*Original Article*

# Prevalence of white spot lesion formation during orthodontic treatment

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**ABSTRACT**

**Purpose:** To quantify the prevalence of white spot lesions (WSLs) on the anterior teeth and, secondarily, to evaluate risk factors and predictors.

**Materials and Methods:** Digital photographs and records of 885 randomly chosen patients were evaluated before and after treatment. Chart information included gender, age, as well as banding and debanding dates. Fluorosis and oral hygiene before and after treatment were also evaluated. Preexisting and posttreatment WSLs were recorded and compared for all 12 anterior teeth. Risk ratios (RR) and absolute risk (AR) were calculated to determine the likelihood and risk of WSL formation.

**Results:** Overall, 23.4% of the patients developed at least one WSL during their course of treatment. Maxillary anterior teeth were affected more than mandibular teeth. The maxillary laterals and canines and the mandibular canines were the most susceptible. There was no significant difference in WSLs between genders. Fluorosis, treatment time in excess of 36 months, poor pretreatment hygiene, hygiene changes during treatment, and preexisting WSLs were all significantly ($P < .05$) related to the development of WSLs. The highest risk of developing WSLs was associated with preexisting WSLs (RR = 3.40), followed by declines in oral hygiene during treatment (RR = 3.12) and poor pretreatment oral hygiene (RR = 2.83).

**Conclusions:** Nearly 25% of the patients developed WSLs while in treatment, depending on fluorosis, treatment time, preexisting WSLs, and oral hygiene. Orthodontists need to be mindful of these risk factors when making treatment decisions. (*Angle Orthod.* 0000;00:000–000.)

**KEY WORDS:** White spot lesions; Orthodontic treatment; Risk ratio; Fluorosis; Hygiene; Treatment time

## INTRODUCTION

Dissolution and deposition of tooth enamel occurs regularly in all teeth. When the pH level in the mouth drops sufficiently, dissolution of calcium and phosphate ions occurs. As the pH returns to normal levels, deposition of these ions from the saliva occurs and the enamel is restored. If the pH stays low for an extended time, more dissolution than deposition occurs. When a net loss occurs, the enamel is defined as decalcified. When light hits an area of subsurface decalcification it scatters differently than when it hits sound enamel. As such, decalcified enamel appears as an opaque, white color and is referred to as a white spot lesion (WSL).[1] Over time, the white spot may recalcify, but the opaque color usually remains, and often becomes stained, making it even less esthetic.[2]

The prevalence of WSLs, based on posttreatment evaluations only, ranges from 0 to 97%[2–13] (Table 1). With the exception of Boersma et al.,[8] who used quantitative light-induced fluorescence, the assessment methods and indices have been similar, but sample sizes and results vary widely. Controlling for pretreatment WSLs, prevalence has been reported to range from 26% to 89%. Again, the sample sizes are vastly different (n = 35–332). Interestingly, the prevalence in studies that included daily fluoride rinses ranged from 89%[10] to 26%.[11]

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**Table 1.** Prevalence of White Spot Lesions (WSLs) Reported in Studies Based on Comparisons of Pre- to Posttreatment Differences or on Posttreatment Evaluation Only[a]

| Study | Design | Index | Sample | Fluoride | Prevalence | Control |
|---|---|---|---|---|---|---|
| Gorelick et al.[3] | DVA | GI | 121 | No Fl | 50% | CG |
| Mizrahi[4] | DVA | MI | 269 | No Fl | 12% | CG |
| Artun and Brobakken[5] | DVA | GI | 60 | Fl rinse | 59% | CG |
| Geiger et al.[6] | DVA | GI | 34 | Fl rinse | 34% | CG |
| Ogaard[2] | DVA | GI | 51 | Fl rinse | 11% | CG |
| Sonis and Snell[7] | DVA | MI | 22 | Fl adhesive | 0–13% | CG |
| Boersma et al.[8] | QLF | QLF | 64 | No Fl | 97% | CG |
| Strateman and Shannon[9] | DVA and P | No. of WSL | 99 (no Fl)<br>110 (with Fl) | Fl gel | 27% (Fl)–<br>58% (no Fl) | I |
| Zachrisson and Zachrisson[10] | DVA | CI | 174 | Fl rinse | 89% | I |
| Lovrov et al.[11] | P | GI | 53 | Fl rinse | 26% | I |
| Chapman et al.[12] | DVA and P | % of surface | 332 | Unknown | 36% | I |
| Tufekci et al.[13] | DVA | GI | 35 at 6 mo<br>37 at 12 mo | Unknown | 38% 6 mo<br>46% 12 mo | I |

[a] DVA indicates direct visual assessment; QLF, quantitative light-induced fluorescence; P, photographic evaluation; GI, Gorelick Index; MI, Mizrahi Index; CI, caries index; Fl, fluoride; CG, used control group for comparisons; I, individual posttreatment status compared with pretreatment status.

