. Localized surface defect (micro-cavity) in enamel only
3	**Cavity**	Enamel/dentin cavity visible with the naked eye; surface feels soft or leathery on gentle probing. There may or may not be pulpal involvement
4	**Inactive, non-cavitated**	Whitish-brownish, or black. The surface is shiny, feels hard, and smooth when the tip of the explorer is moved across the surface. No clinically detectable loss of substance Smooth surface: lesion typically located at a distance from gingival margin
	Inactive cavitated	
5	**Surface discontinuity**	Same as score 4. Localized surface defect (microcavity) in enamel only
6	**Cavity**	Enamel/dentin cavity visible with the naked eye; the surface may be shiny, feels hard on gentle probing. No pulpal involvement

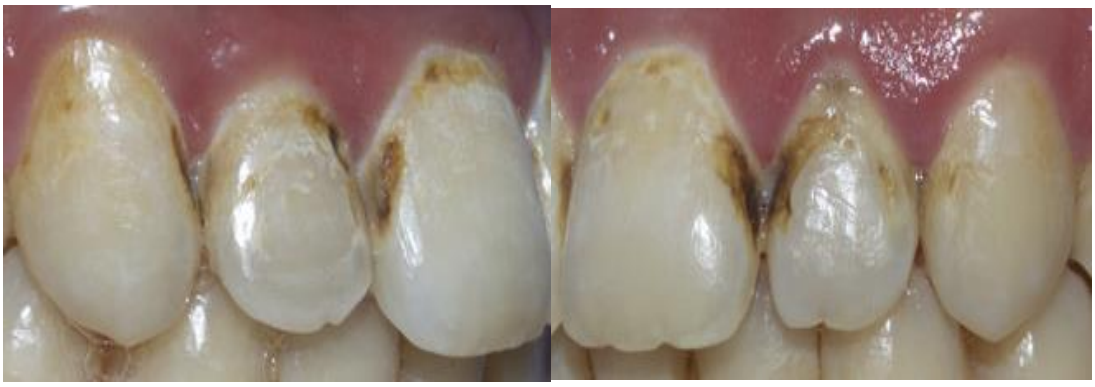


Figure 3: Post-treatment intraoral right and left upper-side views of a patient treated with full fixed orthodontic appliances for 24 months. Note the cavitated and non-cavitated brown spot that can be observed in the cervical areas of maxillary anterior teeth (with permission of Dr Omar Marouane).

Table 4: Characteristics of active and inactive caries lesions* (adopted from JADA)

Activity assessment factor	**Caries lesion activity assessment descriptors**	
	Likely to be inactive/ arrested	**Likely to be active**
Location of the lesion	Lesion is not in a plaque stagnation area	Lesion is in a plaque stagnation area (pit/fissure, approximal, gingival)
Plaque over the lesion	Not thick or sticky	Thick and/or sticky
Surface appearance	Shiny; color: brown-black	Matte/opaque/loss of luster; color: white-yellow
Tactile feeling	Smooth, hard enamel/ hard dentin	Rough enamel/soft dentin
Gingival status (if the lesion is located near the gingiva)	No inflammation, no bleeding on probing	Inflammation, bleeding on probing

*Source: Ekstrand KR, Zero DT, Martignon S, Pitts NB. Lesion activity assessment. Monogr Oral Sci 2009;21:63–90 (See Chaps. 4.1 and 4.3 for addional information on caries activity assessment)

3.3. Transillumination

Transillumination is an additional detection method that has been developed to complement visual-tactile caries detection.

Transillumination has been described from more than 200 years in caries detection. This method has been widely studied, it has been validated histologically and has a level of sensitivity and specificity comparable to a conventional radiograph. This technique uses a high intensity white light positioned in the lingual surface and directed tangentially to the tooth surface to allow early carious lesion detection. Nowadays transullimination techniques has been improved, Some of them are specifically designed for caries detection and can be associated with camera and specific software in order to monitor WSLs overtime. However it should be highlighted that some authors have proposed non-specific devices such as composite curing lights or pocket flashlight in order to detect WSLs (figure 6). [5, 20, 21]

In a recent study, it has been shown that transillumination allows better detection of enamel opacities on anterior teeth by aiding clinical discrimination between healthy an unhealthy enamel. In comparaison with reflected light condition. Transillumination allows detection of subclinical extensions and new lesions undetectable under convention light examination (Table 6).[22]

In addition to increasing the contrast between healthy an unhealthy enamel, tsillumination may also be useful in a better understanding of the lesion body characteristics.[23] Being simple, non-invasive, painless and without any risk to the patient, transillumination represents a promising imaging method for detecting WSLs (table 5).[20]

Figure 4: Transilluminated images representing the appearance of white spot lesions under Fibre-Optic Transillumination (FOTI) (with permission of Dr Omar Marouane).

