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Research Article

Prevalence of white spot lesions and risk factors associated with the COVID-19 pandemic

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ABSTRACT

Background: The objective of this study was to investigate the impact of the COVID-19 pandemic on the prevalence and persistence of white spot lesions (WSLs) among patients treated with traditional braces.
Methods: A group of 434 consecutively finished cases who had pretreatment and post-treatment digital photographs taken were included in this study. Each set of photographs was evaluated by two investigators to determine prepandemic and postlockdown WSLs, in addition to changes in oral hygiene (OH) and other risk factors.
Results: There was a statistically significant difference in the development of WSLs pre–COVID-19 lockdown (PRL) versus post–COVID-19 lockdown (POL) ($P < 0.001$). The overall prevalence for the development of WSLs increased to 52.8% POL. For patients with good pretreatment OH, the risk of developing WSLs POL (42.0%) was two times greater than the rate in PRL (20.1%). For patients whose OH worsened during treatment, 81.2% of POL patients developed WSL compared with 69.6% of PRL patients. The incidence of WSLs was statistically greater in the maxillary anterior region POL than PRL, whereas the incidence in the mandibular anterior region did not reach statistical significance. The distribution of WSLs was greater POL for each tooth irrespective of the arch.
Conclusions: Because of the COVID-19 pandemic, the prevalence of visible WSLs increased from 29.5% to 52.8%. Patients whose hygiene worsened during orthodontic treatment are at an increased risk of developing WSLs.

1. Introduction

At the height of the COVID-19 pandemic in March 2020, many dental services, including orthodontics, were suspended. With the implementation of COVID-19 restrictions, orthodontic departments, offices, and clinics were closed for up to 3 or more months, and patients were unable to access continuing orthodontic care [1]. With shelter-in-place policies in effect, orthodontists communicated with their patients through a smartphone or online teledentistry services; however, these services were not a substitute for in-person monitoring of orthodontic treatment [2,3].

In the years preceding the COVID-19 pandemic, patients scheduled required regular orthodontic visits every 4 to 6 weeks for 2 years or longer [4]. Thus, the suspension of orthodontic appointments, in which routine monitoring of treatment progress and oral hygiene (OH) occur, presented a challenge to patients, parents, and orthodontists.

Even with consistent monitoring of OH prepandemic, approximately one-fourth of patients who underwent orthodontic treatment with traditional braces developed white spot lesions (WSLs) [5,6]. After treatment, some WSLs showed improvement, whereas others left permanent stains, pigments, or discoloration that was clinically observable and often required restorative treatment to improve aesthetics [6–10].

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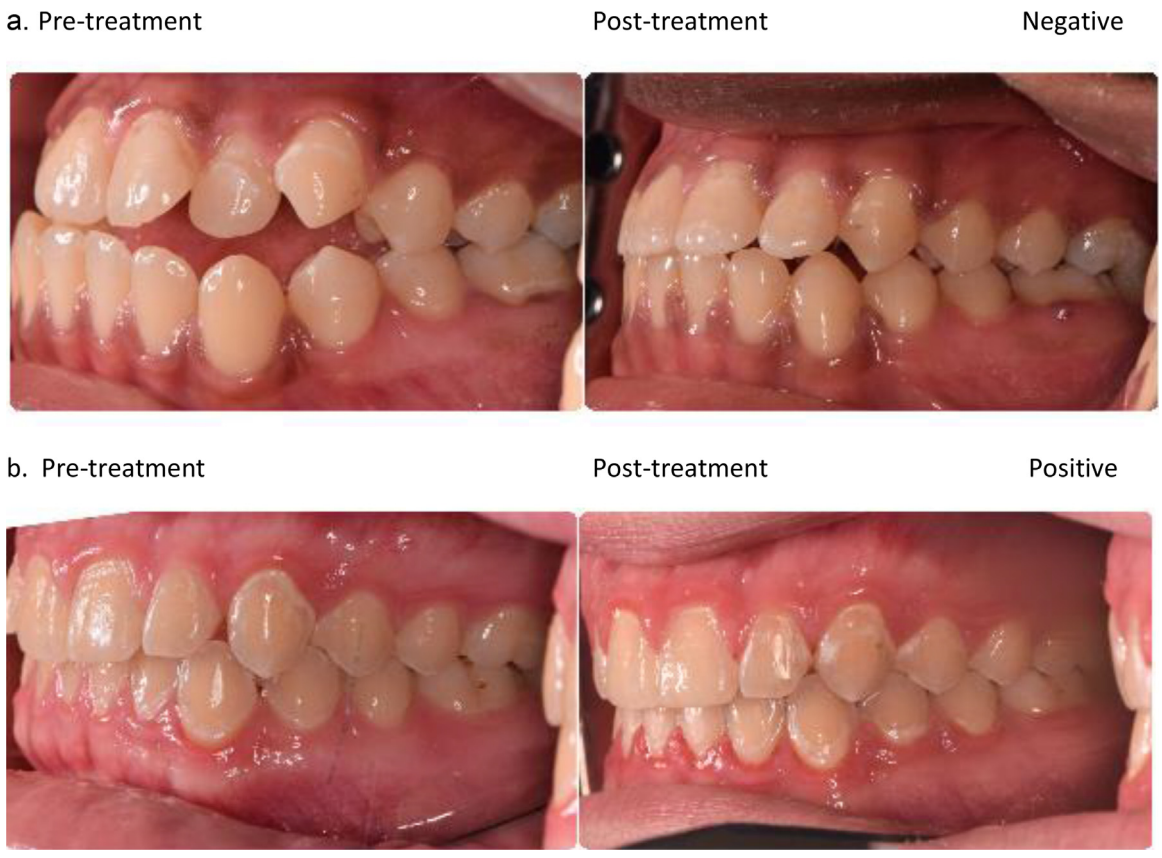