The wide variation in reported WSL prevalence could be due to various factors. Small sample size is certainly one potential factor. The method of detection also plays a role. The most commonly used method for detecting WSLs is direct visual examination. It is a good approach, but it is difficult for a single investigator to consistently evaluate large numbers of patients in different clinical settings or at various time periods. Quantitative light-induced fluorescence evaluation is very accurate and quantitative, but it detects decalcification before it is visible. Photographs, which are available for most patients, provide easily accessible information and have proven to be as reliable as direct visual assessment.[12] Moreover, although some of the studies report the prevalence of WSLs based on all of the teeth, most have studied only the anterior teeth, and others have looked at the maxillary anterior teeth only. Subjects in several studies were given fluoride treatments or were instructed to use fluoride daily. No study has controlled for or considered how fluorosis affects WSL formation.

Because of the lack of consistency across studies, the primary purpose of this study was to determine the prevalence of visible WSLs among orthodontic patients. The secondary goal was to evaluate risk factors that have not previously been evaluated and compared.

## MATERIALS AND METHODS

One thousand charts were randomly chosen from finished cases in the Department of Orthodontics at Texas A&M Health Science Center, Baylor College of Dentistry. This study was approved by the institutional review board at Baylor College of Dentistry. All cases were completed by orthodontic residents and supervised by various clinical faculty. Patients were treated during the period August 2000 to November 2011. To be included, cases had to have adequate quality pre- and posttreatment digital photographs stored in Dolphin Imaging Version 11 (Dolphin Imaging and Management Solutions, Chatsworth, CA). Before treatment, all patients were in late mixed or permanent dentition. No malocclusion was excluded, provided that the gingival third of the anterior teeth were visible in the photographs.

After cases had been excluded (primarily due to poor quality or missing photographs), the final sample comprised 885 patients: 378 males (14.3 $\pm$ 6.0 years old) and 507 females (14.6 $\pm$ 6.0 years old). The anterior six maxillary and mandibular teeth were evaluated (total N = 10,620).

Chart data collected included the patient's age on the initial record, gender, birth date, banding date, and debanding date. Initial and final photographs were retrieved from the Dolphin Imaging System, placed side by side on a computer monitor, and evaluated in a darkened room.

Oral hygiene was evaluated in both the pretreatment and posttreatment photographs. Because the final photographs were taken immediately upon debanding and composite removal, different criteria were applied for the pretreatment than the posttreatment photographs (Table 2). Oral hygiene was not evaluated during treatment. The posttreatment evaluation was primarily based on the positive or negative gingival changes that were evident and were assumed to have taken at least several months to occur.

Fluorosis was evaluated based on the initial photographs due to composite removal and subsequent enamel desiccation in the posttreatment photographs.

**Table 2.** Criteria Used for Evaluating Pre- and Posttreatment Oral Hygiene Status

| Oral Hygiene | Pretreatment Status | Posttreatment Status |
|---|---|---|
| Good | No visible plaque, no gingivitis | No visible plaque, no hypertrophy, gingival bleeding only due to composite removal |
| Fair | Some visible plaque, isolated areas of gingivitis | Some visible plaque, isolated gingivitis or hypertrophy, gingival bleeding only due to composite removal |
| Poor | Thick and/or generalized plaque, with gingivitis | Multiple areas of visible plaque and/or generalized hypertrophy, gingivitis, and gingival bleeding |

Only fluorosis on the anterior teeth was considered. It was deemed to be fluorosis rather than WSLs if it appeared on more than one tooth and extended beyond the incisal edges (Figure 1).

Each tooth was evaluated for any obvious WSLs. If the side-by-side comparison showed an identical white spot in both the pre- and posttreatment photographs, it was considered to be a developmental or fluoridic white spot and was not counted as a WSL (Figure 2). A white spot that was noted in the pretreatment photograph but worsened (enlarged or became more severe) over time was recorded as a WSL (Figure 3). All new WSLs were also counted.