Figure 5: Transilluminated images representing the appearance of white spot lesions under Fibre-Optic Transillumination (FOTI).. (with permission of Dr Omar Marouane)

Table 5: American Dental Association Caries Classification System (adopted from JADA)

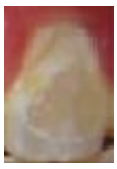
	AMERICAN DENTAL ASSOCIATION CARIESS CLASSIFICATION SYSTEM			
	Sound	**Initial**	**Moderate**	**Advanced**
Clinical Presentation	No clinically delectable lesion. Dental hard tissue appears normal in color, translucency, and glossy.	Earliest clinically detectable lesion compatible with mild demineralization. Lesion limited to enamel or to shallow demineralization of cementum dentin. Mildest forms are detectable only after drying. When established and active, lesions may be white or brown and enamel has lost its normal gloss.	Visible signes of enamel breakdown or signs the dentin is moderately demineralized.	Enamel is fully cavitated and dentin is exposed. Dentin lesion is deeply severely demineralized.
Other Labels	No surface change or adequately restored	Visually noncavitated	Established, early cavitated, shallow cavitation, microcavitation	Spreaddisseminated, late cavitated, deep cavitation
Infected Dentin	None	Unlikely	Possible	Present
Accessible Smooth Surfaces, Including Cervical and Root		 	 	 

Table 6: Characteristics of Fibre-Optic Transillumination (FOTI & DIFOTI)

FOTI and DIFOTI	
Sensitivity	4–94% [8, 9]
Specificity	74–100% [8, 9]
Perceived Ease Of Use (PEOU)a	1. (DI)FOTI is easy-to-use 2. Some experience is required to become skilful at using (DI)FOTI 3. Learning to operate (DI)FOTI is easy 4. (DI)FOTI is flexible to interact with 5. Interacting with (DI)FOTI is mostly clear and understandable, but can be confounded by other conditions (i.e. stain, enamel dysplasia, tooth fracture) 6. It is easy to interact with (DI)FOTI
Advantages/ disadvantages	Advantages : 1. Short learning curve 2. Non-invasive and non-irradiating 3. Suitable for all surfaces and lesion stages 4. Image storage for longitudinal monitoring and patient education (DIFOTI only) 5. Can be used for crown and root fracture detection and canal orifice location **Disadvantages :** 1. Qualitative output requiring subjective interpretation 2. Experience needed to improve consistency of lesion detection and classification 3. Unsuitable for longitudinal monitoring (FOTI only)
Time	15–20 s per tooth surface
Cost	**DiaLUX** ≈£100–200 **Microlux** -Device and one light guide (2 mm or 3 mm tip) ≈ £240 -Additional light guide ≈ £115 -Proximal caries attachment ≈ £100 (requires purchase of disposable tips) Disposable sleeves ≈ £35 per box of 250 **DIAGNOCam** ≈£4500 Reusable tips ≈£160 per tip

3.4. Quantitative light-induced fluorescence QLF

QLF is an optical technology for early detection and quantification of dental caries. Recently, this technique has been suggested as a more accurate method of detecting WSLs

The QLF technology can measure both the mineral content as a fluorescence loss and bacterial activity as a red fluorescence simultaneously (figure 8). The fluorescence changes detected by QLF can be visual-ized as an image, which enables to non-destructively quantify the physical characteristics of caries lesions and monitor its changes as numerical values. [8, 25] QLF is a highly sensitive diagnostic test, but it has largely been limited to research applications and may not be practical for routine diagnosis of WSL in patients undergoing orthodontic treatment (table 7).[11]

Table 7: Characteristics of various QLF devices

	Qraycam™	**Qscan™**	**Qraypen™**
Generation	3rd	3 rd	3rd
	2014	2014	2015
Light source	Dual color LEDs	Single color LEDs	Dual color LEDs
Filters	Integrated glass Inspektor filter	Integrated Inspektor filter	Integrated glass Inspektor filter
Type of device	Handy camcorder	Handy homecare device	Intra-oral camera
Range of capturing	From partial to whole oral cavity		rom individual tooth to whole oral cavity
Zoom and focus	Manual zoom and focus	Not available	Autoadjust focus
Portability	Good	Exelent	Good
Main purpose	Clinical practice	Education and home-use	Clinical practice
Upgraded version (release date)		Qscan Plus™ (2017)	
Product image			