Fig. 1. Examples of pre and post treatment photographs of two patients with pre-existing WSLs, one of which scored negative (A) for developing additional WSLs and one scored positive (B).

The risk of WSL development has been shown to increase with a longer duration of orthodontic treatment, with poor OH before treatment, with a worsening of OH during treatment, and more recently, with the use of traditional braces rather than clear aligners. In addition, the WSLs present before orthodontic treatment are likely to persist or increase in severity [6–8].

Previous studies have shown that the presence of orthodontic brackets alone increases the risk of developing WSLs. The brackets provide extra surfaces to the clinical crown in which plaque can accumulate around, increasing OH challenges during treatment [11]. With the interruption of regular orthodontic appointments because of the COVID-19 pandemic, monitoring and reinforcing optimal OH became challenging. Whether the orthodontic brackets alone or the lack of positive reinforcement in the orthodontic office contributed to the increased WSLs is a factor that remains unanswered [11].

Patients undergoing orthodontic treatment with traditional braces are at risk of developing WSLs. However, it is of interest to investigate whether the COVID-19 pandemic contributed to the development and/or the severity of WSLs. To date, there are no known studies that evaluate WSL development in this context.

This study aims to investigate the impact of the COVID-19 pandemic on the prevalence and persistence of WSLs among patients treated with traditional braces. A secondary aim is to determine the association of other risk factors with the development of WSLs.

2. Methods and materials

This retrospective study used cases completed at the Department of Orthodontics and Dentofacial Orthopedics, School of Dental Medicine, University of Pittsburgh, and approved by the institutional review board (STUDY20040127). There were 434 consecutive patients treated with traditional fixed appliances, which were debonded during the selected time periods. Inclusion criteria consisted of only patients with high-quality pretreatment and post-treatment intraoral photographs, full permanent dentition, and completed pre- and post-treatment Peer Assessment Rating (PAR) scores. After using exclusion criteria of phase 1 treatment, limited or retreatment, surgical treatment, cleft lip and/or palate, other craniofacial anomalies, and clear aligner cases, 372 cases remained for assessment. Of those, 173 were debonded pre–COVID-19 lockdown (PRL) between September 2019 and March 2020, whereas 199 were debonded post–COVID-19 lockdown (POL) between September 2020 and March 2021. At the initial bonding appointment, all patients received a standardized OH kit with written and verbal dietary and OH instructions. Further OH instructions were given throughout treatment during clinic visits.

Pretreatment and post-treatment photographs were evaluated using the Dolphin Imaging Version 11 (Dolphin Imaging and Management Solutions, Chatsworth, CA). Photographs were taken after the patient had brushed to visualize the WSLs better. For standardization, the patients were seated upright in the dental chair with the camera perpendicular to the tooth surface using the same camera settings. For assessment, the images were retrieved, enlarged, placed side by side on the same computer monitor, and evaluated in a darkened room. Previous studies have confirmed the use of photographs to evaluate the prevalence and incidence of WSLs [5,11,12] (Fig. 1). For the evaluation of OH, different criteria were applied to the pre- and post-treatment photographs. As post-treatment photographs were taken immediately after debonding, the criteria for evaluation were different [12] (Table 1). Only

Table 1
Evaluation criteria used for pretreatment and post-treatment oral hygiene scoring

Oral Hygiene	Pretreatment	Post-treatment
Good	No visible plaque, no gingivitis	No visible plaque, no hypertrophy, gingival bleeding only because of composite removal
Fair	Some visible plaque, isolated areas of gingivitis	Some visible plaque, isolated gingivitis or hypertrophy, gingival bleeding only because of composite removal
Poor	Thick and/or generalized plaque, with gingivitis	Multiple areas of visible plaque and/or generalized hypertrophy, gingivitis, and gingival bleeding

Note: Table 1 was adapted from Julien et al. [12].