Cohen's kappa coefficients were calculated to determine the reliability of the assessments. Based on replicate measurements of 25 randomly chosen patients and the classification system of Landis and Koch,[14] perfect agreement (kappa = 1.0) was obtained for lower pretreatment WSLs and for both upper and lower posttreatment WSLs; near perfect agreement (kappa $>$ 0.81) was obtained for posttreatment oral hygiene, and substantial agreements (kappa $>$ 0.65) were obtained for pretreatment oral hygiene, fluorosis, and upper pretreatment WSLs.

### Statistics

Comparisons of frequencies were performed using $\chi^2$ analyses. Statistical significance was set at $P < .05$.

**Figure 1.** Pretreatment photo depicting fluorosis. Fluorosis was defined as significant when it extended beyond the incisal edges and was evident on more than one tooth.

The absolute risk (AR), or the risk of developing a WSL, was calculated as AR = N with disease / Total N. AR describes the chance a given person has of developing at least one WSL. For example, if the AR = 25%, a person has a 1 in 4 chance of developing a WSL.

The risk ratio (RR) is defined by the formula RR= % with WSL / % without WSL. The RR compares the risk of a group's possessing a certain characteristic (such as fluorosis) with the risk for those without that characteristic. It describes the likelihood of a WSL forming within the group.

## RESULTS

Before treatment, oral hygiene was poor in 13% of the patients, fair in 52%, and good in 35%. Fluorosis was noted in 23% of the patients. Preexisting WSLs were found in 9% of the patients evaluated, including 234 teeth (172 maxillary and 62 mandibular).

Posttreatment oral hygiene was found to be poor in 7% of the patients, fair in 42%, and good in 51%. WSLs were identified in 32% of the patients after treatment, with the maxillary and mandibular anterior teeth exhibiting 756 and 278 WSLs, respectively. A total of 800 WSLs formed during treatment, including 584 maxillary and 216 mandibular. Of the patients studied, 23% experienced an increase of at least one WSL while in treatment (Table 3).

The maxillary arch had significantly ($P < .001$) more WSLs, (approximately 2X) than the mandibular arch. The lesions were symmetrical from left to right. The only tooth showing statistically significant ($P < .001$) side differences was the maxillary lateral incisor (Table 4).

Although the central incisors showed no significant differences to one another in either arch, the maxillary lateral incisors and canines developed significantly ($P < .001$) more WSLs than the central incisors. The maxillary lateral incisors showed a significantly greater number of WSLs than the canines in all quadrants except the maxillary right (Table 5).

Patients who exhibited fluorosis before treatment were significantly ($P < .001$) less likely to develop new WSLs during treatment compared with patients with no pretreatment fluorosis. The AR of developing a WSL