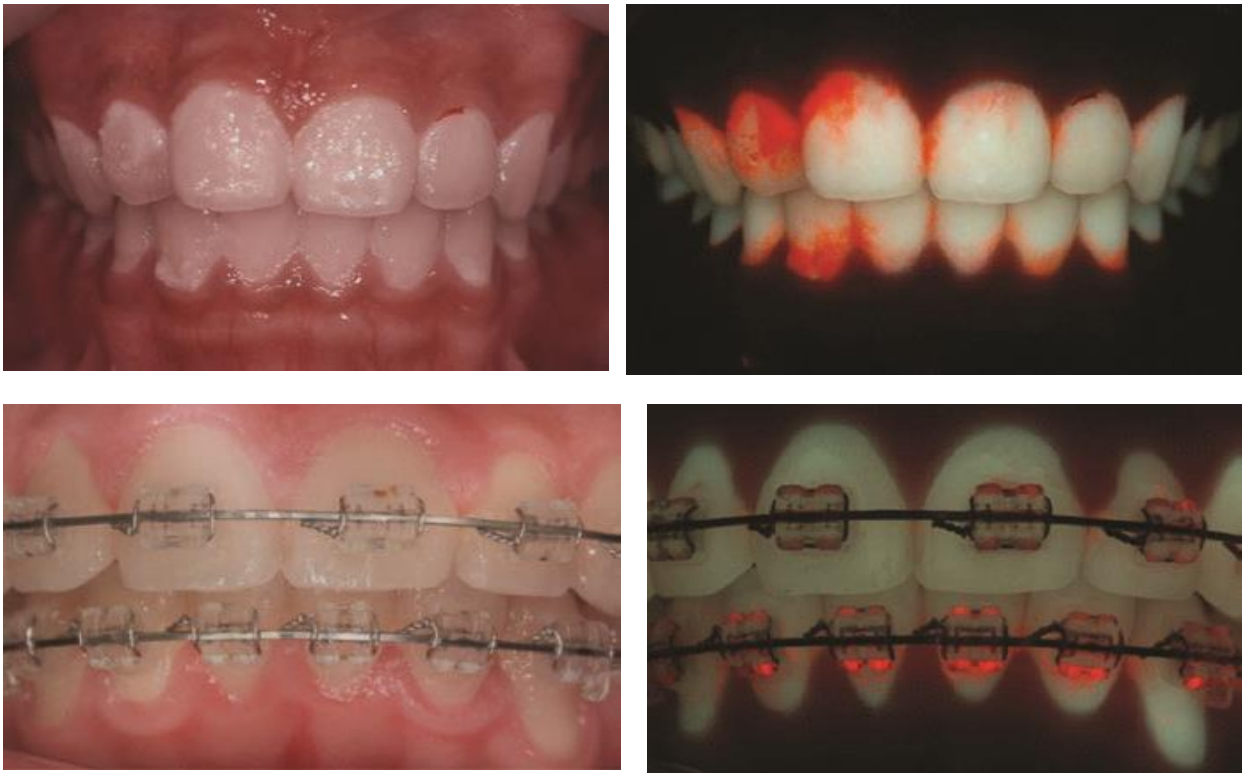


Figure 6: Quantitative light-induced fluorescence images (white-light and fluorescence images) of normal and orthodontic patients obtained using the Qraycam device. (with permission of Dr Omar Marouane)

IV. Prevention of WSLs before orthodontic treatment

4.1.Disruption of bacterial biofilm

Due to the high risk of developing WSLs in patients with poor oral hygiene, it is imperative to motivate patients and linking the commencement of orthodontic treamtnet with improving oral hygiene status. Tooth brushing and flossing are more difficult and time consuming during orthodontic treatment. Thus, comprehensive oral hygiene instructions are crucial including educating patients to clean around each individual bracket-especially between brackets and gingival margins following every meal and snack.[11]

Despite the fact that electric toothbrushes is not essential to maintain good oral hygiene it may be useful to patients who struggle the maintenance of good oral hygiene (table 8).[26].

4.2. Inhibition of demineralization/Promotion of remineralization

4.2.1. Fluoride toothpastes

Flouridated water and flouridated toothpastes are proven to be effective in controlling caries in the general population and are considered imperative in avoiding the development of WSLs. Toothpastes with higher fluoride concentrations (1,500–5,000 ppm) have a greater ability to inhibit demineralization and promote remineralization, therefore they are recommended for patients that presented with poor oral hygiene (table 8) .[11, 27]

Fluoride protects the enamel by converting hydroxyapatite into fluorapatite crystals, which have a lower solubility in the oral environment than hydroxyapatite crystals.[28] Patients are usually advised to brush their teeth at least twice daily, for two minutes each time using toothpastes with higher fluoride concentrations. This is followed by a vigorous swishing of the toothpaste for 30 seconds without rinsing with water, and avoidance of eating or drinking for the duration of 2 hours afterwards. This,procedure has shownto be effective in reducing the incidence of developing WSLs during treatment.[29]

4.2.2. Fluoride rinses

In a systematic review published by Benson et al.[29], it has been shown that daily use of .05 % sodium flouride mouth rinse reduces the incidence and severity of WSLs during orthodontic treatment. Nevertheless, it must be remembered that for fluoride rinses to be successful in prevention of WSL, they must be used consistently, and there is evidence to suggest that compliance with such rinses is poor. [11, 30] Indeed it has been proven that orthodontic patient compliance in a preventive fluoride-rinse program is less than 15 %.[30]

4.2.3. Fluoride-releasing bonding materials

4.2.3.1. Resin Modified Glass Ionomer (RMGICs)

For patients that presented poor oral hygiene, RMGICs have been proposed as bracket bonding materials due to their continuous fluoride-releasing properties during orthodontic treatment.

RMGICs has the ability to absorb fluoride from the environment (e.g., fluoride toothpaste, oral rinse) and then re-release it beneath fixed appliance where WSLs are susceptible to develop. In comparison with conventional resin-based adhesives systems, several studies and systematic reviews have been shown that RMGICs protects the enamel from the development of WSLs during fixed orthodontic treatment. [29, 31-34]

4.2.3.2. Fluoride-releasing composite resins

Composite resins with fluoride-releasing potential have been designed for bonding orthodontic attachments. Unfortunately, it has been shown that most of the fluoride is released during the first few days or weeks after bonding brackets. In addition, and in contrast to RMGICs, composite resins with fluoride-releasing do not have the ability to absorb fluoride ions from the environment. Thus, fluoride-releasing composite resins do not provide the long-term cariostatic effect needed to prevent the development of WSLs. Thus, fluoride-releasing composite resins are not as effective in protecting the enamel against WSLs as RMGICs.[1, 35, 36]