Table 2
Overview of baseline clinical characteristics

		Prelockdown	Postlockdown	*P* value
Sex, n (%)	Male	78 (45.1)	76 (38.2)	0.205
	Female	95 (54.9)	123 (61.8)	
Age (y) mean ± SD		17.6 ± 9.5	16.7 (8.6)	0.337
Pretreatment PAR mean ± SD		20.3 ± 10	22.3 ± 11.1	0.124
Treatment duration (mo) mean ± SD		26.5 ± 9.5	27.0 ± 10.5	0.628

PAR, peer assessment rating.

pretreatment images were screened for the presence of fluorosis. Fluorosis, enamel hypoplasia, demineralization, and other developmental alterations were not scored, and these teeth were excluded.

Each investigator was calibrated by a board-certified orthodontist. The calibrated investigators scored each tooth independently for the presence (positive) or absence (negative) of WSLs. If the lesion was questionable, the tooth was viewed jointly with another investigator, reassessed, and rescored. As such, intrarater and interrater reliability were good to excellent. An identical WSL visible on both the pretreatment and post-treatment photographs was considered developmental and not counted as a WSL. Pretreatment WSLs that enlarged or became more severe in the post-treatment WSL evaluation were counted as a positive WSL result. Any new WSLs were also counted as positive for WSLs.

The weighted PAR score was calculated on pretreatment and post-treatment casts according to DeGuzman et al. [13], including maxillary anterior segment, right buccal occlusion, left buccal occlusion, overjet, overbite, and midline. The PAR index has previously been deemed valid and reliable [14]. The higher the pretreatment weighted PAR score, the more complex the pretreatment malocclusion [15]. The PAR index was used to compare initial case complexity. Patient age at the initiation of treatment and pretreatment weighted PAR score were described with means and SDs. STATA Version 15 (College Station, TX) was used for statistical analysis.

The chi-square test was used for group differences in the number of WSLs, pretreatment OH, changes in OH, pre-existing WSLs, and treatment duration. Independent sample *t* tests were used for continuous variables. The *P* value was set at 0.05. The risk ratio was calculated based on the risk between groups being compared.

3. Results

Baseline clinical characteristics are listed in Table 2. There were no statistical differences between the groups PRL and POL in sex ($P = 0.205$), age ($P = 0.337$), pretreatment PAR score ($P = 0.124$), or treatment duration ($P = 0.628$).

The prevalence of WSLs was 29.5% PRL, which increased to 52.8% after the height of the COVID-19 pandemic, and this difference was statistically significant ($P < 0.001$). The overall likelihood of developing WSLs because of clinics' closure caused by the pandemic was 1.6 times greater when compared with that during PRL (Table 3). There was also a statistically significant difference when looking at sex. The prevalence of WSLs in female patients increased by nearly 20% because of the pandemic ($P = 0.005$), and among male patients increased similarly ($P = 0.027$). Accordingly, the risk of development of WSLs was nearly identical (Table 3).

For those with pre-existing WSLs, there was no statistically significant difference in the development of WSLs in the PRL treatment group compared with that in the POL group ($P = 0.614$). Of those with pre-existing WSLs PRL, 62.5% exhibited increased severity or further incidence of WSLs, whereas 53.5% developed new WSLs or enlarged existing WSLs in the POL group. Consequently, it can be concluded that a patient with pre-existing WSLs was equally likely to develop additional WSLs PRL and POL.

There was a statistically significant difference in post-treatment WSLs between those with good OH pretreatment in both groups,

Table 3
Risk factors for the development of white spot lesions

		Developed WSL			
		Prelockdown, %	Postlockdown, %	Risk ratio (95% CI)	*P* value
Prevalence	Overall	29.5	52.8	1.6 (1.2–2.1)	<0.001
	Female	26.3	45.5	1.7 (1.2–2.6)	0.005
	Male	32.1	50.0	1.6 (1.1–2.3)	0.027
Pretreatment	WSL	62.5	53.5	0.9 (0.5–1.6)	0.614
Pretreatment	Fair	61.5	66.7	1.1 (0.8–1.5)	0.658
OH	Good	20.1	42.0	2.1 (1.4–3.0)	<0.001
Worsened OH		69.6	81.2	1.2 (0.9–1.4)	0.096

CI, confidence interval; OH, oral hygiene; WSL, white spot lesion.