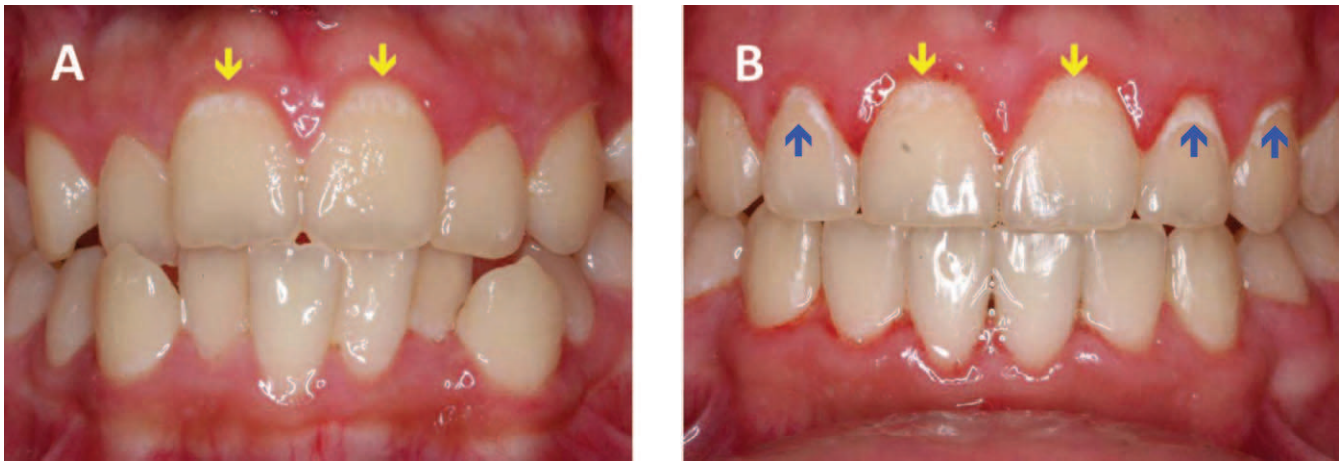


**Figure 2.** (A) Pretreatment photo showing WSLs that did not change during treatment and thus were not counted (yellow arrows). (B) Posttreatment photo showing unchanged WSLs (yellow arrows) and WSLs that developed during treatment (blue arrows) and thus were counted.

during orthodontic treatment was 15% in patients with fluorosis and 26% in those without fluorosis (Table 6). The RR was 1.79, indicating that patients without fluorosis were 1.79 times more likely to form WSLs (Table 5).

A greater percentage of males than females developed WSLs, but the difference was not statistically significant ($P = .30$). The AR was 25% and 22% for males and females, respectively. The RR for males was 1.14 greater than that for females (Table 6).

Patients with fair or poor pretreatment hygiene had significantly ($P < .001$) more WSLs than those with good hygiene. The AR was 17% for patients with good hygiene, 24% for those with fair hygiene, and 38% for those with poor hygiene. Compared with the group with good hygiene, the fair and poor groups had RRs of 1.46 and 2.28, respectively (Table 6).

Patients whose oral hygiene stayed the same or improved during treatment showed no significant reductions in WSLs. However, those patients whose oral hygiene declined experienced significantly ($P < .001$) more WSLs during treatment. The AR was similar in the patients who improved or maintained their pretreatment hygiene. However, the group whose oral hygiene declined had a 59% AR. The RR was 3.17 in the group whose oral hygiene declined (Table 6).

Patients in treatment for 24–36 months showed significantly ($P = .03$) fewer WSLs than those in treatment for >36 months. The AR was 20% for patients treated within 24–36 months and 26% for those who spent more than 36 months in treatment. The RR was 1.31 for patients in treatment >36 months (Table 6).

Preexisting WSLs were found in 76 patients, 87% of whom developed at least one WSL during treatment. Only 26% of the patients with no preexisting WSLs formed WSLs during treatment, a difference that was significant ($P < .001$). In other words, AR increased from 26% in those without preexisting WSLs to 87% if there were preexisting WSLs. The RR, or likelihood of lesion development, was 3.39 times greater in the patients with preexisting WSLs (Table 6).

## DISCUSSION

In this study, 23% of patients developed WSLs, which falls at the low end of the range reported in

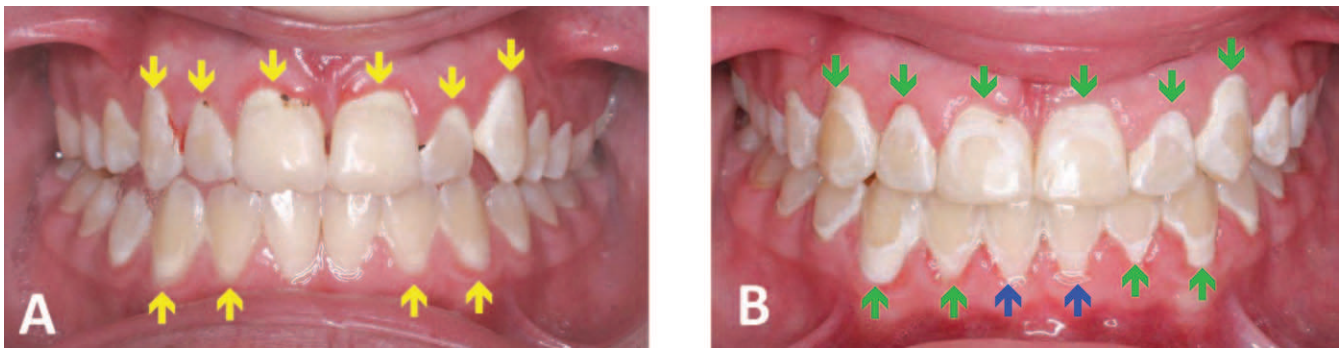


**Figure 3.** (A) Pretreatment photo demonstrating preexisting WSLs (yellow arrows). (B) Posttreatment photo demonstrating preexisting WSLs that worsened during treatment and thus were counted (green arrows), as well as new WSLs (blue arrows).