4.2.4. Fluoride varnish

In addition to the use of fluoride-Releasing Bonding Materials it has been proven that the application of fluoride-releasing varnish around orthodontic brackets—especially for patient that presented poor oral hygiene, can also be employed to help reduce the development of WSLs. One of the benefits of fluoride varnish is that it works in the presence of plaque; thorough cleaning of the tooth surfaces is not necessary prior to application of varnish which may represent a simple method to increase fluoride exposure during orthodontic treatment. [1, 11, 37]]

4.2.5. Amorphous Calcium Phosphate (ACP)

Amorphous calcium phosphate (figure 9) has the potential to prevent the development WSLs and also to promote remineralisation of existing lesions. MI Paste (GC America) is a product that contains casein phosphopeptide ACP, a milk-derived protein. MI Paste Plus is the same product, but also contains 900 ppm of fluoride. Several studies have shown that ACP products are effective in preventing and treating WSLs around the braces.[38-41]

Figure 7: Tooth mousse past from GC

Table 8:Measures for prevention, intratreatment management, and treatment of white spot lesions (WSL)

Prevention protocols		**Itratreatment management (once WSL are noticed)**	**Postorthodontic treatment options for WSL**
Normal/low risk	**High risk (initial risk or poor compliance intratreatment)**		
-Tooth brushing (modified technique) with 1,000-ppm fluoride toothpaste 2 to 3 times daily	-Tooth brushing (modified technique 2-3 times daily) : 5,000-ppm fluoride toothplaste before bedtime and 1,000-ppm all other times using mechanical brush	-Tooth brushing (modified technique 2-3 times daily) with 5,000 ppm at bedtime and 1,000 ppm all other times	-No treatment/monitoring with natural resolution
-Prophylaxis every 4 months -Fluoride varnish every 4 months -0.5% NaFl rinse daily at bedtime	-Prophylaxis every 3 months -Fluoride varnish every 3 months -Xylitol chewing gum 3 to 5 pieces per day for at least 10 minutes per chew -Chlorhexidine rinse (2-week regimen) 30-second rinse daily after brushing before bedtime	-Prophylaxis every 3 months -Fluoride varnish every 3 months -MI Paste Plus (GC America, a+Alsip, IL, USA) application nightly after brushing teeth -Xylitol chewing gum 3 to 5 pieces per day for at least 10 minutes per chew -If above techniques have been utilized and still have progression of WSL and poor compliance, then proceed with EARY APPLIANCE REMOVAL	-Tooth whitening -Resin infiltration technique -Microabrasion / macroabrasion -Tooth preparation and restoration (direct resin or indirect veneers)

V. Management during the treatment

5.1.Reinforcement of oral hygiene and remineralisation protocol

Early detection of white spot lesions during orthodontic treatment is of great importance as it would allow implementing preventive measures to control the demineralization process before WSLs progression. With the aid of intraoral photographs taken before beginning orthodontic treatment, clinician should document any WSLs newly detected and use images for patient education. First, clinician should inform the patient and/or parent that WSLs have been detected, and explain the approaches that will be taken to prevent further damage.[11]

Reinforcement of oral hygiene instructions and diet control are highly desirable in order to maintain excellent oral hygiene. More frequent recalls between regular adjustments are also highly recommended in order to monitor existing WSLs detecting new ones on d to control the oral hygiene.[11]

For patients that presented poor oral hygiene, chlorhexidine rinses may be used to reduce the numbers of cariogenic pathogens. These rinses are recommended to be used in a 2-week regime, with the patient swishing for 30 seconds prior to bedtime. Besides, as with all chlorhexidine products, the clinician should inform patients that there is a risk for developing extrinsic staining of teeth.[27] On the other hand, some authors have proposed to prescribe a more rigorous fluoride regime including 5,000-ppm fluoride gel or toothpaste, and application of fluoride varnish every 3 months or perhaps at every orthodontic visit. However it must be remembered that fluoride do not remineralize WSLs but only prevent the development of WSLs by converting hydroxyapatite into fluorapatite crystals, which have a lower solubility in the oral environment than hydroxyapatite crystals.[1, 11, 37]

From this perspective the use of ACP products and remineralization of existing WSLs seems to be more suitable in this situation. These products should be applied in a pea-sized amount around teeth and orthodontic appliances after brushing teeth. If traditional 1,000-ppm fluoride toothpaste is used, then MI Paste Plus is recommended,

whereas MI Paste should be used if 5,000-ppm fluoride gels or pastes are used.[11, 42-44]

5.2. Early removal of appliances

When all appropriate preventive and management measures have been attempted and patients still fail to improve their oral hygiene, the clinician must use good judgment in deciding when fixed appliances should be removed. If WSLs are developing in the middle of treatment despite all efforts to prevent and treat WSLs them the removal of orthodontic appliance is mandatory if the orthodontic goals have not been completely achieved. Patients and their parents should be informed that in these case scenarios, further risk of enamel damage outweighs the reward of continuing with orthodontic treatment at this time. Patients may be placed in retention and advised that when motivation to maintain excellent home care improves, they can resume orthodontic treatment.[11]

VI. Treatment of the lesions (postorthodontics)

6.1.Therapeutic gradient

Once orthodontic appliances are removed and WSLs exist, the orthodontist must inform the patient of the available treatment options. Nowadays, the therapeutic arsenal available for treating WSLs is vast, based on different principles and their own mechanisms of action. These treatment may range from very conservative option (natural resolution) to more invasive treatment (tooth preparation and restoration).
Faced with this therapeutic panoply, it is sometimes difficult to choose the right treatment according to the clinical situation. (Figure 10) .