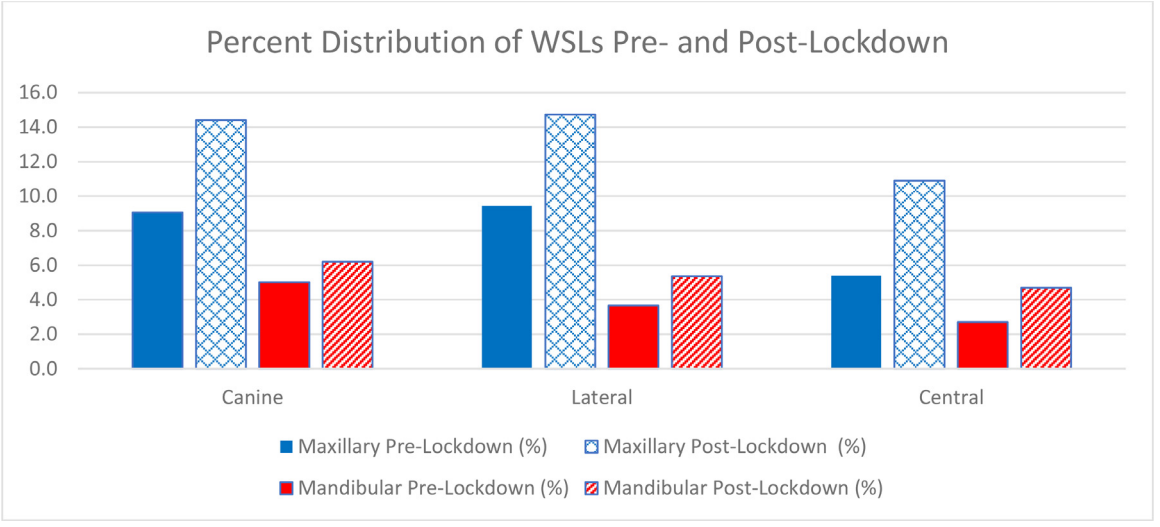

Fig. 2. Percent distribution of WSLs pre- and post lockdown in the maxilla versus the mandible.

Table 4
Percent of patients who developed white spot lesions on the maxillary and mandibular teeth

WSL location	Prelockdown, %	Postlockdown, %	*P* value
Maxilla	28.30	42.70	0.005
Mandible	15.00	18.10	0.431
Total	29.40	45.20	0.002

WSL, white spot lesion.

PRL and POL ($P < 0.001$). In the PRL group, for those with good pretreatment OH, about one-fifth (20.1%) developed WSLs at the conclusion of orthodontic treatment. However, in the POL group, of those presenting with good pretreatment OH, twice as many (42.0%) developed WSLs (Table 3). Thus, the risk of developing WSLs was two times greater as a consequence of the COVID-19 pandemic even when the patient initially presented with good OH.

For those whose OH worsened from the beginning to the completion of treatment, 69.6% in the PRL group developed WSLs. In the POL group, over four (81.2%) of five patients developed WSLs when the OH worsened. Although there was an increase of 11.6% in patients who developed post-treatment WSLs when their OH worsened POL compared with PRL, it was not statistically significant (Table 3).

In terms of the percentage of patients exhibiting WSLs at the end of orthodontic treatment, there were differences between each arch and the overall total. Out of all patients, 45.2% in the POL group developed at least one WSL compared with 29.4% in the PRL group ($P = 0.002$). When each arch was compared individually, significantly more patients (42.7%) developed WSLs in the maxilla POL than PRL (28.3%). In the mandibular arch, 18.1% of the POL group developed WSLs, whereas in the PRL group, 15.0% developed WSLs; however, this was not significant (Table 4).

The distribution of WSLs also varied by tooth. For the PRL maxillary group, the majority of WSLs were formed on the canines (9.1%) and lateral incisors (9.4%), whereas the central incisors (5.4%) exhibited the fewest. The mandibular anterior segment revealed the highest incidence of WSLs on the canines (5.0%), followed by lateral incisors (3.7%) and central incisors (2.7%). In the POL group, a similar distribution was observed. WSLs on the maxillary canines and lateral incisors were the most common, followed by the maxillary central. However, the mandibular arch followed the same pattern as the PRL group (Fig. 2).