**Table 3.** Number of Teeth and Percentages of Patients With White Spot Lesions (WSLs) Before Treatment, WSLs After Treatment, and WSLs That Formed During Treatment

| | Teeth with WSL | | | | | |
|---|---|---|---|---|---|---|
| | Maxillary | | Mandibular | | Total | Percentage of Patients With WSL |
| | No. | % | No. | % | No. | |
| Before treatment | 172 | 74 | 62 | 26 | 234 | 8.6 |
| After treatment | 756 | 73 | 278 | 27 | 1034 | 32.0 |
| During treatment | 584 | 73 | 216 | 27 | 800 | 23.4 |

the literature. It is possible that the numbers of WSLs were overestimated because of possible eruption of teeth or vertical changes of the gingival margins, which could have made them appear to have worsened during treatment. However, because of the relatively limited number of patients with preexisting WSLs, these factors could only have had a very small effect. It compares most closely with the 26% prevalence reported by Lovrov et al.,[11] who also used a methodology based on photographs taken in a university setting. Chapman et al.[12] reported slightly higher results (36%), but they only evaluated the maxillary anterior teeth, which are more likely to have a greater number of WSLs. Two earlier studies that compared pre- to posttreatment WSLs[9,10] were full-banded cases, and another study[13] evaluated the teeth after only 6 and 12 months of treatment, while the brackets were still in place, making identification of the WSL difficult.

Differences in WSL between jaws and teeth have been reported previously. The present study showed that maxillary WSLs were much more likely (73%) than mandibular WSLs (27%), which supports the findings of Lovrov et al.[11] and Gorelick et al.[3] The present study also found WSL formation to be symmetrical left to right; most other studies have found a similar symmetry.[2,3,8,12]

Of the maxillary anterior teeth, the central incisors were the least affected. Most studies have also found either the maxillary laterals[3] or maxillary canines[2,8] to be the most commonly affected teeth. Although there was no difference on the right side, the maxillary left lateral incisors developed more WSL than the canines on the left side. In the mandibular arch, the canines have routinely been found to be the most susceptible. Tufekci et al.[13] found no differences between the teeth, which could have been due to the fact that the subjects in that sample were examined during treatment, and the appliances on their teeth made it more difficult to accurately identify WSLs.

Fluorosis was found to protect against WSLs during orthodontic treatment. Importantly, the visual assessments performed in the present study could have overestimates the prevalence of fluorosis, due to the tetracyline staining for example. Nevertheless, only 15% of the patients with fluorosis had WSLs form during treatment, compared with 26% without apparent fluorosis. Although this relationship has not been previously studied for WSLs, caries in general has been found to occur less frequently in populations with obvious fluorosis.[15]

The percentage of male patients who developed WSLs during treatment was higher (25%) than the percentage of female patients (22%), but the difference was not statistically significant. Other studies have reported a similar trend.[2,4,6,11] Studies reporting significant sex differences all indicate that males are at greater risk of developing WSLs than females.[8,12,13] This may relate to motivation and compliance rather than real gender-based differences.

As might be expected, poor oral hygiene was an important risk factor in WSL formation, as previously demonstrated.[8,11,12] We found treatment-related WSLs in only 17% of the patients with good oral hygiene, compared with 24% that had fair and 38% that exhibited poor initial oral hygiene. This is slightly lower than the 57% reported by Chapman et al.,[12] but that study only evaluated the upper teeth. Lovrov et al.[11] only measured hygiene after treatment, but they still found moderate correlations.

The present study also considered oral hygiene parameters in a new way, based on the changes that occurred during the course of treatment. There was a very strong and significant correlation between those patients whose oral hygiene declined during treatment

**Table 4.** Side Comparisons of White Spot Lesions (WSLs) Formed During Treatment[a]

| | No. of WSLs Maxillary | | | No. of WSLs Mandibular | | |
|---|---|---|---|---|---|---|
| | Left | Right | Probability | Left | Right | Probability |
| Central incisors | 8 | 6 | NS | 3 | 3 | NS |
| Lateral incisors | 17 | 13 | $<.001$ | 6 | 6 | NS |
| Canines | 12 | 12 | NS | 13 | 13 | NS |

[a] NS indicates not statistically significant.