The determination of the severity of WSLs, the color of the lesion as well as the surface integrity are an important factor to record for planning which treatment is most appropriate. Recently, these treatment options have been classified within therapeutic gradient. This gradient aims to classify the treatment option from the most conservative option, more invasive treatment. This therapeutic gradient must be taken into

consideration for choosing the best treatment option that suit with the clinical situation.[45]

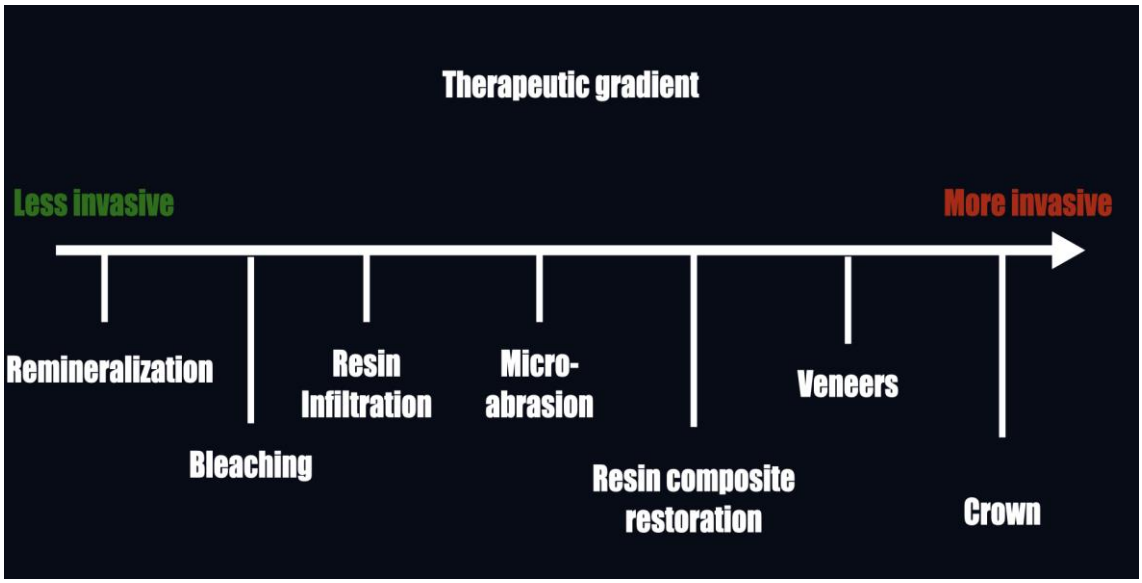


Figure 8: Schematic drawing showing the therapeutic gradient from Tirlet and Attal

6.2. Natural resolution

Several studies have been shown that after orthodontic treatment WSLs tend to decrease in area and improve in their appearance over the first 1 to 2 years after debonding.[46, 47] In another study, Van der Veen et al. used the quantitative light-induced fluorescence method and found that 6 months after bracket debonding, while 33 % of WSLs did remineralize somewhat (lesion regression), the majority of WSLs remained unchanged, whereas 10 % of WSLs worsened (lesion progression).[6]

The lesions activity largely determines the potential for visual improvement over the time. Indeed, active lesions having a better prognosis than arrested lesions. Active lesions do not present well hypermineralised surface layer that cover lesion body and therefore, are more prone to remineralise in comparison to arrested lesions that present hypermineralised surface layer that cover lesion body. Besides, active lesions are more porous and more affected in terms of the degree of hypomineralisation which lead to an easier infiltration of calcium and phosphorous into the enamel during the remineralization process. Although, high-concentration fluorides are important for prevention, their use on active WSLs may arrest the lesions and actually lead to the staining with a color ranging

from brown to dark. From an esthetical point of view stained lesions compromises the final result of orthodontic treatment and are more challenging to treat.[8]
According to the current knowledge it is important to not treat immediately WSLs after bracket debonding and to recall and reevaluate WSLs after 3 or 6 months and to leave natural remineralization taking place.

6.3.Remineralization using casein phosphopeptide-amorphous calcium phosphate (CPP-ACP)

CPP-ACP is bioactive material derived from the milk protein casein, can act as a reservoir of bio-available calcium and phosphate, facilitating their precipitation on the enamel surface and thus effectively enhancing remineralization. Research has indicated that CPP-ACP is anticariogenic and capable of reversing the early stages of enamel lesions in vitro and in clinical research. [48-52]

Depiste the fact that remineralization using ACP product remains the most "biological" approach this approach for treating WSLs has unfortunately many disadvantages. First this treatment procedure need a patient compliance. For several weeks patients should use the paste as instructed. As it has been proven that patient compliance in a preventive program is less than 15 % of orthodontic patients, the effectiveness of this procedure may affected by the patient. [30]

Besides, remineralization using ACP is a long-term therapy and the results are only felt on the aesthetic level after several weeks or months.[53, 54]

Moreover, although the strong evidence in promoting remineralization on WSLs, the efficacy of ACP for the esthetical regression of the lesion remains unclear. Indeed, remineralization using ACP seems to be unsuitable for ICDAS code 2. According to the current knowledge there is a lack of reliable evidence for the treatment of post-orthodontic WSL *in vivo.* [38, 55, 56]

Nevertheless immediately after bracket debonding remineralization using ACP product seems to be beneficial especially if associated with removebal retainer that can be used .