4. Discussion

As indicated in previous studies, there is a substantial risk of developing WSLs among patients treated with traditional orthodontic appliances [5,6]. In this study, the overall prevalence of visible WSLs during orthodontic therapy PRL was 29.5%, similar to that reported by Buschang et al. [6]. However, the overall prevalence increased to 52.8% POL. This suggests that one-half of all patients treated with traditional braces are at risk of developing WSLs as a consequence of the COVID-19 pandemic. Prepandemic, Chapman et al. [11] found a higher incidence of developing WSLs. However, in that study, they could dry the teeth, thereby increasing the visibility of the WSLs. Furthermore, Boersma et al. [16] reported the highest incidence of WSLs after traditional orthodontic therapy. In that study, the investigators used quantitative light-induced fluorescence, a more sensitive assessment, to measure the WSLs as opposed to direct visualization [16]. Therefore, a higher incidence would be expected. For the most part, these findings compared favorably with those reported by other researchers [17,18].

The breakdown by sex revealed similar results. The percentage of female patients POL who developed WSLs during treatment was significantly higher than that of female patients PRL. Similarly, the percentage of male patients POL developing WSLs was significantly higher than that PRL. Investigators who have reported significant sex differences indicated that male patients are at a greater risk of developing WSLs than female patients [11,16]. With a nearly identical risk (1.7 vs. 1.6), the results of this study suggested that rather than actual sex-based differences, the increase in mental health issues, such as depression and anxiety, reported because of the COVID-19 pandemic may have affected both sexes equally [1].

The incidence of pretreatment WSLs was another factor in the development of new WSLs. Of those with pre-existing WSLs PRL, over half developed new WSLs or increased severity of existing lesions. This agrees with the results of other studies [6,11,12]. Of those POL patients with pre-existing WSLs, a similar percentage developed WSLs. These pretreatment WSLs highlight that WSLs are persistent and form irrespective of whether or not patients underwent orthodontic therapy during the pandemic. As patients presenting with pre-existing WSLs are no more likely to develop new or more severe WSLs because of the pandemic, increased monitoring of OH in these patients would be of limited value in the clinical setting.

Pretreatment OH has been linked to the development of WSLs [6,10,12]. In the current study, those who had good pretreatment OH in the POL group were twice as likely to develop WSLs as those in the PRL group. However, those presenting with fair pretreatment OH in either group had much less risk. It has been suggested that the effects of the pandemic may increase psychological distress among children and adolescents. In addition, patient enthusiasm tends to decrease progressively, suggesting that those with good OH may be more affected than those with fair OH. This was also observed in a study by Julien et al. [12], who reported an increased risk with a worsening of OH during treatment, confirming the association between OH and WSLs.

There were differences in the development of WSLs interarch and intra-arch. The results of the current study agreed with other investigators who found that WSLs were more likely to develop on the maxillary teeth rather than the mandibular teeth [6,12]. In the current study, maxillary canines and lateral incisors were equally affected by WSLs, which contrasted with one group of researchers who found the maxillary lateral incisor to be the most commonly affected tooth [17]. Other investigators have reported the maxillary lateral incisors and/or the mandibular canines as the most commonly affected teeth [19,20].

The results of the current study could be used to provide guidance that could be applied clinically. Before initiation of treatment with traditional fixed appliances, patients should be screened for pandemic-associated issues that might cause psychological distress. These include factors that are not routinely assessed at the first appointment, including mental health issues, patient enthusiasm, and motivation [1,21]. Once identified, these patients should be more closely monitored for the development of WSLs.

Certainly, one of the limitations of the present study was the use of direct visualization to determine the presence of WSLs. The sensitivity to diagnose WSLs could have been increased using other methods such as quantitative light-induced fluorescence that identify lesions before they become visible [22]. In addition, the fact that the patients were treated by various residents could have biased the results, although standardized OH instructions and patient appointments were similar. The results of the current study agreed with those of previous studies that have indicated a predilection for WSLs to develop on anterior maxillary teeth. However, there could have been group differences between the severities of WSLs PRL and POL that were not controlled for in the present study. Finally, as this is a retrospective study, future randomized clinical trials are needed to eliminate any pretreatment differences and minimize variances in OH monitoring.

5. Conclusions

Because of the COVID-19 pandemic, the prevalence of visible WSLs increased from 29.5% to 52.8%. PRL or POL patients whose hygiene worsened during orthodontic treatment are at an increased risk of developing WSLs.

CRediT authorship contribution statement

John M. Burnheimer: Conceptualization, Supervision. **Carolyn G. Serio:** Data curation, Writing – original draft. **Brenda H. Loo:** Data curation. **Lily A. Hartsock:** Writing – review & editing.

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