**Table 5.** Tooth Comparisons of White Spot Lesions (WSLs) Formed During Treatment

| | Comparison of Left and Right Central Incisors | | Comparison of Central to Same-Side Lateral Incisors | | | Comparison of Central Incisors to Same-Side Canines | | | Comparison of Lateral Incisors to Same-Side Canines | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % of Patients With WSLs | Probability | % of Patients With WSLs | | Probability | % of Patients With WSLs | | Probability | % of Patients With WSLs | | Probability |
| | | | Central | Lateral | | Central | Canine | | Lateral | Canine | |
| Maxilla | | | | | | | | | | | |
| Left | 8 | NS | 8 | 17 | <.001 | 8 | 12 | <.001 | 17 | 12 | <.001 |
| Right | 6 | NS | 6 | 13 | <.001 | 6 | 11 | <.001 | 13 | 12 | <.20 |
| Mandible | | | | | | | | | | | |
| Left | 3 | NS | 3 | 6 | <.001 | 3 | 13 | <.001 | 6 | 13 | <.001 |
| Right | 3 | NS | 3 | 6 | <.001 | 3 | 13 | <.001 | 6 | 13 | <.001 |

and WSL formation. Approximately 20% of the patients whose hygiene stayed the same or got better during treatment developed new WSLs during treatment. For those whose hygiene worsened, 59% developed WSLs during treatment.

The previous literature is divided as to whether or not treatment time affects WSL development. Lovrov et al.[11] found no correlation between treatment time and WSLs, although Chapman et al.[12] did. Chapman et al.[12] had a much larger sample size (n = 332) than Lovrov et al.[11] (n=53), which may account for the difference. The present study was based on large sample sizes for both the 24- to 36-month group (n = 353) and the >36-month group (n = 518), and significantly more WSLs were found in the >36-month group (26%).

Using preexisting WSLs as predictors of susceptibility during treatment has not been extensively studied. Lovrov et al.[11] found that 47% of patients with preexisting WSLs developed new lesions during treatment, compared with 26% in their total sample. The present study showed 23% of the total sample and 87% of the patients with a preexisting WSL developing at least one additional lesion during treatment. Importantly, the Lovrov et al.[11] sample was considerably smaller (n = 53), the patients were on a daily fluoride rinse, and they had a professional treatment every 6 months in the orthodontic clinic. The patients in the present study followed no formal fluoride regimen.

The present study provides guidelines that can be applied clinically. Before treatment orthodontists can identify patients at greater risk of developing WSLs. For example, males without fluorosis who have poor oral hygiene and preexisting WSLs present the greatest risk of developing WSL. During treatment, orthodontists can watch the more susceptible canines and maxillary laterals, and reevaluate the patient if treatment extends beyond 36 months or if the oral hygiene begins to decline.

## CONCLUSIONS

- Twenty-three percent of patients developed WSLs during orthodontic treatment.
- WSLs were 2.5 times more frequent in the maxillary than the mandibular arch; they were symmetrical from left to right; and they occurred most frequently on the maxillary laterals, maxillary canines, and mandibular canines.
- There was no significant gender difference, but males had a slightly higher risk (RR = 1.14) of developing WSLs than females.
- Five statistically significant risk factors of developing WSL during treatment were identified, including treatment time in excess of 36 months (RR = 1.3), teeth without fluorosis (RR = 1.79), patients with poor oral hygiene (RR = 2.83), patients whose oral

**Table 6.** Comparisons of Patients With and Without Certain Traits Who Developed White Spot Lesions (WSLs) During Orthodontic Treatment[a]

| | % of Patients With Traits Who Developed WSLs | % Patients Without Traits Who Developed WSLs | Probability | Risk Ratio |
|---|---|---|---|---|
| No fluorosis | 26 | 15 | < .001 | 1.79 + |
| Male gender | 25 | 22 | NS | 1.14 |
| Poor pretreatment OH | 38 | 17 | < .001 | 2.28 + |
| Fair pretreatment OH | 24 | 17 | < .001 | 1.46 + |
| OH declined | 59 | 19 | < .001 | 3.17 + |
| Treatment time >36 months | 26 | 20 | .03 | 1.31 + |
| Preexisting WSLs | 87 | 26 | < .001 | 3.39 + |

[a] AR indicates absolute risk; RR, risk ratio; OH, oral hygiene; +, significantly increased risk; NS, not statistically significant.

hygiene declined during treatment (RR = 3.12), and preexisting WSLs (RR = 3.4).

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