6.4.Resin infiltration

Resin infiltration of incipient carious lesions is a relatively new approach for treating WSLs. The idea behind this concept is not new and has been described in early 1970. The concept of infiltrating incipient carious is to infiltrate the micro-porosities of the WSLs with a very low viscosity resin that penetrate deeply the lesion body. Thus, instead of removing the porous carious tissue and to restore it, the aims of resin infiltration procedure is to"fill" the microporosities of WSLs at earlier stage.

The positive aspect of this procedure is to reduce microporosities of WSLs by creating a three-dimensional physical diffusion barrier of resin to prevent acid penetration and to limit further demineralization, incidentally, also to limit subsequent demineralization.Besides this technique is also capable to strengthen the demineralized tissue by mechanical support.[57-59] To this day, Icon (DMG) is currently the only product on the market that uses this approach.

Clinically, after erosion of the relatively hyper-mineralized layer with 15 % hydrochloric acid for 2 min, washing with water and drying with ethanol, the low-viscosity triethylene glycol dimethacrylate (TEGDMA) resin penetrates the porous body of the lesion and is subsequently hardened after exposure to a blue curing light.
The other positive aspect of this procedure the camouflage of the WSLs.((figure 11)

As a matter of fact, the opaque appearance of WSLs is the result of an optical phenomenon that is due to the difference between the refractory index of healthy enamel and demineralized enamel, which is left with voids filled by water or air. As a resin used have a close refractory index as sound enamel, resin infiltration is effective in improving or completely masking WSL. This technique has been validated invitro and invivo study and according to severals studies and systematic review, resin infiltration is the therapeutic of choice for treating WSLs.[2, 60, 61]

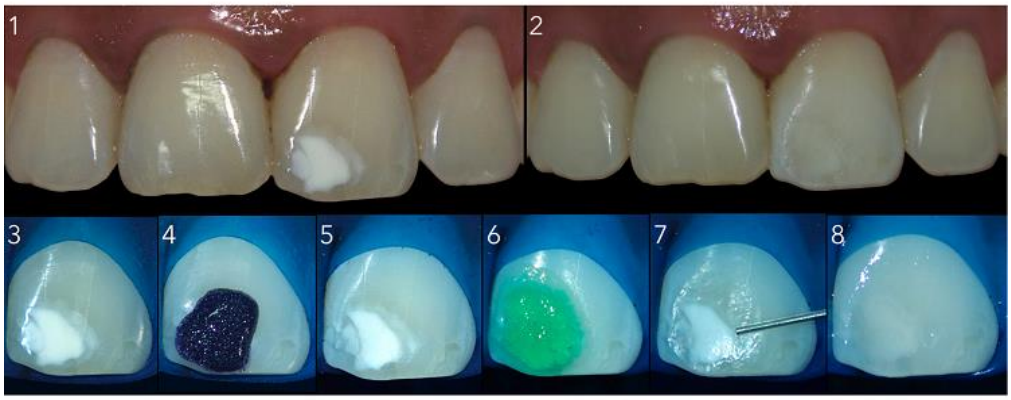


Figure 9: Resin infilitration technique (with permission of Dr Omar Marouane)

*(1, 2) Hypomineralization affecting the cervical third of the central incisor (3, 4, 5, 6) Phase of exposure to the lesion with micro-abrasion followed by the application of hydrochloric acid 15% (Icon etch) for 120s then the lesion was dehydrated with ethanol 99% for 30s (Icon dry) (2, 8) Phase of filling the lesion with the infiltrating resin for 3 min. (Icon infiltrant)..

6.5.Whitening

External bleaching is an another treatment option available for treating and improving the appearance of WSLs .[11]

The aim of external bleaching is to bring healthy and WSLs closer together optically. [62] Lightening reduces the contrast between the WSLs and the remaining tooth structure by increasing the overall brightness of the tooth. Therefore, lightening only makes sense if the tooth is not very bright. Besides, it is very important to keep in mid that external bleaching do not treat WSLs but only camoufle the lesion. From this perspective, and as external bleaching do not treat the WSLs, this procedure should not be recommended.

Nevertheless, external bleaching, in combination or associated with other treatment option may be helpful for removing stains from arrested WSLs that presents a dark or brown clinical appearance and should be considered as a pretreatment.(figure 12)

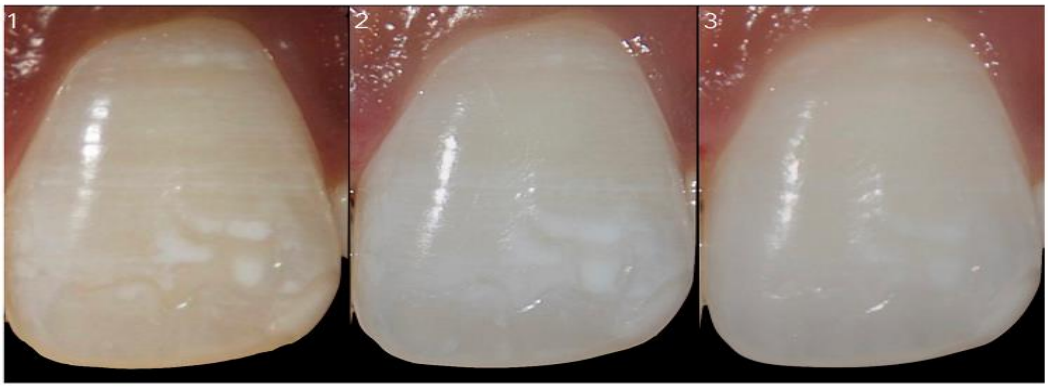


*Figure 10: Whitening technique (*with permission of Dr Omar Marouane)

*(1) Hypomineralization affecting the entire central incisor. The teeth being not very bright, the clarification was proposed in order to ca-muffle this aesthetic defect. (2) Ambulatory lightening with 10% carbamide peroxide (Philips Zoom NiteWhite, Discus Dental, Stamford, USA) made it possible after a week to gain luminosity. (3) By contrast, the cosmetic defect after 21 days has been corrected.

6.6.Microabrasion

Microabrasion is an another treatment option that has been described for treating WSLs related to orthodontic treatment. Mico-abrasion is a chemical and mechanical procedure that remover the outer surface of the enamel. [63] This technique involves using a slurry of pumice or silicon carbide particles and hydrochloric acid for removing the most superficial layers of enamel in concomitance with the lesioned enamel.

According to the product, the pressure used during the procedure and the time microabrasion removes from 25 to 200 µm of enamel thickness. From this perspective, it is very important to remember that micro-abrasion is a depth dependant procedure. Indeed, if the WSLs is deeper than micoabrasion can reach, this procedure will not be effective. In the other hand, as the microabrasion removes the external surface layer of the enamel we have to keep in mind this procedure do not treat WSLs but only try to remove it. From this perspective microabrasion should not be considered as a treatment for WSLs and should not be recommended.

6.7.Resin restorations/Indirect restorations

Patients with cavitated lesions, or more severe WSLs who have already attempted more conservative esthetic treatments without significant improvement may benefit from the preparation of the affected tooth surfaces and restoration with either direct resin restorations or indirect porcelain restoations (figure 13).[11]

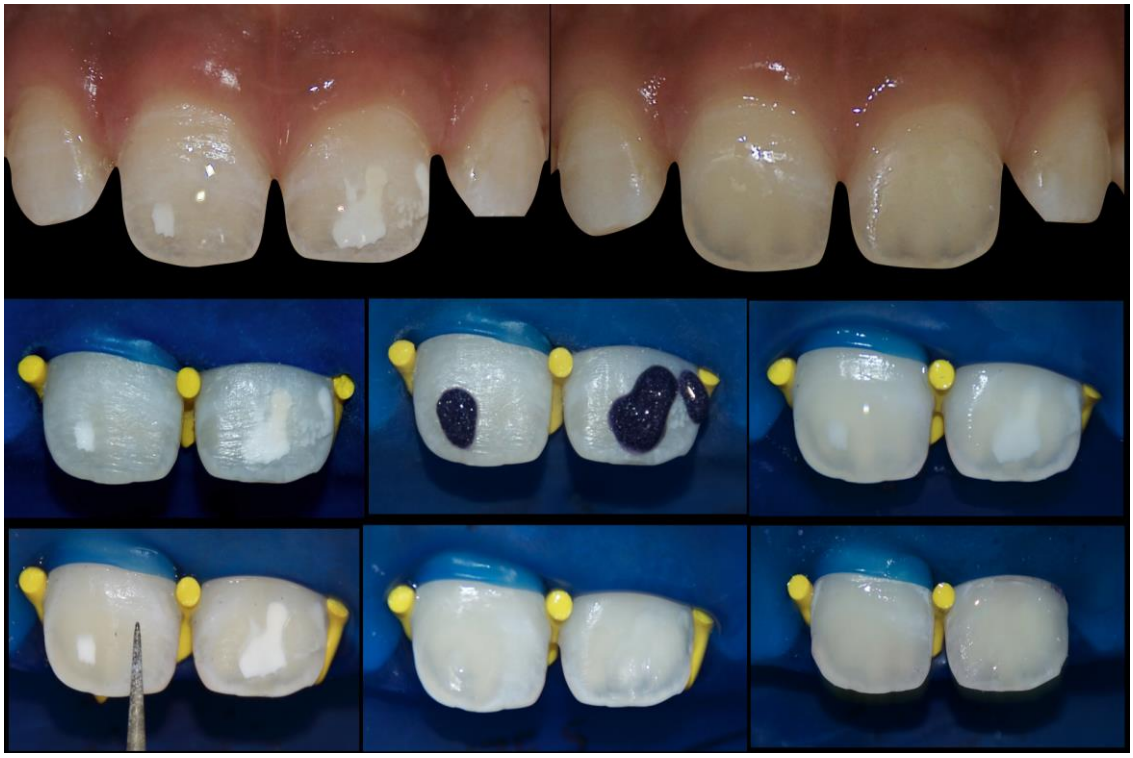


Figure 11: : Clinical case showing the failure of micro-abrasion for eliminating the lesion on the central incisors. Then mechanical removal of the lesion using a diamond burr followed by resin composite restoration allowed to obtain good esthetic result (with permission of Dr Omar Marouane)

Table 9: Summery of white spot lesion Therapeutic

Therapeutic	Action mechanism	Principle
Brightening	increase the overall brightness of the tooth. By contrast, the white spot will be camouflaged.	Optical
Remineralization	Supply of calcium and phosphorus which will fill the mineral deficit resulting in crystalline precipitation and return to normal enamel architecture.	Biological
Micro-abrasion	Physical and chemical treatment of enamel and removal of the outermost layers of the enamel.	Mechanical
Infiltration	Consists of reaching the body of the lesion by a first phase of erosion using hydrochloric acid And then infiltrating it with a very fluid resin having a refractive index close to that of enamel healthy (on enamel = 1.62). Hence the cover-up of the enamel lesion.	Optical
Restoration with composite Resin	Mechanical elimination of the lesion over its entire thickness and replacement of the loss of substance granted by a composite resin.	Mechanical

VII. Discussion

Regrading Regrading the high prevalence of WSLs during orthodontic treatment, we have to keep in mind that WSLs may progress until relatively advanced stage without being detected. Thus, it is very important to early and accurately detect WSLs before, during and after orthodontic treatment.

Nowadays, the most common detection method for WSLs is the conventional visual/tactile examination in reflected light condition. [64,65] Nevertheless, visual/tactile examination presents some limitations such as the difficulties experienced during monitoring the WSLs over a period of time.

From this perspective, additional detection methods employing different characteristics have emerged in the literature to early detect WSLs. In general, those methods present a high sensitivity who is a measurement that determines the probability of actual positives but demonstrate a low specificity who is a measurement that determines the probability of actual negatives.

There is ambiguity regarding the net effectiveness of diagnostic methods, as visual/tactile examination is more specific than sensitive, while newer methods are more sensitive than specific. In this context, it is very important to select the most appropriate detection methods for the best management of WSLs.[66]

To this date, although many diagnostic methods have emerged and studied thoroughly in recent years, however, there is no robust recommendations to follow for choosing the best detection methods for WSLs. Regarding QLF, it has been recently suggested that this method is more accurate in detecting WSLs comared to other reported techniques. Although QLF has been thouroughly investigated, it must be remembered that most studies had explored the technical aspects rather than its diagnostic validity in a clinical setting. Thus, well-designed clinical trials for the performance of QLF are necessary to provide clinically relevant information in order to recommend this method in clinical practice.

As a matter of fact, the heretogenious methodologies followed in the published studies, did not allow relevant comparison between the used techniques of detection of WSl.

Despite the fact that the versatile detection methods have gained popularity, visual examination remains the method of choice for inspecting WSLs across all types of dentitions.[66]

Among the recommended scoring systems, ICADS remains the most widely used compared to Goerlick score and JADA classificationdue (table 5) to its moderate accuracy and reproducibily. Although the score does not determine the activity stage of the lesion. Therefore, Nevadia classification (table 3) is recommended by a number of researchers and clinician due to its sensitivity in detecting the progression of the lesion

Despite the fact that visual inspection presents a good accuracy in detecting WSLs with a trend for higher specificity than sensitivity, we have to remember that the use of validated visual scoring systems in the detection of WSLs is highly recommended to improve its sensitivity and reliability (Braga et al.). The use of a validated scoring systems allows a more accurate diagnosis of caries lesions since it gives practitioners a guideline to how to characterize the lesions that they identify and it provides a rational shortcut associating WSLs with the different categories of the score system. [66]

ICDAS remains the most robust and recommended caries detection system. In addition to ICDAS systems, complementary scoring systems which classify caries lesion activity, can be useful as they are moderately reproducible and accurate. [67]

Regarding the treatment option, the aims of resin composite restorations is to remove the lesion from its entire depth and to restore the cavity it with composite resin in a second step. Although this treatment option improves the aesthetic result, this approach remains invasive and it is not recommended in the current context of conservative dentistry. In this context, micro-abrasion has been suggested as a less invasive approch where chemical and mechanical removal of the most supericial layers of enamel along with the WSL. Although micro-abrasion is considered as a treatment, its indication remains limited to lesions located in the most superficial layers of the enamel. On the contrary, for lesions confined to the thickness of the enamel, this technique, tends to expose the lesion and make it even more visible

While resin composite restorations micro abrasion are mechanical therapies, remineralization, external bleaching and infiltration are optical therapies. Although their modes of action are antagonistic, the aim of these therapies is to bring healthy and WSLs closer together optically.

External bleaching aims to bring the brightness of the tooth closer to that of the stain, while the aim of infiltration is the opposite and consists of modifying the optical properties of the lesion so that its brightness tends to be similar to that of the tooth.

From a therapeutic point of view, and as the remineralization seems to be not effective in masking WSLs, resin infiltration remains the treatment of choice giving it the advantage of being an acceptable compromise solution aesthetically and conservatively.

VIII. Conclusion

WSLs represent a considerable challenge to the quality of orthodontic treatment. Although, it is unrealistic to entirely eleminate enamel demineralization, integrating the risk assessment and caries assessment techniques along side orthdontic treatment is imperative to minimize the development of those lesions.

Raising awareness and motivating patients to maintain excellent level of oral hygiene throughout orthodontic treatment remains the most appropriate measure. In spite of the ample research work related to this field, a high-quality studies implimenting precise protocols are limited. Furthermore, there is a shortage of sound evidence to affirm the efficiency of minimally invasive treatment procedures of post orthodontic WSLs.

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